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The **International Multidisciplinary Scientific GeoConference SGEM (Survey, Geology, Ecology, and Management)** serves as a global platform for pioneering research and scientific dialogue across the diverse fields of geosciences. It is dedicated to advancing interdisciplinary solutions for the most pressing environmental challenges of our time — **Global Warming, Climate Change, CO_2 Reduction, Biodiversity Conservation, and the Development of Green Technologies**. By fostering a collaborative exchange of knowledge and **aligning its objectives** with the **United Nations Sustainable Development Goals (SDGs), SGEM aims to inspire scientific excellence and drive sustainable practices toward a greener, more resilient future for our planet.**

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FOREWORD

Dear Readers,

It is a privilege to introduce the fifth issue of the 24th volume of the **SGEM GeoConference 2024 Conference Proceedings,** dedicated to advancing knowledge in **Ecology and Environmental Protection, Environmental Economics, Education and Accreditation in Geosciences, and Environmental Legislation, Multilateral Relations, and Funding Opportunities.** The collection of papers brings together groundbreaking research and practical solutions aimed at addressing the global environmental challenges of our time.

Interdisciplinary Approaches to Sustainability

This issue highlights the importance of a multidisciplinary approach in tackling complex environmental issues. From studies on **biodiversity** net gain through nature-based solutions to **innovative strategic environmental impact assessments**, the research presented here reflects a comprehensive view of how **science and policy** must align to **achieve sustainable development**.

Highlights

- **Ecology and Environmental Protection**: Topics in this section explore critical areas such as **biodiversity conservation**, **climate resilience**, and ecological monitoring, emphasizing innovative approaches like remote sensing and nature-positive solutions.
- **Environmental** Economics: Research here investigates **circular economy strategies, digital tools for GHG emissions management**, and financial sustainability models, underscoring the economic dimensions of environmental stewardship.
- **Education and Accreditation in Geosciences**: This section examines the role of education in fostering **environmental awareness and innovation**, presenting new methodologies for teaching geosciences and environmental sciences.
- **Environmental Legislation and Multilateral Relations**: The final section delves into the legal frameworks and international cooperation necessary for advancing sustainable development, including insights into the **European Green Deal** and environmental impact assessments.

Meeting Global Challenges

The research in this conference proceedings aligns closely with the United Nations Sustainable Development Goals (SDGs), particularly those addressing **climate action (SDG 13), life on land (SDG 15), quality education (SDG 4)**, and **peace, justice, and strong institutions (SDG 16)**. These studies serve as a beacon for policymakers, industry leaders, and academics striving to create a sustainable future for all.

Commitment to Quality and Rigor

This collection is a product of the SGEM GeoConference's rigorous **peer review process**, ensuring that each paper meets the **highest standards of scientific integrity, originality, and relevance**. The **diversity of perspectives** and **disciplines represented** here underscores our commitment to fostering a collaborative and inclusive scientific community.

A Shared Vision for a Sustainable Future
As we navigate the challenges of **climate change, biodiversity loss, and resource scarcity**, this issue serves as a vital resource for researchers and practitioners dedicated to building sustainable and resilient societies. It is our hope that these proceedings will inspire continued **innovation and collaboration in the pursuit of a healthier planet**.

On behalf of the SGEM GeoConference community, we extend our heartfelt thanks to all contributors, reviewers, and organizers whose efforts have made this conference proceedings possible.

Sincerely yours,

Prof. Dr. hab. oec. Baiba Rivza
Editor-in-Chief of XXIV SGEM GeoConference Proceedings
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President of the Latvian Academy of Agricultural and Forestry Sciences
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SECTION

ECOLOGY AND ENVIRONMENTAL PROTECTION

ACHIEVING BIODIVERSITY NET GAIN THROUGH APPLICATION OF NATURE-BASED SOLUTIONS

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ABSTRACT

Nature-based Solutions represent a set of powerful tools that are intended to reconcile often conflicting economic and nature conservation goals. Rapid infrastructure development threatens biodiversity globally. In this context application of Biodiversity Net Gain strategies start to gain traction. One possible approach to achieve the Net Gain outcomes is to apply Nature-based Solutions. It is, however, important to understand that application of the solutions does not guarantee biodiversity outcomes that could compensate for lost habitats and species beyond the specific situation in focus lost. Thus, in order to ensure that biodiversity Net Gain is achieved design and maintenance of Nature-based Solutions need to explicitly pursue this goal. This requires clear understanding of when the solutions can support biodiversity conservation. Given the wide variety of tools under the Natuure-based Solutions paradigm and the lack of clear guidelines on which factors determine positive biodiversity outcomes, tool application may be problematic. In order to address this problem, we critically evaluate relevant evidence and knowledge, and offer recommendations for conservation practitioners and policymakers.

Keywords: Nature positive, biodiversity conservation, infrastructure development

INTRODUCTION

Today, a widely adapted guiding principle for implementation of sustainable development projects is the Mitigation Hierarchy framework [1]. The framework implies that negative impacts on biodiversity itself also limit the future potential for development of biodiversity. In part, this can be avoided through avoidance, minimization, restoration and offsetting of development project impacts [1]. This is consistent with Biodiversity Net Gain goals since it “is an approach to development that leaves biodiversity in a better state than before” [2]. This is different from traditional approach to biodiversity conservation as it not just implies No Net Loss of biodiversity as a result of development projects but rather improvement of the sate of biodiversity which may mean protecting, restoring or designing habitats that can harbour more biodiversity than was lost as a result of he development project. These outcomes can be achieved through application of different conservation strategies. One particularly promising strategy is the application of Nature-based Solutions. Such solutions “address societal challenges through actions to protect, sustainably manage, and restore natural and modified ecosystems, benefiting people and nature at the same time” [3]. Nature-

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based Solutions are an attractive set of tools for achievement of Biodiversity Net Gain objectives as they provide not only biodiversity values but also can deliver social and economic benefits. However, it has to be kept in mind that simply using nature as a tool for achieving certain social and economic benefits does not necessarily beget biodiversity. In fact, implementation of Nature-based Solutions in some cases may even result in biodiversity loss [4]. For instance, application of forest plantations as Nature-based Solutions for climate change mitigation can result in destruction of biodiverse ecosystems and development of homogenous forest stands, so called "green deserts", which can only support assemblages with low species richness [5]. In other words, if biodiversity concerns are not explicitly embedded in Nature-based Solutions project, biodiversity may suffer and Biodiversity Net Gain is even less likely to be achieved.

However, outcomes of Nature-based Solutions projects are highly uncertain. The projects tend to be implemented in the changing environment and it often takes many years before the new ecosystem becomes capable of maintaining high levels of biodiversity. In the conditions of such uncertainty, it may be highly problematic to plan for the Biodiversity Net Gain outcomes. This in turn can become an obstacle to financing Nature-based Solutions projects, especially in projects funded through offsetting. It may be also difficult to attract private investment, as investors tend to expect guarantees of the project outcomes. To solve this problem it is important to gain understanding of the factors that contribute to positive biodiversity outcomes in Nature-based Solutions projects and be able to develop predictable scenarios of the project outcomes. Thus, in the present article we critically evaluate relevant evidence and knowledge and offer recommendations for conservation practitioners and policymakers.

METHODS

Conceptual research methodology is used in this study. The methodology implies application of interdisciplinary research that can help solve problems. We have chosen theory adaptation approach, which is one of the conceptual research methodology techniques (others include theory synthesis, typology and modelling), because it allows exploring concepts not discussed in existing literature and provides novel insights. As a result, we revealed innovative applications of empirical evidence and knowledge from a range of disciplines. We applied conceptual research at the interface of biodiversity science, sustainability science, ecology and social sciences.

OPPORTUNITIES

First, it is important to recognise when the application of Nature-based Solutions can provide an optimal function in the achievement of Biodiversity Net Gain. Biodiversity credit markets, which support Biodiversity Net Gain strategies currently exist in a few countries (e.g., UK, France, Australia) [6]. This means that implementation of Biodiversity Net Gain strategies in countries without such markets can be either funded through carbon markets, international and local biodiversity conservation funds or through direct economic or social benefit value that can be derived from the projects themselves. In addition, unique characteristics of Nature-based Solutions can help attract funding in absence of biodiversity credit markets. For instance, theuse of nature as a "construction material" is fundamental part of the solutions, this often begets

carbon sequestration value to the projects. The solutions can take different forms, from the most traditional, which includes tree plantation, to other effective approaches, such as wetland or grassland restoration and sustainable agriculture. In all these cases carbon sequestration either in biomass or in soils can help attract funding to Biodiversity Net Gain projects. In addition, Nature-based Solutions projects can often provide direct social and economic value. For instance, the solutions are often implemented for disaster risk reduction purposes. This can also be a part of climate adaptation strategies, as disasters, such as drought and floods, are increasingly frequent in the context of global warming. Long-term benefits from ecological approaches to disaster risk reduction can be translated into monetary value in a relatively straightforward way, facilitating Biodiversity Net Gain projects to procure financing.

There are even more benefits that can potentially be derived from Nature-based Solutions. For instance, implementation of urban green infrastructure, as a widely applied form of the solutions, can provide health benefits to urban and peri-urban populations, deliver cultural and aesthetic values, cool down urban environments, deliver air and water purification ecosystem services and facilitate rainwaterinfiltration. Some forms of Nature-based Solutions can be a part of human economic activity. For example, sustainable working-land management, which includes farming, and forestry practices, allows combining economic activity with biodiversity conservation goals. Additionally, Nature-based Solutions involving parks can be associated with recreational activities, providing income sources from tourism and hospitality businesses. Also, Nature-based Solutions can deliver a wide range of green jobs [7]. Overall, thorough estimation off ecosystem services, economic sustainability and social value, Nature-based Solutions can potentially help achievement of the Biodiversity Net Gain objectives, with or without the prior establishment of biodiversity credit markets.

LANDSCAPE APROACH

While application of Nature-based Solutions is an attractive option for achievement of Biodiversity Net Gain objectives, it is associated with certain challenges. As was mentioned earlier, use of nature as a “construction material” in the solutions does not necessarily provide biodiversity benefits [4]. How can it be ensured that Nature-based Solutions positively contribute to biodiversity conservation? Answering this question is not a trivial task, given the complexity of ecosystems and ongoing environmental change. Nevertheless, scientific evidence from a range of disciplines can at least partially guide practitioners and policymakers who intend to implement Nature-based Solutions with the aim to support biodiversity conservation. One scientific area that merits particular attention in this context is landscape ecology. It is well established that landscape pattern can determine the processes that are fundamentally important for ecosystem ability to maintain biodiversity. Nature-based Solutions are ideally considered from an ecosystem perspective, not just a set of trees, shrubs and other greenery that serve particular practical purposes, such as climate mitigation or disaster risk reduction. We can then explore which spatial characteristics are essential for ecosystems to maintaining biodiversity. Such characteristics include, for example, landscape heterogeneity, diverse topography, landscape connectivity, and the presence of important resources, such as water and nutrients. These factors need to also be considered with respect to spatial and temporal scales, as well as surrounding

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landscapes. This emphasises the importance of the landscape approach in the siting, planning and design of Nature-based Solutions.

OTHER ECOLOGICAL FACTORS

Research on ecosystem restoration has revealed that multiple ecological factors along with landscape pattern can affect its capacity to maintain biodiversity. These factors include soils, recovery of interaction networks and genome-function structure of species assemblages [8]. Considering the factors when deigning or planning Nature-based Solutions may be particularly problematic due to lack of historic baseline data. However, it is possible to use reference data from natural ecosystems in the region. Additionally, it is also possible to plan for high species and genotype diversity, which may help to achieve levels of ecosystem complexity close to natural ecosystems. It is also possible that modern scientific advances will provide more data that will help practitioners and policymakers to harness these ecological factors in order to maximise the capacity of Nature-based Solutions to maintain biodiversity.

COMMUNITY ENGAGEMENT

Along with ecological factors, the value of Nature-based Solutions for the Biodiversity Net Gain strategies heavily depends on stakeholder engagement. As for any biodiversity conservation project, public support is likely to play a critical role. Public engagement can help securing funding essential for development of the Nature-based Solutions projects. Most importantly, however, public support determines the long-term biodiversity outcomes. Without local community engagement implementation of Nature-based Solutions projects may be hindered by competition for land and resources. In case Nature-based Solutions projects are implemented in areas where multiple stakeholders are competing for land, such as for example in modern cities, where securing land green infrastructure may be highly problematic, public engagement and lobbying is critical to make sure that the projects can be implemented. Furthermore, capacity of such solutions to maintain long-term biodiversity largely depends on the environmental consciousness of people who are going to use the site. For instance, citizens need to be aware of the biodiversity value of green infrastructure and support species conservation, rather than disrupting ecosystem integrity through intense recreational activities and pollution. Similarly, inhabitants of adjacent villages, especially in the Global South, need to understand the value of Nature-based Solutions and see clear benefits. Otherwise, they may start hunting, fishing or extracting other resources from the site, thereby fundamentally undermining the biodiversity conservation goals. Furthermore, it was found that local communities often oppose implementation of the nature-based Solutions due to the fear for their land ownership or resource use rights [9]. Close work with the local communities in order to present the rationale of the projects can be crucially helpful in this case. As was mentioned earlier, factors such as creation of green jobs or development of hospitality industry associated with the projects can be harnessed to demonstrate direct contributions to well-being of the general public. In addition, the structure of the society will largely determine key stakeholders, both short-term decision makers and more long-term resource users that sustainability depends on. The first group can be policy makers, members of the government or local authorities, influential individuals or NGOs. As well as providing

the political basis, individuals residents and other concerned citizens of the second group are, themselves, often a part of the implementation of Biodiversity Net Gain projects.

An important aspect of successful implementation of the Nature-based Solutions projects in the context of Biodiversity Net Gain strategies includes a close collaboration between multiple groups of stakeholders, especially in cases when conflicting interests may be an obstacle to project implementation. Environmental non-governmental organizations that tend to lead such projects, need close cooperation with both public and private sector.

HOLISTIC APPROACH

All factors discussed above need to be considered jointly. It is therefore important to develop a holistic approach which could help the implementation of Biodiversity Net Gain strategy with the help of Nature-based Solutions. The approach needs to be integrated into the Mitigation Hierarchy. As was mentioned earlier, the hierarchy consists of four steps, including avoidance, minimization, restoration, and offsetting [1]. This means that in development projects opportunities to completely avoid harm to biodiversity need too be considered; for example, when a road is being constructed it is often possible to plan it in such a way that it does not bisect or closely pass by biodiverse ecosystems. This, however, is not always possible. In which, case a second strategy, namely, impact minimization should be considered. Considering an example of road construction project, minimization strategy could include construction of fencing and wildlife crossings, to reduce roadkill and habitat isolation by roads, and/or hiding powerlines underground to reduce bird-wire collision risk. Integration of Nature-based Solutions, however, is likely to be applicable at the next two stages of the Mitigation Hierarchy.

Where harm avoidance and mitigation are not sufficient, it may be possible to restore ecosystems after the development project is finished. Ecosystem restoration can be implemented in the context of Nature-based Solutions projects. This may be especially relevant if the restored ecosystems are intended to fulfil some of the functions that would deliver social and/or economic benefits. Opportunities for such integrated approach to ecosystem restoration often emerge and should be harnesses in the context of Biodiversity Net Gain strategies. For instance, land rehabilitation after mining or landfill restoration projects can result in green infrastructure development, and these can be considered as Nature-based Solutions projects. Another strategy that provides great potential for application of the Nature-based Solutions for achievement of Biodiversity Net Gain is offsetting. Offsets can be of two types. The first one aims at restoration or rehabilitation of degraded habitats away from the areas directly affected by the development project. The second type of offsets implies averting biodiversity loss in areas where such loss is expected. These strategies are considered in cases when irreversible habitat loss takes place as a result of development. In fact, although the offsetting strategy should be considered only in cases when previous two, on-site strategy steps are not possible to implement, the irreversible habitat loss unfortunately usually takes place in development projects. Any construction works involve loss of habitat areas that will be replaced by buildings or grey infrastructure (e.g., road surfaces.). Thus, for biodiversity to be preserved and even amplified the lost habitats

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need to be protected, restored, or developed elsewhere. Implementation of Nature-based Solutions projects can take different forms in this case. For instance, biodiversity offsetting can take form of sustainable forestry, sustainable farming, natural reserves, geoparks, urban and peri-urban green areas, The main aim here is to make sure that the Nature-based Solutions project over-compensates for lost biodiversity.

For Nature-based Solutions to deliver a maximal contribution for Biodiversity Net Gian strategy implementation it is important to consider how well the projects integrate into the larger landscape. It is also important to consider which species suffered the most from habitat loss associated with the development project. For instance, if the construction project has replaced large proportions of natural meadow or savannah habitats, it is likely that birds and insect pollinators may be most affected. In this case development of sustainable farmlands may be a vital option if these lands are to be managed in a bird/pollinator friendly way and implemented in landscapes that are characterised by open ecosystems. Contrarily, when forest loss happens as a result of the development projects, Nature-based Solutions in the form of afforestation on degraded lands or forest restoration may be a vital option. However, it is important to ensure that tree plantations do not replace biodiverse natural ecosystems and do not form a homogenous landscape. Overall, it is important to ensure the holistic view on both the impacts of development project and consequences of Nature-based Solutions integration into selected landscapes.

CONCLUSION

The aim of this study was to gain understanding of the factors that contribute to positive biodiversity outcomes in Nature-based Solutions projects and how the solutions can be harnessed to achieve Biodiversity Net Gain. We argue that multiple opportunities exist for application of the Nature-based Solutions in this context. Furthermore, the solutions can be a particularly attractive option as they have potential to deliver biodiversity benefits and simultaneously attract stakeholder support, even in absence of biodiversity credit markets. However, mere use of nature as a construction material and functional component in the projects does not guarantee biodiversity benefits. Thus, Nature-based Solutions have to be designed with biodiversity objectives in mind. Landscape approach, consideration of the interaction networks and genome-function structure of species assemblages, and community engagement are critical areas that need to be embedded into the solutions planning, design and management strategies.Additionally, the implementation of Nature-based Solutions need to be integrated into the Mitigation Hierarchy, which forms the basis for Biodiversity Net Gain strategies in development projects. A holistic approach is essential, considering both impacts of the development projects on biodiversity and potential outcomes of Nature-based Solutions implementation in the wider landscape context.

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ASPECTS RELATING TO THE STRUCTURE OF THE TEXTILE FRACTION CONTAINED IN MUNICIPAL SOLID WASTE

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ABSTRACT

The European Green Pact launched a concerted strategy for a "circular", climate-neutral, resource-efficient, and resource-efficient economy. Yet globally, only about 20% of textiles are collected separately from the rest of the waste, with a truckload of textiles sent to incineration or landfill every second, and less than 1% of all textiles in the world are recycled into new textiles. In this context, the environmental impact (air, soil, water) due to the landfilling of these textile wastes is huge. In this regard, the paper addresses the issue of the post-consumer textile fraction (as the last chain link in the current linear economy) destined for municipal waste landfills, as textiles disposed of with mixed waste (TMW) in Romania. After sorting and sorting by category, the TMW textile fraction is analyzed in terms of clothing/non-clothing type, structure, and constituent fiber blend, respectively level of degradation, providing a view on the possibility of "downcycling" reuse.

Keywords: linear value chain, waste, used textiles, reuse

INTRODUCTION

The actual "take-make-use" linear economy model, puts a big pressure on Earth affecting both natural and anthropogenic environments. Among the most numerous and hazardous industrial wastes are chemicals from many industrial fields, including the textile industry, polluting the environment and reaching the human body through food, breathing, direct contact, etc., generating or aggravating numerous diseases [1]. Global textile production almost doubled in the last 20 years and is projected to continue to grow by more than 50% by 2030. In this situation, the overproduction and overconsuming of textiles determine a critical waste generation problem all around the world, and for the majority of these wastes, the final destination is landfills [2], [10]. In this context, global the quantity of textiles that receive a "new life" in new textiles is only 1%. Through the actions against textile waste, mentioned in the literature there are the following: recycling, hosting a clothing swap or exchange, renting the clothing, donation, etc, that led to closing the loop [3].

According to the European Commission, the EU generates 12.6 million tons of textile waste every year (more than 12 kg/person) and ~ 20% of these are collected separately

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and intended for re-use/recycling [4]. While textile/clothing reuse and/or recycling has more than 70 times lower environmental impact, 2025 will be a milestone for EU-27 to collect textiles separately, in line with current EU legislation [5]. In Romania, the overall recycling rate shows a large gap to the recycling target for 2025 (55 %) and a significant drop in 2018 and 2019. In 2020 there was a modest increase bringing the recycling rate to about 2%, compared to 2019, raising the level of 13.7% [6]. (Eurostat, 2022). Considering the 2025 target to selectively collect the textiles in Romania, The Ministry of European Funds and the European Investment Bank (EIB) have signed an agreement (Project Advisory Support Service, PASSA) that will support Romania's authorities in the administration and implementation of solid waste (including textiles)-related projects funded by EU funds up to 2027 [7], [8]. Up to 2.2 million tonnes of textiles will be available for recycling in 2030 with a positive impact on the workplace market, economy, and environment [9].

MATERIALS AND METHODS

The paper deals with the post-consumer textile wastes that are discarded in the proximity of the biggest city of Romania, Bucharest, and the main objective is to study samples, and quantity and to characterize the textile products found in mixed solid wastes. For the research, a batch of ~1100 kg, of municipal waste (mixed waste), from a specialized economic agent that processes municipal wastes has been analyzed to identify the textile fraction from it.

This batch consists of 2 types of wastes, those collected from more or less separately, identified as *Textile Bins (TB),* and those found directly in mixed solid wastes, identified as *No Bins (NB)*. A total of 1065 textile articles (garment pieces), with a net mass of ~364 kg, 404 pieces from TB (150 kg) and 661 pieces from NB (214 kg) were identified and further characterized using a NIR Matoha Fabritell handheld device and own app. The non-textile waste (rubbish) weighed ~736 kg. Most of those textile articles were identified in the wet state and were left to dry in an open space (a depositing shelter) for 48 hours.

The obtaining of each textile product's characteristics was made in two steps: 1) the scanning of each piece of textile, by a volunteer using the NIR handheld device, to assess its composition; 2) organoleptic examination of the characteristics of the related piece of textile-like product type, age group, color and presence of disruptors, degree of degradation, etc, that were captured in the app on the electronic device through a short predefined multiple-choice survey, using an application designed by Matoha Instrumentation Ltd.

RESULTS AND DISCUSSION

The examination of the textile fraction included in the mixed waste batch reveals the following aspects:

- From the point of view of the garment type, according to the organoleptic examination of the volunteer, most textile pieces are tops, of medium to basic quality, in both NB (52.8%) and TB (52.6%), followed by bottoms (21.9% - NB and 20.79% - TB), overall (10.14% - NB and 5.2% - TB), others (6.05% - NB and 7.4% - TB), and accessories, babies, and underwear (under 5%) in both categories (fig. 1). Accessories means medium or small items like hats, gloves socks, scarfs, etc.

- Figure 2 reveals that the most identified textile articles are for adults in both NB and TB (76.2% - NB and 78.7% - TB) of the whole garment examined, followed by other textiles (~11% - NB and 10.6% - TB), those for children (9.8% - NB and 7.6% - TB), and those for babies with under 3% in both cases. Other kinds of stuff identified are with non-wearing application (e. g. bed sheets, curtains, etc.)

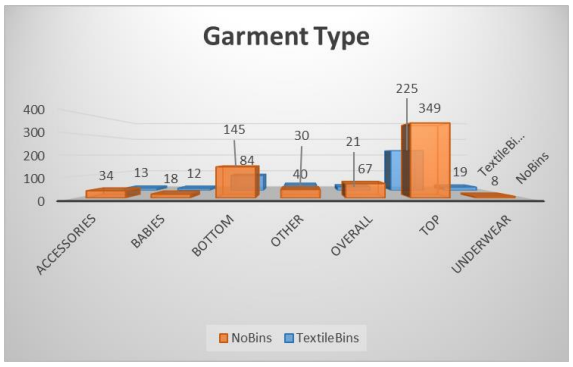


Figure 1: Garment type for NB and TB

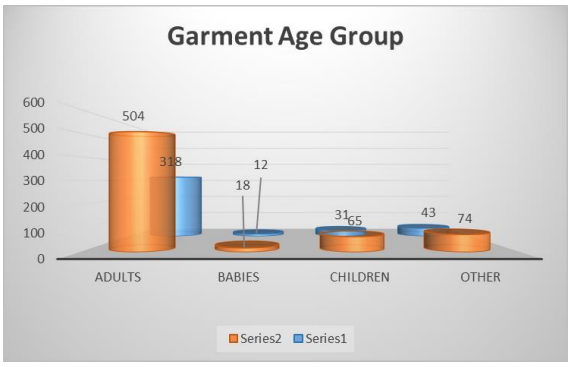


Figure 2: Garment age group for NB and TB

- In this study: the color of the textile piece was considered the solid or dominant color of it. The predominant color identified in the batch, multicolor, textile articles are the most, in both NB and TB categories (27.4% - NB and 29.4% - TB), followed by blue articles (23.1% - NB and 25.6% - TB), black (20.9% - NB and 16.4% - TB), grey, and white (~14% in both TB and NB cases) (Figure 3). The multicolor-identified articles are both those with prints of many colors and also with component pieces of different colors. The textile pieces with another color besides the 5 groups identified in Figure 3, (e.g. yellow, green, pink, etc) weren't considered in this research.

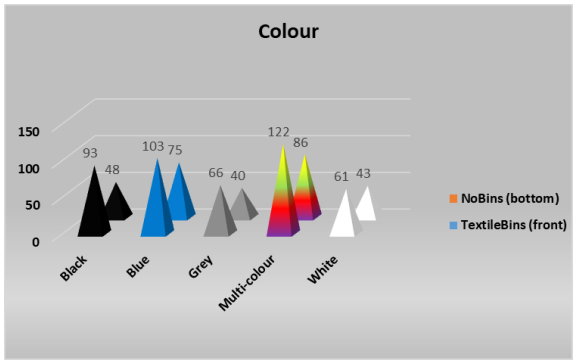


Figure 3: Identified colors for NB and TB

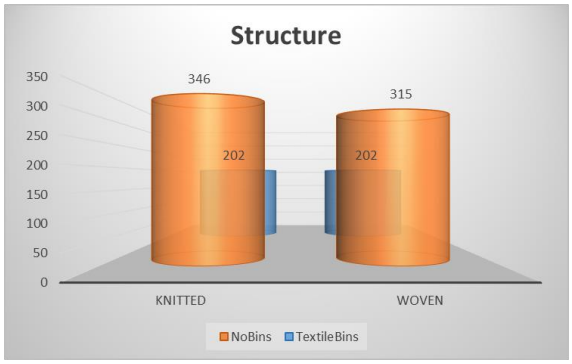


Figure 4: Textile structures for NB and TB

- From the point of view of the textile structure, the textile pieces with knitted structure (or most knitted surface) are preponderant at 52.3%, in the case of those collected from NoBins, followed, of course by woven articles (or most woven surface) with ~47.6%. (Figure 4). In the case of textile pieces collected from TB, the percentages for those with woven and knitted structures are the same (50%). The percentages are quite similar when considering that each fabric's structure offers a particular comfort, adapted to our wearing needs. Moreover, the fabric's structure is most relevant when considered as raw material/feedstock for the recycling process, because the

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technological process and types of equipment can significantly vary from woven structures to knitted ones. Due to the technical limitation of the app., a few of the nonwoven articles were not considered in this research.

- Fibrous composition represents one of the most important characteristics of a textile article, being a kind of classification of fabrics by what type of fiber they are made of. Choosing an optimal fiber composition is essential both for the skin and comfort of use, but also when considering environmental protection, and eco-friendly aspects of life. Also, knowing the fibrous composition of a textile article with a fibrous blend intended for the recycling process is crucial for choosing the chemical technological process, to save a type of fiber.

- In our case, textile pieces with a fibrous blend composition (identified in Figure 5 as the other compositions), represent the most articles both in the NB and TB categories, besides those made of 100% single fiber type. So, textiles with other compositions represent 59.4%, in the case of NB and 52.9% in the case of TB, followed by those made of 100% cotton fibers (16% - NB and 26.7% - TB), those made of 100% artificial fibers (viscose) (13.7% - NB and 6.9% - TB), those from 100% polyester (7.72% - NB and 8.17% - TB) and those made of 100% acrylic fibers (generally winter articles) (3% - NB and 5.2% - TB).

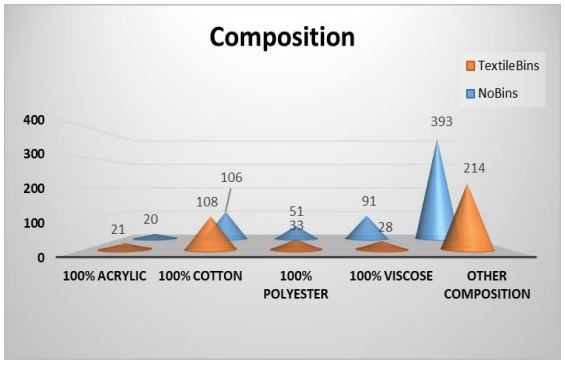


Figure 5: Fibrous composition for NB and TB

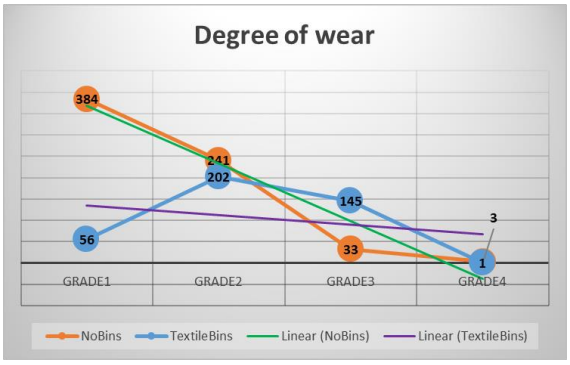


Figure 6: Reuse grade for NB and TB

- Another important parameter, which characterizes the two categories of textile articles identified in TMW, respectively those identified from NB and those from TB, is the degree of wear. Five degrees of wear have been identified, depending on which textile article can be reused under optimal conditions (grade 5) and which cannot be reused for its original purpose (grade 1). The latter are most often destined for disposal.

So the 5 degrees of wear are *degree 1*- textile pieces with (e.g. multiple stains, holes, missing buttons, broken, zippers, including clothes impossible to identify); *degree 2* - textile pieces with (e.g. multiple stains and holes, missing buttons and/or zippers) but the garment possible to identify; *degree 3* – textile pieces with (e.g. reduced number and small size of stains or holes and/or some discoloration and pilled or thinned to a major extent); *degree 4* – textile pieces that are visibly worn with minor hole(s) or stain(s) or fabric being to a minor extent thinned or pilled (not all of these factors together); *degree 5* - new textile items with tags, without tags or like new, no visible damage [11].

In our study, grades 1, 2, and 3 were identified as the most analyzed textile articles in both NB and TB. Particularly, in the case of NB the textile pieces identified with grade 1 count 58%, in comparison with those from TB, that count (13.8%) (Figure 6). Textile

pieces with grade 2 are the majority (50%) in the case of TB, in comparison with those from NB (36.4%). Textile pieces having grade 3 count 35.8% (TB) and only 5% in the case of NB. The number of pieces with grade 4 is very low in both NB and TB categories, counting under 0.5% in both cases.
There was a tendency for wearers to collect separately the garment garments that are not in wear classes 3-4, and to dispose of them together with household waste in classes 1 and 2.

CONCLUSIONS

The textile fraction of a TMV sample, available from both Textile Bins and NonBins, was analyzed. Thus, 62% were identified in the No Bins category, while the difference was made up of textile items in the Textile Bins category. This shows the reticence of the population to collect textiles separately in general, regardless of the negative environmental impact.

The vast majority of textile items identified as a fraction of municipal waste, although they should not exist, constitute upper-body clothing/tops (mostly knitted textile structure shirts) of medium to basic quality. Following the organoleptic examination, it was found that the identified textile articles show a poor condition, given by the wearing behavior over time (e.g. large dimensional deformations, stains, holes, and areas with rare structure, with missing/degraded disturbers (buttons, staples, labels, zippers, prints).

A significantly higher percentage of adult clothing was disposed of with household waste compared to children's and baby clothing, most of the items having a fibrous composition of 2 or more fiber categories (e.g. cotton + PES) have been identified.

It was also found that the textile articles analyzed can be classified into high wear grades (1-3), with a strong tendency towards grade 1 (with the highest wear grade) for NoBins textile articles.

The most common fiber composition in the analyzed garments has a blend of at least 2 components, often cotton and PES, but less often 100% natural, man-made, or synthetic fibers.

A very small number of articles were found to be made of fibers considered noble (wool, other angora hair, cashmere), silk, linen, hemp, and fibers which give products a high level of comfort and aesthetics.

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ASSESSMENT OF THE BIODEGRADABILITY OF CATIONIC FLOCCULANTS BY MICROORGANISMS ISOLATED FROM SEWAGE SLUDGE OBTAINED ON WASTEWATER TREATMENT PLANTS

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ABSTRACT

Annually, a city with 500,000 inhabitants generates approximately 115.5 million cubic meters of wastewater. The treatment of this wastewater is efficiently managed using activated sludge, which comprises a diverse community of protozoa, infusoria, lower crustaceans, algae, and microorganisms. These organisms facilitate the effective treatment of large volumes of wastewater in treatment plants. However, the activated sludge proliferates by consuming organic materials in the wastewater, resulting in the accumulation of substantial volumes of sewage sludge in these plants. To manage this sludge, it is pre-dewatered using flocculants.

While flocculants are effective for dewatering, the presence of polyacrylamides poses a challenge due to their resistance to degradation and potential environmental toxicity. Therefore, before the biological treatment of sewage sludge, it is essential to purify it from flocculants. This study aimed to isolate bacteria capable of degrading cationic flocculants from the activated sludge of municipal wastewater treatment plants, screen their growth rates, identify the most promising microorganism species, and evaluate their ability to degrade cationic flocculants.

Two bacterial isolates were obtained, capable of growing on a medium where the sole carbon source was Greenlife K-35 and Mainfloc 5858 brand flocculants. The most effective isolate was identified based on growth curves. DNA sequencing of the 16S rRNA region by the Sanger method identified this strain as Pseudomonas nitroreducens. In the presence of this strain, the degradation rates of Mainfloc 5858 and Greenlife K-35 were 61.5% and 59.6% at 28 days, respectively, as evaluated using the OxiTop system.

Keywords: sewage sludge, biodegradability, cationic flocculant, OxiTop® measuring systems

INTRODUCTION

The industrialization of society has led to rapid urban growth and the generation of substantial volumes of various urban wastes. One significant type of waste, which is increasing annually, is domestic wastewater. The most commonly employed method for treating domestic wastewater is biological treatment. During this treatment process, excess activated sludge is produced. This sludge is characterized by a high content of

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organic matter, high viscosity, and the presence of fine particles, with water content in sewage sludge reaching up to 99% [1].

Dehydration of excess activated sludge is a crucial component of sludge treatment and utilization in wastewater treatment plants. High molecular weight polymeric compounds, known as flocculants, are used in this process. Flocculants facilitate the formation of globules, decrease the settling time of particles, and reduce the water content in the sludge, resulting in the formation of sewage sludge. The advantage of polymer flocculants lies in their ability to form large, dense, compact, and strong flakes with excellent sedimentation properties compared to those obtained through coagulation. Polyacrylamide-based flocculants are commonly used in wastewater treatment systems [2].

Polyacrylamides are water-soluble synthetic linear polymers made from acrylamide or a combination of acrylamide and acrylic acid. These polymers undergo thermal degradation at temperatures ranging from 175 to 300°C and can also undergo photodegradation [3]. Utilizing different concentrations of flocculants is an essential part of the sludge conditioning process, as it helps reduce the water content of the sludge, enhances the safety of subsequent disposal, and lowers the economic costs associated with sludge treatment [1].

In the agglomeration process of polyacrylamide with sludge particles, the interaction forces between water and the sludge flakes vary in strength. Depending on these interaction forces, water is classified as either free or bound. The primary challenge in sewage sludge dewatering is reducing the bound water content [4].

Various physico-chemical or biological methods are employed to address the reduction of bound water in sewage sludge. One biological method involves the degradation of polyacrylamide by microorganisms. Research on the biodegradation of PAM and its derivatives has primarily emerged in the past two decades, with a focus on the biodegradation of acrylamide. Studies have shown that microorganisms can utilize not only acrylamide but also PAM and its derivatives as the sole source of nitrogen and/or carbon under both aerobic and anaerobic conditions [5]. Microbial degradation results in the reduction of polymer molecular weight, viscosity, and the conversion of amide nitrogen to ammonia.

The method entails isolating microorganisms (bacteria, protozoa, fungi) from waste that are capable of actively degrading polyacrylamide, cultivating these cultures, and adding them to the waste to accelerate the biodegradation process. The isolation of several biodegrading species and the use of a consortium of microorganisms promise more efficient waste biodegradation.

MATERIALS AND METHODS

Sewage sludge sampled at wastewater treatment plants in the Republic of Tatarstan was used as the research object. The sludge samples were collected from the centrifuge, where excess activated sludge from the aeration basin is processed, and flocculant is added (sample SC). For the isolation of destructor microorganisms, a modified Bushnell Haas (BH) medium was employed. This medium included the following mineral salts: $K_2HPO_4 \cdot 3H_2O$ (1.39 g/L), KH_2PO_4 (1 g/L), $MgSO_4 \cdot 7H_2O$ (0.2 g/L), $FeCl_3 \cdot 6H_2O$ (0.08 g/L), and $CaCl_2$ (0.02 g/L). Various grades of cationic flocculant Greenlife K-35 and Mainfloc 5858 were added at a concentration of 0.5%.

The OxiTop® test system was utilized to determine biodegradability based on the OECD 301 standard [6]. For this purpose, 150 ml of modified BH medium were added to 1-liter glass containers of the OxiTop system (WTW, Germany). To these containers, 0.5% flocculant and 5 ml of microorganisms isolated from sewage sludge were added. Sodium hydroxide (NaOH) was used as a CO_2 absorbent, and the analysis period was 28 days.

Species identification of isolates was conducted through Sanger DNA sequencing by specialists from Syntol Research and Development Company, Moscow. Bacterial DNA was extracted using the FastDNA® SPIN Kit for Soil (MP Biomedicals, 29525 Fountain Parkway, Solon, OH 44139 California, US) following the manufacturer's instructions [7]. The resulting nucleotide sequences were merged using the EMBOSS Merger website. To determine the taxonomic affiliation of the samples, the Basic Local Alignment Search Tool (BLAST) program was used to find areas of local similarity between sequences. The program compared the nucleotide sequences with databases on the NCBI website and calculated the statistical significance of matches for each pair of compared sequences.

RESULTS

Microorganisms from sewage sludge were isolated on BH solid agar medium with flocculant at a concentration of 0.5% as the sole food source. The isolates obtained are summarized in Table 1.

Isolate №1	Isolate №2
	

The growth rate of isolates isolated from sewage sludge was evaluated in BH medium containing cationic flocculants of Mainfloc 5858 and Greenlife K-35 grades over 14 days. The screening of the growth rate of isolates is presented in Figure 1.

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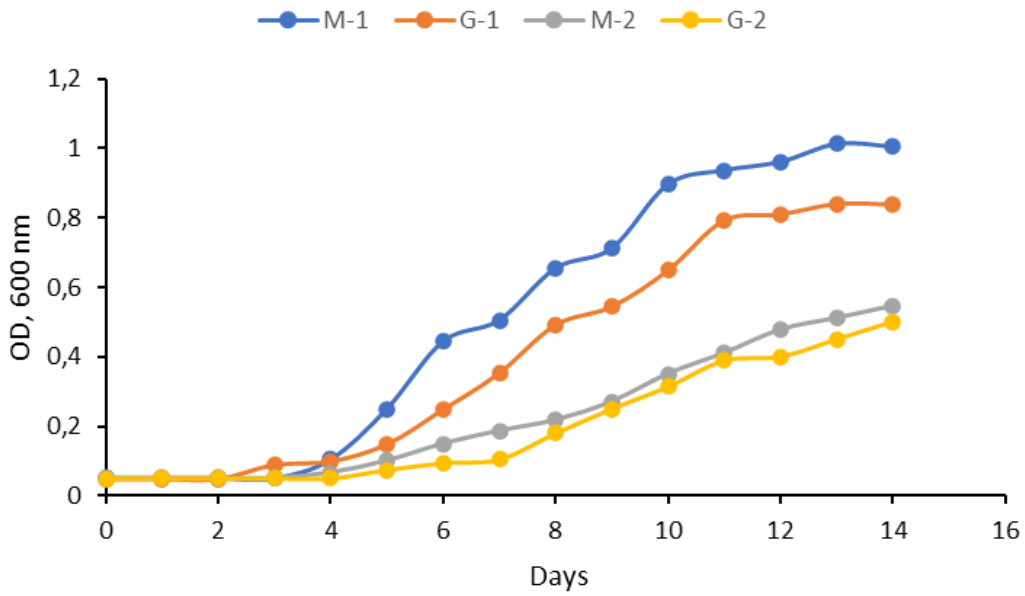


Figure 1: Growth curves of isolates 1 and 2 in the presence of flocculants Mainfloc 5858 and Greenlife K-35 (M and G, respectively) over 14 days at 28 °C.

Based on growth curves, it was determined that isolate No.1 exhibited maximum growth in the presence of different grades of flocculant. Species identification using Sanger sequencing was performed for isolate No.1 as the most promising microorganism. Identification using 16S rRNA sequencing revealed the microorganism to be *Pseudomonas nitroreducens*.

Next, the ability of *Pseudomonas nitroreducens* to degrade the cationic flocculants Mainfloc 5858 and Greenlife K-35 was evaluated using the OxiTop system (Figure 2).

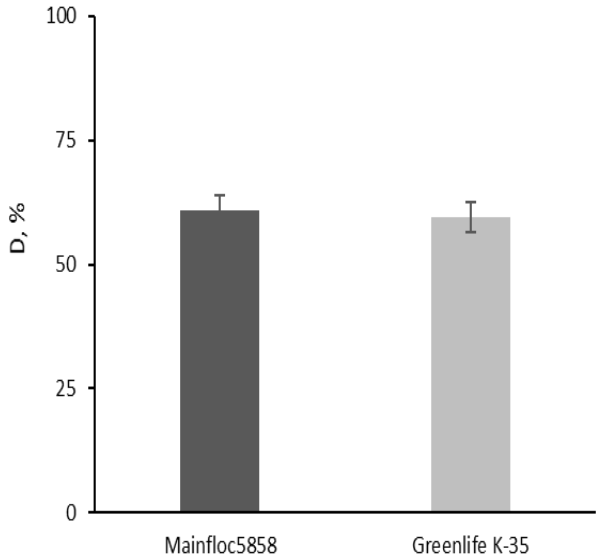


Figure 2: Biodegradation rate of flocculants Mainfloc 5858 and Greenlife K-35. The biodegradation rates were 61.5% and 59.6%, respectively.

DISCUSSION

Flocculation is one of the most common methods for sludge dewatering in wastewater treatment plants today, with polyacrylamide-type flocculants being the most frequently used [1]. Polyacrylamide can serve as both a carbon and nitrogen source for microorganisms. This study focused on isolating and identifying microorganisms on media where the only carbon source was cationic flocculants. The number of microorganisms capable of degrading these flocculants was found to be limited.

Screening of growth curves for two microorganisms isolated on medium with cationic flocculant revealed that isolate No.1 was 1.8 and 1.7 times more efficient in degrading flocculants of the Mainfloc 5858 and Greenlife K-35 brands, respectively.

The use of 16S rRNA gene sequences to study bacterial phylogeny and taxonomy is a widely used method due to its effectiveness [8]. *Pseudomonas nitroreducens*, isolated from sewage sludge and identified using molecular techniques, is known for its ability to utilize the biocide 2-hydroxybiphenyl as its sole food source, this bacterium can degrade N-(3-oxododecanoyl)-L-homoserinlactone (OdDHL), enhance plant growth by stimulating cell development, and improve nitrate uptake [9, 10]. This makes *Pseudomonas nitroreducens* a promising biocontrol agent [11].

The biodegradation of two grades of cationic flocculant by the microorganism isolated from sewage sludge was found to be substantial. Polyacrylamide serves as both a carbon and nitrogen source for microorganisms. Different microorganisms have varying effects on polyacrylamide biodegradation. For example, *Bacillus* species isolated from contaminated soil and activated sludge of oil fields can biodegrade polyacrylamide up to 36.3% [12]. While a group of sulfate-reducing bacteria can improve polyacrylamide biodegradation up to 61.2% using PAM as the sole carbon source [5].

CONCLUSION

Polyacrylamide-based flocculants are widely used in wastewater treatment due to their effectiveness in forming large, dense, and compact flakes that facilitate sedimentation. These flocculants serve as both carbon and nitrogen sources for various microorganisms, enabling their growth and metabolic activities. However, the presence of polyacrylamides poses a challenge due to their resistance to degradation and potential environmental toxicity. The study's focus on isolating microorganisms capable of degrading these flocculants addresses a critical gap in wastewater management.

The study successfully isolated microorganisms capable of degrading cationic flocculants from sewage sludge sampled at wastewater treatment plants in the Republic of Tatarstan. The isolation was conducted on a modified Bushnell Haas (BH) medium, utilizing flocculants as the sole carbon source. Two isolates were identified, with Isolate No.1 demonstrating superior growth and biodegradation capabilities. The growth rate of the isolated microorganisms was evaluated over 14 days in the presence of cationic flocculants Mainfloc 5858 and Greenlife K-35. Isolate No.1 showed maximum growth, which was further confirmed by Sanger sequencing to be *Pseudomonas nitroreducens*. This microorganism exhibited remarkable efficiency in degrading the flocculants, achieving biodegradation rates of 61.5% for Mainfloc 5858 and 59.6% for Greenlife K-

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35, as assessed using the OxiTop system. The findings underscore the potential of using specific microorganisms, such as *Pseudomonas nitroreducens*, for enhancing the biodegradation of toxic components in wastewater treatment systems. The use of such microorganisms can significantly reduce the bound water content in sewage sludge, facilitating more efficient dewatering processes. This approach not only improves the safety and economic feasibility of sludge disposal but also enhances the overall sustainability of wastewater treatment plants.

The study opens avenues for further research into the optimization of conditions for microbial degradation of polyacrylamides. Future studies could explore the synergistic effects of using consortia of microorganisms to enhance the biodegradation process. Additionally, investigating the genetic and metabolic pathways involved in polyacrylamide degradation could provide deeper insights into improving the efficiency

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BEST AVAILABLE TECHNIQUES: CHALLENGES AND OPPORTUNITIES IN THE FOOD INDUSTRY

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ABSTRACT

The article considers challenges and opportunities of Best Available Techniques (BAT) in the food industry, analysing cases of intensive poultry rearing and milk production. Authors emphasise that the food industry is one of the primary sectors of the world economy. According to The Food and Agriculture Organization of the United Nations, by 2050, a 70% increase in world production will be required to meet the needs of the planets expected 10 billion population. The authors discuss the potential for further development of the sector applying BAT principles, including approaches to reduce energy, water consumption, and enhancing the environmental performance of food production processes. The article compares BAT-associated resource consumption and emission levels in the European Union (EU), Russia and India. The article emphases that there is a room for significant improvement of energy and water management practices in the sectors, both in Russia and India. Techniques to be considered for the practical implementation are described in the European vertical (sectoral) and horizontal Reference Documents on BAT (BREF) as well as in the new Russian BREF on Energy Efficiency. Authors note that wastewater from milk industries and even poultry farms is often treated by Municipal Wastewater Treatment Plants (MWWTP), and recommend application of both techniques and BAT-associated emission levels stated in the Russian Reference Document on BAT for Municipal Wastewater Treatment Plants in the developing countries.

Keywords: Best Available Techniques, food industry, dairy industry, poultry rearing, resource efficiency, environmental performance

INTRODUCTION

Food production and processing industry is one of the key sectors of the world economy. Due to continuous population increase, demand for food has created serious challenges for the governments around the globe in terms of resource efficiency enhancement, emission reduction and sound environmental management. If there is any

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chance to feed new generations while solving pollution and climate challenges, there is a need for environmentally sound solutions and technologies.

The Food and Agriculture Organization of the United Nations indicates that by 2050, a 70% increase in current food production will be necessary [1] to satisfy the needs of 10 billion population in developing and developed countries. The solution is to find ways to produce more food whilst using fewer resources (firstly water and energy) and simultaneously reducing various environmental emissions.

The concept of Best Available Techniques (BAT) is known as an instrument for regulating not only environmental performance and resource efficiency of the key resource-intensive industries such as steel, refining, chemical and cement production but also for food supply sector fundamental to meeting human needs [2].

The BAT concept was put forward in the 1960s and subsequently received an international recognition by various research schools in the Northern Europe, United Kingdom, Germany, United States of America, and Soviet Union [2]. The BAT-related solutions are usually associated with low-waste and cleaner industrial production, high resource efficiency, low pollutant and (since recently) greenhouse gas emissions. Besides, BAT principles are used to form industrial symbioses by closing the loop and returning industrial waste back into the production process and/or market as a product or raw material for another sector.

A distinctive feature of the BAT-related approach lies in establishing quantitative parameters for the resource consumption of technological processes and emissions of certain process-specific substances. These parameters are used as a basis for setting conditions for granting integrated environmental permits, developing environmental performance enhancement programmes and designing green projects [2, 3].

The food processing related sectors are chosen as in many regions they are listed among the critical drivers of growth and acknowledged as high priority industries by the governments. These sectors show strong potential for developing employment opportunities, generating income, while causing significant environmental impacts at the same time.

In various countries BAT-associated key environmental issues and resources efficiency parameters are usually described in specific BAT Reference Documents (the “BREFs”). BREFs contain descriptions of a range of industrial processes as well as the end-of-pipe techniques, BAT-associated emission and consumption levels. But most importantly, these documents identify sectoral BAT and emerging techniques, characteristic of the country or region.

The article aims at comparing approaches to (1) selecting key environmental issues, (2) identifying sector-related BAT, and (3) setting quantitative BAT-associated resource consumption and emission levels for major food producing sectors across various economies. It also discusses applicability of new approaches to enhance industrial resource efficiency and environmental performance.

MATERIALS AND METHODS

It is a common practice in various legislative frameworks [2, 3, 4] to include several food industry-related industries in the lists of sectors regulated by BAT: (1) food, drink

and milk industries; (2) intensive rearing of poultry and pigs; and (3) slaughterhouses and animals by-products industries.

In this article, we consider approaches to establishment of BAT-associated emission levels (BAT-AELs) and resource efficiency parameters for dairy production and poultry rearing in the EU, Russian Federation and India.

The process starts at collecting performance data provided by the sectoral enterprises or installations by designated agencies: Seville Bureau on Integrated Pollution Prevention and Control, Russian BAT Bureau or Indian Central Pollution Control Board. The installations receive special questionnaires prepared by the Technical Working Groups, fill them with the data on technologies implemented, resource consumption, and environmental performance and submit questionnaires back to the national Bureaus [2]. Benchmarking can be organised at both national (like in Russia or India) and regional (like in the EU) levels in order to establish BAT-associated environmental performance and resource efficiency levels as well as to form lists of the Best Available Techniques to be implemented by the regulated industries.

The most important part of the benchmarking process is to identify key environmental performance issues (or marker) parameters that are associated with the technological processes. These parameters form necessary basis for setting conditions of integrated environmental permits; they are included in environmental self-monitoring programmes, and compliance with them is reported to the environmental authorities [2].

The marker parameters and BAT-AELs for various sectors of the food industry discussed in this article are the international and national open-source data used for various environmental and technological regulation purposes, namely BREFs and similar standards.

RESULTS

Dairy industry

Being a vital source of nutrition for millions of people around the world, dairy industry has demonstrated a substantial growth up to 887 million tonnes in 2021. It was primary driven by increase of dairy herds and pasture availability in India and Pakistan; by 2031 these two countries will be producing more than 30% of world's share of milk [5]. It is expected that overall milk consumption to increase up to 21.9 kg by 2031 in developed countries like the EU or the Russian Federation and 5.4 kg in developing countries like India, Pakistan and African states, respectively [5].

The dairy production process is characterised by an extensive water consumption; foremost water is used on cleaning and disinfection purposes. As a result, industrial wastewater contains significant amounts of soluble organic matter, suspended solids, nitrate, nitrites, ammonia and phosphates as well as residues of cleaning agents.

Naturally, environmental authorities set requirements to wastewater treatment. Table 1 presents compiled data on BAT-associated emission levels set by the reference Documents on BAT for food, drink and milk in the EU (in 2006 and in 2019) and for Municipal Wastewater Treatment Plants in Russia (in 2019) and for milk industries (still under discussion, to be set in 2024).

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Table 1. Characteristics of Treated Dairy Effluents

Parameters	BAT-associated emission levels, mg per litre			
	EU, food, drink and milk industries, 2006 [6]	EU, food, drink and milk industries, 2019 [7]	Russia, milk industries, 2024 (tentative)	Russia, MWWTP, 2019 [8]
Biological oxygen demand, BOD_5	< 25	≤ 20	≤ 30	≤ 12
Chemical oxygen demand, COD	< 125	< 125	≤ 150	≤ 80
Total suspended solids	< 50	< 50	≤ 50	≤ 15
Total nitrogen	< 10	2-20	≤ 25	≤ 12
Total phosphorus	< 9	< 4	≤ 12	≤ 5

India has no official requirements to the treated milk industry wastewater composition, but open data show [9] that concentrations of marker substances vary a lot and can be quite high:

- biological oxygen demand: 40-4500 mg/l;
- chemical oxygen demand: 80-3300 mg/l;
- total suspended solids: 24-4500 mg/l.

Poultry rearing

The poultry rearing process refers to breeding of domesticated birds such as chickens, turkeys, ducks, goose etc. for farming meat or eggs for food. Chickens are most numerous and popular poultry species in most countries.

Broiler birds are raised especially for meat production and most commonly reared in a deep litter shed, where feed and water are given by hanging feeder and watering. Chicks are moved in the shed freely. Depending on the weight of the bird, the birds are sold for slaughtering from 40th to 45th days.

The most common pollutant emitted from the poultry farms during chick rearing process is ammonia [10, 11]. It is one of the most concerned substances in terms of air quality, environmental impacts, and manure nutrient losses. Hydrogen sulphide, ethyl mercaptan, dimethyl sulphide, methyl alcohol, sulphur dioxide and dust emissions are also formed in hen houses (during chick rearing and mixing and grinding various ingredients of feed) [10, 11]. In the EU, BAT-AEL is set only for ammonia. In Russia, environmental authorities tend to expand lists of marker parameters including malodorous substances (Table 2); in the United States of America, hydrogen sulphide emissions from the hen houses are also included into the list of key environmental issues [12]. This leads to additional costs for poultry farms and installations: the installations are required to monitor emissions of other substances in addition to measuring ammonia concentration.

Table 2. List of Air Emission Marker Parameters for Intensive Rearing of Poultry

Parameters	BAT-associated emission levels, kg per bird place per year	
	EU, intensive rearing of poultry and pigs, 2017 [10]	Russia, intensive rearing of poultry and pigs 2023 [11]
Ammonia	0.13-0.25	1.76
Hydrogen sulphide	n/a	0.27
Dimethyl sulphide	n/a	0.79
Ethyl mercaptan	n/a	0.002

DISCUSSION

Dairy industry

In the EU requirements to dairy wastewater treatment remained unchanged between 2006 and 2019. It is understandable as they are already quite strict, and technical and technological solutions for dairy wastewater treatment largely remain the same.

In Russia, sectoral Technical Working Group has been reviewing BREF for milk industries since January 2024. This is why Russian data presented in Table 1 are tentative; the official requirements will be adopted in October-November 2024. Still, it is already known that most industries do not discharge treated wastewater into natural waterbodies: they contract municipal wastewater treatment plants, which treat mixed wastewater and discharge treated effluents characterised by the BAT-associated emission BAT-AELs presented in Table 1.

Russian BREF for Municipal Wastewater Treatment Plants is a unique document prepared by national engineers and environmentalists in 2015 and reviewed in 2019 [8]; there are no analogues in the world. Back in 2020 this BREF was first discussed in BRICS. Considering strengthening collaboration of BRICS (BRICS+) countries, it can be recommended to use Russian approaches for treating dairy wastewater on Municipal Wastewater Treatment Plants in India. Moreover, Russian BREF can be used as a model for developing an Indian BAT-related guidance document or environmental standards.

Another challenge for large non-EU producers lies in reducing water and energy consumption by setting relevant resource consumption levels and developing approaches (including management systems) to achieve new, more progressive requirements [13].

Resource and energy consumption for food production sectors and its quantification is a complex issue. Technologies applied in this sector vary substantially depending on structural and production characteristics of the farms and plants [14].

Dairy processing is considered one of the most energy intensive sectors within the food industry. BAT-related specific energy consumption levels for installations located in developed countries are (in MWh per tonne of raw milk processed) [10]:

- for market milk: 0.1-0.6;
- for cheese and cheese projects: 0.10-0.22;
- for powder milk: 2.0-3.0;

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- for fermented milk: 0.2-1.6.

According to the information provided by the Russia's Technical Working Group producers of powder milk consume about 4.5-5.5 MWh/t. Similar parameter for cheese and cheese products varies from 0.12 to 0.30 MWh/t. Modern industries consume less than 0.1 MWh/tonne of raw milk processed.

In order to decrease energy consumption, it is recommended to implement an appropriate combination of (1) common techniques including cogeneration, heat recovery, reducing heat losses by insulation and various process control system under regulation and control, and (2) a set of sector-specific BAT including installation of energy-efficient homogenisers, regenerative heat exchange in pasteurization and ultra-high-temperature milk processing without intermediate pasteurisation.

Poultry rearing

BAT-associated level of ammonia emissions set in Russia is roughly 10 times higher than that in the EU. In the United States of America ammonia emissions from broiler farms vary from 0.15 to 1.0 kg per bird place per year [12]. The primary ammonia emission influential factors include poultry housing systems, seasonal changes, feed management, bedding materials, animal densities, and animals' activities. These factors can impact both indoor air quality and emissions [10, 11, 12, 15]. Thus, it is viable to organise special sectoral studies to understand better difference in emission levels and opportunities for environmental performance enhancement.

There are no available open data on BAT-associated air emission levels for Indian poultry, nevertheless, there are marker parameters established in the sectoral guidance documents [16]: (1) ammonia and hydrogen sulphide gaseous emissions from hen houses and (2) dust generated from the feed mill operation during mixing and grinding of various feed ingredients.

Based on the EU experience, it is prudent to analyse applicability of such measures as manure removal by belts (in case of enriched or unenriched cage systems), forced ventilation system and infrequent manure removal, and use of an air cleaning system (for example, wet acid scrubber) [10].

Wastewater treatment wise, it is advisable to minimise water usage, segregate rainwater from wastewater streams that require treatment. Segregation can be carried through implementing separate collection in a form of properly designed and maintained drainage systems. Wastewater can be treated by sedimentation and/or biological treatment. Wastewater with a low pollutant load can be treated by the means of swales, ponds, constructed wetlands, soakaways, etc. Wastewater streams can be settled in ponds or lagoons, before landspreading [10].

Thus, for developing countries it is critically important to perform additional analysis of technological processes of poultry farming described by the European and Russian BREFs and consider establishment of an additional marker, typical parameters suited for the national technological processes.

CONCLUSION

Concept of the Best Available Techniques is a staple for establishing quantitative parameters for assessing environmental performance and resource efficiency of various food production sectors around the world.

Procedures for development and review of the BREFs are quite similar in most countries and consist of several steps: (1) data gathering on environmental performance and resource consumption of all installation in a given industrial sector; (2) benchmarking procedure; (3) establishment of marker parameters and BAT-associated emission levels, environmental performance and resource efficiency levels.

There are certain challenges that should be addressed while developing and reviewing BREFs for food-related sectors: (1) need to further develop energy and water consumption levels associated with the BAT in order to increase industrial resource efficiency; (2) need to refine methodology for setting marker parameters for every industrial process within the BAT implementation area.

These challenges shall be addressed by policy-makers and research institutes while reviewing environmental, industrial and food policies.

Due to the fact, that the sectoral BREF for Municipal Wastewater Treatment was prepared, reviewed and is being used only in the Russian Federation, it can be recommended as an example for the Republic of India and other developing economies [17]. BRICS countries started discussing opportunities for learning from the Russian experience in the field of Best Available Techniques back in 2020, and Russian presidency in BRICS in 2024 opens up large potential for the practical steps in this area.

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CHALLENGES AND RISKS OF GEOTOURISM DEVELOPMENT ON THE EXAMPLE OF THE FORMER MINING REGION OF THE CENTRAL SPIS IN SLOVAKIA

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ABSTRACT

The aim of the paper is to highlight the potential of old mining regions for the development of geotourism. The region of Central Spiš was known for its long-standing mining and industrial activity. In the 1990s, a decline regime began, mining activities gradually ceased and the mines were closed. The region subsequently experienced an economic and social decline. The mining areas, mining buildings and facilities have been preserved in the individual villages. Mining landforms are also preserved, both on the surface and underground. Due to their rich mining history and preserved technical heritage, the sites under study have significant potential for the development of geotourism. There are other sites in their vicinity that are suitable for tourism development and should be linked into a broadly conceived offer. It is important to mention that there are also certain risks and threats which require a more in-depth analysis and assessment of their negative impacts. The result of our analysis is a passporting of the individual impacts and a subsequent assessment of the positive and negative impacts on geotourism development.

Keywords: geotourism, challenges, risks, mining landforms, central Spiš region

INTRODUCTION

The Spiš region has a rich mining past At the time of the greatest boom, both villages were built. Rudňany was one of the most prosperous villages in the region [7]. In addition to prosperity, mining caused negative impacts on the landscape. The whole area is contaminated with heavy metals [1], there are a large number of mining landforms in the landscape, which put a special burden on the environment [6], [8]. Significant negative elements are the Markušovce tailings impoundment and the Baniská undermined area [3], [5]. In the 1990s, the process of mining decline in Spiš began. With the decline of mining, the villages also declined. Later on, mining activity stopped completely and with it came the first problems. The undermined territories fell into disrepair, buildings fell into disrepair [4]. On the other hand, it is essential to preserve the mining heritage, both the mining forms in the landscape and the mining technical monuments [9]. There is also an immense amount of natural and cultural heritage in the area.

MATERIALS AND METHODS

We used several methods in the preparation of the article. In the preparatory phase, we collected, studied and processed the literature. In the implementation phase we paid attention to field methods. In the field we applied methods such as mapping,

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observation and photo documentation. Important documents were reports from the Dionýz Štúr Geological Institute. In the final stage, we processed the collected data and created maps, which were the output of the field research. Also the output of the research are photographs that compare the situation in the past and today. Based on the data, in the last part of the work we created a SWOT analysis, which helped us to show the further possible development of the villages.

STUDY AREA

Rudňany is located 15 kilometres east of Spišská Nová Ves in the Hnilecky Hills, which are part of the Slovak Ore Mountains and since its foundation it has been connected with mining activities. The area of the municipality is 13.63 km2, the population is 4999 (31.12.2023) and the population density is 366.76 inhabitants per km². The altitude of the village ranges from 475 m a. s. l. to 959 m a. s. l. For almost 700 years of mining, approximately 42 million tonnes of ore have been mined in Rudňany. In the 70-80s it was the largest underground ore plant in the former Czechoslovakia [7].

The village of **Poráč** is situated in the Hnilecky Hills, which are part of the Slovak Ore Mountains. It is the highest village in the Spišská Nová Ves district with an altitude of 778 m a. s. l. The area of the village is 18.85 km2, the number of inhabitants is 1009 (31.12.2023) and the population density is 53.53 inhabitants per km².

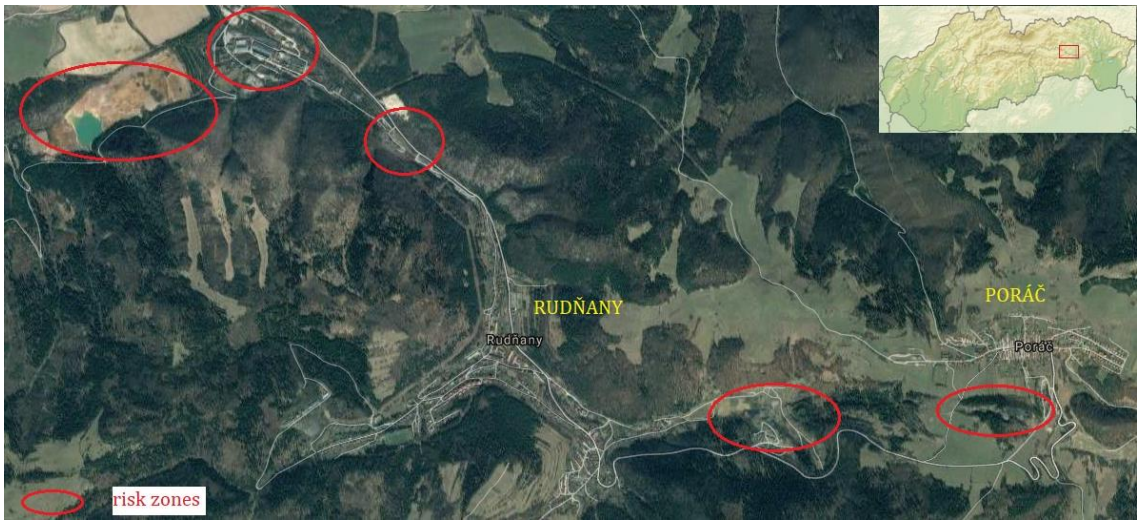


Fig. 1 Spatial distribution of the villages Rudňany and Poráč
Source: own processing, maps source: https://earth.google.com

NEGATIVE BARRIERS TO THE DEVELOPMENT OF THE RUDŇANY-PORÁČ AREA

The Baniská cave area is located between the villages of Poráč and Rudňany. It is approximately one kilometre long and its width varies from 15 to 65 metres. Its character is linear. The Baniská area is one of the most affected areas in the Poráč-Rudňany deposit. Due to the geological instability of the area, it is regularly monitored and geodetic measurements are carried out at certain time intervals. Measurements between 1997 and 2007 have shown that the decline is continuing, with an increasing

tendency to collapse. Over the period of the measurements, the average subsidence has reached 200mm/year. Based on these results, it is recommended to continue the measurements with a 10-year interval [4], [6]. The last collapse was on 21/9/2009, forming a circular crater with a diameter of 25 to 30 meters and a depth of 400 to 500 meters. Its formation was accompanied by strong waves and noise, which was felt by the inhabitants of a Roma settlement 500 meters away from the area. Geological reports in 2010, 2011, 2012 showed that no new collapsed area was detected in the area [2]. The accompanying phenomena of these collapses are the destruction of soil resources and vegetation cover, and the disruption of the habitats of many animals [1].

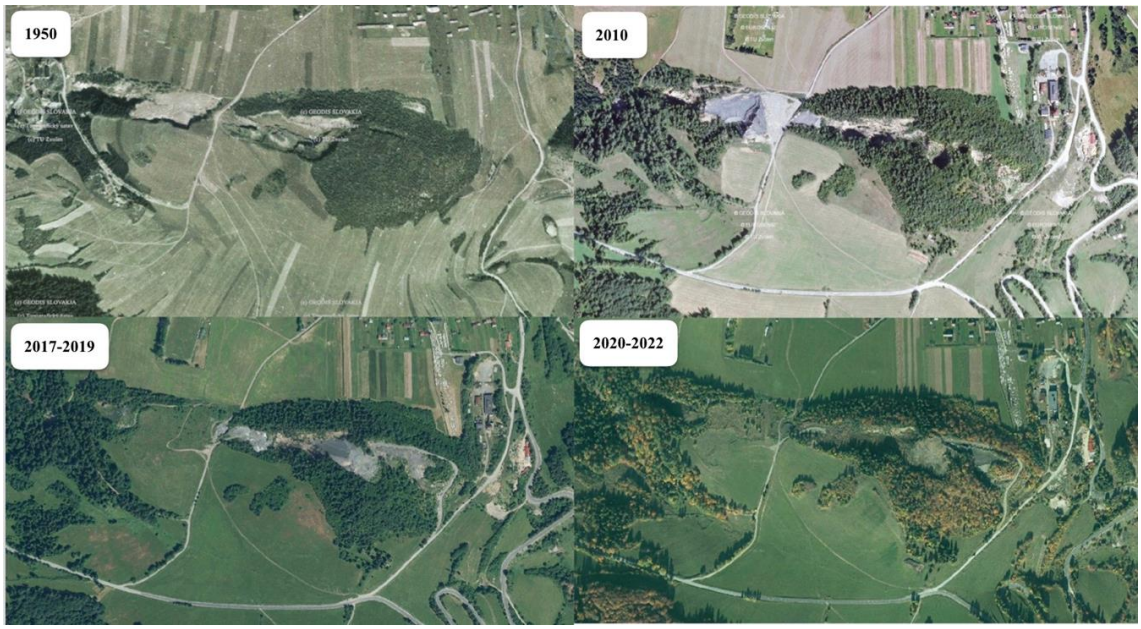


Fig. 2 Spatial changes of the undermined area “Baniská”
Source: own processing, maps source: https://earth.google.com, https://gis.tuzvo.sk

Another negative impact in the study area is represented by the locality "Pätoracké", where the Roma community lives. It is located on the edge of the collapse zone. This part of the village used to house the entire community system and the municipal office. In 1970, as a result of mining activities, people were evicted from this part. But the local Roma gradually started to build illegal dwellings in this area. However, with the efforts of the municipal authority, some of the inhabitants have been moved out of the cave-in zone, but some still inhabit this dangerous zone.





Fig. 3a Roma settlement "Pätoracké" **3b** Hills "Stôžky" behind the mercury plant
Source: terrain research

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POTENTIAL OF THE TERRITORY OF THE RUDŇANY AND PORÁČ MUNICIPALITIES

At present, there are positive aspects to the area in addition to the negative impacts of mining activities. A **historical mining trail** has been created in the village of Rudňany. On the route there are important mining objects which are connected with the mining past in the village. Perhaps the most famous object is the portal of the Rochus adit, which has been a National Cultural Monument since 1973. The second object is the Church and Chapel of St. Clement, the bell tower. A Memorial to the victims of fatal work accidents is erected in the main cemetery. The Rudňany Mining Archive was opened on 9.9.2004 with the help of the municipality and the Rudňany Miners' Guild. The seventh stop on the mining trail is the Západ mine and the Mier shaft, which is registered as a national cultural monument. In the area of the Západ Mine and the Mier shaft there is the Terézia adit. The last object is the portal of the Križová adit.



Fig. 4 Locations for the development of geotourism in the Poráč village
Source: https://naucnechodniky.eu/poracsky-banicky-chodnik/

In the village of Poráč there is **the Poráč mining trail**, which consists of three circuits. The first circuit starts and ends in the recreation centre near the Pavol adit. It is at this place that the mining museum "*The Poráč Mining Company*" is located. The second circuit is enriched by the Jozef adit, which is already located in the western part of Baniská. The third circuit includes the connection of all the tunnels. In addition to the varied mining past, the village of Poráč attracts tourists with the ski resorts Poráč Brodok and Poráčska dolina, where there is also a recreation centre Poráč Park. For children there is an interesting water attraction called *"Let's play at miners"* which shows how water was used in the mining industry.

RESULTS – SWOT ANALYSIS

The studied sites have a high potential for geotourism development due to their rich mining tradition and the uniqueness of the natural environment. There are also risks resulting from long-standing mining activities - undermined area, heaps, tailings, etc. We have used swot analysis to evaluate their positives and negatives and point out its development potential.

Tab. 1 SWOT analysis of the Rudňany yillage

INTERNAL ENVIRONMENT			
STRENGTHS	Points	**WEAKNESSES**	Points
Rudňany:		*Rudňany:*	
natural potential	5	polluted stream	3
high population	4	inadaptable Roma	4
sufficient space facilities	3	heaps	3
activity of the inhabitants	4	undermined area	3
health centre	2	tailings	3
developed infrastructure	3	insufficient school facilities	2
miners' guild	5	homeless	3
qualified inhabitants	3	lack of job opportunities	4
updating the website	4	high number of unemployed	4
preserved traditions	4	poor services	2
active mayor	4		
good school facilities	3		
favourable geographical location	4		
TOTAL:	**48**	TOTAL:	**31**
EXTERNAL ENVIRONMENT			
OPPORTUNITIES	Points	**THREATS**	Points
Rudňany:		*Rudňany:*	
mining museum	5	absence of development documents	5
revitalisation of the village area	4	rapid increase in the Roma population	5
solving the Roma issue	5	the departure of young people for work offers	4
interest in the village as a potential mining village	3	weak support from the government	4
creation of suitable conditions for socially disadvantaged inhabitants and for young families	4	landslide	4
		criminality	5
cooperation between the municipality and the local government	3		
TOTAL:	**24**	TOTAL:	**27**

Source: own processing

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Tab. 2 SWOT analysis of the Poráč village

INTERNAL ENVIRONMENT			
STRENGTHS	Points	**WEAKNESSES**	Points
Poráč:		Poráč:	
advantageous geographical location	4	decline in the number of young people	4
all year round tourism	4	lack of job opportunities	4
ski resort, cross-country skiing trails, cycling routes	4	undermined area	3
protected areas	4	heaps	3
significant archaeological sites	3	weak support for small and medium-sized enterprises	2
recreation centre	4		
reconstructed centre of the village	5	a lack of government funding	4
mining museum	5		
updating the website	2		
handicraft development	4		
TOTAL:	**39**	TOTAL:	**20**
EXTERNAL ENVIRONMENT			
OPPORTUNITIES	Points	**THREATS**	Points
Poráč:		*Poráč:*	
improving the pension situation of the population	3	poor promotion	4
improving quality of life	4	proximity to other (tourist) centres	3
raising living standards	4	young people leaving for work offers	5
mining museum in the premises of the mine	5	absence of development documents	4
completing the infrastructure	4		
TOTAL:	**20**	TOTAL:	**16**

Source: own processing

In the case of Rudňany we see **a defensive strategy**, which confirms that the municipality should use all its strengths against potential threats. The municipality can build on its mining history, which can attract tourists. For Poráč, we came up with an **offensive strategy**. There are two ski resorts and a recreation centre. Tourists are also attracted by its mining history, in which both villages are the same. Another advantage of Poráč is the long-standing festival in honour of mining called "*Šachtare volajú*", which is known in the region for its 30-year history. In the future, the municipality may make the Poráč mine building available for use as a mining museum.

DISCUSSION

The Spiš region suffered significant losses after the end of mining activities, as opportunities for young people left with mining. One of the problem areas is the settlement of 'Pätoracké'. The inhabitants have been moved to new flats built by the municipality with the help of the state. With hindsight, we can say that this problem was not solved by the relocation. The inhabitants of the settlement continue to build illegal dwellings in the cave-in zone. The only access road to the village of Porac is also located in this area. The development of the problem of illegal constructions in the cave-in zone is at an unsolvable stage. Rudňany, despite its rich mining past, is not popular with tourists. The reason for this is the high number of maladjusted citizens, who undermine the attractiveness of the village. The reason why Rudňany is not popular in the tourism sector is also the fact that it has no tourist attraction apart from mining. Despite the problems, Rudňany has made great strides in recent years. In addition to the construction of new housing in the village, there is also a new community centre for the elderly. The municipality also has a problem with high crime rates. These reasons put the municipality of Rudňany in a worse position in our SWOT analysis.

In the village of Porac, mining also affected the lives of the local inhabitants. The main problem is the lack of young people. The local population is slowly dying out, but due to the more attractive environment there is a high number of immigrants. In addition to its mining past, the village has a recreation centre which is popular. Two ski resorts help tourism development. The largest is the road to the village, which passes close to the problematic Roma settlement of Pätoracké. In our SWOT analysis, despite an almost similar mining past, the village of Poráč fared better. The village has a significant potential for geotourism development. The premises of the Poráč mine building are being transformed into a mining museum, which will be open to the general public.

CONCLUSION

The undermined area Baniská is the most prominent negative element in the landscape. The belt is divided into several parts. The western part closest to the village of Rudňany has already been stabilised. According to geologists, between 2018 and 2021 there was no landslide in the area and so they describe it as temporarily stabilized. A similar case is also in the central part. This part is the most extensive part in terms of area. At present, it is completely buried not only by ash but also by soil and is covered by vegetation. Despite reclamation, this area is not completely safe. There are continuing landslides in the eastern part, which is the only one not filled to the original level. The entire cave zone of one kilometre has been filled in with power plant fly ash. Fly ash was delivered to Porac on a daily basis by heavy goods transport, which contributed significantly to the subsidence of the road. A bigger and longer-term problem was the wind, which carried the fly ash around the village. Dirty houses, pavements, cars and the whole village under a fine layer of ash. Eventually the problem was solved by bringing in soil and completely filling in the area of the cave-in.

Natural conditions were also disturbed at the other end of the village of Rudňany. In addition to the Baniská, there is a tailings pond in the region. The western part of Rudňany is affected by this particular form of mining, which is caused by the former mercury. In front of the village there are three hills called 'Stožky', which were the most affected area in the surroundings. In hindsight, we can now say that the area has been

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successfully reclaimed, as the hills are now almost completely covered with forest vegetation. This is where the municipality of Porac is in a better starting position in the process of municipal development. In the surroundings of Poráč we can find beautiful nature, whether it is the well-known natural destinations. The nature of the village has not suffered as much damage as the nature around Rudňany. The exception is the often mentioned Baniská area. Despite this, Poráč is a popular location for geotourism, which is indicated by the fact that the municipality is working on making as many tunnels accessible as possible. Mining has been part of the village and the whole region, it is important to preserve its heritage for future generations and to develop its potential for tourism.

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COMPARATIVE ANALYSIS OF WATER POTENTIAL MEASUREMENTS AND CLIMATIC DATA IN SLOVAKIA

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ABSTRACT

In our study, we used the measurement of water potential using a pressure chamber, and we compared the collected data with the data from the Nove Zamky meteorological station for the period 21.6.2023 - 22.8.2023. The aim of the work was to compare the data collected using water potential measurements from two locations in the Nove Zamky area with the corresponding meteorological data collected from the meteorological station also located in Nove Zamky. After data collection, we then determined whether the technology of water potential measurement using a pressure chamber can capture changes in the different water regimes of the area and whether it can be used in the future in the context of soil moisture regime management. The amount of water available to a plant can be monitored using the water potential, which indicates the potential energy used by plants to fix water in plant tissues. For these measurements we use a portable, pressure chamber designed for leaf water potential measurements. The pressure chamber creates a space in which we can adjust the pressure values up to the point at which the leaf releases the water from the wefts. Most of the leaf is contained within the enclosed environment of the chamber and only a small part of the stem is exposed to the external environment through a flexible seal located on the top cover of the chamber. The pressure required to form a drop of water on the cutting surface of the petiole is an indication of the energy required to keep this drop in the leaf. High pressure to expel a drop of water from the leaf sheath indicates high tension and water stress in the plant. Pressure measurements are expressed in pascals. The experiment took place in two walnut orchards in Nove Zamky. The subjects of the measurements were 20 trees of the species Royal Walnut *(Juglans regia)*, which were divided into four rows, with 5 trees in each row. In the first walnut orchard there were 15 measurement subjects and in the second orchard there were 5 trees that were subjected to leaf water potential measurements. We collected 3 leaf samples from each tree, which were then analyzed using a pressure chamber. The values of all measurements for a particular day were then averaged, and the result was taken as an indicator of the average leaf pressure on the day of measurement for the Nove Zamky area. These values were then compared with the data from the weather station, namely with the average daily temperature, average precipitation and humidity. The

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results show us that the water potential measurements are in partial agreement with the meteorological data presented. Therefore, we can conclude that the chosen method is able to capture changes in the water regime of a given plant and can be further used as a suitable tool in the management of the soil moisture regime.

Keywords: water potential, climatic data, walnut trees, drought stress

INTRODUCTION

Stress is a major challenge in efforts to enhance crop productivity. Among abiotic stresses, drought is one of the most critical factors because it impacts the morphology, physiology, ecology, biochemistry, and molecular characteristics of plants. Drought is a broad term with varying definitions across different fields. Biologically, drought stress manifests as a reduced water potential in plant tissues due to a soil moisture deficit (hydrological drought) resulting from prolonged dry conditions. In precision agriculture, drought is defined as a period of water scarcity leading to soil moisture deficit, ultimately negatively impacting crop yields. While the primary cause of drought is lack of rainfall, other climatic factors, such as temperature, also contribute. Additionally, non-climatic factors, including human activities, land cover, and soil type, can influence water availability [1]. Prolonged drought is regarded as one of the most destructive natural hazards, contributing to economic burdens and social issues. Overall, up to 92% of water consumption is attributed to agriculture [2]. The 21st century has witnessed several drought events around the world during its first two decades [3-4]. Arid and semi-arid regions are confronting significant challenges concerning water availability. The demand for water is projected to rise due to climate change, which will negatively impact crop production. Furthermore, climate change is anticipated to alter rainfall distribution, affecting both irrigated agricultural land and rain-fed areas [5]. Among other things, drought can also have a negative impact on soil microorganisms, which can lead to reduced enzyme activity, loss of nutrient cycling (e.g. C, N, P), loss of soil fertility and thus loss of plant productivity, especially for crops sensitive to this stress factor [6]. Drought impacts not only aboveground carbon (C) processes, but also soil carbon stocks by altering the carbon supply from aboveground and belowground biomass and carbon outputs from soil organic matter (SOM) mineralization [7]. Given that soil is the primary carbon sink in terrestrial ecosystems, even little reductions in soil carbon can result in large increases in atmospheric carbon. An increase in soil C losses has a beneficial effect on global warming [8]. In the study of plant stress, stress is characterized as any adverse environmental factor that affects living organisms, and stress tolerance is defined as an organism's ability to survive under such conditions. These conditions or stresses can be either biotic or abiotic [9]. Drought represents one of the most serious abiotic stressors, and challenges for agricultural productivity, significantly impacting growth. Drought disrupts numerous physical and biological processes, hindering plant growth and development. Although plants can often endure water-limited conditions, this resilience comes at the cost of substantial loss of overall biomass and productivity [10].

MATERIALS AND METHODS

Field measurements were conducted at the experimental site of a private walnut orchard located in the cadastral area of Nove Zamky (47°59′49″N; 18°11′26″E), at an elevation of 115 meters above sea level. This site is situated in the southern part of the Nitra region, in the western part of the Slovak Republic, and is part of the Danube Lowland, specifically the Novozamocka plain, according to Slovakia's regional geomorphological division. Soil morphological studies conducted by the Slovak University of Agriculture in Nitra in 2017 identified predominantly calcareous chernozems with a clay texture in this area. This soil contains 1.61% organic matter and has a humus layer pH range of 5.6 to 6.5 at a depth of less than 0.09 meters. Climatically, the experimental site is classified as a warm and very dry area with moderate winds. It is one of the driest and warmest regions in Slovakia, with an average annual air temperature between 9 and 10 °C, an average air temperature of around -2 °C in January, and 20 °C in July. The average annual rainfall in this area ranges from 500 to 550 mm (30-40 mm in January and less than 60 mm in July), while the average annual evapotranspiration is between 700 and 750 mm. During the winter months, snow cover on the soil surface lasts less than 40 days and does not exceed 200 mm.

The experimental plant used was the Royal Walnut *(Juglans regia L.),* a thermophilous tree with a massive crown. This species is widespread throughout Slovakia up to an altitude of 900 m. Its root system is deep and branched, allowing efficient absorption of water and nutrients from the soil, which is essential for its growth and development, especially in moisture-limited conditions. With excessive irrigation, trees are susceptible to root rots such as Phytophthora spp. [11].

The main analytical equipment was a Model 670 pressure chamber from Edaphic Scientific, which is specifically designed to measure water potential in large leaves and small shoots. It has a chamber diameter of 100 mm and a depth of 180 mm, making it suitable for larger samples. The instrument comes standard with a compression cavity sealing system that features a 1/2-inch compression cavity seal and liner. This model is recommended where large sheets need to be worked with, as a significant amount of nitrogen is required to fill its large chamber. A weather station situated within a walnut orchard recorded meteorological data. We mostly used daily rainfall totals and average daily temperatures for our purposes. The experiment consisted of water potential measurements using a pressure chamber, and we compared the results with data from the corresponding weather station. The subjects of the measurements were 20 trees of the species Royal Walnut *(Juglans regia),* organized into four rows with five trees in each row. In the first walnut orchard, 15 trees were measured, while in the second orchard, 5 trees were subjected to leaf water potential measurements. We collected 3 leaf samples from each tree, which were then analysed using a pressure chamber. The values of all measurements for a particular day were averaged, and the result was used as an indicator of the average leaf pressure on the day of measurement for the Nove Zamky area. These values were then compared with data from the weather station, specifically the average daily temperature, average precipitation, and humidity.

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RESULTS

The study analyzed the relationship between the water potential in walnut leaves and various weather parameters, including precipitation, temperature, and humidity. The daily precipitation data revealed significant variability. Notable increases included June 23, June 27, July 1, July 5, July 10, and August 17. The largest single-day decrease, aside from the 100% drops, occurred on August 18 with a 98.90% reduction from 27.2 mm to 0.3 mm. Moderate changes included a 125% increase on June 28 and a 66.67% decrease on July 13. Overall, the precipitation data exhibited a pattern of sharp increases followed by substantial declines, indicating high variability in daily measurements. Temperature changes were more consistent compared to precipitation but still exhibited fluctuations that influenced the water potential in walnut leaves. The most significant percentage increases occurred on July 24, 2023 (23.91%), and the most substantial decreases occurred on July 25, 2023 (-24.21%). July 26, 2023, and August 6, 2023, also saw large decreases of -20.83% and -19.25%, respectively. The humidity data from June 21, 2023, to August 22, 2023, showed notable fluctuations. The largest increase occurred on July 21, 2023, with a 51.72% rise from the previous day. Conversely, the most significant decrease was observed on June 25, 2023, with a 17.11% drop from June 24, 2023. Throughout the period, humidity changes were frequent, with both increases and decreases occurring in close succession, highlighting a period of instability in humidity levels. The average daily percentage change was relatively moderate, indicating a general trend of variability rather than stability. As for the water potential, notable changes include decrease of 43.48% from June 21 to June 27, followed by increase of 93.04% from June 27 to June 30. Subsequent fluctuations were observed, with a notable increase of 42.66% from July 3 to July 6 and a decrease of 35.32% from July 31 to August 3. The highest recorded increase was 93.04% between June 27 and June 30, and the highest decrease was 43.48% between June 21 and June 27.

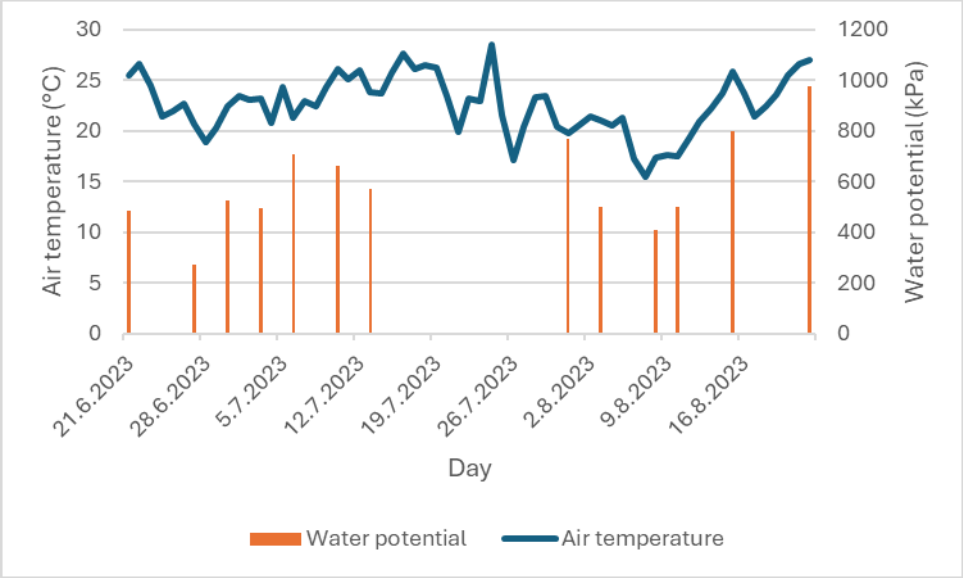


Figure 1 Comparison of average air temperature with leaf water potential changes

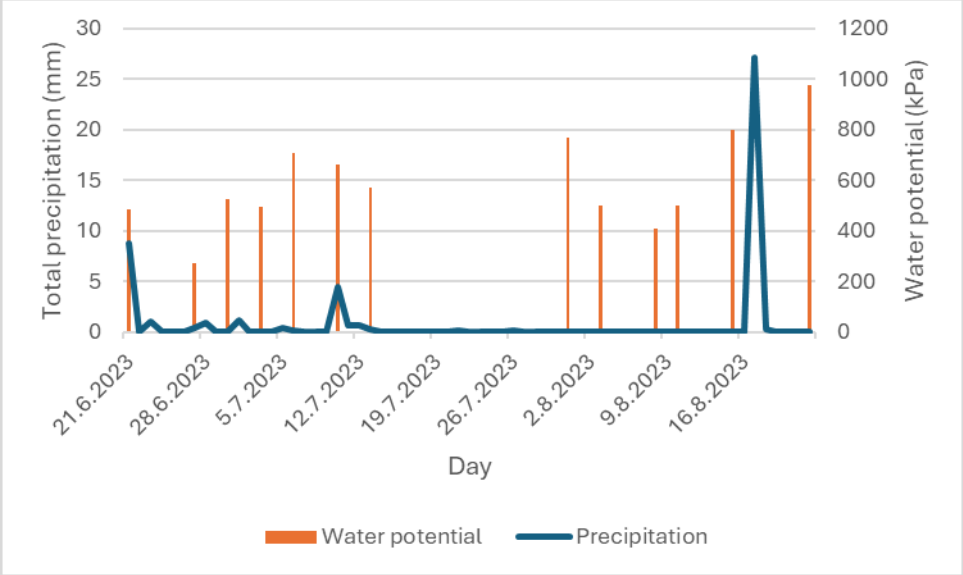


Figure 2 Comparison of rainfall totals with leaf water potential

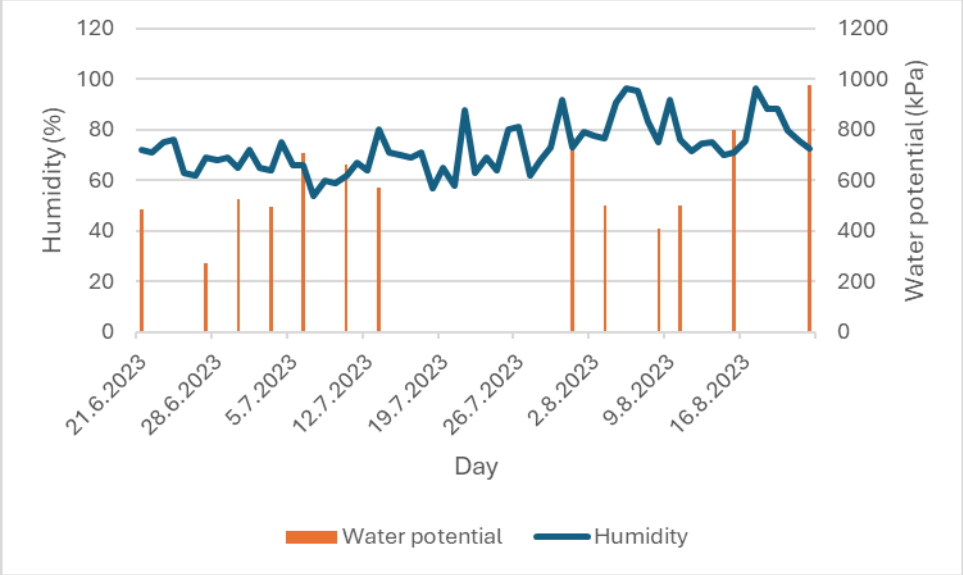


Figure 3 comparison of air humidity with water potential in the leaves

DISCUSSION

The study demonstrates correlation between leaf water potential measurements in walnut trees and climatic parameters such as precipitation, temperature, and humidity. Using a pressure chamber effectively captured the dynamic water regime of the trees, reflecting environmental variations throughout the study period. Significant decreases in water potential, such as the 43.48% drop from June 21 to June 27, were linked to reduced precipitation and higher temperatures, indicating increased water stress. Conversely, a 93.04% increase from June 27 to June 30 was associated with subsequent rainfall, alleviating water stress. The findings suggest that water potential measurements can complement meteorological data, enhancing agricultural water management by

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providing insights into plant responses to environmental stress. This integrated approach is particularly useful in drought-prone regions.

CONCLUSION

This study explored the relationship between leaf water potential in walnut trees *(Juglans regia)* and various climatic parameters, including precipitation, temperature, and humidity, in the Nove Zamky region. The findings indicated noticeable variability in water potential values, which corresponded to fluctuations in weather conditions. The water potential values showed notable changes, with the most substantial increase of 93.04% occurring between June 27 and June 30, and the most significant decrease of 43.48% from June 21 to June 27. These fluctuations were aligned with the observed variations in temperature, precipitation, and humidity during the study period. Specifically, the data revealed that sharp increases in precipitation often preceded significant increases in water potential, while high temperatures and low humidity were associated with decreases in water potential. The results support the hypothesis that water potential measurements using a pressure chamber can effectively capture changes in the water regime of walnut trees, reflecting the impact of varying climatic conditions. This method proved to be a reliable tool for monitoring plant water status and can be beneficial for managing soil moisture regimes, especially in regions susceptible to drought. The observed correlations between meteorological data and water potential measurements suggest that integrating these methods could enhance the precision of agricultural water management practices. Future research should aim to refine these measurements and explore their application across different crop species and environmental conditions to further validate their effectiveness in sustainable agriculture.

ACKNOWLEDGEMENTS

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CONTEMPORARY MORPHODYNAMICS OF THE RIVER CHOROKHI DELTA ON THE BLACK SEA EAST COAST

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ABSTRACT

The River Chorokhi delta is located in the southeastern part of the Black Sea, including Batumi city with its coastal part, which today is heavily washed away. Until the 90s of the 20th century, its litho- and morphodynamic peculiarities were mainly conditioned by the solid runoff of the Chorokhi River. Before the construction of dams in Turkey, its volume was 2.5 million m³/per year. In the last 25 years, due to the dams built in Turkey, solid runoff has been catastrophically reduced by 60 times. Also important was the river-sea mouth migration. In the last century, as a result of the construction of a spur on the Batumi cape and the stopping of the alongshore sediment transport, the beach sediment was accumulating in both the above-water and underwater parts of the shore. As a result of upper limit accumulation of material, it is periodically deposited at great depths of the adjacent submarine canyon. There was clearly marked the trend of constant retreat with different rates of entire coastal part of the Chorokhi River delta, towards the land.

It is necessary to remove the excess material accumulated near the Batumi Cape and artificially deposit it in other damaged areas as necessary so that the deep submergence of the distal part of the cape provoked by the 1999 earthquake in this area does not happen again. In modern city-building and agricultural activities, the peculiarities of local morphodynamics are often not taken into account. All this, against the background of the rise of the world ocean level, poses a serious threat to the coastal environment. In the conditions of the extreme shortage of solid runoff of the Chorokhi River, in order to preserve the coast, it is necessary to develop methods appropriate to the existing situation.

Keywords: sediment transport, morphodynamic, submarine canyon, technogenic impact

INTRODUCTION

Coastal zone of Choroki River delta located in the south-east part of the Black Sea is characterized with extremely complicated geo-environmental parameters. Upon completion of Holocene transgression, in Georgia, at the estuaries of large rivers powerful accumulation zones were formed.-[1],[2] one of such areas is the coastal part of Chorokhi River delta. Actually, City of Batumi occupies almost entire northern part of the delta. Here are the beaches of gravel-pebble-sand composition. Regarding current rapid climate changes and increasing elevation of the sea level, as well as strong anthropogenic impact, the accumulative formations are relatively easily washed out [3], [4]. Heavy geo-

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ecological condition of the Black Sea shores is also emphasized in works [5], [6], severe hydro-meteorological situation at Black Sea coastal region of Georgia [7] A. Kikava et al., [8] and since 1984, there was recorded certain elevation of the sea level and re-activation of force 7 storms. Work [9] showed that in Black Sea coastal region of Georgia, impact of the technology-related factor has exceeded normal in the 20th century. Specifically, the following natural factors impact the object of research: geological structure, tectonics, sea eustatic fluctuations and significant solid runoff of Chorokhi River – 2.5 million m³/year before construction of the dams [10]. Construction of Batumi port in the second half of 19th century caused dramatic changes of morpho- and lithodynamics of the adjacent coastal zone. Regarding peculiarities of local morphpdynamic processes, i.e. powerful alongshore sediment transport, permanent sanding of the port area took place. Therefore, to stop this process, in 1906, to the south from the port, at 70° azimuth, 170 m long r/c spur was constructed. As a result, the port sanding has stopped, in turn, immediately to the south, width of the beach increased drastically and accumulated material periodically displaced from the shore and underwater slopes towards the greater depths [2], [11], [12].

Construction of the hydropower stations in Chorokhi River basin in the end of 20th century and resulting almost entire stopping of the solid runoff to the sea have particularly significant impact on the morphodynamics of the sea shores [13].

Regarding the heavy geo-environmental situation, further challenge is to maintain the sea shore relief and environment, to greater or lesser extent, in the conditions of very powerful anthropogenic impact and identification of the possible mitigation measures.

In the 20th century and especially in its second half, for the construction and other purposes, tens of million cubic meters of the materials were withdrawn from the beaches. According to the data of Georgian National Environmental Agency, only since 1972, annually 600000 m³ material was extracted from the bed of Chorokhi River. Extraction of the material from the river bed continued event after construction of the dams, i.e., after development of the irreversible process. Before, in the second half of 19th century, construction of Batumi Port had significant impact as well.

MATERIALS AND METHODS

The survey area is located in the south part of Black sea coast Georgia. There is complex interaction between natural and anthropogenic systems. In the research process the cartographic, geodesic, aerial-cosmic, comparative geographic, lithological, general scientific methods, processing of the historical materials (maps and other archive materials) were applied. Bathymetric mapping of the underwater slope was conducted. It was researched with the aqualungs and other sea equipment, also, images of the underwater slope were taken using the sonar equipment.

RESULTS

Georgian Black Sea shore, even in case of the best scenario of contemporary climate changes, faces significant challenge. Global warming only aggravates the existing and expected problems. Primarily, this affects the future litho- and mothphodynamics of the sea shore. It should be also mentioned that the relief close to the current one and hence, similar climatic conditions were formed in the conditions of the most recent

transgressions of Black Sea, 5-6 thousand years ago [1]. Human's decisive role in contemporary climate and environment change is emphasized in work [14] and this can be seen apparently on the Black Sea shore in Georgia. Since end of the 18th century, precise maps of the eastern coastal region were developed [2] Fig.1. Fig.2. and this, together with the modern research methods, allow development of the forecasts of the shore development. Before wide and drastic interference into the natural environment, the beach-building sand-pebble-gravel material from Chorokhi River, occurred at the river mouth created the alongshore flow. Under the influence of the dominating south-west-west storms moved to quite far distances to the north and reached Natanebi River mouth, located in 40 km. Svishevski cartographic materials of 1832, Map [2], show that Chorokhi River flowed into the sea as two main branches: southern branch – in the area of current Chorokhi River mouth and the northern one - Mejina River (3.2 km to the north from current Chorokhi River mouth). On the map of 1890, the system of the northern branch has disappeared (it is not visible any more) and in its place, there is Mejina River mouth [2] article Russo et.al, 2023, map]. Thus, by the end of 19th century, the new estuary moved to the immediate vicinity of the head of Chorokhi submarine canyon. As a result, the process of loss of the main part of the beach-building material delivered from the river to the sea (about 90%) in the great depths commenced. On the natural conditions, Chorokhi River annually delivered to the sea about 5 million m³ of alluvium per annum, among them, 2.5 million m^3 was the beach-building fraction [10]. Of them, the coarse fraction, pebbles and stones, was about 0.4-0.5 million m³ per annum and the remainder was coarse sand. More fine material (D average <0.25 mm) floated to the open sea and involved into the sedimentation processes ongoing on the bottom. Thus, concentration of the entire runoff of Chorokhi River in the southern branch system of delta has changed the processes ongoing within the entire lithodynamic system of the coastal area significantly. In 1930-1980m here the sea has washed out about 40 ha area Thus, in 1880-1926, the average annual rate of retreat of 3-3.5 km section of the shore, located at the north from Chorokhi River, was 5.2 m.

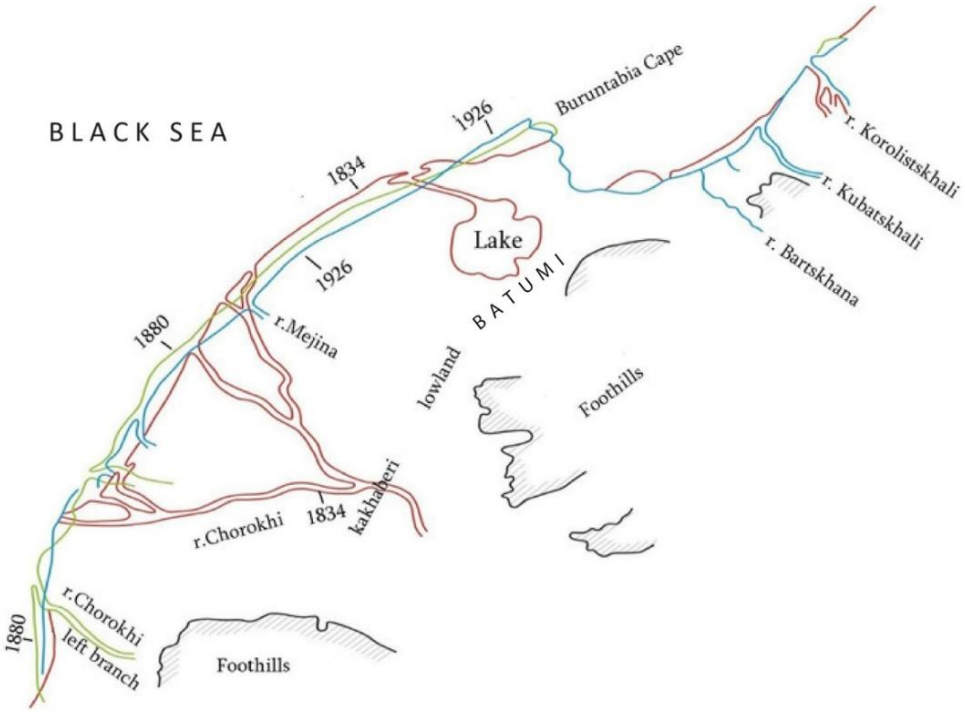


Fig.1. Coastline since 1880 [2]

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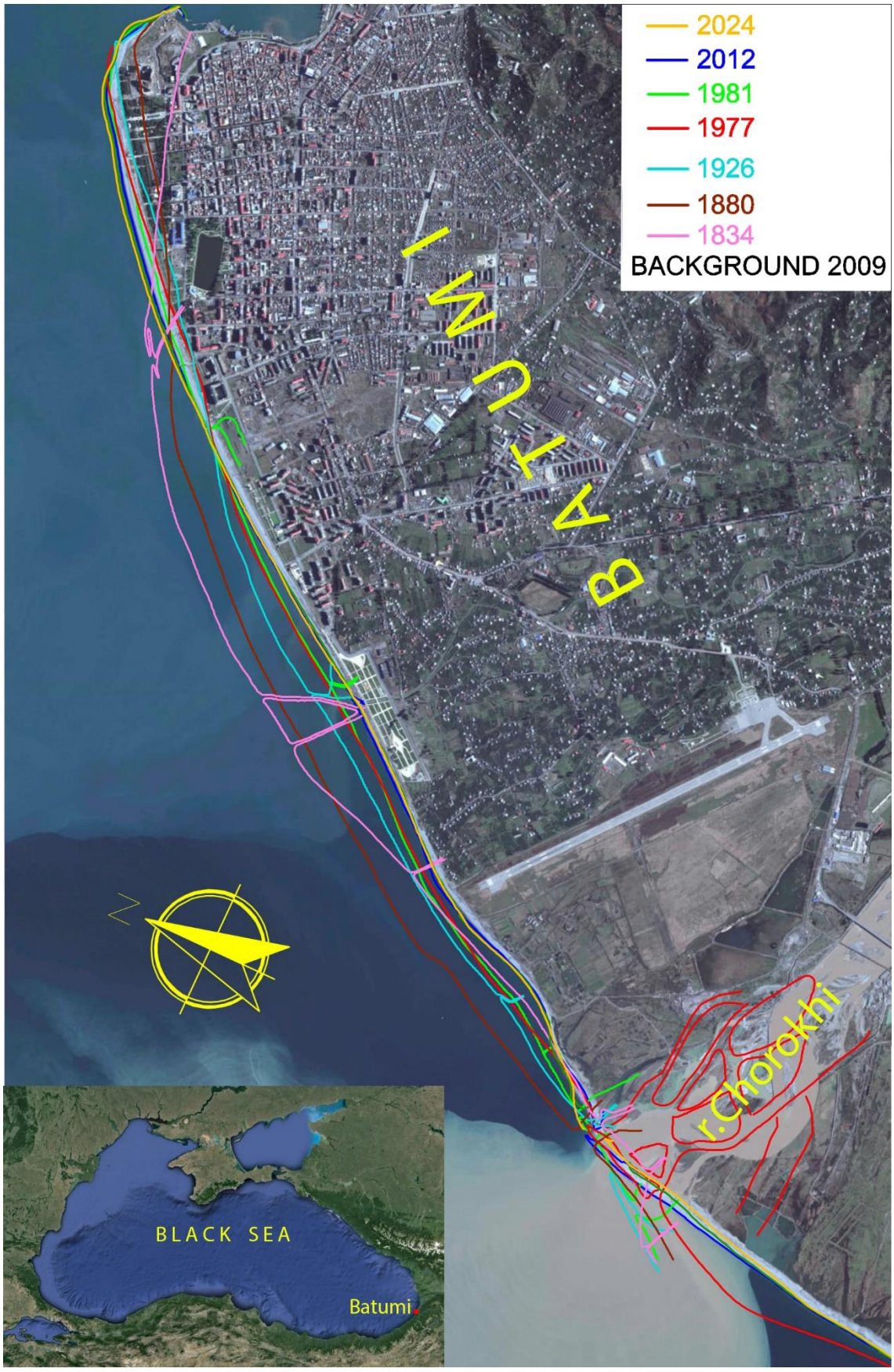


Fig.2 Schematic map of Changes of Chorokhi delta coastline by the years



Fig.3 Coastal erosion at south of Chorokhi river-mouth

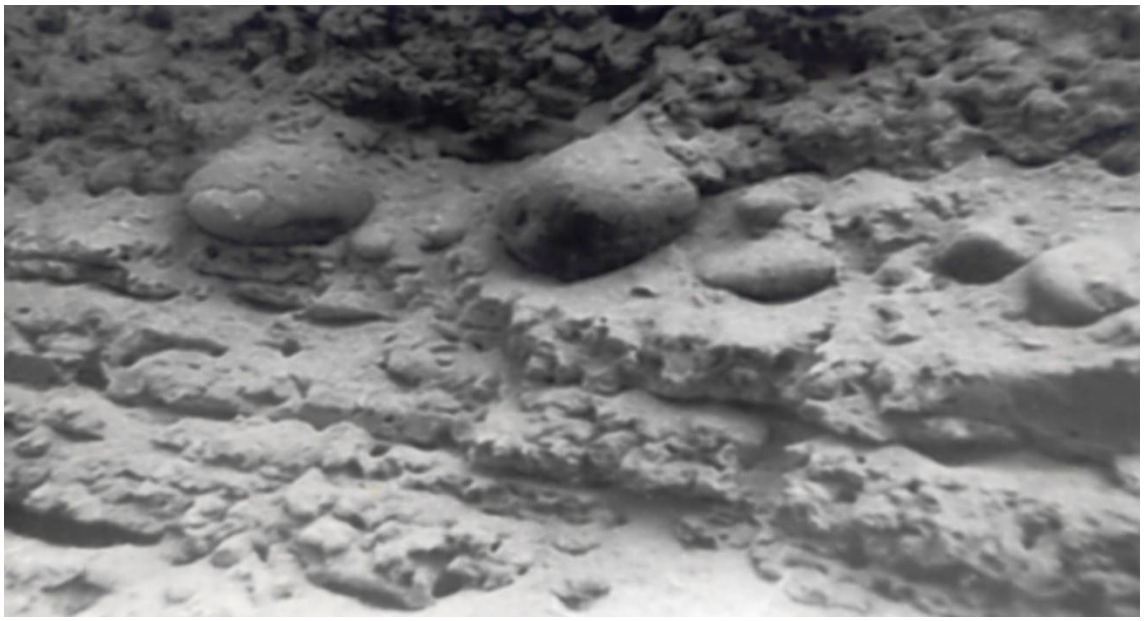


Fig.4. Eroded slopes of Batumi Submarine canyon, exposing course deposits, 18m depth.

DISCUSSION

In 1878, construction of the spur at Batumi cape has dramatically changed the shore lithodynamics. Erosion processes developed beyond Chorokhi River delta as well. Their main causes are as follows:

1. Chorokhi River runoff could not reach this section anymore;

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2. About 12 million m³ of the beach material was extracted directly from the sea shore for the construction purposes.

In the 70s of the past century, in the bed of Chorokhi River, the factory of inert materials was launched, its capacity was about 0.5 million m³ /per year. Both, quantity and grain size of the material delivered to the sea shore area has decreased significantly. In particular, average diameter of the grains reduced from 53 mm to 18 mm from 1972 to 2000

Table 1. Variation of average diameter of r. Chorokhi sediment

year	1972	1978	1983	1988	1989	1991	1993	1995	1999
Av.d.mm	53.2	45.6	34.0	27.1	20.0	20.6	13.0	19.2	18.0

Sea shore section of 1.2-2.0 km length located to the north from current estuary of Chorokhi River is one of the section most affected by erosion in the region. For last 150 years, the sea moved back to about 400 m and washed several rows of the houses of local population. Loss of the excess part of the alongshore sediment materials accumulated at Batumi cape, mostly to the great depths, takes place mostly in the period of storms. On 14 January 1999, in the east from the spur, about 200 m long beach section, with 11.000 m² total area, has detached from the shore and fall down to the great depths in the sea. It should be noted that in this case, the process was provoked by the earthquake near Trabzon, Turkey [2]. Expectedly, such processes can repeat and therefore, preventive measures are necessary. First of all, it is necessary to extract the excessive material accumulated at the cape and delivery to the affected areas. Especially, regarding that Georgian National Environmental Agency, in collaboration with the local government has successfully performed similar work with great care and precision few years ago.

CONCLUSION

Geo-environmental problems of 20th century on the Black Sea shore of Georgia and within Chorokhi River delta are currently more prominent, compared with the previous years:

1. Mechanism of delivery of the river materials feeding the beaches is entirely broken. Due to closing with the hydro-engineering structures, Chorokhi River with several million m³ solid runoff delivers almost nothing to the sea shore. The river fed the shore not only within the delta but also to the north, to about 30 km distance. Materials extracted from the river beds was and is used for construction of the roads and buildings, resulting in severe lack of the sediments on the sea shore.

2. As a result of construction, the relict beaches actually protecting the shoreline and alongshore levees are widely destructed.

Further development of the beach washing processes depends on the rate of moving back of Chorokhi River mouth and this process, even extended in time, is still inevitable.

Process of elevation of the sea level, due to the global causes, would be destructive for the sea-side part of Chorokhi River delta, as the lithodynamic processes in the sea shore

area, among them, balance of the send –pebble material, were destroyed irreversibly. It is apparent that in the conditions of the cheap construction materials' extraction at current rate, it will be exhausted soon and in the nearest future, the construction firms will have to rely on the mountain quarries and delivery of the materials for beaches' rehabilitation from the mountain quarries would be much more expensive. In this situation, artificially adding of great quantities of the sediments to all damaged sections of the sea shore is impossible. It would be more effective to conduct restoration measures at the most vulnerable and significant sections if this sections are identified by means of scientific-research work and monitoring.

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CORRELATION OF REMOTE SENSING DATA (NDVI) WITH GROUND MEASURED DATA

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ABSTRACT

The overall objective of using Normalized Digital Vegetation Index – NDVI is to improve the analysis of vegetation information with remote sensing data. Such estimates are often derived by correlating the NDVI values measured remotely with the ground measured values of some variables.
In the conditions of the experiment carried out with zucchini the NDVI index was measured with a Trimble Green Seeker handheld sensor at the full growth. Applied fertilizers contain various nitrogen and phosphorus sources, including ammonium and nitrate, phosphates, and polyphosphates.
The highest NDVI value (0.802) was obtained with ammonium nitrate from nitrogen treatments without phosphorus fertilization. The nitrogen source fertilizer with the highest NDVI on a polyphosphate background was KSC - 0.800. The same fertilizer performed best in an orthophosphate background, with an NDVI of 0.815. Best NDVI values were obtained on orthophosphate background. Obtained results are statistically proven. Stronger correlation coefficient exists between NDVI and Zucchini yield – 0.72. The overall goal of using Normalized Digital Vegetation Index – NDVI to improve the analysis of vegetation information with remote sensing data is successful.

Keywords: NDVI, zucchini yield, nitrogen, phosphorus, potassium

INTRODUCTION

The overall objective of using NDVI is to improve the analysis of vegetation information with remote sensing data. Studies have shown that NDVI is effective in assessing various properties of vegetation, including LAI [1], leaf chlorophyll concentration [2], plant productivity [3], plant stress [4]. Such estimates are often derived by correlating the NDVI values measured remotely with the ground measured values of these variables. NDVI reliability directly determines the robustness of NDVI-related models [5].
Additional studies have shown that various spectral vegetation indices, calculated from visible and near-infrared (NIR) reflectance data, are linearly related to canopy light

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interception [6]. Additional research shows a strong relationship between Landsat normalized difference vegetation index (NDVI) and fractional cover for multiple horticultural crops [7]. As such, it appears that indices such as NDVI can potentially track canopy development and light interception.
About 2.0 million hectares of land in the EU was used to produce fresh vegetables in 2022, representing an estimated 1% of the EU's total utilized agricultural area, on which 59.8 million tons of crop were produced. The group of fresh vegetables that comprises tomatoes, peppers, aubergines, melons, courgettes, cucumbers and gherkins (i.e. vegetables cultivated for fruits) accounted for a little over one-quarter (27.2 %) of this total area. Like other types of crop, production levels of fruits and fresh vegetables are sensitive to weather conditions (EUROSTAT, 2024).
Zucchini refer to the Cucurbitacea. They are used for fresh consumption, processing and preservation. The fruits of these vegetable species are rich in vitamins and mineral salts, fibre, carbohydrates and pectic substances. Their high biological value is also complemented by the low calorific value of the fruit 34 cal/100g fresh mass of the fruit [8].
Zucchini squash (Cucurbita pepo L.) is an important commercial crop that has gained popularity for both open-field and protected cultivation in the Mediterranean region, especially in Italy, where 12,200 ha are cultivated each year (www.istat.it). Zucchini is normally grown in soil under greenhouse conditions using a drip-irrigation system during the spring-summer and the summer-fall seasons in order to respond to the high demand of this fresh product on both national and international markets.
Climatic variations resulting from seasonal fluctuation and artificial greenhouse climate can affect crop performance like growth, yield and water use [9]. Zucchini crops are sensitive to water deficits [10] and weeds [11]. That is why an irrigation and development survey is indispensable. Drip irrigation systems can provide water and nutrients directly to the crop at the root zone, results in higher yield with saving water by increasing the irrigation efficiency [12]. According to a study carried out by [13] in the conditions of fertigation with nitrogen fertilizers, the highest yield of zucchini was obtained on a phosphorus background composed of orthophosphates.
Among the various spectral vegetation indices derived from remotely sensed imagery, one of the most widely used vegetation indices is the normalized difference vegetation index (NDVI), which is defined as the difference between the red and near-infrared (NIR) reflectance divided by their sum [14]. Previous studies showed that NDVI is strongly related to the fraction of absorbed photosynthetically active radiation (FPAR) [15], leaf area index (LAI) [16], and net primary production (NPP) [17]. NDVI has also been used in a range of applications including the study of vegetation–climate interactions [18], detection of long-term vegetation changes [19], assessment of vegetation functional characteristics [20] and modelling of the global carbon balance [21].

MATERIALS AND METHODS

Normalized Digital Vegetation Index –NDVI

The NDVI index formula is based on the fact that chlorophyll absorbs the red spectrum, while the mesophilic leaf structure reflects NIR.

NDVI values therefore range from -1 to +1 where negative values correspond to no vegetation [22]:

NDVI = (NIR - Red) / (NIR + Red)

NIR- (Near infrared) is the near infrared region of the spectrum.

RED - The red area of the visible light spectrum

NDVI is a coefficient linking the reflection of red and near infrared light [NDVI=(NIR-RED) / (NIR+RED), where NIR and RED are the quantities of near infrared and red light reflected by vegetation and captured by the sensor of the investigative device - satellite, drone, ground instrument.

The NDVI index is associated with many plant properties. It is used to determine the health status of plants, to depict phenological changes, to estimate green biomass and yield from crops and other applications. Normalized Differential Vegetative Index (NDVI) has been used for decades as a predictor of vegetative biomass [23].

In the conditions of the experiment carried out the NDVI index was measured with a Trimble Green Seeker handheld sensor (Fig. 1) after the last fertigation event in sunny weather at midday times.



Figure 1. Trimble Green Seeker handheld sensor

Test crop - Zucchini (Cucurbita pepo L.)

In the first year of the research, field fertilizer experiment with zucchini was set. The variety is Eskenderany F1. This is a hybrid zucchini with a light green colour from Seminis. The plants are strong, half-upright and compact, resistant to low temperatures. The growing season is 40-45 days after transplanting. The fruits are shiny with a length of 18-20 cm.

Water regime was maintained by drip irrigation according to development stage and needs of the zucchini. Water content during the growing period was at 80% of Field capacity. Fertilizers were applied with the irrigation with rates depending on crop growing intensity.

Fertilizers and tools

Fertilizers with a different source of nitrogen (ammonium and nitrate) and a different source of phosphorus (orthophosphate and polyphosphate) were used.

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Sources of nitrogen:

KSC III for vegetables – (N- 15%, P_2O_5 -5%, K_2O -35%, B -0.1%, Fe-0.1%, Mo-0.1%). Nitrogen is represented by 11.7% nitrate and 3.3% ammonium nitrogen.

SULFAMMO (N-PRO) (N-25%, SO_3-31%, MgO-2%). Based on ammonium sulphate. Ammonium nitrate NH_4NO_3 ammonium nitrate fertilizer (N - 34%).

Ammonium sulfate $(NH_4)_2SO_4$ ammonium fertilizer (N – 21%) – to equalize the treatments with Eurofertil Plus 36 to those with Duofertil TOP 34.

Sources of phosphorus:

1. Duofertil TOP 34 (N-P-K 5-19-10 + 19 SO_3 + 0,1% B + 0,1% Zn). Contains polyphosphates.

2. Eurofertil Plus 36 (Physio +) (P_2O_5 – 12%, K_2O – 24%, SO_3 – 15%, B – 0.2%). Contains orthophosphates.

3. Triple super phosphate (P_2O_5 – 46%) - to equalize with phosphorus the treatments with Eurofertil Plus 36 to those with Duofertil TOP 34. Contains orthophosphates.

Potassium source:

Potassium sulfate (K_2SO_4) – 50% K_2O – to equalize the amounts of potassium.

Most fertilizers contain more than one nutrient. Macro elements are equal in content in each treatment by the means of simple fertilizers. There is no complete alignment of trace elements by treatment. The approach was to carry out trials with complete macronutrient fertilization and conditions close to practice. Fertilizers with a modern formulation of one manufacturer and widely used by farmers.

Soils were analyzed by following methods:

- Inorganic nitrogen by [24]
- Available forms of phosphorus and potassium by AL method of [25]
- Electrical conductivity of soil by a Decagon tool for direct measurement of water content, electrical conductivity, salt content and soil temperature.

RESULTS AND DISCUSSION

Fertilizers influence on Zucchini yields are presented on Figure 2. It is obvious that polyphosphate source is negatively acting on zucchini yield. The orthophosphate source of Eurofertil has a strong positive impact on all treatments.

Development quality of zucchini was expressed and assessed by the NDVI index and was determined at the full growth. Phosphorus sources have same impact on NDVI as in yield survey. On background phosphorus fertilization, the fertilizers Sulfammo and KSC performed best. Orthophosphates gave the best basis for plant development and in them the indicators for all nitrogen fertilizers and control were highest (Fig. 3 and Table1).

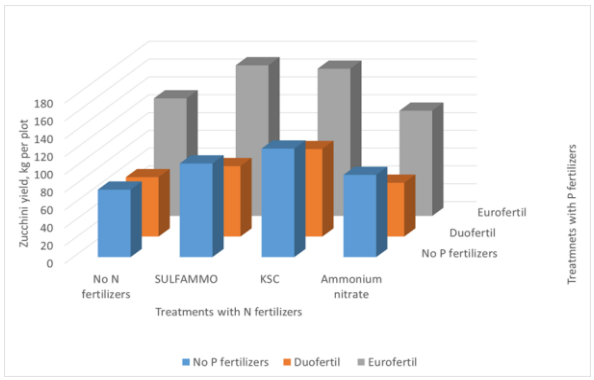


Figure 2. Zucchini yield depending on the fertilization with nitrogen and phosphorus fertilizers

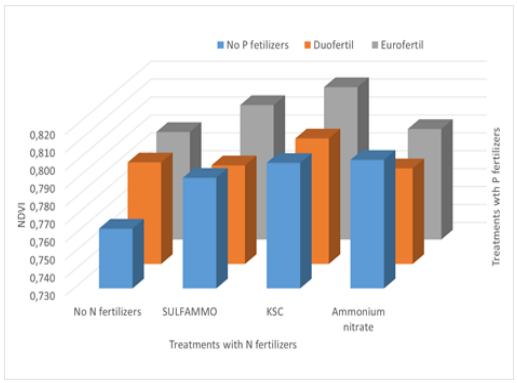


Figure 3. NDVI index depending on the fertilization of zucchini with nitrogen and phosphorus fertilizers

Table 1. NDVI when fertilizing zucchini with nitrogen and phosphorus fertilizers

Treatments	No fertilizers	SULFAMMO	KSC	Ammonium nitrate
Control	0,763	0,792	0,800	0,802
Duofertil	0,787	0,785	0,800	0,783
Eurofertil	0,790	0,805	0,815	0,792

Statistics of obtained results

The results were treated statistically with an ANOVA multifactorial analysis for influence of nitrogen fertilizers on phosphorus fertilizers as background and for the influence of phosphorus fertilizers on nitrogen fertilizers as background. In the first analysis it is seen that all nitrogen fertilizations differ significantly from the control treatment for NDVI (Fig. 4).KSC fertilizer is statistically different than other nitrogen fertilizers, too. Impacts of fertilizers Sulfammo and Ammonium nitrate are not statistically different between them. Phosphorus fertilization with orthophosphates differed significantly from the control and polyphosphate treatment significantly (Fig. 5).There is not statistical evidence that treatments Control and Duofertil are different.

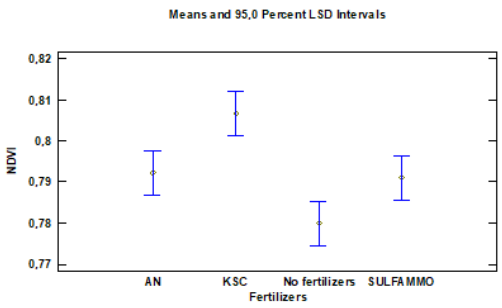


Figure 4. Graphical presentation of lower and upper limit of N Fertilizers treatments

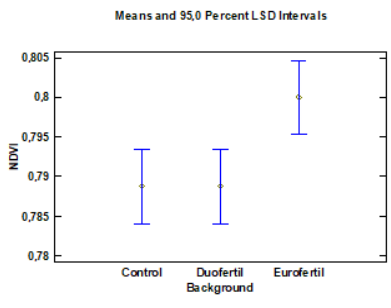


Figure 5. Graphical presentation of lower and upper limit of P Background treatments

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Table 2 information shows Pearson product moment correlations between each pair of variables. These correlation coefficients range between -1 and +1 and measure the strength of the linear relationship between the variables.

Table 2. Correlations between studied indicators in 0-30 cm soil layer

EC	***EC***					
K	-0,2579	***K***				
	0,4184					
N	-0,3463	-0,1929	***N***			
	0,2702	0,5481				
NDVI	-0,0423	0,4455	-0,5653	***NDVI***		
	0,8961	0,1466	0,0554			
P	-0,2757	0,3824	0,3593	-0,0489	***P***	
	0,3857	0,2198	0,2514	0,8801		
Yield	0,2984	0,2056	**-0,5853**	**0,7163**	-0,2632	***Yield***
	0,3461	0,5214	**0,0456**	**0,0088**	0,4085	

Correlation

P-Value

Correlation coefficients smaller than 0.3 is showing a weak strength, between 0.3 and 0.7 is a medium and larger than 0.7 is showing a strong correlation strength. The second number in each location of the table is a P-value which tests the statistical significance of the estimated correlations. P-values below 0,05 indicate statistically significant non-zero correlations at the 95,0% confidence level. The following pairs of variables have P-values below 0,05: N and Yield; NDVI and Yield. The negative correlation between inorganic nitrogen content and zucchini yield is explained by the stronger nitrogen assimilation and uptake in higher yields treatments.

Simple regression exists between NDVI as independent variable and Yield as dependent variable, which is showing their quantitative relation described by the following linear model:

$Y = a + b*X$

The equation of the fitted model is:

Yield = -1433,36 + 1942,86*NDVI

Since the P-value in the ANOVA table is 0.0088 which is less than 0,05, there is a statistically significant relationship between Yield and NDVI at the 95,0% confidence level. The R-Squared statistic indicates that the model as fitted explains 51,31% of the variability in Yield. The correlation coefficient equals 0,716, indicating a moderately strong relationship between the variables (Fig. 6).

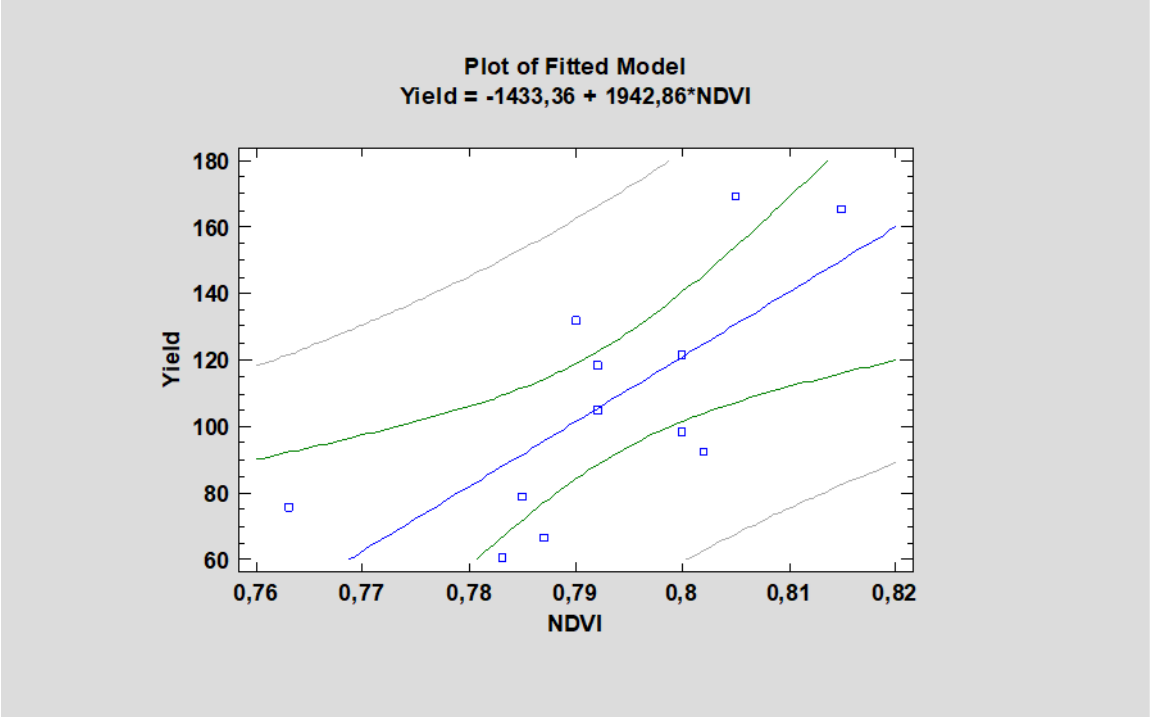


Figure 6. Plot of fitted model

CONCLUSIONS

This study successfully demonstrated the use of the Normalized Digital Vegetation Index (NDVI) for improved vegetation analysis via remote sensing. NDVI proved effective in assessing vegetation health and coverage.

Experimentally, orthophosphates outperformed polyphosphates, indicating their higher efficacy in promoting plant growth. Additionally, ammonium was found to be a more effective nitrogen source than ammonium nitrate on a phosphorus background, enhancing nutrient uptake and plant growth.

KSC fertilizers were highlighted for their role in plant nutrition due to their provision of essential microelements along with nitrogen. This suggests a comprehensive benefit over other nitrogen fertilizers.

Future research should focus on validating NDVI in various settings, exploring the long-term impacts of ammonium use, and optimizing the application of KSC fertilizers across different crops. These findings can inform better fertilization practices and sustainable agricultural strategies, contributing to increased productivity and environmental conservation.

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CURRENT ASPECTS CONCERNING QUANTIFICATION OF PHARMACEUTICAL WASTE FROM WATER SOURCES

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ABSTRACT

As a result of increasing water consumption by pharmaceutical industries, hospitals, and the population, large volumes of liquids discharges containing pharmaceutical compounds have been generated worldwide. Even though there is a consistent contribution on the sustainable management of these contaminants, the efforts to reduce this pollution are progressing on a rather small scale. Such pollutants can be introduced into water-receiving bodies either directly, through animal and human excretions, or through unregulated disposal and anthropogenic activities, resulting in their presence in small amounts in aqueous systems. Even if they are in small amounts these classes of contaminants are persistent or partially degraded during treatment processes and thus may cause adverse effects on human and animal health as a result of bioaccumulation. This paper summarizes the main aspects referring to quantification of pharmaceutical waste from both drinkable and industrial waters in order to provide efficient solutions to counteract their negative impact on environment and human health.

Keywords: pharmaceutical pollutants, wastewaters, depollution system

INTRODUCTION

Pharmaceutical products (PhP) represent one of the most abundant classes of emerging pollutants, being supposed or suspected to cause adverse effects on the environment and human health.

Recently many pharmaceutical substances have been detected into the water bodies, including surface, ground, and wastewaters, at the concentration levels of nanograms (ng/L) until micrograms per liter (μg/L) or even below [1]. During the last period many residues of PhP have been detected in water flows, lakes and seas, as well as in the effluents and sludge resulted from treatment and cleaning station plants over the world [2].

Even though many PhP are not very persistent, their continuous addition in small amounts from different sources could cause significant hazardous effects. More than 3000 PhP frequently used have been registered only on European Union market [3]. In the specialty literature PhP are also designated as “pseudo-persistent” compounds [2], [4].

Different from other classes of emerging pollutants, like CFC, PCB or PAH, pharmaceutical compounds cannot be classified as homogeneous groups of substances and have no similar physical, chemical and biological characteristics, even though they

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have a specific role in the organism [3]. In this context, PhP are characterized by the following properties [5]: polarity, polymorphism, enantiomorphism, affinity for lipids, different ionization degrees.
Pharmaceutic compounds have usually higher molar mass as compared to the other contaminants (>500 Da). Most PhP are persistent in the natural environment by accumulating in various life forms and thus remain biologically active for long time periods. Finally, these compounds accumulated in living organisms, are metabolized, and a result major change will be produced in their chemical structure and toxic activity [2].
One may conclude that the PhP should be periodically monitored and necessary measures for their removal from water flows should be undertaken. In spite of these warning considerations, the effects caused by PhP on human health and terrestrial ecosystems are only recently observed and their monitoring techniques in aquatic systems should be continuously developed in order to assure the compliance with regulations in force according to recent European Water Directives.

MATERIALS AND METHODS

Materials

Pharmaceutical drugs, such as ketoprofen, naproxen, diclofenac sodium, ibuprofen etc., of reagent grade, were provided by Sigma-Aldrich Germany and used as received. All reagent solutions were prepared using deionized water. A stock solution was prepared for each PhP by dissolving appropriate amount from corresponding chemical in 100 mL methanol.

Characterization methods

Merk Spectroquanta kits (Germany) have been used for chemical oxygen demand (COD) (10 – 150 mg/L), total nitrogen (TN) (10 – 150 mg/L), N – NO_3^- (1.0 – 50.0 mg/L), N – NH_4^- (4.0 – 80.0 mg/L), total phosphorous (TP) (0.5 – 25 mg/L). Biological oxygen demand (BOD_5), total suspended solids (TSS) have been determined by Standard Methods for the Examination of Water and Wastewater [6]. Fourier transform infrared spectroscopy (FT-IR) spectra of the samples were obtained using a Perkin-Elmer FT-IR spectrophotometer model Spectrum One, with the use of KBr disks, in absorbance mode and in the spectral region of 400-4000 cm^{-1}. Thermogravimetric analysis (TGA) was carried out with a Setaram Setsys TG-DTA 16/18. The morphology of the samples was examined using a JEOL JMS-S40A scanning electron microscope (SEM) equipped with an energy dispersive X-ray Oxford ISIS 300 microanalytical system. PhP concentrations before and after removal from water samples have been determined by HPLC (Shimadzu ultra-fast liquid chromate-graphy UFLC. Separations were achieved on analytical reversed phase Extend – C18 column (3.5 μm, 4.6 nm x 150 nm Agilent Germany) at a mobile phase flow rate of 1 mL/min under isocratic conditions using a mixture of ultrapure water/acetonitrile/trime-thylamine/acetic acid (59.0:40:0.5:0.5v/v). The sample size injected was 10 μL and UV detection wavelength was 240 nm. The X-ray diffraction (XRD) tests were performed using Bruker, D8 Advance, Germany. The morphology of samples was determined by scanning under Co Kα radiation (wavelength 1.789 A) at 40 kV and 45 mA.

RESULTS

Concentrations of pharmaceutical contaminants in natural waters used for human and animal consume

Research studies demonstrated that not all pharmaceutical products are similarly metabolized. For instance, the antibiotic amoxicillin is metabolized only in proportion of 40%, the atenolol (betablocker) – 10%, carbamazepine – 97%, cetirizine (antihistaminic) – 50%, diclofenac – 85%, erythromycin (antibiotic) – 75%, ibuprofen (analgesic) – 90% [1].

As example, a number of 42 PhP has been selected and classified according to their therapeutic applications as following: 1 – antibiotics, 2 – analgesics, 3 – beta-blockers, 4 – drugs for blood pressure reduction, 5 – cardiovascular, 6 – anticonvulsive, 7 – antidepressive, 8 – antiepileptic, 9 – antihypertensive, 10 – antihistaminic, 11 – antipsychotic, 12 – agents for lipid reduction, 13 – agents for pain calming, 14 – non-steroidal anti-inflammatory drugs (NSAID).

Table 1. Concentrations of maximum admissible values of PhP in ground water

a) for human consume

Name of PhP	LDTD mg/day	ADI µg/kg/day	DWC µg/L
Aspirin	NA	NA	105
Carbamazepine	200	2.8	100
Cimetidine	400	5.7	200
Ciprofloxacin	500	7.1	250
Diazepam	5.0	0.071	2.5
Metoprolol	50	0.71	25
Nadolol	40	0.57	20
Naproxen	440	6.3	220
Roxithromycin	300	4.3	150
Ibuprofen	800	11.4	400

LDTD – Lowest Daily Therapeutic Dose
ADI – Acceptable Daily Intake
DWC – Concentration of PhP in drinking water

b) for veterinary consume

Name of PhP	ADI µg/kg/day	DWC µg/L
Amoxicillin	0.43	1.5
Acid acetyl salicylic	8.3	29.0
Cefalexin	10.0	35.0
Chlortetracycline	30.0	105
Diclofenac	0.5	1.8
Erythromycin	5.0	17.5
Sulfametaxazol	10.0	35.0
Sulfamethazine	10.0	34.9
Tetracycline	30.0	105
Trimethoprim	20.0	70.0

ADI – Acceptable Daily Intake
DWC – Concentration of PhP in water for veterinary use

This selection has been made in accordance with the interest manifested by various countries for monitoring the most dangerous micro-pollutants for human and animal health existent in surface and ground waters. Most of data collected are provided from European countries: Germany, France, Great Britain, Spain, Portugal, Italy, Serbia, but also from other continents: South Africa, Australia, U.S.A.

Some representative values for maximum admissible PhP concentrations in ground water for human consume are collected in Table 1a, and for animal consume in Table 1b.

Unfortunately, there are no European or national legislation norms stipulating regulations particularly devoted to establishing the maximum admissible levels of PhP in potable water.

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In this context Table 2 presents the data of PhP monitored mainly in China [7] and Taiwan [8], but also in Serbia [9], Italy [10] and U.S.A., [11].

Table 2. Concentrations of PhP in potable water at consumer tap

No crt	Name of PhP	Conc. ng/L	No crt	Name of PhP	Conc. ng/L
1	Acebutolol	0.7 (Taiwan)	**10**	Ketoprofen	16.0 China
2	Acetyl salicylic acid	< LoQ = 1.4 (China)	**11**	Metronidazole	4.9 – 35.6 Taiwan
3	Atenolol	3.6 – Taiwan 19.5 – USA	**12**	Metoprolol	< LoQ = 83.5 – Serbia 7.3 – Taiwan
4	Carbamazepine	< LoQ = 8.7 – Serbia 0.4 – 37.9 – Taiwan 1.05 - Italy	**13**	Nalidixic acid	1.6 – 16.4 - Taiwan
5	Ciprofloxacin	1.6 – Taiwan	**14**	Naproxen	< LOD – 17.17 – China 27.6 – Serbia 12.8 – Taiwan
6	Diazepam	1.9 – China	**15**	Norfloxacin	2.8 – 9.3 – Taiwan
7	Diclofenac	<LoD – 2.37 – China 2.1 – 33.2 – Taiwan	**16**	Propranolol	< LoQ = 4.3 - Serbia
8	Erythromycin	2.2 – 54.8 – Taiwan	**17**	Sulfadiazine	0.1 – 14.4 – Taiwan
9	Ibuprofen	< LoD = 17.17 – China 92.15 – Serbia	**18**	Sulfamethoxazole	<LoD = 1.81 – China 0.1 – 18.2 – Taiwan

LoQ – Limit of quantification
LoD – Limit of detection

DISCUSSION

Risk evaluation caused by PhP present in drinkable water on human health and environment

Toxicity evaluation of PhP is mainly based on the following assumptions:

- Many inferior organisms (for example, Daphnia) possess receptors similar to those of human beings;
- Drugs are usually linked to some human receptors, but similar receptors can be also observed outside human body at many micro-organisms from aquatic and terrestrial ecosystems;
- Evaluations made relative to PhP impact on environment are covered by many restrictive conditions – regulations, that are compulsory before their launch on market.

A report emitted by World Health Organization (WHO) [1] summarizes the results of research performed in Great Britain, Australia and United State of America referring to risk evaluation of PhP from drinkable water. Starting point of these studies consists of two components: acceptable daily intake – ADI and minimum therapeutic dose – MTD.
Limits of exposure to drinkable water (Margins of exposures – MoE) have been determined by comparing with ADI or MTD, or sometimes, with Drinking Water Equivalent Level (DWEL). It follows that the evaluation of safety of drinkable water quality may be made based on MoE value of the pharmaceutic substance of interest.
Analysis of previous results indicated that the exposure to the PhP concentrations existent in drinkable water seems not to affect human health, these concentrations being by one thousand lower than minimum therapeutic dose applied [1]. However, it should

be mentioned that the long-term effect of water consume on human health is not known, even though PhP are present in very low concentrations. [12]. Moreover, PhP are also consumed with many aliments, by means of vegetables, fruits, meet, fish, thus overpassing the quantification limit. Considering that life expectation is of 70 years, I_{70}, PhP values taken over the lifetime are usually less than daily therapeutic doses [13]. It should also mention that such toxicity studies are usually made on only one PhP contaminant, while in real cases there is a mixture of many compounds. That is why, the cumulative effect of these contaminants in drinkable water could cause serious problems.

According to some authors [14], the following water quality indicators are: Predicted No Effect Concentration – PNEC, and Critical Environmental Concentration – CEC.

The indicator PNEC is defined as being the value of PhP concentration in water which cause no hazardous effect on a given organism. This value may be estimated by using the existent ecotoxicity tests.

Models of risk evaluation

The evaluation methods of risks of pharmaceuticals presence in water and food implies the establishment of acceptable daily intake (ADI) or tolerable daily intake (TDI) by different calculation variants, i.e. by application of extrapolation of the uncertainty factors at selected points of departure (PoD) from the toxicological and epidemiological database. An accepted PoD is the concentration at which no adverse effect is detected (NOAEL – no observed adverse effect level), or, less optimal, the minimum concentration at which an adverse effect is felt (LOAEL – the lowest observed adverse effect level) combined with another uncertain factor. PoD can also be deduced from the statistical analysis of the data regarding a dose – response from a clinical study [1].

The European Medicines Evaluation Agency (EMEA) proposed a forecasting model for the presence of pharmaceuticals in drinkable water based on the usage of PhP and the quantity of wastewater discharged by the population into the sewage network. Drug consumption can be evaluated by inverse calculus, by using the pharmaceuticals concentration of the influent in the wastewater treatment plant. The first approach has been realized by applying a methodology realized in 2001 by Daughton, [4]. This method can be applied to evaluate the legal and illegal consumption of medicines. The evaluation *via* this computation model assumes the following hypotheses:

- possible losses from the sewage network are neglected;
- possible modification of the concentration of pharmaceuticals caused by the adsorption on particles in suspension is neglected;
- possible direct introduction of pharmaceuticals in sewage network is neglected;
- it is assumed that the number of inhabitants in the evaluation period remains unchanged.

Since 2014, other models have been added. For instance, a model elaborated by O'Brien and others [15] which evaluates the population from the studied area by using Bayesian interference based on the consumption of pharmaceuticals and personal care products.

Technological operations

From the technological operations applied to remove pharmaceuticals from water (micro-, ultra-, nanofiltration, reverse osmosis, advanced oxidation), the adsorption on granular activated carbon (GAC) deserves special attention since it devolves upon the

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smallest investments; this technique has good efficiencies at removal of organic micropollutants, inclusively the pharmaceuticals, at small concentrations in water; the adsorbent material (GAC) can be regenerated after exhaustion; the installations with GAC can be easily exploited at the current qualification level of the personnel.

The phenomenon, as it occurs in water, contains four phases: transport of the solvent in the liquid phase, diffusion in the film from the surface of the liquid, diffusion in the pores of the adsorbent and attachment to the solid phase by Van der Waals forces. For this reason, such a process is considered interesting for future studies focussed on existing models.

CONCLUSION

1. Pharmaceutical products are essential drugs for human and animal health. However, their increasing production and consumption (6.5% annual increase) became alarming when the presence of PhP in aquatic systems was signaled. Laboratory experiments demonstrated that PhP could cause major changes in the fish behavior, important troubles of endocrine glands, high toxicity for reproduction, increasing risks of pulmonary and prostate cancer, while the excessive use of antibiotics is related to the increase resistance to antimicrobial drugs.
2. Technical literature and research studies reported in various countries during the last 2-3 decades indicated concentrations in PhP in surface and ground waters subjected to the influence of wastewaters less than 100 ng/L, and in drinkable waters less than 50 ng/L. Moreover, the acute and chronic effects of PhP on flora, fauna and humans are not well established yet, neither the maximum admissible limits in water nor environment are not regulated by legislation in force. There is only one information on norms established for ground waters from Australia.
3. Cleaning water stations in use have not been designed to remove PhP from wastewaters, and PhP applied in agriculture and aquaculture are often discharged directly into natural aquatic systems. About 40-90% of PhP orally administered are evacuated by excretions in public sewerage.
4. Rehabilitation of both treatment and cleaning station plants by completing exclusively of the existent technologies will not solve the PhP problem, as there are numerous limitations referring to the efficiency of PhP removal, high investments and exploitation costs which also suppose a high energy consume.
5. A critical analysis of these conclusions resulted in formulation of the following recommendations:
- Elaboration of an inventory of human and animal pharmaceuticals discharged in aquatic systems under the studied area.
- Including PhP monitoring into national monitoring programs without affecting monitoring procedures of the existing water parameters and indicators.
- Elaboration of adequate sampling methodologies of analysis methods for PhP in water.
- Standardization of admissible limits for PhP present in natural, drinkable, and wastewaters.
- Realization of research devoted to establishing the effects of PhP in drinkable water on humans, flora, and fauna.

One may conclude that the initiation/continuation of research for finding optimal solutions for rehabilitation of treatment and cleaning plants remains one of the most important tasks for micropollutants removal, including PhP, with particular attention on rural and isolated areas.

ACKNOWLEDGEMENTS

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DEVELOPMENT OF A GENERATOR OF GLUED LAMINATED TIMBER ELEMENTS SECTIONS USING ARTIFICIAL INTELLIGENCE

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ABSTRACT

Within the current framework of approaching different directions of carbon emissions reduction policy, wood fits as an environmentally friendly building material with low production in terms of energy consumption. In this manner, timber combines its qualities such as high strength/weight ratio and rigidity/weight, low specific gravity, recovery/recycling that make it competitive with classic building materials with the demands of climate change green deal. One specific attention has to be given to the design and execution of civil structures in terms of geometric dimensioning of structures, which favors constant rectangular sections, easy to size.

This article proposes the initialization of a generator of optimized geometries for glued laminated timber (GLT) structural elements that can provide in a reasonable time through artificial intelligence different solutions. Otherwise, this would have required the use of topological optimization by the finite element method with long analysis times. From a scientific point of view, this approach has been applied only on small part elements in order to solve specific problems of the artificial intelligence-optimized design chain.

The results demonstrate the reduction of the amount of material, the improvement of production costs and the optimization of the mechanical behavior of the structural elements in glued laminated timber.

Keywords: timber, glued laminated timber, artificial intelligence, environment, carbon emissions

INTRODUCTION

This article uses the information obtained in an ongoing research project that aims to develop an expert software tool based on artificial intelligence, which offers optimized geometric solutions for glued laminated timber (glulam) elements.The project proposes the creation of a generator of optimized geometries for glulam structural elements that can provide in a reasonable time, for unique projects, solutions that would otherwise require, using topological optimization through MEF, long analysis times, limiting the application only to structures with a high degree of typification.

In this article, the basic parameters that will be used in the numerical analysis were studied through laboratory determinations. Afterwards, numerical optimization models are

presented to identify the analysis conditions and the objective functions. Based on the probable domains of variation of the geometry of the elements in the GLT, different optimized configurations were analyzed that will be used to create the database necessary for training the AI.

MATERIALS & METHODS

Solid wood elements and glulam elements were tested as well as their cooperation to determine the contact properties:

A common wood essence (spruce) was the material currently used for glued laminated timber elements according to the standard SR EN 338 [3].

For joining together, the glulam elements and the polymer fiber system an epoxy resin-based adhesive is necessary: Melamine-urea-formaldehyde adhesives MUF, the adhesive used for processing the glued laminated timber elements, is one of the most commonly used adhesives in the wood industry.

The following laboratory tests were performed:

a. Tests to determine the basic parameters for wood elements that will be later used in numerical analyses. 10 pieces of wood samples were tested for each type of test.
b. Shear strength tests on glulam samples in order to analyze their cooperation to determine the contact properties.

The tests were done in the laboratories of the Technical University of Construction Bucharest.

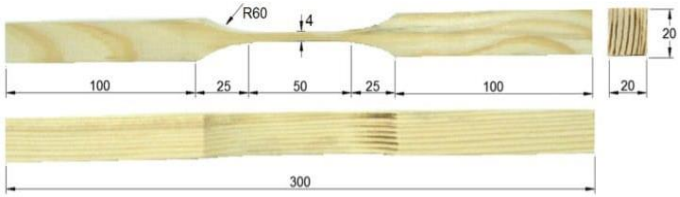
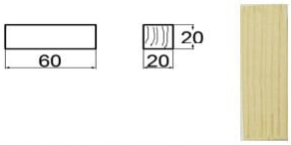
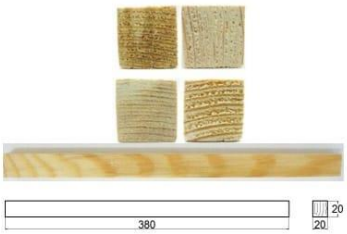
In order to verify the mechanical parameters obtained in the experimental tests, an elasto-plastic modeling was carried out in an explicit dynamic formulation in order to be able to follow the evolution of the deformations over time, using the Abaqus program.

The results of the experimental tests were used in the development of numerical models for the optimization of GLT glued laminated timber beams using the Abaqus program.

RESULTS

In a first step, tests were carried out on solid wood samples to determine the basic parameters. Table 1 shows the results of these tests.

Table 1. Results of laboratory tests on wooden samples

Test number	Test specimen Sample size (wxh – L)	Average strength value
Traction parallel to the fibers		f_t= 93.61N/mm²
Compression parallel to the fibers		f_c= 40.85N/mm²
Bending		f_{inc}= 79.58N/mm²

In the second step, shear resistance tests were carried out on glued laminated timber specimens. The shear box for these tests can be seen in Figure 1.



Figure 1. Shear tests in the laboratory

For each type of test in the laboratory, the specimens had specific dimensions, according to SR EN 408+A1:2012, PI/C-106.

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Table 4. Determination of breaking strengths at different stresses

Effort type	Specimen dimensions (L x w x h) No. tested pieces	Average value a breaking strength (N/mm2)
Compression perpendicular to the fibers	250mm x 100mm x 200mm 15 pieces	$f_{c,90}$ = 2.83 N/mm2
Compression parallel to the fibers	200mm x 100mm x 600mm 15 pieces	$f_{c,0}$ = 34.05 N/mm2
Bending	3800mm x 100mm x 200mm 5 pieces	f_m = 32.76 N/mm2
Tension perpendicular to the fibers	250mm x 100mm x 400mm 15 pieces	$f_{t.90}$ = 0.75 N/mm2
Shear parallel to the fiber	300mm x 32mm x 55mm 10 pieces	f_v = 4.02 N/mm2
Modulus of elasticity in compression parallel to the fibers		$E_{q,0}$ = 6128.9 N/mm2
Modulus of elasticity in tension perpendicular to the fibers		$E_{t,90}$ = 61.00 N/mm2
Modulus of elasticity in bending		$E_{m,g}$ = 9561 N/mm2

The tests revealed values much higher than the shear resistance of the wood material (**Figure** 1). It was found that the yielding of the sample was done through wood and not through adhesive.

The elasto-plastic modeling consisted in replicating the sample used in the direct shear testing equipment, namely a sample having a side of 60×60mm and a height of 20mm. The shear plane was established halfway through the specimen, resulting from the boundary conditions (Figure 2). Loading was applied by imposed strain at constant rate.

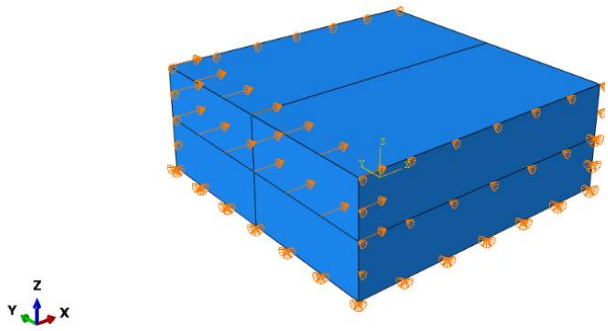


Figure 2. The model used zones of

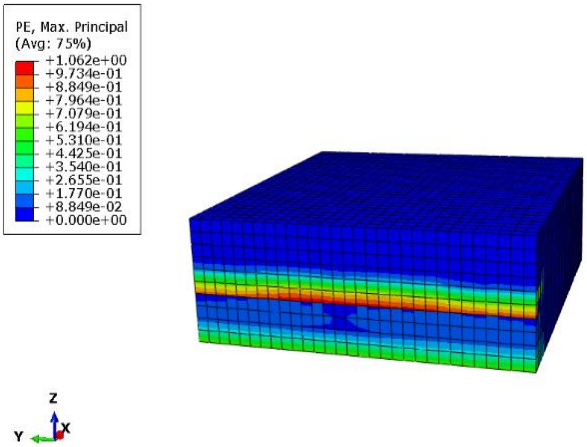


Figure 5: Formation of the plastic tangents in the sample

The deformations had compatible shapes and magnitudes (Figure 3 and Figure 4),

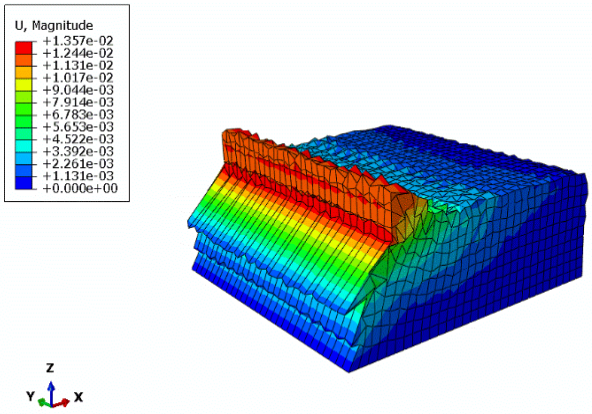


Figure 3. Deformation of the model



Figure 4. The real model

The yielding of the element occurred according to the imposed plan, the local crushing being insignificant (Figure 3), which is also confirmed by the development of tangential efforts in the direction of the formation of the failure plan (Figure 4).

Strain compatibility was monitored by recording the strain history at a point belonging to the failure surface (Figure 5). Comparing these results with those obtained from the laboratory determination, it can be seen that the mobilization of deformations is done in a similar way.

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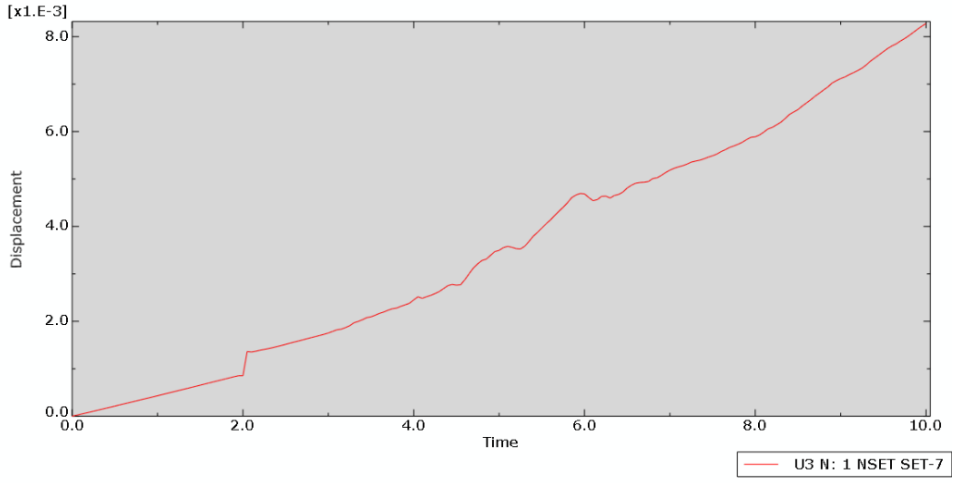


Figure 5: Time history for displacements in a point of the yield surface.

Using the experimentally obtained results, the database of optimized models obtained by generating, based on Monte-Carlo simulation principles, a sufficient number of models using scripts for the automation of MEF runs was created.

To create the numerical models using the topological optimization method, 23 wooden elements with dimensions 10.00mx 0.16mx 0.04m and two supports with dimensions 0.6mx 0.16mx 0.04m were used (Figure 6).

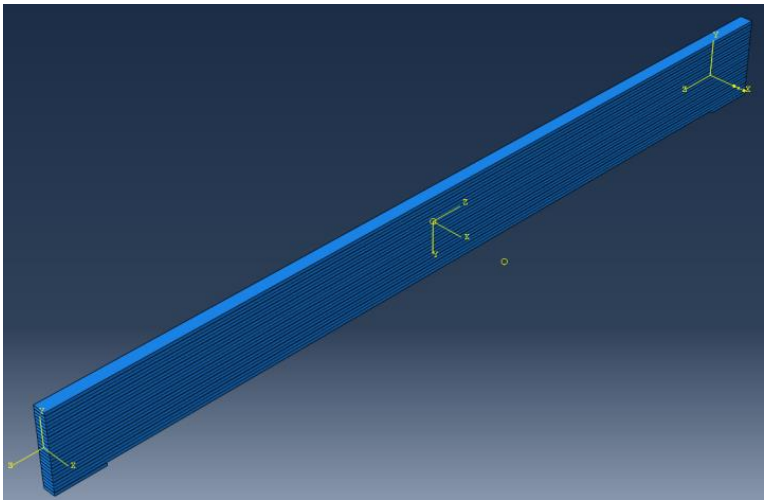


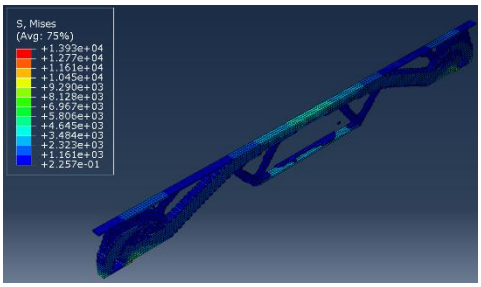
Figure 6. Computing assembly in 3D view

DISCUSSION

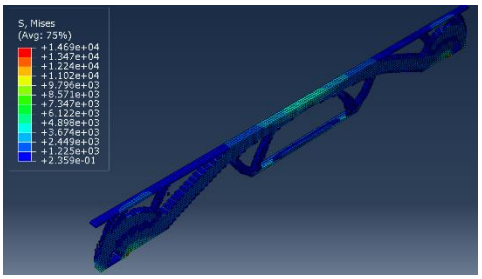
For each model to which different geometric constraints were applied the script was used to run 30 models with different mechanical parameters. To create the database, various geometric constraints were applied, namely: "Demold control", "Plannar symmetry", "Point symmetry" and "Milling control". The results were collected in a database. Based on the probable domains of variation of the geometry of the elements in the GLT, a database for training the AI will later be compiled.

In the following, the results obtained for each optimization model with the related cycles are presented:

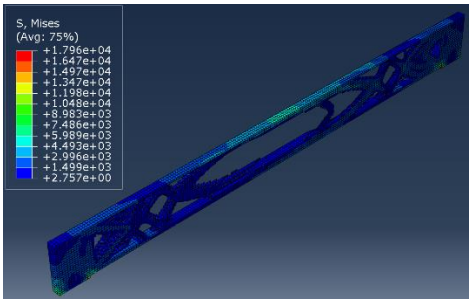
Condition Demold



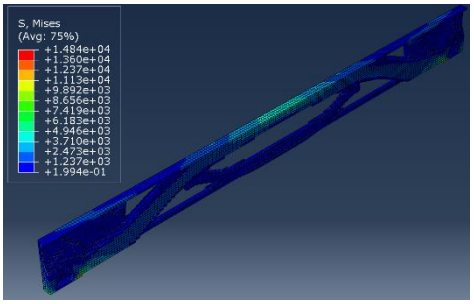
Milling condition



Planar Symmetry condition



Condition Symm Point



Following the analysis carried out, a series of optimized forms of GLT beams were obtained from the point of view of resistance, stability, and material consumption.

CONCLUSION (future possible research area / optional)

These optimized GLT beam shapes will be the starting point for creating a database of optimized models, taking into account the fact that topological optimization through MEF is achieved the faster the shape from which the analysis is initiated is closer to the final solution.

Based on the probable ranges of variation of the geometry of the elements in the GLT, different optimized configurations will be analyzed and a database for AI training will then be built.

Although isolated and incompletely characterized solutions are found in the literature [1][2][3][4][5], such a database is not freely accessible, so it will be possible to provide researchers with a starting point for future research.

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DEVELOPMENT OF AGROECOLOGY IN THE CONTEXT OF GLOBAL RISKS AND OPPORTUNITIES

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ABSTRACT

The purpose of the article is to develop a concept of agroecology development in the context of global risks and opportunities. Research methodology. Using the methods of system analysis, impact modelling and economic assessment of the environment, the ways of implementing agroecological methods, in particular, environmental, economic and socio-cultural impact, are considered. Research results. 1. An analysis of agroecology as an interaction between agricultural production and the natural environment with the aim of creating sustainable and efficient agroecosystems is presented. 2. The concept of agroecology as a resource base for agricultural production and reduction of the ecological footprint in the context of global risks and opportunities is formed. The scientific novelty of the study is that it analyses the functions of agroecology as an interaction between agricultural production and the natural environment, identifies advantages and disadvantages, opportunities for sustainable development and minimisation of negative environmental impact; considers elements of the social content of the concept of agroecology. These concepts, scientists and trends are combined to create an integrated approach to agriculture that not only ensures the production of products, but also preserves the natural environment, promotes social justice and ensures the sustainability of agroecosystems. The practical significance of the study is that it aims to identify key challenges and opportunities for the further development of agroecology in the context of global environmental security and sustainable agricultural production. The implementation of these concepts can help to address the challenges associated with the destruction of biodiversity, soil degradation and water pollution in modern agriculture.

Keywords: agroecology, negative environmental impact, sustainability of agroecosystems, biodiversity, global challenges, opportunities

INTRODUCTION

The development of agroecology in the context of global risks and opportunities is caused by ongoing shocks against the background of rapid technological change and economic uncertainty, as the world suffers from dangerous crises - climate and conflict. The development of agroecology is affected by climate change, the global pandemic, economic crises, cyber threats, geopolitical conflicts, demographic challenges, and

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biotechnological risks, which pose global risks to the development of agroecology. Climate change can lead to extreme weather conditions, sea level rise, destruction of ecosystems and threats to food security; the emergence of new diseases, especially in the context of global mobility, can lead to the rapid spread and large number of cases in a short time; global economic difficulties, financial concerns and crises may have widespread impacts on global stability; attacks on information systems, cyber-espionage and cyber-terrorism may have serious consequences for national and international security; increased tensions between countries and conflicts may cause instability and threaten international security: population growth, population ageing, mass migration and uneven distribution of population can cause various problems for society; development of new biotechnologies can create potentially dangerous scenarios, such as misuse of biological weapons or uncontrolled release of genetically modified organisms. These are only general areas of global risks. Underlying geopolitical tensions, coupled with an outbreak of active hostilities in many regions, are contributing to an unstable global order characterised by polarised narratives, eroding trust and insecurity. At the same time, countries are struggling to cope with the effects of record-breaking extreme weather, as efforts and resources to adapt to climate change are not matching the type, scale and intensity of climate events already occurring. Cost-of-living pressures continue to rise amid persistently high inflation and interest rates, as well as continued economic uncertainty in most countries [1]. The future is uncertain. Many different kinds of futures can be imagined over the next decade. We hope that agroecology can minimise global risks and seize long-term opportunities and solutions.
The purpose of the study: to develop a concept for the development of agroecology in the context of global risks and opportunities.
Objectives of the study: 1) to analyse agroecology as an interaction between agricultural production and the natural environment in order to create sustainable and efficient agroecosystems; 3) to formulate the concept of agroecology as a resource base for agricultural production and reduction of the ecological footprint in the context of global risks and opportunities.

MATERIALS AND METHODS

The materials and methods used to develop a vision for agroecology in the context of global risks and opportunities can include a variety of scientific, technical and social approaches. An overview of possible materials and methods that can be used to develop such a vision is provided below: 1) SWOT analysis, which identifies the strengths, weaknesses, opportunities and threats of an agroecological approach in the context of global risks. 2) Systemic analysis aimed at studying the interaction between the elements of the agroecosystem and identifying the best strategies for sustainable development. 3) Stakeholder engagement, which includes agribusiness, academia, government and the public in the concept development process. 4) Impact modelling, which is aimed at using mathematical models to analyse possible scenarios and their impact on agroecosystems. 5) Economic analysis, which is based on the assessment of the economic efficiency and profitability of agroecological approaches compared to traditional methods. 6) Social impact assessment, which aims to examine the social aspects of agroecology, including the impact on employment, food quality and community life. 7) Stakeholder analysis, which is based on identifying and engaging key stakeholders to ensure support and successful implementation of the concept. The use of these materials and methods can help to create a comprehensive and effective

concept of agroecology development that takes into account global risks and opportunities for sustainable development of the agricultural sector and overcoming the environmental crisis as a factor in achieving economic sustainability in the context of the European Green Deal Voronkova, V., Nikitenko, V., Oleksenko, R., Andriukaitiene, R., Polysaiev, O. [2].

RESULTS

The study reveals the essence of agroecology as a scientific field that studies the interaction between agricultural production and the natural environment in order to create sustainable and efficient agroecosystems; agroecology is presented as a resource base for agricultural production and reduction of the ecological footprint.

1.Agroecology as the interaction between agricultural production and the natural environment to create sustainable and efficient agroecosystems.

Agroecology is a scientific field that studies the interaction between agricultural production and the natural environment to create sustainable and efficient agroecosystems. This approach stems from the realisation that agriculture must be aligned with ecological processes to ensure sustainable production and preservation of the natural environment. The theory of agroecology focuses on the study of the complex interaction of plants, animals, soil and climate in agriculture. It takes into account the diversity of agroecosystems, their structure and functions, as well as the impact of agricultural activities on biodiversity and environmental sustainability [2]. The practice of agroecology involves the implementation of specific methods and technologies aimed at optimising production with due regard to environmental aspects. Such methods may include: 1) Organic agriculture, which includes the use of organic methods of growing plants and animals without the use of synthetic chemicals. 2) Agroforestry, which is based on growing forest crops or forests on the margins or along fields, creating green corridors with forest plantations to preserve biodiversity and maintain ecological balance. 3) Polyculture, which includes the cultivation of several species of plants or animals on the same field to increase biodiversity and reduce the risk of pests and diseases. 4) Agroforestry, which aims to integrate forest trees with crops to create sustainable and productive systems. 5) The use of effective soil and water management systems, based on minimising soil and water losses and increasing their water-bearing and protective role. Agroecology is aimed at ensuring food security and preserving the environment for future generations. The application of these principles in agriculture can lead to the creation of sustainable and environmentally friendly production systems [3].

Table 1. Functions of agroecology as an interaction between agricultural production and the natural environment: advantages and disadvantages

Agroecology function	Advantages	Disadvantages
Sustainability of ecosystems Low productivity	Agroecological methods contribute to the development of sustainable agroecosystems, which reduces vulnerability to pests, diseases and other stressors	Some agroecological methods may be less productive than conventional agricultural production methods

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Soil conservation Increased costs	Agroecology is aimed at preserving and restoring soil fertility, which increases the productivity of agricultural land	Some agroecological approaches may require more labour and other resources
Minimising pollution . Dependence on weather conditions	The use of environmentally friendly production methods helps to reduce water, soil and air pollution	Some agroecological methods may be more sensitive to weather conditions, which can affect crop yields
Increasing biodiversity The demand for re-education of farmers	Agroecosystems can contribute to the conservation and restoration of natural biodiversity	Adoption of agroecological practices may require re-education and training of farmers
Promoting health Possibility of higher product prices	Environmentally friendly products produced using agroecology methods can lead to improved product quality and contribute to human health	The use of agroecological methods can increase production costs, which can lead to higher product prices

Agroecology is a scientific field that explores the interaction between agricultural production and the natural environment in order to create sustainable and efficient agroecosystems [4]. The main idea of agroecology is to develop agricultural production methods that take into account natural processes to the maximum extent possible and minimise the negative impact on the environment. Despite these shortcomings, agroecology is recognised by many experts as a promising approach to agricultural production aimed at ensuring sustainable development and environmental protection. Despite the challenges, agroecology is an important direction for the development of agricultural production, especially in the context of growing awareness of environmental issues and the need for sustainable food production. The further development of agroecological approaches can contribute to the sustainable development of the agricultural sector and food supply in the future. In the context of global challenges, the implementation of agroecological practices can be time-consuming and require significant efforts and resources, especially at the initial stage. Achieving sustainable and effective agroecological results may require long-term research and adaptation of methods to specific climatic and geographical conditions. Some crop types may face particular challenges in the context of agroecology, requiring the development of special approaches. The effectiveness of agroecological practices may vary depending on the region, soil, climate conditions and other factors. Implementation of agroecology may require active cooperation between farmers, scientists and the public, as well as continuous improvement of methods and technologies [5].

2.Agroecology as a resource support for agricultural production and reduction of ecological footprint

The aim of agroecology is to maintain the resource base of agricultural production and reduce the ecological footprint, toxic substances, soil disturbance and water pollution of agricultural land by managing nutrient cycles, protecting pollinators and beneficial microorganisms, maintaining soil health and conserving water. This is consistent with the concepts of organic farming, permaculture, conservation agriculture, agroforestry,

organic farming and permaculture. The only difference is that most farming practices focus only on actions at the scale of the farmland, not at the scale of the overall ecological landscape [6]. Ecological agriculture aims to maintain biodiversity and ecosystem services, support sustainable agricultural production, and improve the livelihoods and quality of life of rural people; an effective ecological agricultural system both establishes co-management of the three sustainable goals and reduces conflicts between Agroecology thus sees rural communities as key managers of biodiversity and ecosystem services. owned or managed by local communities and farmers. The ten elements of agroecology emerged from a multi-stakeholder process aimed at developing a framework for system redesign that could be optimised and adapted to local conditions. The ten elements of agroecology were initially developed between 2015 and 2019. The main themes of the presentations at the 1st International Symposium on Agroecology for Food Security and Nutrition provided the initial agreed basis: resource use, efficiency, diversity, resilience and synergies as the main ecological characteristics of agroecology. However, the Regional Conference strongly called for strengthening the social content of agroecology. Thus, these elements, derived from the regional consultations, were grouped into five additional elements: co-creation of knowledge, human and social values, cultural and food traditions, responsible management and others. International and FAO experts conducted several rounds of review, improved the titles and content of the elements and drew up a coherent and unified content outline, emphasising the inextricable link between ecological agriculture and its ten elements, and finally finalised the framework.

Table 2. Elements of social content of the agroecology concept

Criterion	Content of the agroecology concept
1. Diversity	Diversification is crucial for transforming the agroecology to conserve, protect and enhance natural resources while ensuring food security and nutrition
2. Collaborative knowledge creation and sharing	Collaborative knowledge creation and sharing
3. Synergy	Synergies can improve key functions of food systems, supporting production and multiple ecosystem services
4. Efficiency	Innovative agro-ecological methods allow to increase productivity with less external inputs
5. Recycling	Increased recycling means lower economic and environmental costs for agricultural production
6. Sustainability	Building the resilience of people, communities and ecosystems is crucial for sustainable food and agricultural systems
7. Human and social value	Protecting and improving rural livelihoods, equity and social well-being are crucial for sustainable food and agricultural systems
8. Cultural and food traditions	Supporting healthy, diverse and culturally appropriate diets, agroecology contributes to food security and nutrition while maintaining healthy ecosystems

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9. Responsible management of land and natural resources	Sustainable food production and agriculture requires responsible and effective governance mechanisms at different levels - local, national and global
10. Circular economy and solidarity (circular economy)	A circular and solidarity economy that reconnects producers and consumers, offers creative solutions for our life on Earth and provides the social foundations for inclusive and sustainable development. "Ecological agriculture" that combines farmers' livelihoods, production and ecology in a win-win situation

Agroecology, working at the landscape scale, extends the concepts of wildlife conservation and agricultural production, and contributes to the development of rural livelihoods The ten elements of ecological agriculture were formally proposed at the second FAO International Symposium on Ecological Agriculture in April 2018 and have continued to evolve since then. The Global Symposium on Soil Erosion (GSER19) was held on 15-17 May 2019 at FAO Headquarters in Rome, Italy, and was organised by FAO and its global partners. The Symposium highlighted, among other things, that "If we do not act now, more than 90% of the world's soil will be degraded by 2050". The symposium resulted in the adoption of an action plan aimed at intensifying efforts to combat soil erosion at various levels of governance - minimising soil erosion to enhance food security, ecosystem services and stimulate the restoration of eroded land. Global Symposium on Soil Erosion (GSER19) http://naas.gov.ua/slide/globalniy-simpoz-um-z-eroz-runtu-gser19/ Agroecologists study issues related to four systemic properties of agroecosystems: 1) ecosystem productivity, 2) ecological stability, 3) sustainability, and 4) equity. In contrast to disciplines that deal with only one or more of these attributes, agroecologists consider all four attributes as interrelated and integral to the success of an agroecosystem. Recognising that these attributes are manifested at different spatial scales, agroecologists do not limit themselves to studying agroecosystems at any one scale. Agroecology includes three land use sciences: agriculture, forestry and agroforestry. Although they use their plant components in different ways, they share the same theoretical core. It is important to provide a theoretical framework for the hitherto missing land use science. This allows for progress in bio-agroecosystems, including multi-species plantations in forestry and agroforestry. Since organic agriculture claims to support the health of soils, ecosystems and people, it has many similarities with agroecology, which does not mean that agroecology is synonymous with organic agriculture. It is also important to note that organic standards vary greatly between countries and certification bodies. The three main areas that agroecology addresses include: 1) environmental impact; 2) animal welfare issues; 3) social aspects [7].

DISCUSSIONS

Among the discussions, it should be noted that agroecology has been developed by such authors as: 1) Alternative farming methods: Rodeilte Wennermark is a Swedish ecologist who has made a significant contribution to the development of agroecology. He emphasises the importance of understanding biological processes in agriculture and the use of natural mechanisms to control pests and diseases. 2) Systemic agroecology: Miguel Alternat is a French scientist who develops the concept of systemic

agroecology. He emphasises the importance of considering agricultural systems as holistic, interdependent systems where different components interact and influence each other. 3) Agroecosystems and biodiversity: Edward Goldsmith is an ecologist and the author of the concept of "agroecosystem". He emphasised the importance of considering agriculture as part of a natural ecosystem rather than an isolated system. 4) Agroecological technologies: Frederick Horton was an American physicist and agronomist who worked to develop agroecological technologies, such as soil and water conservation methods, that contribute to sustainable agriculture. 5) Social agroecology: María Mercedes Conil is a Spanish scientist who focuses on the social and economic aspects of agroecology. She studies the interactions between rural communities, consumers, and agricultural enterprises to create equitable and sustainable agricultural systems. These concepts and scholars come together to create a holistic approach to agriculture that not only produces food, but also preserves the natural environment, promotes social justice and ensures the sustainability of agroecosystems. The implementation of these concepts can help to address the challenges associated with the destruction of biodiversity, soil degradation and water pollution in modern agriculture. This problem is discussed in the author's article on the formation of a paradigm for sustainable agricultural development in the context of the management experience of industrialised countries by Vitalina Nikitenko, Valentyna Voronkova, Roman Oleksenko, Halyna Matviienko, Oksana Butkevych [1].

CONCLUSIONS

The practical formation of a sustainable agroecology paradigm is becoming a critical task in light of the growing challenges related to food supply, conservation of natural resources and reduction of environmental impact. This article examines the management experience of industrialised countries and its application to the paradigm of sustainable agricultural development. The application of holistic strategies and the integration of environmentally friendly practices in production are key aspects of this paradigm. The article analyses the best practices of agricultural management in countries with a high level of industrial development, including the use of the latest technologies, developed systems of agricultural technology and stimulation of innovation in production. The results of the study allow us to identify promising strategies and approaches for implementing the paradigm of sustainable agroecological development in the context of global challenges and realising the possibilities of the management experience of industrialised countries.

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ECOLOGICAL MONITORING OF SOIL AND PLANT CONDITIONS IN SPECIALLY PROTECTED NATURAL AREA

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ABSTRACT

Environmental monitoring in specially protected areas is a vital problem, especially in places subject to anthropogenic impacts. The Tunkinskaya Valley (190 km long) is the western extension of the Baikal rift zone. On the territory of the valley there is a national park of federal significance. At the same time, the territory is subject to intensive anthropogenic load. The Tunkinskaya Valley is an attractive place for tourists. The local population (20,000 people) is engaged in cattle breeding. Industrialized areas of the Baikal region may also have an impact on the valley ecosystems.

The paper presents the results of ecological monitoring of soils and vegetation of valley from 2018 to 2022. During the field research, soil profiles were laid out, and vegetation communities in the reference areas were described. More than 100 soil and plant samples were collected.

During laboratory studies the organic matter content, mechanical composition of soils, acidity, content of heavy metals (Ba, Cd, Co, Co, Cr, Cu, Fe, Mn, Ni, Pb, V, Zn) in soil samples and pine bark (a proven bioindicator of atmospheric pollution) were determined within the atomic emission method. Statistical processing of the data was carried out.

Acidity in samples of pine bark varies from 3.89 to 5.43, the environment is acidic, which indicates the entry of sulfur compounds into the atmospheric air. Exceedances relative to clarks were obtained for Cu, Fe, Zn, Pb. Such exceedances are caused by the wood burning and motor transport using. Exceedances of standards for Cu were found in soils.

During our research, the fact that the soils and vegetation of the Tunkinskaya Valley have a great diversity and mosaic distribution was found out. Thus, regular ecological monitoring of changes in the natural environment should be carried out in this park.

Keywords: environmental monitoring specially protected areas, ecosystems, soils, plants, heavy metals.

INTRODUCTION

In 1991, the Tunkinsky National Park was established to protect unique and reference natural areas, preserve and restore biodiversity [1]. This territory is part of the Baikal rift zone. The great diversity and special character of land cover distribution is due to the region's location in the contact zone of three natural biogeographical areas - the

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Central Siberian taiga, the South Siberian mountainous-mountainous-taiga and the Baikal-Dzhugdzhur mountainous-mountainous-taiga [4].

Within the park's territory are distinguished: Tunkinskaya Golts, occupying the northern part of the park; the Khamar-Daban range and its spurs, covering the southern, central and eastern parts of the park territory, and a chain of intermountain basins located between them. The Tunkinskaya depression is 200 kilometers long and 20 to 40 kilometers wide.

High spatial heterogeneity of climatic, geological-geomorphological and phytocenotic conditions, which determines the formation of a great diversity of soils belonging to 4 soil formation trunks, 14 departments, 56 types in the territory of the Tunkinskaya Basin and its mountainous frame [2].

The vegetation is represented by mountain-tundra, mountain-meadow, mountain-taiga and taiga communities in combination with mountain-steppe communities.

Over 1000 species of vascular plants grow on the territory of the park, among which the most numerous are forest and meadow herbaceous plants. The main forest-forming species is cedar (*Pinus sibirica*) - 51.9 %. Cedar forests rise up to the upper boundary of the forest, above in the subalpine belt there are communities of cedar shrub (*Pinus pumila*). 25.8 % of the forest area is covered by larch (*Larix sibirica*), pine stands account for 8.1 % (Pinus sylvestris), spruce (*Picea obovata*) - about 1 %, minor areas are occupied by fir (*Abies sibirica*). Among small-leaved forests (10.3 %) the most widespread are birch (*Betula platyphylla*) - 8.5 % and aspen (*Populus tremula*) - 1.6 %.

The total area of the park is 11,836.62 km2. The Tunkinsky district is visited by more than 100 thousand people annually. Numerous mineral springs Arshan, Zhemchug in combination with dry sunny climate and widespread coniferous forests have made this area popular as a zone of resort recreation and treatment.

The local population (20 thousand people) is engaged in cattle breeding. The main degradation processes occurring in the steppe soils of the Tunkinskaya valley are deflation and pasture erosion. On the territory of the Tunkinskaya Basin more than 50 % of the territory of the part of the basin is occupied by agricultural lands, of which 36 % are represented by arable lands and former arable lands.

Industrial enterprises that may have a negative impact on the Tunkinsky Valley are located in the Irkutsk Oblast. The valley ecosystems may be affected by enterprises of the Irkutsk-Cheremkhovo industrial hub - the main types of industrial sectors here are mining (Slyudyanka) and pulp and paper and food industries (Baikalsk and Kultuk), non-ferrous metallurgy (Shelekhov), chemistry and petrochemistry (Angarsk), machine building (Irkutsk). Stove heating prevails on the territory of the park, and a brick-making workshop is functioning.

MATERIALS AND METHODS

To assess the state of the environment in the study area of the Tunkinsky Valley, samples of pine bark *Pinus sylvestris* L. (table 1). Pine bark samples were taken from several trees within the sample area, from each tree along the entire circumference of the trunk at a height of 1.3 metres. Trees of approximately equal age, trunk diameter and height were selected. The trunks were preliminarily stripped of lichens. Samples of pine bark were taken in places with different anthropogenic load in Arshan settlement.

Table 1. Location of reference areas.

№ pine bark sample	№ soil profile	Place of sampling
1	8	up the slope, 150 m from the Papiy source
2	9	near the Datsan "Bodhidharma"
3	10	the floodplain of lake Asanur, 5 m near the arable land
4	11	the extinct volcano Ulyaborsky, near the Khurai-Hobok settlement
5	12	the territory of the health resort and sport school of Arshan settlement
6	13	the forest in front of the entrance to the Arshan settlement, near the road 150m
7	14	South-West slope of the Peak of Love, 200 m from the foot up Arshan settlement

Active and potential acidity of soils was determined by potentiometric method. The content of total carbon in soils was determined by the Tyurin method. Granulometric composition was determined by N.A. Kachinsky. The content of mobile forms of heavy metals in samples was determined by atomic emission method on optical emission spectrometer ICPE-9000 in the Research Park of SPbU in the Resource Centre "Chemical Analysis and Materials Research Centre".

The clarks of heavy metal content in plants according to Dobrovolsky were used as a criterion for assessing the level of air pollution [3]. To find the strength of the relationship between chemical elements, the correlation coefficient was calculated and the correlation graph of the research results was constructed.

RESULTS

The average height of trees was 14 m, the height of peeled crust was 3.5 m, bonitet from 2 to 4 class, the condition of needles by the presence of chlorosis and necrosis according to Schubert was estimated in average as 3 points. Acidity in the collected samples of pine crust varies from 3.89 to 5.43. Tree crust pH value of 5.89 was noted in the sample collected near Datsan Bodhidharma. The nature of changes in Cu, Zn and Pb content can be traced in Figure 1.

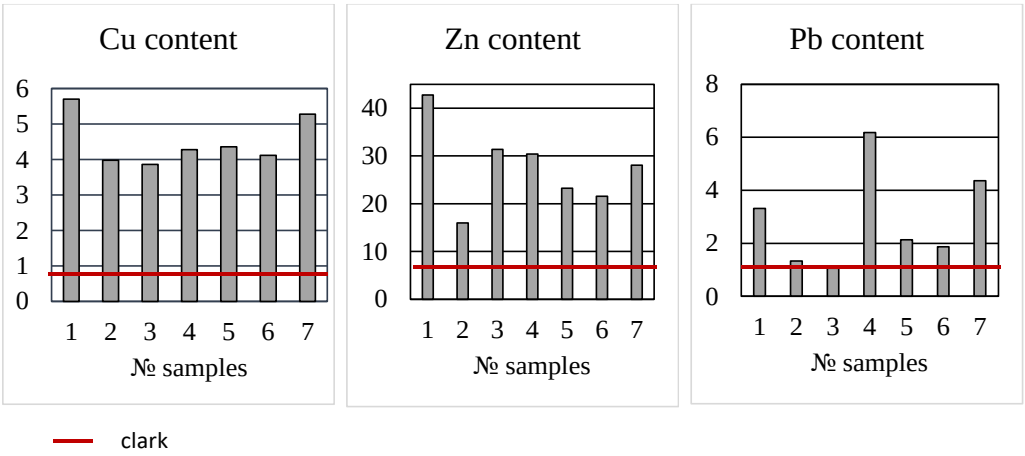


Fig. 1. Cu, Zn and Pb content in pine bark, 2022, ppm.

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Exceedances of zinc relative to the clark (7.5 ppm) were observed in all analysed samples on average 4 times (table 2). Maximum zinc content (42.8 ppm) was observed in the territory of the sanatorium. The minimum zinc content (5.9 ppm) was observed in the sample collected near Datsan Bodhidharma (Fig.1).

Table 2. Content of heavy metals in pine bark in the Tunka Valley based on the results of 2021 and 2022, ppm (n = 7).

	Fe	Mn	Ni	Cr	Cu	Pb	Sr	Zn	V
Average	481	31	1.34	0.8	5.7	2.6	18.1	20.6	4.89
Min – max	104 – 1192	12 – 54	0.5 – 1.3	0.2 – 2.3	4 – 9	1.1 – 6	2 – 53	9.5 – 43	0.3 – 12
Median	390	32	1.02	0.5	5.3	2.0	14.4	18.2	1.84
Clark according to Dobrovolsky	250	205	2	1.8	0.8	1.25	35	7.5	1.5

Exceedances of lead relative to the clark (1.25 ppm) were observed in samples on average 2.5 times. The maximum concentration of lead (6.2 ppm) was observed in the area at the foot of the Tunkinsky mountains (the beginning of the "Love Peak" ecological trail) (sample area 4). The minimum lead content (1.1 ppm), not exceeding the clark, was noted in sample area 3 on the territory of an extinct volcano (Fig. 1).

Table 3 presents the carbon content and acidity of the studied soils. These characteristics were determined for soil transects laid out in the territory of Arshan settlement. Section No. 9 - low thickness Leptosols Yermic earth on quaternary sediments, Section No. 11 - Cambisols Dystric on volcanic sediments (Fig. 2), Section No. 14 - low thickness Podzols Entic on deluvial sediments.

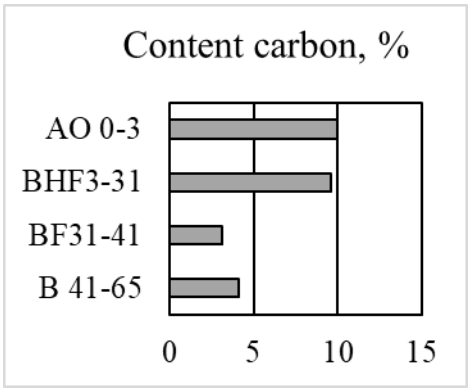
Table 3. Carbon content and pH in soils of Tunkinsky National Park.

N section, genetic horizon, depth, cm	Soil name	C, %	pH_{H20}	Soil texture
№11				
O (0-5)	Cambisols Dystric	10.03	5.9	Light silty-sandy loam
BHF (5-31)		9.61	6.4	Medium silty-silty loam
BF (31-41)		4.11	7.9	Sandy loam
BC (41-65)		3.12	8.8	Sand
№9				
O (0-3)	Leptosols Yermic	8.10	5.8	Silt-sandy loam
АУ (3-13)		3.03	6.1	Light silty-sandy loam
BM (13-35)		3.83	8.3	Medium silty-silty loam
№14				
O (2-12)	Podzols Entic	7.71	7.4	Silt-sandy loam
BHF (15-30)		7.29	8.3	Medium silty-sandy loam

Humus formation processes occurring in the upper organogenic horizons produce organic substances, which are capable of downward migration enriching mineral horizons of profiles. For lignite soils, the main concentration of carbon is in the upper horizons.

In Podzols Entic of forest communities it is possible to trace a sharp decline in carbon concentration in mineral horizons of soil sections (Fig. 3). According to the

granulometric composition, the BF horizon belongs to: silt-sand sandy loam, horizon B2 - medium silt-sand loam.

A) 

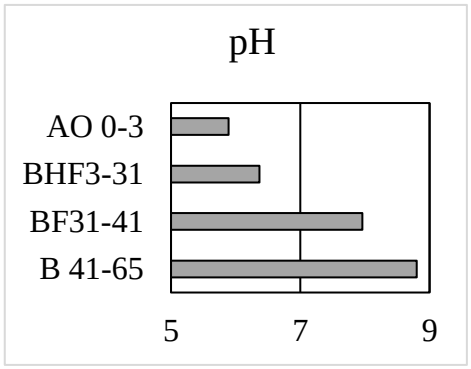
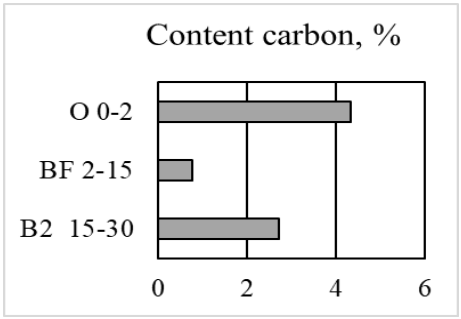
B) 

Fig. 2. Carbon content, % (A) and pH (B) in profile No. 11 (Cambisols Dystric on volcanic deposits).

A) 

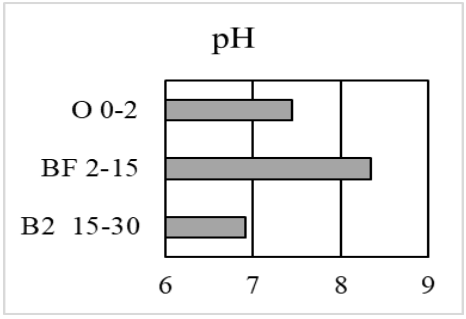
B) 

Fig. 3. Carbon content, % (A) and pH (B) in profile No. 14 (Podzols Entic on colluvial deposits).

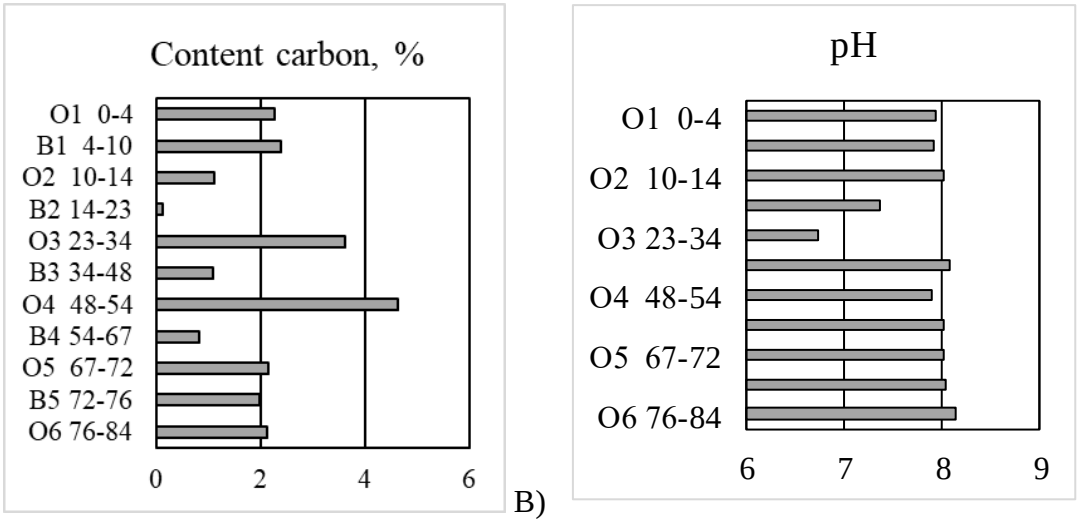
In section No. 12 (Anthrosols on dealluvial deposits) carbon content is higher in organogenic horizons, but it can be traced that the concentration in the middle profile of the soil section is characterised by the maximum, namely in the O4 horizon - 4.64, the minimum content in the upper horizon B2 - 0.83. The section is also characterised by alkaline reaction of the medium (Fig. 4).

The acidity of the prevailing number of analysed soil samples is close to neutral and slightly alkaline. The upper horizons of the soil stratum and humus mass are characterised by the reaction of the medium close to neutral (pH 6.5-7.2), and in the middle and lower parts of the profile - weakly alkaline/alkaline medium. The acidity of the medium affects the migration ability of heavy metals (Table 4).

Table 4. Content of mobile forms of heavy metals in soils of the Tunka Valley in 2022, ppm (n=52).

	Ba	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Sr	V	Zn
Average	67.37	0.30	0.61	3.75	167	103.9	0.99	0.77	30.91	0.15	5.19
Min	17.54	0.06	0.11	1.95	12	12.6	0.29	0.27	3.96	0.04	0.58
Max	168.4	0.53	2.09	12.20	1124	296	2.86	2.33	102.8	0.84	24.20
Median	57.00	0.34	0.52	3.45	99	84.4	0.88	0.65	27.51	0.12	3.32
MPC	-	-	6	3	-	100	4	6	-	-	23

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A) B)

Fig. 4. Carbon content, % (A) and pH (B) in profile No. 12 (Anthrosols on deluvial deposits).

Direct dependence between elements Cr-Fe, Cr-Pb, Cu-Zn, Pb-Zn, and inverse dependence between elements Cu-Mn, Mn-Zn was determined. Average variation is characterised by Ba, high by Cu, Fe, Ni, and abnormally high by Cr, Mn, Pb, and V.

DISCUSSION

The crust of pine trees in the studied area is acidic, which indicates the intake of acidifying substances, including sulphur oxide, into the atmospheric air. This is associated with the use of stove heating in the settlements of the Tunkinskaya valley. Samples taken near the road (3.91), sanatorium and sports school "Sayany" (3.89) are the most acidic, which is associated with the location of the points near the sources of anthropogenic impact.

According to the data obtained (tab. 2), we can see exceedances of iron, copper, lead and zinc relative to the vegetation clark. Exceedances of copper relative to the clark (0.8 ppm) were observed in all analysed samples on average 6 times. The maximum copper concentrations were observed in samples taken in the territory of the sanatorium and the "Sayany" sports school, and in the forest 150 m from the road, respectively. Exceedances of Cu, Zn and Pb can be associated with unfavourable fire hazardous situation, which was in the territory of the Siberian Federal District and the Far East in the period from June to October 2021-2022. Irkutsk region and the Republic of Buryatia were covered with smog, and these chemical elements are contained in the products of emissions from fires. The use of stove heating in settlements also affects the state of atmospheric air.

Many crushed stone inclusions are present in the profiles of the studied soils. Mountainous and rugged relief favourably influence formation of high-skeleton soil. This indicates that the soil cover of the territory is young in development, which was formed by recent processes of soil mass destruction as a result of various exogenous processes.

Soil acidity decreases with depth, which is connected with chemical composition of soil-forming rocks. According to the granulometric composition, the AO horizon is

classified as: light dusty-sandy loam, B- horizon is loose light fine sand, BHF horizon is medium silt-dusty loam.

Due to mudflows, bulk horizons in Anthrosols were formed in which carbonate leaching does not occur.

The distribution of heavy metals is closely related to the humus content of soils in the Tunkinskaya Valley. High accumulation of heavy metals occurs in soils with high humus and peat content. Exceedances of MPC on the territory of the Tunkinskaya valley were noted for Mn on average 2 times in all soil sections, for Cu and Zn in Histosols Fibric, Podzols Entic и Albeluvisols Gelic. The highest content of Mn, Ni and Fe was observed near Lake Yerganginskoe in Albeluvisols Gelic. In general, the presence of permafrost hinders migration. Increased content of chemical elements is more often found in soils of heavy granulometric composition.

The content of mobile forms is variable and depends on many factors, including precipitation, acidity of precipitation and soils, etc. The content of mobile forms of trace elements obtained in 2022 exceeds those determined in 2021. Exceedances of MAC standards [5] are observed for Cu, Mn, Zn.

CONCLUSION

During the conducted research it was found that soils and vegetation of the Tunkinskaya valley have a great diversity and mosaic distribution. In forest communities were identified: Albeluvisols Umbric, Cambisols Dystric, Phaeozems Albic. Anthrosols were described in the zone of mudflow influence - after mudflow descent, soil formation processes start anew. Histosols Fibric containing perennially frozen horizons were studied on the shores of Lake Okinskoye and Lake Yerganginskoye.

The average humus content in Cambisols Dystric was 6.01 % per dry soil, in Podzols - 2.66, in Albeluvisols Umbric - 3.95, Anthrosols - 2.03. Alkaline reaction of the environment of the analysed soils indicates the predominant carbonateness of soil-forming rocks of the region and salinity of the soils themselves. Presence of underground mineral springs increases alkalinity in lower horizons. The upper horizons of such soils have neutral reaction that speaks about leaching regime of soils in the upper horizons.

In terms of granulometric composition the studied soils are mainly dusty-sandy and silty-sandy sandy loams, light dusty-sandy and medium silty-sandy loams. In the profiles of the studied soils there are many rubbly inclusions. Mountainous and rugged relief favours formation of high-skeleton soil.

Concentrations of mobile forms of TM in Pinus sylvestris L. pine crust were higher than their clarks in plants for Fe (104-1192 ppm), Pb (1.1-6.2 ppm), Cu (3.9-8.6 ppm), Zn (9.5-42.8 ppm). Increased content of Cu and Zn was found in all analysed samples of Pinus sylvestris L. Crust samples of Pinus sylvestris L. crust have increased content of heavy metals Fe, Pb, samples taken in the territory of the sanatorium and sports school "Sayany", at the beginning of the ecological trail and 150 m from the road to Arshan settlement. The pH values in the pine bark samples are acidic, which indicates that sulphur oxide and other acidifying substances are entering the air. Acidity in the collected samples of pine bark varies from 3.89 to 5.43. Samples taken near the road (3.91) and the sanatorium and sports school "Sayany" (3.89) have the most acidic

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environment, which is associated with the location of points near sources of anthropogenic impact.

Heavy metals concentrations in soils were determined in the following ranges: Ba 18-168; Cd 0,06-0,53; Cr 0.11-2.09; Cu 1.95–12.2; Fe 12-1124; Mn 13-296; Ni 0.29-2.86; Pb 0.27-2.33; Sr 3.96-102,8; V 0.04-0.84; Zn 0.58-24.2 ppm; the concentrations of Co, in the samples were below the detection threshold.

It is necessary to conduct regular ecological monitoring of changes in the natural environment in Tunka National Park.

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To the staff of the Resource Centre "Chemical Analysis and Materials Research Centre" of the SPbU Research Park.

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ECOLOGICAL ROLE AND SPATIAL VARIABILITY OF WINDBREAKS IN SLOVAKIA: IMPLICATIONS FOR CLIMATE-RESILIENT AGRICULTURAL LANDSCAPES

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ABSTRACT

Windbreaks play a crucial role in mitigating the impacts of climate change and preserving agricultural landscapes. This study addresses the knowledge gap concerning windbreaks in Slovakia, analysing 47 windbreaks comprising 24 trees and shrubs species. Predominantly, windbreaks feature Robinia pseudoacacia (21.8%), Populus nigra (16%), and Acer platanoides (8.7%) among trees, and Rosa canina (18.4%), Sambucus nigra (3.5%), and Crataegus oxyacantha (2.5%) among shrubs. Spatial analysis underscores variations in windbreak characteristics, encompassing length, width, and species composition. The study delineates windbreaks into non-permeable (3 pieces), with an average length of 882.87 meters, width of 6.05 meters, and height of 9.37 meters, showcasing the highest species diversity (averaging 4.74 species), semi-permeable windbreaks (13 pieces), with an average length of 608.307 meters, width of 5.53 meters, and height of 8.57 meters, and permeable windbreaks (31 pieces), averaging a length of 327.66 meters, width of 5.23 meters, and height of 9.52 meters. Even though the calculated ecological stability did not demonstrate significant growth, other vital parameters underscore the importance of windbreaks. These include the fact that windbreak protection effects cover 43% of total arable land, and by employing the windbreaks as a barrier, the unprotected field length has decreased by 3,6%. The ecological significance of windbreaks lies in reducing wind erosion, conserving soil moisture, protecting crops, and enhancing biodiversity. By employing geospatial tools, this research provides insights into windbreak attributes and their ecological roles, essential for sustainable land management practices amidst changing climatic conditions.

Keywords: windbreaks, spatial variability, climate resilience, ecological role, agricultural landscape

INTRODUCTION

Vegetation plays an important role in the landscape. It is essential for productivity and ecological stability. Windbreaks on agricultural lands provide indirect economic benefits like controlling soil erosion, protecting livestock, and managing wind and snow, complemented by direct advantages such as increased crop and livestock yields,

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improved aesthetics, and wildlife habitat [1]. In Slovakia, windbreaks have historically mitigated environmental problems, especially in sparsely forested lowlands with light, dry soils. Protective shelterbelts, which date back to the 1950s in Czechoslovakia, have left a lasting imprint on the landscape, although some areas have since suffered neglect and deterioration. Several factors influence the effectiveness of windbreaks, including height, optical porosity (OP), orientation, length, and location within the landscape [2]. OP, determined by photographic analysis [3], is commonly used to assess the effectiveness of windbreaks. Medium density barriers reduce wind speed by at least 20% over a greater distance than either high density fences or high porosity barriers [4]. Typically, windbreaks with a porosity between 20 and 50% provide the most effective leeward protection [5, 6]. The taxonomic composition of a windbreak plays an important role in determining its effectiveness in reducing wind speed. In addition, the vegetation diversity within the windbreak can be assessed using structural indices and functional assessments. [7]. To increase the ecological stability (ES) of the landscape and to promote the conservation of biodiversity, it is advisable to use native species for afforestation [8]. Despite the recognised benefits, understanding the spatial variability of windbreaks in Slovakia's agricultural landscapes is crucial for land management strategies that maximise their ecological and economic benefits [9]. Understanding this variability is essential for developing effective land management strategies that take local conditions into account and maximise the ecological and economic benefits of windbreaks.

MATERIALS AND METHODS

Study area

The study area, located in south-west Slovakia, covers a total area of 57.08 km^2. It includes five cadastral areas of Čechynce, Veľké Janíkovce, Malý Cetín, Veľký Cetín and Golianovo (Figure 1).

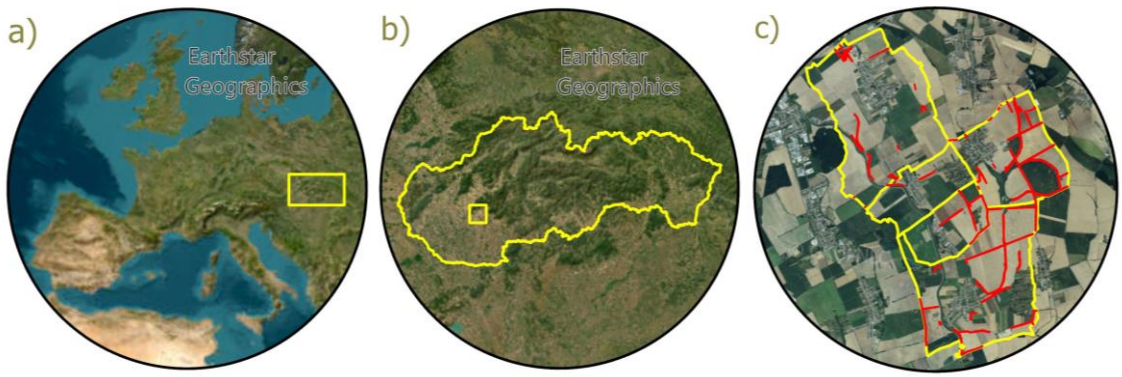


Figure 1 Study area a) within Europe, b) within Slovak republic, c) detail of cadastral areas (yellow color) and mapped windbreaks (red color)

The land use composition of this area portrays a landscape characterized by significant agricultural and urban elements, with arable land dominating at 79.64% and urban/built-up areas occupying 6.34% of the total area (Table 1). While this distribution might suggest a heavier focus on agricultural production and human settlement, there are

notable efforts towards incorporating ecological considerations. Windbreaks, covering 2.00% of the landscape, play a crucial role in mitigating wind erosion and maintaining soil health, demonstrating efforts towards sustainable land management. Despite its relatively small acreage, the presence of windbreaks is essential for ecological stability. While the composition may not be entirely balanced in terms of land use distribution, it reflects a complex interplay between human activities and ecological considerations, highlighting ongoing efforts to achieve sustainability and resilience in the landscape.

Table 1 Land use composition

Land use	Acreage (ha)	%	Land use	Acreage (ha)	%
Arable land	4546,52	79,64	Other land	118,8	2,08
Urban / Built up land	361,76	6,34	**Windbreaks**	**114,36**	**2**
Inland water bodies	164,75	2,89	Permanent grass cover	44,49	0,78
Garden	160,41	2,81	Forest	44,11	0,77
Vineyard	141,18	2,47	Orchard	12,32	0,22

Within this study we analysed 47 windbreaks comprising 24 trees and shrubs species. To assess the optical permeability of individual windbreaks, detailed photographs of linear vegetation were captured during the months of September to October 2022. Utilizing photographs obtained in the field, we evaluated the optical transmittance of individual strips of linear vegetation using a script written in the Python programming language. This evaluation involved quantifying the number of black and white pixels in the photographs [10]. The pixel count was then converted into percentages, and based on the percentage scale of optical transmittance, the data were categorized into three distinct classifications: permeable, semi-permeable, and non-permeable [11]. The objective of the field survey was to document the parameters of linear vegetation within the designated extravillas of the cadastral territories. The evaluation parameters of linear vegetation included location coordinates, length (m), width (m), and height (ascertained using the mobile application "Arboreal" for height calculation via camera). Additionally, vegetation types were identified using the mobile application "PlantNet," supplemented by species verification through the "Tree Atlas." The abundance of linear vegetation species was recorded both in absolute counts and as percentages of total vegetation observed. The protective zones of the windbreaks were defined for the prevailing wind orientations from north-west and south-east for permeable windbreaks as 25H, for semipermeable as 35H and for non permeable as 10H (Figure 2).

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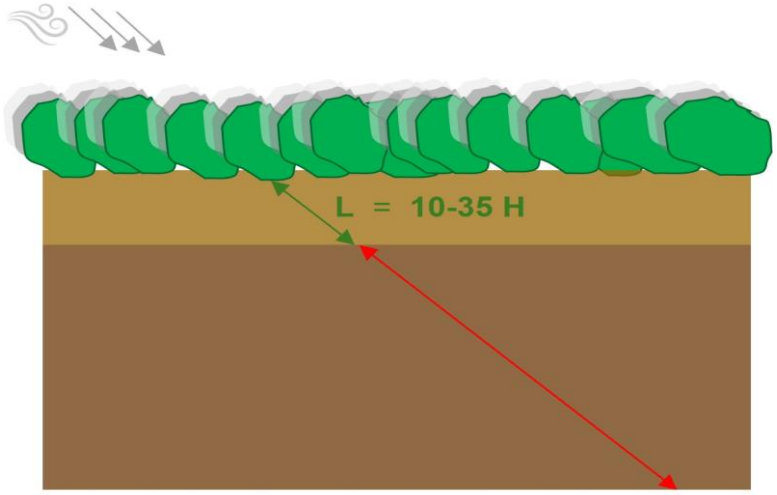


Figure 2 Protective (green) and non-protective (red) length of the field in the prevailing wind direction

Calculation of the Coefficient of Ecological Stability (CES) [12]

$$CES = \frac{1,5A+B+0,5C}{0,2D+0,8E}$$

where:
A – % of areas with the 5th level of ES (forests, water bodies)
B – % of areas with the 4th level of ES (riparian vegetation, small woody vegetation)
C – % of areas with the 3rd level of ES (meadows, pastures)
D – % of areas with the 2nd degree of ES (arable land)
E – % of areas with the 1st degree of ES (built-up areas)

Table 2 Evaluation of CES values

CES Value	Evaluation
< 0.1	Degraded landscape
0.1 - 1	Disturbed landscape
1	Balanced landscape
1 - 10	Landscape with dominant natural elements
> 10	Natural or semi-natural landscape

RESULTS

We classified optical porosity according to three categories: permeable (>60%), semi-permeable (30-60%), non-permeable (<30%). The representation of permeable windbreaks was 6.39%, semi-permeable 25.53%, and the non-permeable windbreaks represent 68.08%. Subsequently, we categorized the number of pieces of vegetation types (trees, shrubs) in individual windbreaks. The total number of analysed trees and shrubs was 6 696 (Figure 3).

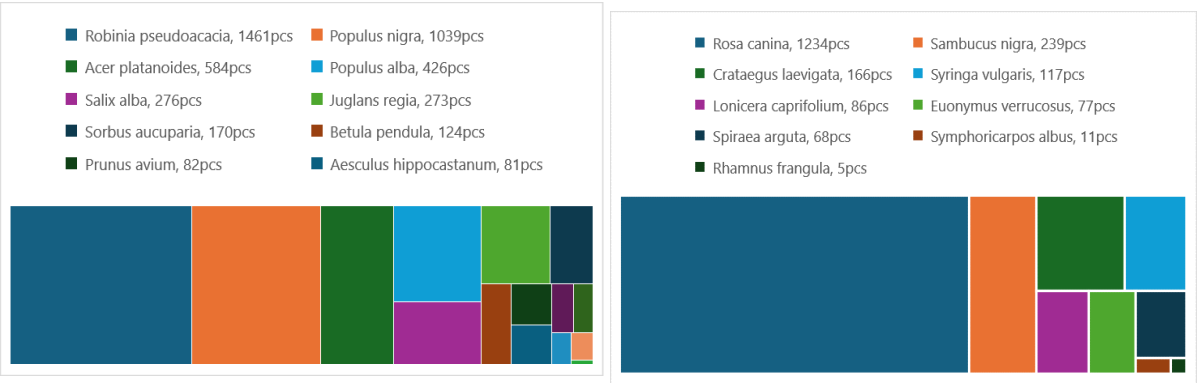


Figure 3 Total number of analysed trees and shrubs

The windbreak composition predominantly consists of *Robinia pseudoacacia*, *Populus nigra*, and *Acer platanoides*, which collectively account for approximately 45.6%, 33.4%, and 18.9% of the total tree population, respectively. These species likely contribute to the effectiveness of the windbreak in providing shelter and ecological benefits. Additionally, the diversity of shrubs, with Rosa canina being the most abundant at 53.8%, enhances the overall structure and functionality of the windbreak. The presence of a variety of tree and shrub species indicates a well-balanced ecosystem within the windbreak, potentially attracting diverse wildlife and contributing to biodiversity conservation efforts. Overall, the composition suggests a resilient and multifunctional windbreak system with the potential to offer numerous environmental and ecological benefits to the surrounding area.

The total length of all windbreaks was 36260 m (average length is 771m). To calculate the protection length of the windbreak we used geoprocessing tool of the ArcGIS Pro flow length (FL) (implementing flow direction of northwest prevailing wind) (Figure 4).

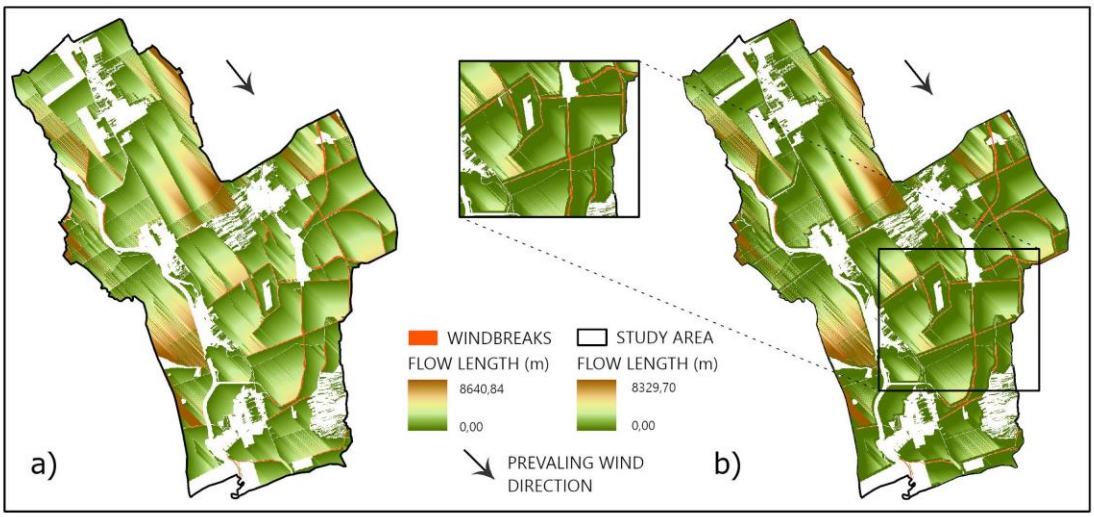


Figure 4 FL in the prevailing wind direction in the study area (a) LF with no protective windbreak effect; b) LF with protected windbreak effect)

The average field length without the protection of windbreak was in the study area 662,57m. After implementing the protective impact of the windbreaks (depending on their optical porosity 10-30H) the maximum non protected field length has decreased by 3,6% (311,14 m) and the average non-protected field length on the arable land has decreased by 37% (413,01m) and the non-protected area has decreased by 43,3 %.

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Based on the analysis of non-protected flow lengths in the prevailing wind direction, we observed different categories reflecting the distribution of flow lengths. These categories show the percentage distribution of flow lengths within certain ranges. This analysis allows us to understand the distribution of flow lengths within each category, providing insight into where most flows fall and their relative proportions (Figure 5).

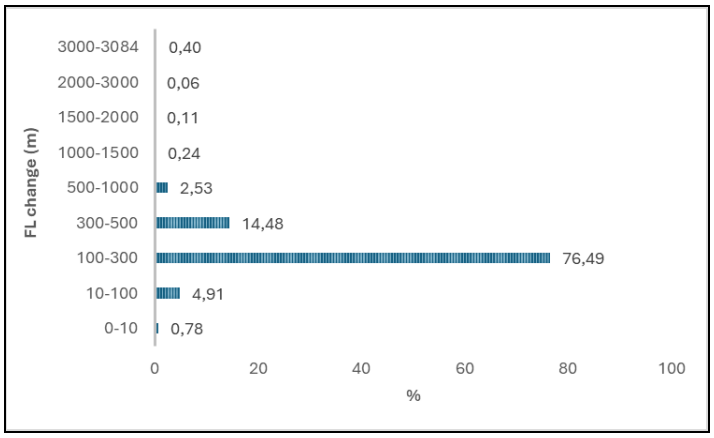


Figure 5 % distribution of FL change

To summarise the results and confirm the importance of windbreaks in the agricultural landscape, we calculated CES of the study area (Figure 6). The data show fluctuations in CES values from 2000 to 2024, with a decreasing trend until 2018 and a significant increase until 2024. This suggests periods of instability followed by some improvement in ecosystem stability. When the windbreaks were excluded from the calculations, the change in CES in the study area was minimal. When the windbreaks and their shelterbelts were included in the calculations, ecological stability increased by 42% (1.17), which can be interpreted as a balanced landscape.

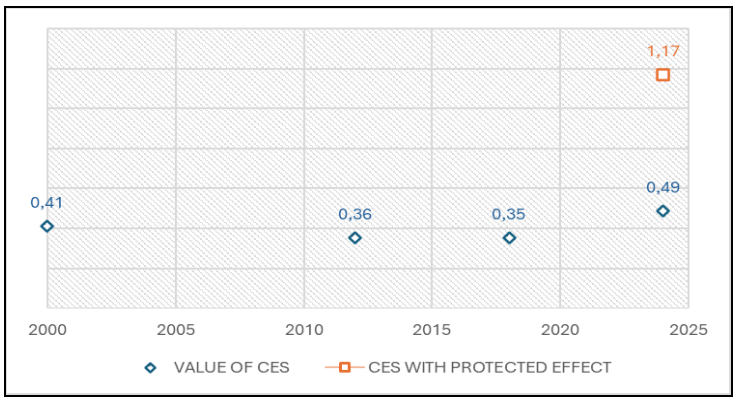


Figure 6 CES of the study area (2000-2024)

DISCUSSION

The research aims to understand the ecological role and spatial variability of windbreaks in Slovakia's agricultural landscapes, providing insights into management strategies for establishing climate-resilient agricultural landscapes. The results of the study shed light on several key aspects related to windbreaks and their impact on ecosystem stability and agricultural productivity. Firstly, analysis of windbreak composition reveals a diverse range of tree and shrub species, indicating a well-balanced ecosystem within windbreaks. This finding is consistent with the hypothesis that diverse vegetation within

windbreaks contributes to their effectiveness in providing shelter and ecological benefits. The dominance of species such as *Robinia pseudoacacia*, *Populus nigra* and *Acer platanoides* supports existing literature on the importance of specific tree species in windbreak effectiveness [13]. In addition, the assessment of the protective effect of windbreaks on arable land shows a significant reduction in non-protected field lengths with the implementation of windbreaks. This confirms the hypothesis that windbreaks reduce wind erosion and maintain soil quality, in line with other research [14]. The calculation of CES also highlights the positive contribution of windbreaks to landscape equilibrium and resilience, supporting the notion that windbreaks enhance ecological stability in agricultural landscapes. The spatial variability of windbreaks within Slovak landscapes adds a nuanced dimension to the results, emphasising the importance of tailored management strategies that take local conditions into account. This finding highlights the need for context-specific approaches to windbreak management, considering factors such as topography, climate, and soil characteristics [15].

CONCLUSION

The study highlights the crucial role of windbreaks in agricultural landscape management by categorising them according to porosity and analysing their composition. It reveals a diverse mix of tree and shrub species, suggesting resilient ecosystems that potentially enhance biodiversity. The establishment of windbreaks significantly reduces the length of unprotected fields, mitigating wind erosion and maintaining soil quality. The analysis shows localised effects on wind flow patterns within certain distances. Overall, well-designed windbreaks offer tangible benefits for ecosystem stability, soil conservation and the enhancement of biodiversity in agriculture. The results suggest that well-designed windbreaks contribute to ecological resilience and provide tangible benefits to agricultural productivity. However, further research is needed to explore the long-term effects of windbreaks on ecosystem dynamics and to optimise their design and management for maximum effectiveness. In addition, assessing the socio-economic impacts of windbreak establishment and maintenance would provide valuable insights into their wider implications for sustainable land use practices.

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ECOPHYSIOLOGICAL RESPONSE OF INVASIVE SPECIES ON SPOIL HEAP WITH DIFFERENT TYPE OF RECLAMATION: *SOLIDAGO GIGANTEA* AITON STUDY

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ABSTRACT

Coal mine spoil heaps are subject to reclamation processes in order to restore their environmental, social and economic functions. The reclamation may consist of placing soil layers (topsoil, TS) on the surface of the bare rock (carboniferous rock accompanying the coal seam) and then planting vegetation. However, waste rock (bare rock, BR) is usually left in place without overburden due to high costs. In both cases, there is a spontaneous succession of consisting vegetation of native and alien species.

In this study, we compare the efficiency of seed germination populations of the alien invasive species *Solidago gigantea* Aiton (*Sg*) originating from the TS and BR areas of the same spoil heap and the ecophysiological response of plants grown from germinated seeds. The research was carried out under laboratory conditions, measuring the content of pigments in leaves, the efficiency of the photosynthetic apparatus (EPA), plant height and response to environmental stress factors (H_2O_2, MDA concentration).

Significant differences between the two groups were tested using the t-test ($p<0.05$). The results showed that the seeds from *Sg*BR germinated (GP) more effectively (*Sg*BR–93.5%, *Sg*TS–82.69%) and had a higher germination synchrony index (Z) (*Sg*BR–0.21, *Sg*TS–0.16). However, the seeds from *Sg*TS showed a higher mean germination time (MGT) (*Sg*BR–5.75, *Sg*TS–7.9). There was no statistically significant difference between plants grown from *Sg*BR and *Sg*TS seeds in plant height, content of chlorophyll *a*, flavonols and anthocyanins. However, plants from *Sg*BR seeds exhibited higher stress tolerance, indicated by higher H_2O_2 content and better photosynthetic apparatus performance parameters–higher F_V/F_M, PI_{abs}, PI_{total}, F_V/F_O, and lower V_J, V_I.

Further studies at the genomic level of both populations are recommended to obtain more detailed information on the adaptation mechanisms.

Keywords: novel ecosystems, reclamation processes, coal-mine spoil heaps, seeds germination

INTRODUCTION

Coal mining activities often go far beyond the mining process itself, resulting in extensive spoil heaps characterized by barren rock and other wastes. It has significant impact on the environment, especially vegetation and soil (Di Carlo et al., 2019). The degraded state of these post-industrial landscapes poses a huge challenge to environmental sustainability.

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Therefore, despite the lack of a precise definition of "proper condition", the key element of the effort is to restore the heaps to their ecological, social, and economic functions, which is usually achieved through reclamation processes in accordance with the guidelines of Polish law (Ustawa o ochronie gruntów rolnych).
The most common reclamation method is active revegetation which includes layering soil, using topsoil, over bare rock heap surface. Along with initiating vegetation growth, this practice aims to establish diverse plant communities capable of stabilizing the ground, improving soil formation, and facilitating ecosystem restoration. However, implementing such often faces financial constraints, leading to the pragmatic decision to leave the bare rock in place, devoid of protective soil cover. This practice is called passive regeneration. Nevertheless, it is known that the process of spontaneous succession on undisturbed land is characterized by richer species diversity, the diversity of ecological species in terms of habitat requirements and forest formation (Navarro-Ramos et al., 2022). Because of these discrepancies, spontaneous succession is crucial in studying vegetation dynamics on post-industrial sites, where native and invasive alien plant species compete for ecological dominance. Understanding their ecophysiological responses to different substrates can inform management practices and develop effective reclamation strategies.
In this study, we focus on invasive plant species *Solidago gigantea* Aiton grown from seeds collected from two distinct areas of a spoil heap: a reclaimed area with topsoil and an unreclaimed area consisting of bare rock. By growing these seeds under controlled laboratory conditions, we aim to evaluate how the original substrate influences the germination and ecophysiological parameters of the resulting plants. This approach allows us to isolate the effects of the substrate on plant responses, providing clear insights into whether the physiological response to different reclamation practices is a matter of adaptation or phenotypic plasticity of the species

MATERIALS AND METHODS

The study species is giant goldenrod (*Solidago gigantea* Aiton) which is a perennial herbaceous species of the *Asteraceae* family. It exhibits high reproductive capability, competitive nature, and allelopathic potential. The species reproduces both generatively and vegetatively. It is native to North America where primarily grows along forest edges, roadsides, secondary old fields, and unmanaged areas. In central Europe, *S. gigantea* is widely naturalized and found in dry and anthropogenic habitats such as uncut grasslands, wetland edges, riparian habitats, forest edges, and roadsides. It also thrives in post-industrial areas like hard coal mine heaps, which present challenging environmental conditions, including drought, poor water retention, salinity, and nutrient-poor soils (Bochenek et al., 2016; Kompała-Bąba et al., 2021; Weber & Jakobs, 2005).

The giant goldenrod seed material was collected in the Upper Silesia Coal Basin region in Southern Poland, where industrial activities have significantly affected habitat conditions. For our investigations we chose the “Sośnica” hard coalmine spoil heap, located in Gliwice (50°16'22 “N, 18°44'43 ”E). It is an example of a new ecosystem created by human activity. The heap was subjected to reclamation treatments, with active revegetation (TS) chosen for one half and passive regeneration (BR) for the other half. The heap is almost 2 km long, 900 m wide and 30 m high, and covers an area of 170 ha. It consists of carbon-rich carboniferous rocks, mainly siltstone and claystone, as well as sandstone, conglomerate and coal shale. The unfavorable soil structure leads to abiotic stress factors, such as poor or no water retention, rapid drying of the surface layer, low

organic matter and nutrient content, and often high temperatures and salinity (Kompała-Bąba et al., 2019).

To examine species physiological response to different reclamation practices, we established 5 sample plots of *Sg* in both the topsoil (TS) and bare rock (BR) areas on the coal mine spoil heap in August 2020. Then we analyzed the germination parameters of *Sg* and transferred the obtained seedlings to a greenhouse for cultivation under controlled conditions. At the end of the experiment, we measured the functional traits and collected the leaves to analyze oxidative stress parameters.

To measure the germination parameters, from each plots, we selected randomly 200 seeds under the binocular, put into the paper bags and stratified in a refrigerator at + 8 °C for three months. After that period of time we placed 50 seeds in four replications (200 seeds in total) on filter paper moistened with distilled water in Petri dishes and put in a phytotron germination chamber FITO 700 for 29 days. The seeds were germinated at a humidity of 60% and a photoperiod of 16h/8h, with a dawn time of 0.5h and a dusk time of 1h. The lighting comprised 22% CW and 22% WW light. The temperature in the chamber was maintained at 24°C during the day and 20°C at night. During the experiment, the number of germinated seeds was counted daily to calculate germination parameters according to Ranal and Santana (2006). The formulas were translated into Python source code using the NumPy, SciPy and Pandas libraries (https://github.com/aleksanderbies/top_soil_and_bare_rock_seeds_germination_params.git).

Next, we transferred 12 seedlings from *Sg*TS and *Sg*BR populations to a greenhouse and placed in containers filled with soil substrate (GO M11 Seeding Compost, Jiffy International, A.S. Norway). Once they had reached an appropriate size, three individuals were repotted into dedicated 3-litre pots with fresh substrate. The plants were cultivated for 20 weeks under controlled conditions. The growing conditions were kept constant at a temperature of 21°C, humidity of 45% and light intensity of 987 lux. After 20 weeks we measured the vertical height above the substrate for each plant (Pérez-Harguindeguy et al., 2013). The measurements of pigments and photosynthetic apparatus efficiency (PAE) were performed *in vivo* on five representative leaves from each replication. Measurements of chlorophyll, flavonols and anthocyanins were performed using the Dualex Scientific+ sensor device (Force-A, France) on the second and third leaves of the plants (see more Cerovic et al., 2012; Julkunen-Tiitto et al., 2015). Chlorophyll *a* fluorescence was measured using a plant efficiency analyzer (PocketPEA Fluorimeter, Hansatech Instruments Ltd., England) on fresh and healthy leaves without visible damage according to Kalaji et al. (2014). Further analysis of chlorophyll *a* fluorescence and photosynthetic efficiency (PAE) was based on the JIP test concept (Goltsev et al., 2016; Kalaji et al., 2014).

To assess oxidative stress indicators, we took randomly three leaves from each plants on the last day of cultivation under controlled conditions. We measured the level of hydrogen peroxide (H_2O_2) and malondialdehyde (MDA) according to Bouazizi et al. (2010). In this procedure, 0.1 g of plant leaf tissue was weighed, homogenized in 1.5 ml of 0.1% trichloroacetic acid (TCA), and centrifuged at 12000 × g for 15 minutes. To 0.5 ml of the resulting extract, 0.5 ml of 10 mM phosphate buffer (pH 7) and 1 ml of 1M potassium iodide were added. A blank sample contained 0.5 ml of 0.1% TCA instead of the extract. The absorbance was measured at a wavelength of 390 nm. The method of calculating the

MDA level involves the reaction of MDA with thiobarbituric acid (TBA), forming a pink-colored reaction product. From the collected leaf samples, 0.3 g of tissue was weighed, homogenized in 4 ml of 0.25% TBA in 10% TCA and incubated for 30 minutes at 100°C in a water bath. After cooling, the samples were transferred to Eppendorf tubes and centrifuged at 10000 × g for 10 minutes. A blank sample consisted of 2 ml of 0.25% TBA in 10% TCA. The absorbance was measured at wavelengths of 532 nm and 600 nm.

The averaged results for *Sg*TS and *Sg*BR were analyzed for normal distribution using the Shapiro-Wilk test. Further analyses were performed using the parametric Student's t-test, with the significance level set at $p \leq 0.05$.

RESULTS

The results of the study revealed significant differences in the germination dynamics of seeds from the *Sg*BR and *Sg*TS populations. In particular, seeds from *Sg*BR showed a significantly higher germination percentage (GP) of 93.5% compared to 82.69% observed for seeds from *Sg*TS. Moreover, seeds from *Sg*BR showed an increased germination synchrony index (Z) of 0.21 compared to 0.16 in seeds from *Sg*TS. However, despite these differences, seeds from *Sg*TS required a longer mean germination time (MGT) of 7.9 days compared to 5.75 days for *Sg*BR seeds (Figure1).

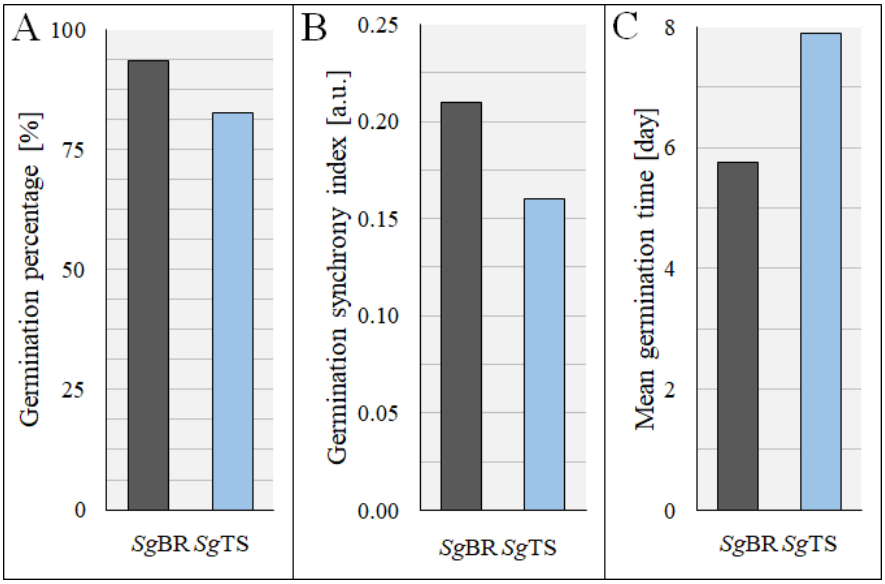


Figure. 1. Germination percentage (A), germination synchrony index (B) and mean germination time (C) Solidago gigantea seeds from bare rock population (*Sg*BR) (gray) and topsoil population (*Sg*TS) (blue). Average values (n = 1000). No statistical differences are marked ($p < 0.05$).

We didn't observe any statistically significant differences between mature *Sg*BR and *Sg*TS plants regarding plant height, chlorophyll *a*, flavonols, and anthocyanins content (Figure 2.A). Specifically, the average plant height for *Sg*BR was 25.79 cm (±12.65 cm), slightly higher than the 22.59 cm (±10.54 cm) recorded for *Sg*TS. The chlorophyll *a* content index was measured at 31.84 (*Sg*BR) and 33.07 (*Sg*TS), while the flavonoid levels were 0.67 (*Sg*BR) and 0.78 (*Sg*TS), and anthocyanin were 0.015 (*Sg*BR) and 0.020 (*Sg*TS). These findings indicate comparable growth and pigment accumulation patterns across both groups.

No statistically significant differences were observed in the malondialdehyde (MDA) content between *Sg*BR and *Sg*TS, indicating similar lipid peroxidation levels. However, *Sg*BR plants exhibited higher stress tolerance, as evidenced by a higher content of hydrogen peroxide (H_2O_2) (Fig. 2.B). The MDA for *Sg*TS was 0.027 µmol g-1 FW, and for *Sg*BR it was 0.028 µmol g-1 FW. H_2O_2 for *Sg*TS was 13.0 µmol g-1 FW, and for *Sg*BR it was 16.7 µmol g-1 FW.

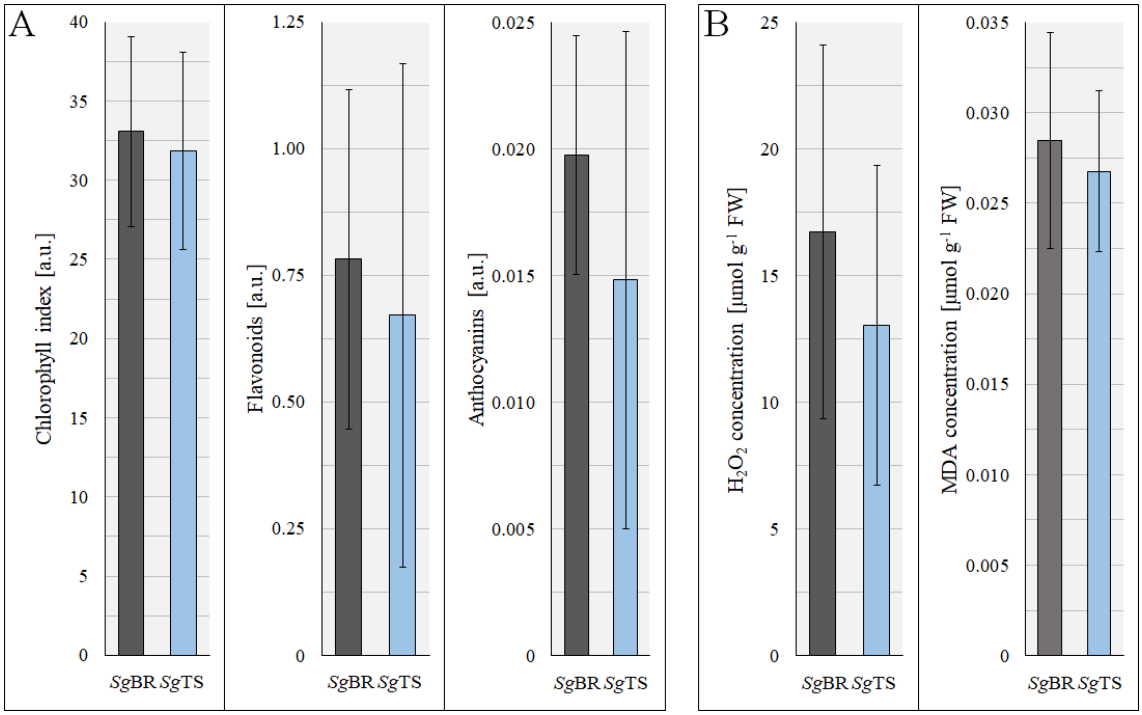


Figure 2. Chlorophyll index, anthocyanin, flavonol content in relative units (A) and malondialdehyde (MDA) and hydrogen peroxide (H2O2) concentration (B) in Solidago gigantea leaves grown from seeds from bare rock population (*Sg*BR) (gray) and topsoil population (*Sg*TS) (blue). Average values ± SE (n = 50). No statistical differences are marked ($p < 0.05$).

*Sg*BR and *Sg*TS differed the shape of the OJIP curve in slight manner (Figure 3), however, further analyses showed unfavourable differences for *Sg*TS within the PSII, manifested by a lower efficiency of the water-splitting complex on the donor side of PSII and performance index on absorption and total basis due to seed origin from topsoil.

*Sg*BR and *Sg*TS plants showed no significant differences between F_O, F_M and t_{Fm} parameters (Table 1). However, *Sg*BR had differentially higher fluorescence values at K point ($F_{300\mu s}$) by 7.15% in the phase corresponding to water splitting, confirming a higher yield of the water-splitting complex in PSII (F_V/F_O) by 4.49%. *Sg*BR exhibited a higher potential yield of PSII (F_V/F_M) by 0.73%, a significantly higher performance index (PI_{abs}) by 28.88%, and a total performance index (PI_{tot}) by 48.20%. *Sg*BR had lower values of V_J and V_I than *Sg*TS by 8.55% and 2.98%, respectively, indicating better electron acceptance from the PQ pool and increased electron transfer efficiency in PSII. Similarly, M_o (dV/dt_o) is another important indicator of electron transfer capability from Q_A to Q_B, and the decrease in M_o aligns with the above conclusion. The average values of electron transport quantum yield (at t=0), φE_o, were significantly lower in *Sg*BR populations

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compared to *Sg*TS populations. Moreover, the maximum quantum yield of primary photochemistry, φP_o, ranged from 0.826 in *Sg*TS to about 0.832 in *Sg*BR. In addition, parameters representing specific energy fluxes per active reaction center: ABS/RC, TR_O/RC, and DI_O/RC were markedly lower in *Sg*BR, and for electron transfer site within PSI—from PQH_2 to PSI end acceptors: φR_o, and that the trapped exciton carries an electron to the electron transport chain outside Q_A (ΨE_o) were markedly higher in *Sg*BR populations.

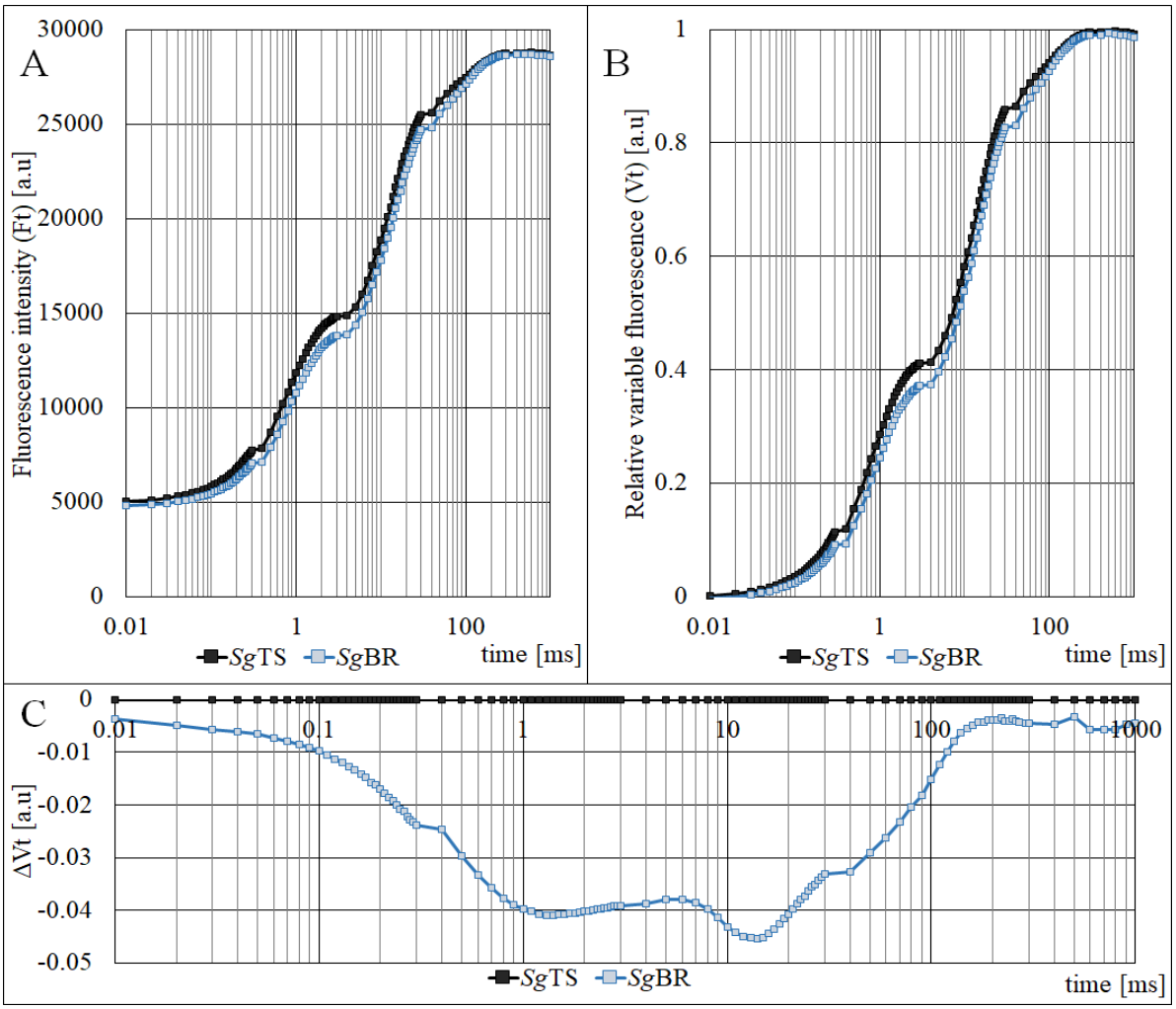


Figure. 3. The OJIP chlorophyll *a* fluorescence transient curves (A), O-P normalized curves (B) and relative variable fluorescence [$\Delta V_t = ((F_t - F_O)/(F_M - F_O)) - V_{tREF} = V_t - V_{tREF}$] (C) on log time scale in *Solidago gigantea* leaves grown from seeds of the bare rock (*Sg*BR) and topsoil (*Sg*TS) populations. For ΔV_t analysis, the fluorescence of population *Sg*BR was the reference and equaled 0.

Table 1. The chlorophyll fluorescence (ChlF) parameters in 30 min dark-adapted leaves of *Solidago gigantea* from control bare rock (*Sg*BR) and topsoil (*Sg*TS) spoil heap spopulations. Average values ± SE (n = 60). No statistical differences are marked ($p < 0.05$).

ChlF parameters	*Sg*BR	*Sg*TS
F_O	4866.4 ±738.5	5011.2 ±548.8
F_M	28883.5 ±2040.3	28851.9 ±2705.8
t_{FM}	478.2 ±169.2	490.3 ±168.4
$F_{300\mu s}$	7249.4 ±1491.5	7807.4 ±1318.7
F_V/F_O	5.000 ±0.557	4.785 ±0.501
F_V/F_M	0.832 ±0.016	0.826 ±0.017
PI_{abs}	9.408 ±4.280	7.299 ±3.774
PI_{tot}	3.379 ±2.165	2.280 ±1.697
V_J	0.358 ±0.075	0.391±0.080
V_I	0.837 ±0.041	0.863 ±0.042
M_o (dV/dt_o)	0.329 ±0.103	0.395 ±0.135
ABS/RC	1.088 ±0.150	1.197 ±0.200
TR_o/RC	0.904 ±0.112	0.987 ±0.151
DI_o/RC	0.185 ±0.043	0.211 ±0.052
ET_o/RC	0.575 ±0.061	0.592 ±0.058
φP_o	0.832 ±0.017	0.826 ±0.016
ψE_o	0.642 ±0.075	0.609 ±0.080
φE_o	0.535 ±0.069	0.504 ±0.072
δR_o	0.252 ±0.052	0.224 ±0.056
φR_o	0.136 ±0.036	0.114 ±0.036

DISCUSSION

The research results showed that despite seed germination and cultivation in the same controlled greenhouse conditions and on the same substrates, the two populations of goldenrod differed slightly in some of the studied parameters of their response to environmental stress. This may indicate inherited mechanisms of stress response related to the conditions prevailing in their respective habitats.

Environmental conditions and abiotic stresses affect the functional traits of seeds. Seeds from *Sg*BR exhibited greater vigor, which may result from higher resistance to environmental factors (Figure 1). Sg seeds do not show signs of dormancy, so storage methods and conditions are unlikely to affect their vigor. Goldenrod, as an invasive species, is also characterized by high competitiveness due primarily to the absence of natural enemies and its high germination capacity (Bochenek et al., 2016). This is evident in the MTG and Z. If synchrony Z equals 0, it means that the tested seeds germinated at the same time (Ranal & Santana, 2006). Nearly all *Sg* seeds from BR germinated at a similar time, shortly after the onset of germination. This may be related to the fact that

immediately upon receiving signals of suitable germination conditions, *Sg*BR seeds start germinating to gain an advantage over other species.

In its natural environment, *Sg* can reach heights of up to 280 cm (Weber & Jakobs, 2005). This is due to competition for environmental resources such as light availability. In conditions with relatively low levels of stress factors, such as in a greenhouse, *Sg* is not forced to compete with other species, resulting in shorter growth. Under controlled conditions, goldenrod from both populations achieved approximately the same average height. This characteristic likely results from its rapid ability to adapt to changing environmental conditions and the high phenotypic plasticity of the species (Szymura & Szymura, 2015).

The action of abiotic and biotic stress factors contributes to the excessive production of hydrogen peroxide in plant tissues, one of the compounds classified as ROS (Jubany-Mari et al., 2009). Slightly higher concentrations of H_2O_2 and MDA, a product of lipid peroxidation, were detected in the leaves of the *Sg*BR population (Figure 2.B). The higher values of these indicators may result from the so-called transgenerational stress memory, which involves the development of defense mechanisms and their transmission to the next generation to enable a faster response to changing environmental conditions (Lukić et al., 2023). In contrast, *Sg*TS may not have developed enough genetically fixed traits, so in the absence of environmental stimuli, there is no significant increase in the production of H_2O_2 and MDA.

Flavonols and anthocyanins play an important role in regulating ROS concentrations in plant cells, and their levels increase with the production of reactive oxygen species (Daryanavard et al., 2023; Li & Ahammed, 2023). Higher levels of flavonols and anthocyanins were observed in the *Sg*BR population compared to the SgTS population (Figure 2.A).

The values of chlorophyll α fluorescence parameters did not show any response to stress factors in *Sg* for both BR and TS (Table 1). The t_{FM} parameter, which typically ranges from 500 to 800 ms, was 478.2 ms (BR) and 490.3 ms (TS), indicating the absence of environmental stress factors (Kalaji & Łoboda, 2010). Analyzing the ex situ results on *Sg* leaves, the maximum photochemical efficiency of PSII (F_V/F_M) ranged from 0.7 to 0.76, which is typical for plants under stress factors such as drought, high temperature, or intense sunlight (Kompała-Bąba et al., 2021). For the BR and TS populations under controlled conditions, this index was 0.832 for BR and 0.826 for TS, indicating a slight impact of environmental stress.

Analyzing the ChlF induction curve, which corresponds to the transfer of excited energy to the reaction centers, *Sg*TS is characterized by higher growth (Figure 3). The minimal increase in the parameters φRo and φEo, observed in *Sg*BR, is associated with a slowdown in electron transport linked to the impact of stress factors (Table 1). Higher values of these indicators in *Sg*BR may indicate the development of adaptive mechanisms in the form of genetically fixed traits that protect against abiotic stress factors present in their habitat.

CONCLUSION

The ecophysiological response of the *Sg* population varied depending on land use. In post-industrial areas, such as coal mining waste dumps, abiotic conditions generate more intense environmental stress for plants, leading to the development of stress response mechanisms, most likely in the form of transgenerational responses. The Solidago gigantea population exposed to more intense stress factors in the BR area exhibited more efficient and accelerated germination times. The harsh conditions of the BR area (higher intensity of stress factors) caused the plants to display higher chlorophyll α fluorescence values, disrupted electron transport, and lower photochemical efficiency of PSII as part of their adaptation to environmental conditions. Furthermore, it can be concluded that invasive species manage well regardless of the substrate, as differences in parameters were minimal and the method of reclamation does not significantly impact this case.

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EFFECT OF FREEZING ON THE STATOBLAST OF THE INVASIVE BRYOZOAN *PECTINATELLA MAGNIFICA*

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ABSTRACT

Statoblasts are dormant, asexual propagules critical for the survival and dispersal of bryozoans, such as *Pectinatella magnifica*. Understanding the resilience of statoblasts to environmental stresses is crucial for predicting the response of bryozoan populations to changing conditions. This study investigates the effect of freezing on the viability of statoblasts from *P. magnifica*. Statoblasts were collected from *Pectinatella magnifica* colonies in the Protected Landscape area and Biospheric Reservation Trebonsko. Molecular analyses were used to assess the freezing effect on the statoblasts, especially analyses of the amount and quality of extracted DNA. Statoblasts were subjected to varying degrees of freezing temperatures and durations to simulate natural and extreme conditions. Preliminary findings suggest that freezing significantly affects statoblast viability and germination potential, with survival rates varying depending on the intensity and duration of freezing.

Furthermore, differential responses among statoblast populations from diverse habitats highlight potential adaptations to local environmental conditions. These results contribute to our understanding of bryozoan life history strategies and their resilience to environmental stressors, providing insights into the ecological dynamics of freshwater ecosystems. Further research is needed to elucidate the mechanisms underlying statoblast responses to freezing and their implications for bryozoan population dynamics in changing environments.

Keywords: *Pectinatella magnifica*, statoblasts, freezing, DNA

INTRODUCTION

Pectinatella magnifica, commonly known as the magnificent bryozoan, is a fascinating organism that belongs to the phylum *Bryozoa*. *P. magnifica* is primarily found in freshwater environments, especially in slow-moving or stagnant water bodies such as ponds, lakes, and reservoirs. Originally, it came from North America, but nowadays, it has a cosmopolitan distribution in various regions across North America, Europe, and Asia [10]. This bryozoan prefers areas with abundant aquatic vegetation and a rich supply of organic matter [8].

Temperatures above 20°C are essential for colony development. Therefore, in the environment of the Czech Republic, the first individuals develop at the turn of May and June. During the summer, there is a massive increase in *P. magnifica*, especially near the banks of water reservoirs, where there is enough vegetation, serving as a treasure for the

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attachment and development of large, gelatinous colonies reaching a weight of up to several kilograms [3].

With the end of summer and the temperature drop in the Czech Republic around the end of September, individuals, zooids fields and a massive release of mature internal buds and statoblasts. Statoblasts contain the embryo of the future zooid, which fully develops during the winter period and hatches with the following season, thus enabling the formation of a new colony. The decomposition of *P. magnifica* colonies contributes to nutrient cycling in freshwater ecosystems. As these bryozoans die and decay, they release nutrients into the water, which aquatic plants and microorganisms can utilise [8].

One of the significant ecological roles of *P. magnifica* is as a filter feeder. It plays a crucial role in maintaining water quality by filtering and consuming suspended particles, including phytoplankton, bacteria, and detritus. This filtering action helps clarify the water and can be beneficial in reducing algal blooms in freshwater ecosystems [2]. Gelatinous colonies can also shelter various organisms, especially insects [5].

While *P. magnifica* plays several beneficial roles in freshwater ecosystems, it can also have some negative impacts under certain conditions. *P. magnifica* exhibits a unique and fascinating reproductive strategy. It reproduces asexually through budding, where new colonies develop from the parent colony [10]. This asexual reproduction allows for rapid population growth and the formation of extensive colonies, especially under favourable environmental conditions. Sexual reproduction in *P. magnifica* involves the release of larvae, which are free-swimming and eventually settle to form new colonies [11]. The timing and frequency of sexual reproduction are influenced by environmental factors such as temperature, water quality, and food availability. The rapid growth and expansion of *P. magnifica* colonies can outcompete native aquatic species for resources, potentially altering the structure and composition of freshwater communities [10]. In some instances, *P. magnifica* colonies can even proliferate rapidly and form dense aggregations, clogging waterways, intake pipes, and irrigation systems. This can result in reduced water flow and impede aquatic organisms' movement.

MATERIALS AND METHODS

For this study, internal buds (statoblasts) were used and collected in the Vesely sandpit in PLA and BR Trebonsko. This sandpit was chosen to source many bryozoan colonies and had a stable water level. The stability of the water level is essential for the development of *Pectinatella magnifica* colonies. Veseli sandpit has a high number of littoral plants, especially willow groves. Brunches, which are submerged, are suitable substrates for colony development.

Samples of internal buds were collected in September 2022, when the season of Pectinatella magnifica growth ends and matured statoblasts are fully released from dying colonies. Collected samples were divided into four groups and prepared for the isolation of DNA.

Group 1: Native samples left to natural development in the studied locality.

Group 2: Samples were stored in the fridge at a temperature of 4°C.

Group 3: Samples, which were stored at -20°C.

Group 4: Samples, which were deeply frozen at -80°C.

Tested samples of internal buds were isolated and analysed immediately after collection, in 3 months of storage, 6 months, and 9 months. Statoblasts in the pit should, during this time, fully develop and hatch in June next year. Stored statoblasts were aliquoted into tubes for each isolation separately to avoid damage to the samples during repeated thawing and freezing. Samples from the native group were collected in the locality before each testing round. The collection of native samples in the winter months was made possible by the ability of statoblasts to form floating clumps, which, in most cases, are caught in the vegetation near the shore. For each round of DNA analyses, twenty samples of statoblasts were made for each group to get statistically significant results.

All samples were tested on the quality and amount of DNA. These parameters were taken as indicators of the quality of the studied statoblasts.

The CTAB-PVP isolated DNA of statoblasts (Cethyltrimethyamonium bromide polyvinyl pyrrolidone) technique [4]. This isolation technique was found to be best for getting a high amount of clear DNA. Quality and quantity parameters were controlled by spectrophotometer BioSpec Nano, which can identify all tested parameters in one single microlitre of analysed DNA sample. The amount of DNA was measured in nanograms per microliter. The cleanliness of DNA was measured in two different parameters, OD 260/280 and OD 260/230. Both parameters correspond to the spectrophotometric absorbance measured at the respective wavelengths at an optical distance of 0,209 mm. DNA of the best quality, according to [9] varies for the parameter OD 260/280 between 1.8 – 2.0, when lower measured values may indicate the presence of proteins, phenols, or other contaminants. According to the user manual, values higher than the set optimum do not indicate any problem with the purity of the sample. In the case of an OD value of 260/230, the pure DNA range is between 2.0 - 2.2. Lower values, in this case, may indicate contamination of DNA; higher values, on the contrary, may indicate contamination of the application plate or the blank sample. Both parameters can also be distorted by air bubbles in the measured sample [9].

The results of the DNA analyses were compared, and the storage technique was determined to be closest to the results corresponding to the natural development of statoblasts at the monitored location.

RESULTS

The study results were measured and entered in Tables 1 and 2 for clarity. The tables contain average values determined after measuring the parameters of all tested samples corresponding to each round of the experiment.

Table 1. Amount of isolated DNA

Amount of DNA				
Month	Native	4°C	-20°C	-80°C
0	74,75	74,75	74,75	74,75
3	93,21	108,06	215,31	313,11
6	396,17	196,15	426,18	312,07
9	889,74	299,79	637,29	314,96

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Table 2. Quality of isolated DNA

Quality of DNA								
	Native		4°C		-20°C		80°C	
Month	260/280	260/230	260/280	260/230	260/280	260/230	260/280	260/230
0	1,59	1,77	1,59	1,77	1,59	1,77	1,59	1,77
3	1,61	1,79	1,6	1,8	1,69	1,82	1,03	1,17
6	1,78	1,96	1,73	1,85	1,76	2,04	1,16	1,01
9	1,83	2,16	1,71	1,77	1,82	2,11	0,93	1,29

The first round of isolation was made immediately after collection on the locality. Due to the same starting position of all types of samples, only one isolation cycle was performed, which has an informative value for all studied categories. In this cycle, it was found that the average amount of isolated DNA was only 74,75 ng/µl of sample. Parameter OD 260/280 was 1,59, and OD 260/230 was 1,77. The earned results showed a low amount and quality of DNA at the beginning point.

After 3 months of storage, the second round was divided into all four 4 groups, which were compared together, and even the change was monitored since the first round. The amount of earned DNA rose in all 4 groups when the highest growth was in samples which were stored at -80°C. On the other hand, their quality got worse rapidly. Parameters of quality rose in other samples.

Isolation after 6 months showed a great rise in the amount of DNA in native samples and samples stored at -20°C. Samples stored at 4°C rose slightly, and samples from -80°C did not change much—the quality of studied samples rose in all categories except -80°C, which was approximately stable.

After 9 months, the Native samples gave the highest amount of isolated DNA and the best quality. Samples in the locality were caught in littoral shrubs, and some of them were hatching at the time of collection. The best results were measured in the -20°C group from stored samples. In this group, there was a measured increase in the amount of DNA, which resulted in "clean" DNA. Samples from +4°C also had a rising amount of DNA, but the rise was slow. The quality of stored samples was slightly worse than the 6-month results. The worst samples were measured at -80°C, approximately stable since the first after-freezing measurement.

The results show that the most similar results were obtained from samples from natural conditions and from- 20 °C.

DISCUSSION

In the study, were compared frozen samples with the natural development of internal buds of *P. magnifica*. The low quality of starting a round of isolation was most likely caused by the high amount of storage substances intended for the nutrition of the developing embryo.

The isolation results from the +4°C group showed similar development to those of natural samples, but only during the first half of the experiment. In the final isolation, there was

a noticeable deterioration of quality isolated DNA, probably by degradation of samples after a long period of temperatures above 0°C without exposure to lower temperatures. Similar results were gained [7] during the statoblasts hatching experiment.

The -20°C group was most like the Native samples. In this group, a higher amount of earned DNA and the optimal quality, like natural samples when budding, was earned quicker than in nature. It was found that the optimal quality of statoblasts for DNA isolation was already achieved after 6 months of storage at -20°C. According to the study aimed at the optimal age of stored samples, good quality lasts about 2 years of storage. After this time, the amount and quality of DNA in these samples began to decline [6]. This is probably caused by the freezing damage of samples containing a large amount of water. Freezing harm is a potential cause of the quick rise of the amount of DNA in -20°C stored samples. The second reason for the quick rise in the amount and quality of DNA is the acceleration of the dormancy period, which lasted the whole winter in studied native samples. According to [1], a temperature of 20°C is optimal for most samples of various origins.

The worst results were earned from the -80°C group. In this group, the amount of earned DNA rose after freezing, but the quality decreased. DNA's amount and quality parameters in deep freezing temperatures remained stable during the experiment. The bad quality of DNA after deep freezing is probably caused by freeze damage of samples because of the high amount of contained water. Freezing of the internal structures of the statoblast caused the release of stock substances into the sample and, thus, the deterioration of its quality.

CONCLUSION

The study compared different storage methods for *Pectinatella magnifica* statoblast to its natural development in the water pit. The work aimed to determine the effect of different temperatures on the amount and quality of statoblasts and define the best way to store samples intended for molecular studies. To achieve the set goal, a series of measurements was carried out that monitored changes in the quantity and quality of isolated DNA under the influence of different temperatures over time. After these measurements, it was found that the best way of storage is at a temperature of -20 °C, where the best results are gained after 6 months of storage. After comparing to naturally developed samples, it was found that temperatures below 0°C are necessary for statoblasts in nature, too, for the development of quality colonies in conditions in Central Europe. This phenomenon was supported by samples from the 4°C group, which began to degrade after the absence of freezing temperatures. The worst way of storage was deep freezing in -80°C. This type of storage, without any protection, caused damage to internal structures and contamination of samples by stock substances.

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EFFECT OF NANOFIBRES RELEASED AS RESPIRATOR WASTE ON *VIBRIO FISCHERI*

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ABSTRACT

In recent years, there has been an exponential increase in the production and use of nanotextiles in the form of respirators and face masks due to the Covid-19 situation that has occurred worldwide. From 2023 onwards, the rate of use of this protective equipment is already decreasing again but respirators are still widely used in many countries as a preventive measure against the spread of respiratory diseases. One of the drawbacks of using respirators as respiratory protection was that they were not managed appropriately in terms of production, processing, use and waste management, which lead to environmental pollution. The aim of this paper is to carry out ecotoxicological tests according to current European standards (ISO 11348-3:2007 Water quality – Determination of the inhibitory effect of water samples on the light emission of *Vibrio Fischeri* (Luminiscent bacteria test) and Czech legislation (Law No. 541/2020 Coll., Waste Act and Decree No. 8/2021 Coll., Waste Catalogue). The first part of the article describes polyvinyldene fluoride (PVDF), which is the base material for the manufacture of tested materials (PP-PVDF-PP, PP-PVDF and Nanovia mask) and also explains why the *Vibrio Fischeri* bacteria have been chosen to perform the tests. The second part of the paper focuses on the description and results of the experiments carried out, which showed that the fibres released in the aquatic environment do indeed have a toxic effect on the test organisms, as EC_{50} can be determined for all tested materials since in all cases an inhibition of at least 50 % was achieved.

Keywords: Ecotoxicity, *Vibrio Fischeri*, respirators, nanofibres, nonwovens

INTRODUCTION

The production of plastics is constantly increasing due to their extensive use in storage, manufacturing, industry and research. This situation logically leads to an increase in the amount of plastic waste, which pollutes the soil and water. Although it may not seem so at first sight, this process is also associated with economic losses and endangerment of lives. In many parts of the world, there are various legal and illegal dumps of such waste, and 80 % of all waste is plastic, as it is very difficult to dispose of compared to other waste. This already complicated situation has not been helped by the course of 2020, when Covid-19 spread around the world, which was subsequently declared a

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pandemic by the World Health Organisation (WHO), and various measures began to be taken around the world to prevent, or at least slow down, the spread of this newly discovered virus. Although on May 5th 2023 the WHO lifted the global health emergency declared in connection with covid-19 in January 2020, the spread of diseases will continue unabated. One of these measures used worldwide was the use of disposable respirators, either surgical or cloth, and later the use of respirators with a minimum protection level of FFP2 became more common. These are non-woven fabrics that are made up of plastic micro and nano fibres. However, with the production of these personal respiratory protective devices in huge quantities, the problem of disposal has also arisen, as used respirators and hoods are not infrequently dumped loose anywhere in outdoor areas, be it parks, meadows, water bodies or built-up areas. In this way, plastic microfibres and nanofibres are released into the environment, where they can harm a wide variety of organisms and, consequently, the entire ecosystem.

MATERIALS AND METHODS

Nonvowens

Before the introduction to nonwovens, it is first necessary to mention what nanofibres are actually composed of. As the name suggests, these are fibres of sizes 10^{-9} according to the International Unit System. In this particular case, they are fibres in the sense of long threads with nano dimensions, usually with a fibre diameter of up to 500 nm. Non-wovens are therefore formations of textile fibres, filaments or yarns which are interconnected by techniques other than weaving, knitting, bobbin making, plaiting and tufting. [1]

The materials tested are multi-layered polypropylene textiles, which are generally produced by a combination of two methods, the first of which is spunbond (S) and meltblown (M). Both technologies work on a very similar principle, the main difference being the use of air, as in the case of spunbond technology a small volume of air at ambient temperature is used, whereas meltblown technology uses a high velocity (100-500 m/s) flow of hot air. The differences in preparation mean that the properties of the fabrics are different. While spunbond produces fabrics that are predominantly coarser and larger in diameter, meltblown technology produces smaller fibres and, in general, it has to be said that there are many more fibre diameter options compared to the former. Another difference is the strength, where spunbond fabrics are much stronger in tension, the compressive strength is not as high, but it is still much higher compared to the second technology, which does not have a high strength, but the filtration properties are excellent. In practice, because of these unique properties of the fabrics produced in this way, both methods are often combined - a multi-layer structure is often used (SM for PP-PVDF, SMS for PP-PVDF-PP). Another option is to combine both of these methods with nanotextiles to achieve better filtration properties. [2]

The results were also compared with other literature where experiments were conducted on 32 plastic products to determine the EC_{50}. The materials tested included polycarbonates, polyurethanes, polyvinyl chlorides, polyethylene, polystyrene, melamine, polyester and polypropylene. [9 of these 32 materials tested proved toxic after 48 h when tested at relatively high concentrations of 5 - 80 g/l. Interestingly, of the 8 plastics tested with admixture of PVC, which is generally considered hazardous due to the principle of production (polymerization of vinyl chloride monomers, which is classified as carcinogenic [4, 5], only 2 selected products were non-toxic (wet part of

the floor and protective gloves). The toxic ones included, for example, a piece of pipe, children's bath toys, artificial leather or a tablecloth. [3] Other plastics tested included, for example, polypropylene in the form of plastic piping and water containers, and neither material was toxic even at high concentrations. [3] Interestingly, in the case of polypropylene, it is the same starting material as in the case of respirators and face shields. [3, 4, 5]

Preparation of the ecotoxicity test

First, the focus was on aqueous leachates. These were prepared by mixing 100 g of materials with one litre of distilled water and then shaken on a shaker for 24 hours [6]. Subsequently, the leachates were filtered and their pH was adjusted to give a final pH between 7.3 and 8.1.

Biotests are often problematic in that they are relatively time-consuming and also make it difficult to determine the weaker toxicity of substances if mortality of individuals is assessed. It is these shortcomings that are addressed by an ecotoxicity test that uses the bioluminescent bacterium *Vibrio Fischeri* (*Aliivibrio Fischeri*) [7, 8]. The use of these bacteria is mainly to determine the toxicity of wastewater, pure chemicals and chemical mixtures [9]. The test is carried out in accordance with the standards EN ISO 11348-1, EN ISO 11348-2 and EN ISO 11348-3, while in the Czech Republic the third mentioned test is the most frequently used, as it uses lyophilized bacteria and this test is used for the purpose of the conducted experiments. The essence of the test consists in measuring the bioluminescence of the bacteria in the presence of aqueous leachate at 0, 15 and 30 minutes. The value obtained is then compared with the results of a control sample where the concentration of the pollutant is zero and only a 2% NaCl solution is used. The decrease in the bioluminescence value of the bacterium is due to disturbances in cellular metabolism. The determination is carried out using a fluorescence luminometer, see Figure 1. The temperature plays an important role in the test, which must be kept constant at 15 °C. The undisputed advantages of the test are high reproducibility, low acquisition cost and time-saving. [10]



Figure 1 LUMIStherm incubation block and LUMIstox 300 luminometer

The bacteria are usually stored in a special protective solution consisting of D-glucose monohydrate, NaCl, L-histidine and bovine serum albumin, which protects them from frost damage. However, it is necessary to thaw them before starting the test. Once thawed, a reactivation solution is used which also contains D-glucose monohydrate,

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NaCl, $MgSO_4$-$7H_2O$, KCl and HEPES (2-[4-(2-hydroxyethyl)piperazin-1-yl]ethane sulfonic acid. [10]

Carrying out the ecotoxicity test

First, the tube of the reclamation solution was removed from the freezer and thawed and heated to 15 °C in a heated LUMIStherm incubation block. At the same time, clean cuvettes were placed in all positions in the incubation block (A1 - A10, B1 - B10, C1 - C10) and 1.5 mL of 2% NaCl solution, p.a., was pipetted into cuvettes A2 - A10. To cuvette A10 was also added 1,5 mL of non-woven leachate and then mixed. Subsequently, 1.5 mL of the solution was pipetted from cuvette A10 into cuvette A9 and the solution was again mixed. This was followed up to cuvette A2 where the twin dilution method was completed. An important part of the experiment was to change pipettes between each dilution to avoid cross-contamination of the individual cuvettes. [10]

Once the tempering of the reclamation solution was completed, work with the LCK 480 type lyophilized bacteria microtube followed the requirements of the standard and the bacteria were stirred in a water bath at 20 ± 2 °C for 2 minutes. Two minutes in the water bath is sufficient time to thaw the bacteria, which are transferred to the incubation block and pipetted with 0,5 mL of the recultivation solution. After 15 minutes, the bacteria in the recultivation solution are mixed and poured into a tube containing this solution. Subsequently, the bacteria in the recultivation solution could be pipetted into the prepared B1 - C10 cuvettes, 0,5 mL each. From the moment the bacteria were pipetted into the B1 cuvette, a countdown of 15 minutes was taken after which the test itself could begin. After this time interval, the luminescence of the bacteria in cuvette B1 is first measured, the value recorded and 0,5 mL of the solution from cuvette A1 (in this case the control sample) is pipetted into the cuvette. After 30 seconds, the same procedure is repeated with cuvette C1, and this procedure is followed throughout the series until the I_0 values of all cuvettes are obtained and the solution from the A series cuvette reservoir is added. The same procedure is repeated after 15 and 30 minutes to obtain values for I_{15} and I_{30} respectively. All the values obtained are then used for the inhibition calculations from which the EC_{50} values are based.

RESULTS

The concentration of the leachates when the tests were performed was equal to 3.789; 7.578; 15.156; 30.3125; 60.625; 121.25; 242.5; 485; 970 mL/L. After measuring the luminescence intensity before and after exposure to the test material, the parameters fkt (correction factor), Ict (corrected value), Ht (inhibition) and Γt were calculated when t = 15 and 30 minutes, respectively. Although 9 different values are given for the leachate concentrations, not all values were used in the calculation of the EC_{50}, since according to the standard all those values must be excluded where there was stimulation, i.e. the bacteria showed greater luminescence after the addition of the leachates than before. The table below shows the individual luminescence for all materials. Tests were also conducted with the potassium dichromate standard prior to the start of testing, all of which yielded toxicity results in accordance with the standard.

Table 1 Summary of bacterial luminescence results for aqueous leachates tested after 0, 15 and 30 minutes

Conc.	Nanovia			PP-PVDF			PP-PVDF-PP		
(mL/L)	I_0	I_{15}	I_{30}	I_0	I_{15}	I_{30}	I_0	I_{15}	I_{30}
0 (B1)	1566.2	1477.2	1443.2	1648.2	1587.3	1541.1	1609.9	1566.6	1539.0
0 (C1)	1596.0	1547.2	1482.0	1579.5	1571.4	1489.2	1569.0	1593.2	1462.6
3.789 (B2)	1520.8	1486.2	1406.6	1565.7	1521.9	1430.7	1466.2	1473.0	1444.2
3.789 (C2)	1505.8	1417.8	1390.6	1580.7	1496.7	1467.6	1474.8	1428.4	1375.6
7.578 (B3)	1429.8	1446.2	1419.4	1540.8	1424.1	1346.7	1514.6	1493.4	1480.6
7.578 (C3)	1478.2	1489.2	1431.6	1562.1	1452.9	1380.6	1524.2	1543.4	1495.4
15.156 (B4)	1554.2	1482.2	1435.8	1531.8	1392.9	1320.9	1521.0	1497.6	1464.0
15.156 (C4)	1487.6	1395	1370.4	1529.4	1467.0	1378.5	1527.4	1472.6	1470.0
30.313 (B5)	1571.8	1420.6	1380.2	1580.7	1446.6	1385.7	1510.2	1440.2	1387.0
30.313 (C5)	1552.4	140.07	1406.2	1542.6	1440.3	1378.8	1569.0	1487.4	1485.4
60.625 (B6)	1509.0	1300.6	1303.6	1571.4	1454.1	1449.0	1444.8	1331.6	1322.0
60.625 (C6)	1539.8	1337.0	1381.4	1568.4	1433.1	1404.9	1441.0	1347.4	1327.8
121.250 (B7)	1492.6	1082.8	1169.0	1500.6	1218.3	1189.2	1463.2	1284.4	1268.4
121.250 (C7)	1487.0	1123	1188.0	1582.5	1208.4	1254.9	1547.0	1344.0	1336.6
242.500 (B8)	1476.8	860.2	961.8	1486.2	1035.9	1059.0	1460.2	1170.4	1174.4
242.500 (C8)	1532.6	878.4	979.0	1496.7	1008.6	1087.5	1534.4	1216.2	1254.8
485.000 (B9)	154.05	581.0	670.6	1437.0	739.5	783.0	1492.4	935.4	1006.4
485.000 (C9)	1491.6	580.0	646.8	1420.8	741.9	777.0	1481.4	924.6	969.2
970.000 (B10)	1321.2	268.4	281.0	1463.1	500.7	479.7	1496.2	642.0	648.0
970.000 (C10)	1515.4	320.4	347.8	1465.8	464.7	513.3	1548.8	663.2	671.8

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Calibration lines were also constructed from the values obtained, see Figure 2, 3 and 4.

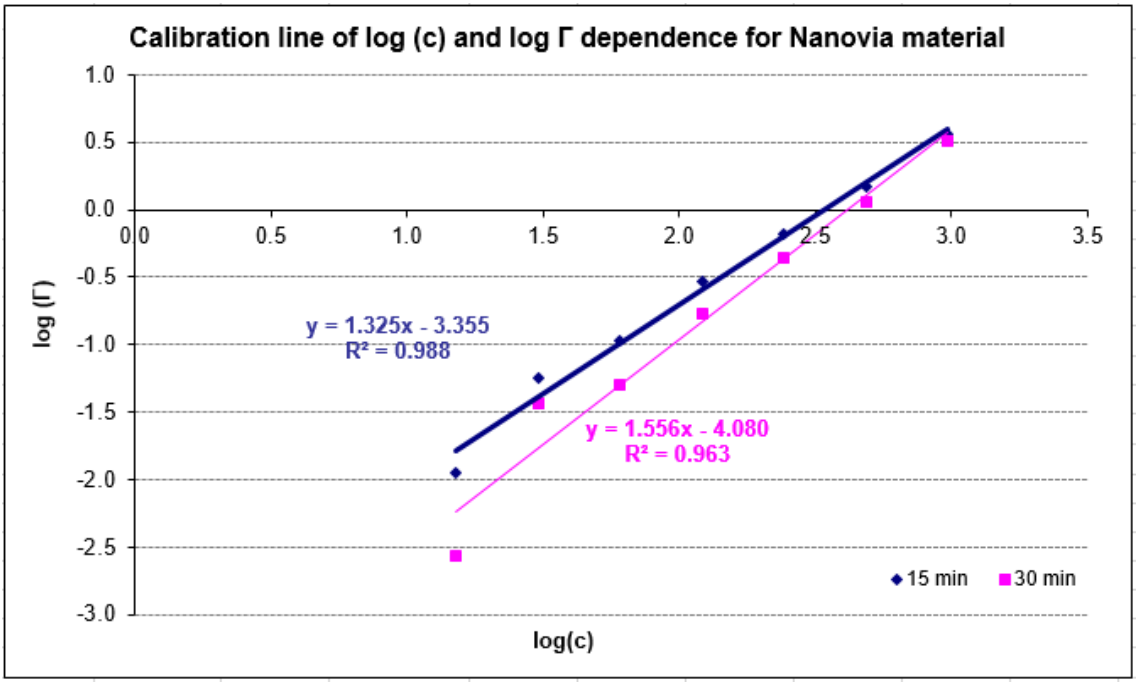


Figure 2 Calibration curve of log concentration versus inhibition (Nanovia)

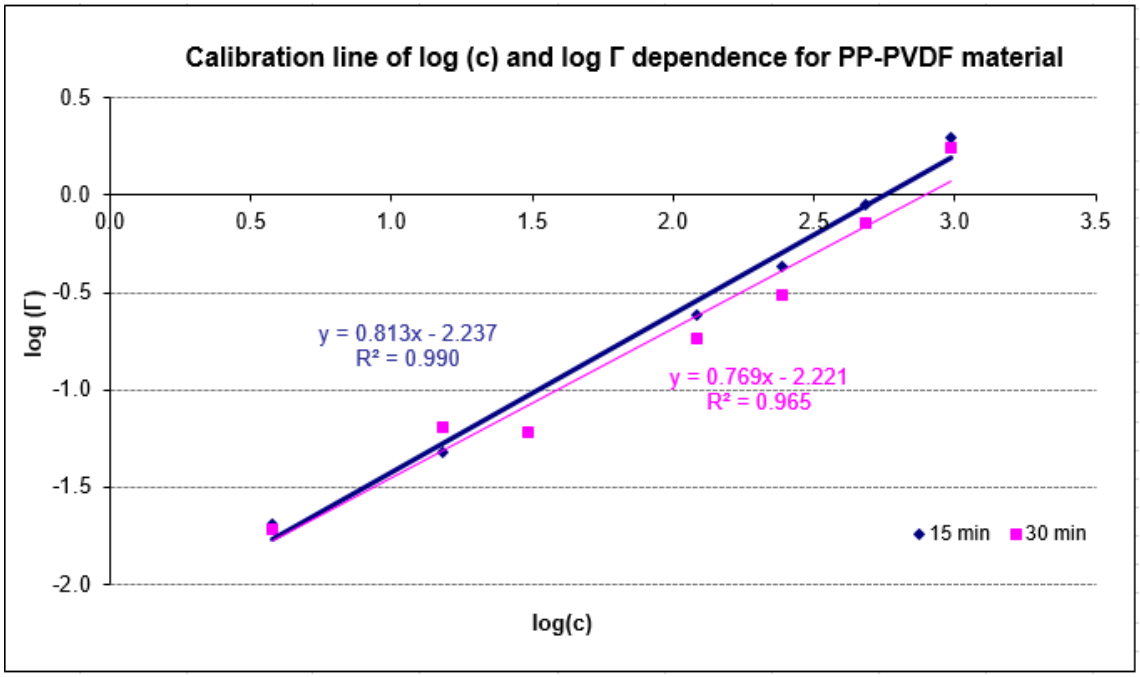


Figure 3 Calibration curve of logarithm of concentration versus inhibition (PP-PVDF)

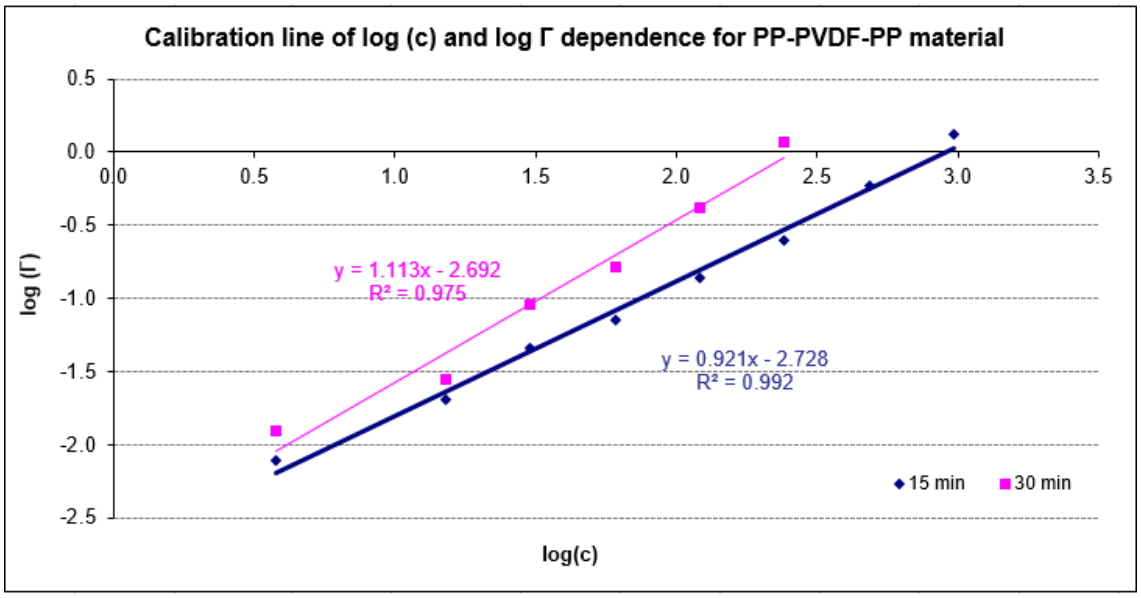


Figure 4 Calibration curve of logarithm of concentration versus inhibition (PP-PVDF-PP)

DISCUSSION

From the above results it is evident that in all three cases there was an ecotoxic effect of the aqueous leachates on *Vibrio Fischeri* bacteria. Interestingly, the tests showed a sharp decrease in luminescence between 0 and 15 minutes, and the results after 15 and 30 minutes did not differ much. In all cases, however, it can be clearly determined that there was an increase in inhibition with increasing concentration of aqueous effluents. Thus, from the results obtained, the EC_{50} for the materials tested can be determined, the EC_{50} for the aqueous leachate of the Nanovia face mask being 336.46 mL/L after 15 minutes and 400.898 mL/L after 30 minutes. For the PP-PVDF material, the EC_{50} was determined to be 556.11 mL/L after 15 minutes and 717.117 mL/L after 30 minutes. For the last material PP-PVDF-PP, the EC_{50} was 898.92 mL/L after 15 minutes, 887.987 after 30 minutes, making this material the only one with an increase in ecotoxicity after 30 minutes.

CONCLUSION

In this paper, an ecotoxicity test of aqueous leachates from nonwovens was performed on *Vibrio Fischeri* bacteria. Nonwovens were chosen for the purpose of this research because they are widely used in a wide range of industries, namely, for example, as air particle filters, in water purification, they serve as personal protective equipment, both in the form of protective clothing in the health sector and, for example, as protective respirators, which are and will always be used, that is, not only in times of pandemics, for example, in Asian countries due to high dust levels. However, when these materials are used and disposed of, there is primary and secondary degradation of the plastic, which leads to environmental pollution, and it is precisely for this reason that it is useful to experimentally test the effect of the particles released in this way on the various environmental components. From the results obtained it was quite clear that in all cases (i.e. Nanovia face masks, PP-PVDF and PP-PVDF-PP materials) there was a toxic effect on the tested bacteria, as there was a linear increase in inhibition with increasing

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concentration, where in all cases the inhibition exceeded 50% and thus an EC_{50} value could be determined. In the case of the Nanovia face mask, a value approaching 80% was measured and thus this was the material that was most harmful. However, this result can be attributed to the fact that, in terms of materials, it was the most processed in terms of life cycle, as it was a finished product and not just an intermediate as was the case with the other two materials. Thus, from the point of view of the Czech legislation, the limit threshold, which sets the maximum possible inhibition at 50 % for a material to be declared non-toxic and environmentally benign, was not met.

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EVALUATION OF THE IMPACT GENERATED BY ECONOMIC ACTIVITIES IN THE EASTERN PART OF THE JIU VALLEY

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ABSTRACT

The assessment of the influence of economic activities on the population in the eastern region of the Jiu Valley (located in the south-western part of Romania) entails several stages. These include measuring the extent of air pollution, selecting a tool for evaluating air quality, and most importantly, implementing a method for estimating the environmental impact.
The objective of the study is to analyze the environmental conditions by analyzing the data collected from the six designated locations and utilizing the Global Pollution Index (GPI) methodology to measure the extent of air pollution. The assessment of the influence and combined effects of pollution on environmental components or terrestrial ecosystems will examine the impacts caused by pollutants both separately and together. In order to emphasize the relationship between pollutant concentrations and the reference level, each pollutant that is correlated with the lower assessment threshold will be graphically displayed. This will be followed by assigning suitability ratings, calculating the areas in the graphs that are generated, and determining the overall pollution index for the area being studied. The data collected during the monitoring experiment, regarding the appropriateness ratings scale that measures pollution levels, suggest that we are in a location with possibly high pollution due to the presence of dust and nitrogen oxides in the atmosphere.

Keywords: impact, pollution, assessment, quantification, environment

INTRODUCTION

Along with the fast development of the global economy, the challenge of air pollution has become increasingly evident. Issues related to air quality are complex and are receiving growing attention. In most cities, multiple monitoring stations are located in different locations to report air quality indicators in real-time [5], however, in the Jiu Valley, there is only one monitoring station in its western part, which prompted us to conduct monitoring and assessment of air quality in the eastern part of the Jiu Valley.
The Jiu Valley is an intramountain depression located in the southwestern part of Romania, in Hunedoara County, comprising six towns and several surrounding villages. The depression's character facilitates the accumulation and stagnation of cold air,

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leading to frequent temperature inversions even between low altitude relief units [3,13]. The Jiu River basin includes the East Jiu and West Jiu rivers, along with over 50 of their tributaries.

Atmospheric pollution in the Jiu Valley benefits from the high frequency of thermal inversion phenomena, especially during the year's cold period. The formation of this thermal inversion layer leads to retention of pollutants near the ground, resulting in breathable air being loaded with emissions from thermal power plants, burning of fossil fuels in individual households and exhaust gases. The environmental factor most affected by mining exploitation is the land, including its soil and subsurface, impacting the entire local ecosystem [13].

The current global context necessitates the assessment of the impact generated by each pollutant on the surrounding environment and its effects on humans [4]. Therefore, for the eastern part of Jiu Valley, the study focused on the effects of pollutants generated by economic activities on the East Jiu River and on the population in the eastern part of Jiu Valley.

A large number of scientific studies are recommended for addressing environmental issues, including the assessment of the impact generated by various human activities on the environment [1,2,5,6,10-12]. The most commonly used method for assessing air quality is the global impact index method, which has also been applied in the present study.

MATERIALS AND METHODS

The research is primarily based on data gathered from monitoring atmospheric pollutants related to health and focuses on six air pollution indicators: particulate matter (PM10 and PM2.5); carbon monoxide (CO); nitrogen dioxide (NO2); sulphur dioxide (SO2); ozone (O3); BTEX (Benzene, Toluene, Ethylbenzene, and Xylene isomers).

To obtain a clear picture of the atmospheric pollution levels in the eastern part of Jiu Valley, 6 (six) air quality monitoring points were placed to capture pollutant emissions from main sources along their dispersion paths. Thus, 2 (two) monitoring points were placed in unpolluted areas, considered reference points for the studied area [4]. These two points were found in the University area in Petroșani and the INCD INSEMEX testing ground area, considered unaffected by major pollution phenomena (control samples) to monitor air quality indicators regulated by Law 104/2011. Additionally, 4 (four) air quality monitoring points were placed in the cities of Petrila and Petrosani.

To have a more objective assessment of the impact of atmospheric pollution, much lower limits than reference values were applied for quantifying pollution. Lower assessment thresholds, limit values for human health protection, and stoichiometric calculations were used to obtain reference values.

Table 1.1 presents a comparative overview of the typical values used in the assessment of air pollution in accordance with Law 104 of June 15th, 2011, regarding ambient air quality [7].

For the NO indicator, the reference value was obtained through stoichiometric calculation, taking into account the stability and forms of nitrogen oxides encountered in the surrounding environment. Similar reference values were attributed to the BTEX group indicators (Toluene, Ethylbenzene, Xylene) due to their positioning in the BTEX grouping.

Table 1.1. Aggregation of the values used in the environmental impact assessment process

Measured parameter / m.u.	Threshold value (Law 104/2011)	Lower assessment threshold / Human health protection / Stoichiometric calculation (Law 104/2011)
Carbon monoxide (CO) [ppm]	10	4 (Lower assessment threshold)
Ozone (O_3) [µg/m^3]	120	120 (Human health protection)
PM 2.5 dusts [µg/m^3]	25	12 (Lower assessment threshold)
PM10 dusts [µg/m^3]	50	25 (Lower assessment threshold)
Nitrogen oxide (NO) [µg/m^3]	-	150 (Stoichiometric calculation)
Nitrogen dioxide (NO_2) [µg/m^3]	200	100 (Lower assessment threshold)
Sulphur dioxide (SO_2) [µg/m^3]	350	150 (Lower assessment threshold)
Benzene (C_6H_6) [µg/m^3]	5	2 (Lower assessment threshold)
Toluene ($C_6H_5CH_3$) [µg/m^3]	-	2 (Lower assessment threshold)
Ethylbenzene (C_8H_{10}) [µg/m^3]	-	2 (Lower assessment threshold)
Xylene (C_8H_{10}) [µg/m^3]	-	2 (Lower assessment threshold)

Once the field data has been centralized, the use of an intuitive approach to assess air quality is necessary. There are several methods available for air quality assessment, based on the probability theory (Markov chain method), vectorial/matrix calculation (semi-quantitative rapid assessment method), and, last but not least, the use of evaluation grades scales (global impact index method) [8].

Having sufficient data to realistically represent the pollution state of the eastern part of Jiu Valley (without using tools such as interpolation or statistical calculation), the global impact index method was chosen.

Global impact index method

The global impact index method allows the assessment of environmental health or pollution state and the quantitative expression of this state based on an indicator resulting from a ratio between the ideal value and the current value of specific environmental quality indicators [9].

The method involves several stages of synthetic assessments based on quality indicators that are likely to reflect a general state of one of the analysed environmental factors, followed by their correlation through a graphical method. In this sense, the quality of each environmental factor, at a given moment, will be ranked on a scale of evaluation grades, assigning grades to express the proximity or deviation from the ideal state.

The scale of evaluation grades is expressed through grades from 1 to 10, where 10 represents the natural state unaffected by human activity, and 1 represents an irreversible and highly severe situation of deterioration of the analysed environmental factor. Generally, it is considered possible to assess the environmental quality of a specific area and moment through air quality, water quality, soil quality, health of the population, and deficit of recorded plant and animal species.

The suggested method follows the same stages of assigning evaluation grades for each analysed quality indicator considered representative for characterizing the quality of the evaluated environmental components. Thus, evaluation scales are developed based on the maximum allowed concentrations according to current legislation, followed by ranking the analysed quality indicators on these scales and assigning evaluation grades. Finally, evaluation grades are obtained for each evaluated environmental component. By applying the calculation formula for the global pollution index, this method of

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quantifying the impact on the environment can be used even when only one environmental component is considered in the evaluation process. The next step is the calculation of the global pollution index.

The Global Pollution Index of an ecosystem (GPI) results from the ratio between the surface representing the ideal state (SI) and the surface representing the real state (Sr) [9]:

$$I_{PG} = \frac{S_I}{S_r} \quad (1)$$

The new formula for calculating the global pollution index for the calculation of the global pollution index becomes:

$$I_{PG} = \frac{100}{b^2} \quad (2)$$

where b represents the arithmetic mean of the evaluation grades obtained by the evaluated environmental components.

After calculating the global pollution index, the environmental impact is ranked as follows (Table 1.2):

Table 1.2 Ranking environmental impact based on GPI (Global Pollution Index).

I_{PG}	b	Rank	Environmental health status
$I_{PG = 1}$	10	A	Natural environment unaffected by human activity
$1 < I_{PG} < 2$	9,99 – 7,07	B	Environment subject to the effect of human activity within permissible limits
$2 < I_{PG} < 3$	7,07 – 5,77	C	Environment subject to the effect of human activity, causing discomfort to life forms
$3 < I_{PG} < 4$	5,77 – 5,00	D	Environment affected by human activity, causing disturbances to life forms
$4 < I_{PG} < 6$	5,00 – 4,08	E	Environment severely affected by human activity. Dangerous for life forms.
$I_{PG} > 6$	≤ 4,08	F	Degraded environment, unsuitable for life forms.

Evaluation grades are assigned on a scale from 1 to 10, where 10 represents the natural state unaffected by human activity, and 1 represents an irreversible and highly severe situation of deterioration of the analysed environmental factor [8]. The ranking of evaluation grades is established as follows (Table 1.3):

Table 1.3. Scale of evaluation grades

Analysed indicator (IA)	Evaluation grade
IA→ 0,1% CMA	10
IA < 70% CMA	9
70% ≤ IA ≤ 80% CMA	8
80% CMA ≤ IA < 90% CMA	7
90% CMA ≤ IA < CMA	6
CMA ≤ IA < 150% CMA	5
150% CMA ≤ IA < 200% CMA	4
200% CMA ≤ IA < 250% CMA	3
250% CMA ≤ IA < 300% CMA	2
IA ≥ 300 % CMA	1

RESULTS AND DISCUSSION

Thus, evaluation grades are further developed (Table 1.4 and Table 1.5), grades are estimated according to the established intervals, and, last but not least, the global pollution indices are calculated. In order to elaborate evaluation scales for NO, Toluene, Ethylbenzene and Xylene indicators, a limit value was assigned through correlation and stoichiometric calculation with indicators from the same group of pollutants.

Table 1.4. Evaluation grades for the indicators determined during monitoring

NB	CO [ppm]	O_3 [µg/m^3]	$PM_{2,5}$ [µg/m^3]	PM_{10} [µg/m^3]	NO [µg/m^3]	NO_2 [µg/m^3]
10	<0,004	<0,12	<0,012	<0,025	<0,15	<0,1
9	0,004÷2,8	0,12÷84	0,012÷8,4	0,025÷17,5	0,15÷105	0,1÷70
8	2,8÷3,2	84÷96	8,4÷9,6	17,5÷20	105÷120	70÷80
7	3,2÷3,6	96÷108	9,6÷10,8	20÷22,5	120÷135	80÷90
6	3,6÷4	108÷120	10,8÷12	22,5÷25	135÷150	90÷100
5	4÷6	120÷180	12÷18	25÷37,5	150÷225	100÷150
4	6÷8	180÷240	18÷24	37,5÷50	225÷300	150÷200
3	8÷10	240÷300	24÷30	50÷62,5	300÷375	200÷250
2	10÷12	300÷360	30÷36	62,5÷75,5	375÷450	250÷300
1	>12	>360	>36	>75	>450	>300

Table 1.5. Evaluation grades for indicators determined during monitoring

NB	SO_2 [µg/m^3]	Benzene [µg/m^3]	Toluene [µg/m^3]	Ethylbenzene [µg/m^3]	Xylene [µg/m^3]
10	<0,05	<0,005	<0,005	<0,005	<0,005
9	0,05÷35	0,005÷3,5	0,005÷3,5	0,005÷3,5	0,005÷3,5
8	35÷40	3,5÷4,0	3,5÷4,0	3,5÷4,0	3,5÷4,0
7	40÷45	4,0÷4,5	4,0÷4,5	4,0÷4,5	4,0÷4,5
6	45÷50	4,5÷5,0	4,5÷5,0	4,5÷5,0	4,5÷5,0
5	50÷75	5,0÷7,5	5,0÷7,5	5,0÷7,5	5,0÷7,5
4	75÷100	7,5÷10,0	7,5÷10,0	7,5÷10,0	7,5÷10,0
3	100÷125	10,0÷12,5	10,0÷12,5	10,0÷12,5	10,0÷12,5
2	125÷150	12,5÷15,0	12,5÷15,0	12,5÷15,0	12,5÷15,0
1	>150	>15,0	>15,0	>15,0	>15,0

To highlight the correlation between pollutant concentrations and the reference level more effectively, each correlated pollutant has been correlated with the lower assessment threshold.

Subsequently, quality ratings will be assigned, areas under the generated graphs will be calculated, and the overall pollution index will be computed. It is noted that such graphs were created for each monitored point; however, for reasons of space in the document, only one of them is randomly presented.

The analysis of the results includes assigning evaluation grades as shown in Table 1.6.

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Table 1.6. Evaluation grades assigned to each indicator for the six analysed locations

Measured indicator	Evaluation scale (MP1)	Evaluation scale (MP2)	Evaluation scale (MP3)	Evaluation scale (MP4)	Evaluation scale (MP5)	Evaluation scale (MP6)	Ideal situation
CO	9	9	9	9	9	9	10
O_3	9	9	9	9	9	9	10
$PM_{2,5}$	5	3	5	5	2	5	10
PM_{10}	7	5	7	8	5	5	10
NO	7	9	6	9	9	9	10
NO_2	4	5	4	5	6	5	10
SO_2	9	9	9	9	9	9	10
Benzene	9	9	9	9	9	9	10
Toluene	9	9	9	9	9	9	10
Ethylbenzene	9	9	9	9	9	9	10
Xylene	9	9	8	9	9	9	10
$\sum NB/n$	**7.82**	**9.44**	**9.33**	**11.25**	**9.44**	**9.67**	**12,22**

Visually, the data obtained after processing the input values (transforming the concentrations obtained in situ into statistical indicators) are represented in Fig. 1.1.

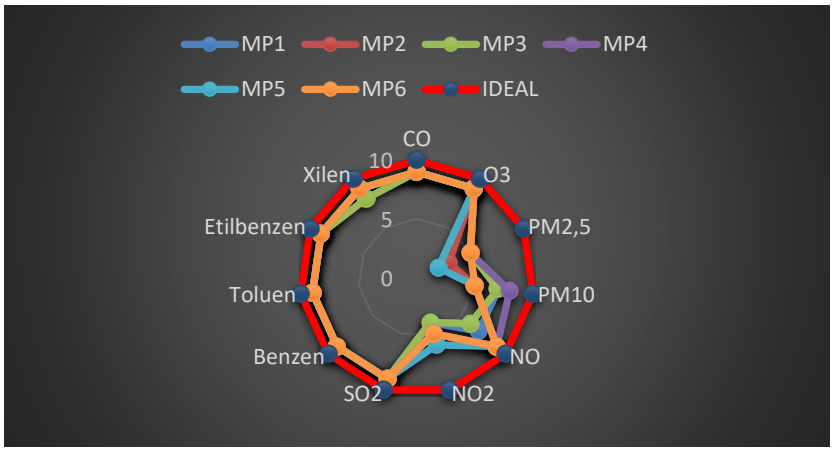


Fig. 1.1. Graphic representation of the processing of field data to identify the pollution level associated with the six monitored locations.

The global pollution index was individually obtained for the six locations studied and is presented tabularly in Table 1.7.

Table 1.7. The global pollution index calculated for the six monitoring points.

IPG / MP	**MP1**	**MP2**	**MP3**	**MP4**	**MP5**	**MP6**
	1.56	1.29	1.31	1.09	1.29	1.26

In accordance with theoretical aspects regarding environmental impact assessment through the Global Pollution Index, the environmental health status is quantified into 5 subclasses, with class A being attributed to a natural environment unaffected by human activity, and at the opposite end, class F representing a degraded environment unsuitable for life forms.

Following the environmental investigation process and data processing, the Global Pollution Index (GPI) for the six monitored locations (in terms of atmospheric pollution) ranges from 1.09 to 1.56. This allows us to assess that the identified impact

falls into class B, namely "Environment subject to the effect of human activity within permissible limits". Additionally, the values obtained during the monitoring process, related to the evaluation grades scale according to the degree of pollution, reveal that we are in an area with potentially significant pollution caused by the presence of dust and nitrogen oxides in the atmosphere.
Data synthetically presented shows the presence of pollution with dust (PM2.5 and PM10) as well as the presence of nitrogen oxides represented by NO and NO_2, indicating pollution of both physical and photochemical nature (caused by nitrogen oxides - critical components of smog). The opportunity remains open for future studies on the nature of the dust measured during the ecological investigation in order to identify its composition and characteristics.

CONCLUSIONS

Local atmospheric pollution originates from numerous emission sources, both natural and anthropogenic, with the latter becoming dominant at local level.
The database in this study compiles air quality measurements over a period of four months in the eastern part of the Jiu Valley, and the results obtained regarding air quality have shown that the air is polluted mainly with suspended particulate matter PM10, PM2.5 and nitrogen dioxide. The exceeding of the maximum allowed values is estimated to be caused by activities carried out in the areas where the mobile laboratory is located, with a significant portion attributed to the heating agent used both in mining units and in households, considering the relatively low temperature during the winter-spring season.
For a more objective assessment of the impact caused by atmospheric pollution, much lower limits were used compared to reference values for quantifying pollution. Lower evaluation thresholds, limit values for human health protection, and stoichiometric calculations were used to obtain reference values.
With sufficient data to realistically represent the pollution status of the eastern part of the Jiu Valley (without using tools such as interpolation or statistical calculation), the method of the global impact index was chosen.
Following the environmental investigation process and data processing, the Global Pollution Index (GPI) for the six monitored locations (in terms of atmospheric pollution) ranges from 1.09 to 1.56, allowing us to assess that the identified impact falls into class B, namely "Environment subject to the effect of human activity within permissible limits".
The values obtained during the monitoring process, related to the evaluation grades scale according to pollution degree, reveal that we are in an area with potentially significant pollution caused by the presence of atmospheric dust and nitrogen oxides. The opportunity remains open for future studies on the nature of dusts measured during the ecological investigation in order to identify their composition and nature.

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GREENHOUSE WITH WASTE SUBSTRATE POWERED BY RENEWABLE ENERGY SOURCES

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ABSTRACT

The main purposes of the project were to analyze the possibility of using waste from the energy sector - fly ash from the lignite combustion process - as a growing medium, as well as to use the electricity obtained from the photovoltaic panel to power the equipment located in the constructed greenhouse. In addition, the project involved the development of a connection of equipment to ensure proper air parameters for growing plants. The constructed and equipped greenhouse stand was used to perform vase tests on white mustard seeds. The test was carried out in four trials for each of the adopted ash concentrations in the growing medium. The grown plants were examined for plant length and root length. The experiment showed a positive effect of the ash substrate on the growth of the above-ground part of the plant and the number of germinated seeds. These results suggest that fly ash can play an important role as a substitute for traditional crop substrates, contributing to the efficient use of waste from the energy sector.

Keywords: Waste from the energy industry, RES-powered greenhouse, renewable energy sources, growing plants on waste substrates

INTRODUCTION

Poland's coal-based power industry poses challenges for power plants and waste management facilities. Waste from the power industry accounts for 13% of the total amount of industrial waste generated in the country . The amount of coal combustion products (CCPs) generated depends on the scale of a company's operations. It is estimated that between 900 million tons and 1,000 million tons of waste associated with power generation are generated worldwide. In Poland, approximately 60% of the waste generated, or about 20 million tons, is currently managed [1].

Coal combustion products are managed in industries such as building materials, road construction and mining. An innovative solution is constantly being sought to manage waste in other industries, including agriculture as a soil additive, environmental protection as a sludge neutralizing agent and other industries. The use of fly ash and bottom ash depends on the variable chemical properties of the products, which are directly dependent on the varying composition of the coal mined [2].

Scientific publications consider the use of energy waste in various sectors of the economy, including as fertilizers in agriculture. Due to the fact that fertilizers made from ashes increase water retention, reduce soil mass, improve physical properties. The chemical

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composition of ashes varies widely, but is rich in ionic and oxide compounds that are well absorbed by the root systems of plants. Plants need the provision of not only nutrients for their growth, but also the right environmental conditions, such as proper temperature, humidity, and access to light. Plants vary greatly in the specific value of these factors in the environment. Common characteristics of plants grown in agriculture are high temperature and heat, moderate humidity, access to light, and access to water in the soil.

The use of a laboratory environment, a greenhouse, makes it possible to provide the required and favorable conditions for plant growth. A controlled environment extends the growing time of plants and makes it possible to grow them throughout the year. However, this is a process that requires the provision of heat, or energy. In our concept of the greenhouse as a platform featuring a greenhouse structure, equipment to provide humidity, heat, or light, also ensures its independence related to the use of a renewable energy source. In the first concepts of the idea, work was done on the use of a solar collector to provide adequate living conditions. However, a problem arose due to the provision of other environmental factors affecting growth, which will enable the use of an electric power source. This contributed to equipping the greenhouse with a photovoltaic panel. Solar cells change the sun's radiant energy into electricity. The energy is created in real time and can only provide equipment with the right values for operation during the time the panel receives sunlight. Equipping the greenhouse with a battery to store energy will ensure that greenhouse devices continue to operate in the absence of favorable radiation.

The publication is an introduction to research on the use of coal combustion products (CCPs) from the power industry as fertilizer for the agricultural industry. For this purpose, tests were conducted on: water extracts from a universal horticultural soil with a slightly acidic reaction, and a mixture of ashes from lignite combustion. The mixture consists of bottom ash at 20% and fly ash for the remainder. Pot tests were also performed on Sinapis alba with different concentrations. And also the fertility of the soil structure by determining the organic fraction content.

Sinapis alba is one of the most useful plant species used in the reclamation process. As a melliferous, annual plant, it actively cooperates with calcium compounds present in soils, which promotes the initiation of biological life. The organic matter and sorption complex it creates promotes the accumulation of nutrients and water, which helps restore soil structure. In addition, it has high germination rates of 85% to 99% and performs well in nutrient-rich soils, making it an ideal candidate for use in soil remediation processes [3].

MATERIALS AND METHODS

Figure 1. shows individual components of the system which are: a humidity sensor that monitors the level of humidity in the growing environment, heating cable and heaters as devices that provide heat to maintain the right temperature of the air inside the stand, a thermostat that controls the temperature, keeping it in between 23°C and 26°C, a humidification device that ensures the right level of humidity in the air for the plants, and lighting that provides a source of artificial light that simulates natural sunlight, necessary for the process of photosynthesis. These elements are powered by energy generated by a solar panel. For the proper functioning of the entire system, there is also need for a transformer that changes the voltage of the electric current to the required level

for the various components of the system, a battery as a storage of electricity that provides power to the system in the absence of solar energy, and a voltage regulator that provides a constant electric voltage to power the components of the system. This plant growing station allows for precise control of environmental conditions such as temperature, humidity and lighting, which is crucial for optimal plant growth. By using solar energy, the system is more environmentally friendly and can operate independently of external energy sources.

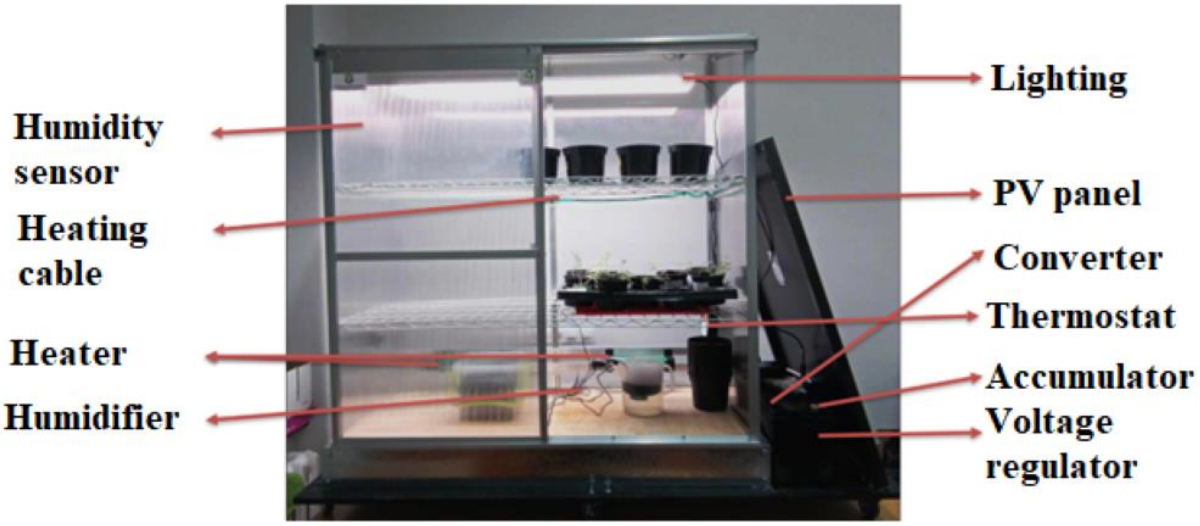


Figure 1. Greenhouse construction with the location of equipment

Figure 2. shows a diagram of the connection of the equipment used in the greenhouse, to the source of energy that is the photovoltaic panel. A PV panel converts solar energy into direct current (12 V DC), which is regulated by a voltage regulator. The current is then directed to the battery which stores the energy. The DC current from the battery is converted by an inverter to AC (230 V AC). The AC current powers system components such as lighting, heating cable, heater, humidity sensor and humidifier. The scheme also includes 5 V and 12 V DC outputs from the voltage regulator, which can power additional devices.

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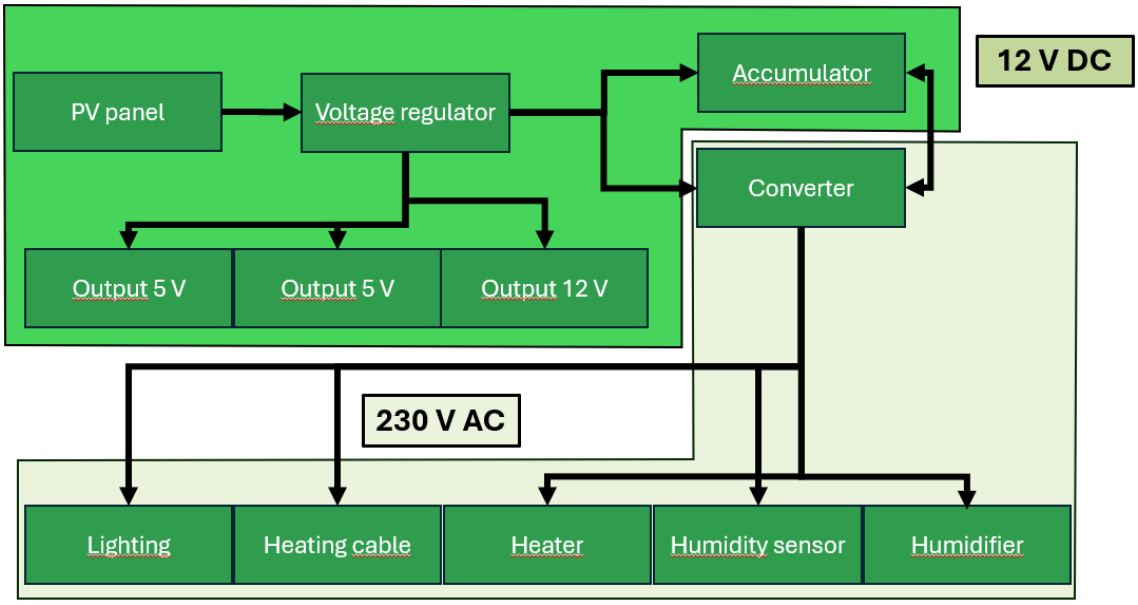


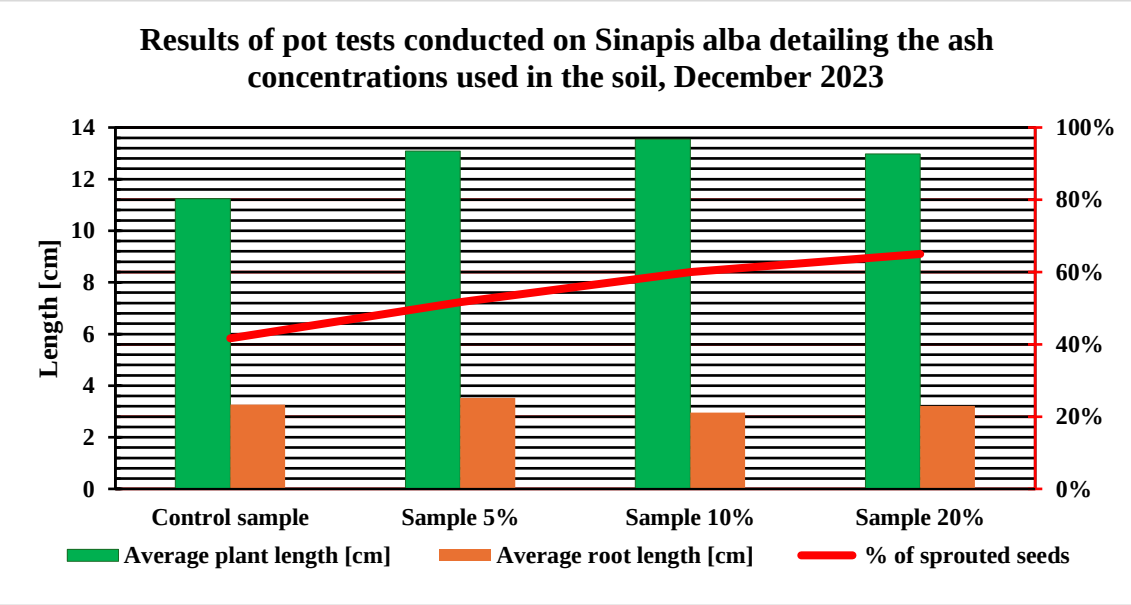
Figure 2. Schematic of the power supply of a greenhouse for growing plants using solar energy

Preparatory process for the start of vase testing included determination of active acidity, testing of conductivity of the solution, electrical voltage, and salinity of the solution. Determination of active acidity consisted of the preparation of water extracts was carried out on the basis of PN-Z-15011-3. 50 g of test compost and 200 g of water were weighed into a conical flask, the test was repeated twice. And also 50 g of the tested ash mixture and 200 g of water, the test was repeated three times. The flask was subjected to gentle stirring for 30 minutes. The contents were drained and the water extract was analyzed.

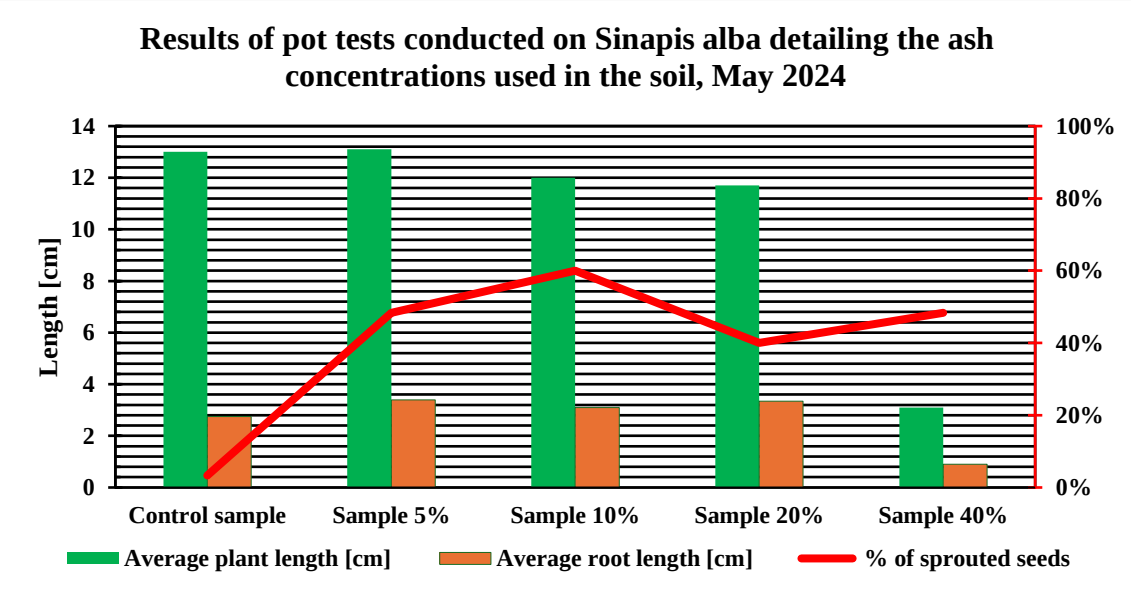
The content of the organic fraction was also examined based on the standard PN-Z-15011-3. The soil sample was subjected to roasting at 500 degrees celcius. The weight of the soil sample before and after roasting was determined.

After the determination of the above elements, it was proceeded to carry out vase tests. A 1500 g mixture of soil and ash with concentrations of 5%, 10%, 20% and 40% was prepared into containers in duplicate, and two control samples were prepared. Thirty sinapis alba seeds were added to each container and covered with about 0.5 cm of soil in a random distribution. At the start of the study, the containers were watered with 150 ml of water, and during the study the containers were watered with 100 ml of water every 3 days. The ambient atmosphere was 23 to 26 degrees, and the humidity was about 50%-60%. After 21 days, the plants were measured and average values were worked out, and coarse errors were eliminated for calculating average values. And the number of plants germinated values included [4].

TABLES, GRAPHS & FIGURES



Graph 1. Results of pot test concluded on December 2023



Graph 2. Results of pot test concluded on May 2024

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Table 1. Parameters obtained for garden soil extract and extract of ash mixture

Parameter	**Reaction of the solution**	**Conductivity**	**Salination**	**Electrical voltage**
Symbol	**pH**	æ $\boldsymbol{lub\ \gamma}$	**SAL**	**U**
Unit	$[\boldsymbol{H^+}]$	$\frac{\boldsymbol{\mu S}}{\boldsymbol{cm}}$	$\frac{\boldsymbol{g}}{\boldsymbol{dm^3}}$	$\boldsymbol{mV}$
Garden soil extract	5,395	1434	0,5	98,4
Extract of ash mixture	12,957	12670	7,2	-279,6

RESULTS

Graph 1. shows the results of the vase tests carried out in December 2023. Analysis of the graph in terms of average plant length shows that the highest values were achieved by the trial with 10% ash concentration. On the other hand, in terms of the percentage of germinated seeds, the highest results were achieved by the trial with 20% ash concentration.

Graph 2. shows the results of the vase tests performed again in December 2024, to which a sample with 40% ash concentration was added. Analysis of the graph shows that the longest average plant length was achieved by the trial with 5% ash concentration. In contrast, the highest percentage of germinated seeds was achieved by the sample with 10% concentration.

Considering both tests, it can be concluded that the final best conditions for germination and plant growth are provided by the sample with 10% ash concentration.

During the analysis of the germinated seeds, attention was also paid to the number of outgrown leaves in each trial. The sample with 5% ash concentration showed a decrease in the number of leaves of 66.1% compared to the control sample. The sample with 10% concentration showed the largest increase in the number of leaves of 6.78% compared to the control sample. In the sample with 20% ash concentration, the number of leaves also increased, by 3.39%. In the sample with 40% ash concentration, the number of leaves grown was 16.95% lower than in the control sample.

The soil used with a high organic content of more than 90% showed very good accumulation properties during pot tests. As a result, the addition of ash containing a high conductivity and salinity index could be well absorbed by the soil formation. The high conductivity and salinity of the extract demonstrates the ash's ionic complexity, as well as the presence of salt compounds in the soil environment. The aqueous stratum also showed better electrical conductivity, which promotes the assimilation of organic matter by plants.

CONCLUSION

Management of emerging waste is one of the key aspects of today's world. Many economies are still based on coal-fired power generation, which makes the research conducted more valuable. The results of the pot tests show the positive effect of using fly ash and bottom ash in the agricultural industry as a fertilizer for crops, neutralizing acidic soils.

The results obtained show a clear correlation with the objectives of the study. The optimal concentration for use as a fertilizer for this ash mixture becomes a soil solution in the range of 5% to 10% ash. The December 2023 study clearly indicated a concentration of 10% in terms of plant size, as well as seed germination efficiency. Repeated testing in May 2024 indicated a range closer to the 5% concentration. The May 2024 study also looked at the number of leaves developed by the plant, for the 5% and 10% samples the number of leaves developed was higher. Hence the conclusion that access to more nutrients promotes faster plant growth. Which may shorten the growing season.

ACKNOWLEDGEMENTS

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INFLUENCE OF WATER MIST AND ITS PARAMETERS ON FIRE SUPPRESSION

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ABSTRACT

Water mist systems are increasingly used in a wide range of applications. These systems play an important role in fire suppression, firefighting, and generally in combating the effects of fire. Water has the ability to reduce ambient, flame and fuel temperatures. It is also capable of wetting the fuel and preventing the spread of flames to unburned fuel. It has the ability to displace oxygen and combustible gases from an area, reduce the spread of radiant heat, or trap toxic or other particles from smoke. The effectiveness of water mist depends on its parameters. This article focuses on the most important ones, namely spray angle, water flow rate, flow velocity, working pressure, water mist droplet size, and also the temperature of the water source. The different parameters are interrelated and changing one parameter we can achieve a change in another parameter. It is necessary to keep in mind that it may not be the case that the highest or lowest values are the most effective. It is always necessary to determine experimentally or numerically the most effective value of a given parameter. At the same time, it is worth mentioning that it is not only the extinguishing agent that matters, but also the fuel that burns. With that said, the results cannot be applied in general and each fuel type may react differently to water mist. The paper describes the different parameters and the method we use to measure the droplet sizes of water mist, including the results from experimental measurements made using laser diffraction at the Technical University of Ostrava.

Keywords: Water mist, water mist parameters, droplet size distribution, laser diffraction

1. INTRODUCTION

Water has the highest specific heat of liquid and solid substances and also has a large heat of vaporization. It occurs in the form of watercourses, lakes or man-made bodies of water, making water the most accessible, economical and environmentally advantageous extinguishing agent. Water is capable of reducing the temperature of the fuel, the flames and the surroundings. It is also capable of displacing oxygen and combustible gases from around the fire or shielding the radiant heat component. At the same time, water mist is able to trap smoke particles, thus achieving better visibility and facilitating evacuation. [US NFPA 750 [2] defines water mist as a water spray that is 99% composed of droplets less than 1000 μm in diameter at minimum operating pressure within one meter of the nozzle mouth. Water mist systems are being increasingly used across a spectrum of applications. Starting with use in the fire protection of commercial buildings, various types of vessels, temperature reduction in industrial processes or directly for cooling heat-

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stressed parts in industry. Water mist systems can be used in a wide range of fire applications. These include cable, fuel, oil fires or fires in transformers, compressor stations, tunnels or other confined spaces. High pressure water mist systems are modern systems that can keep up with the trend of reducing water consumption. [1] High-pressure water mist systems use up to 90% less water than a conventional sprinkler, but offer the same effectiveness in fighting fires. In the case of archives, churches or historic buildings, extinguishing with excess water can cause more damage than the fire itself. [3]

2. Water mist parameters

The effectiveness of water mist depends on the type of fire and the parameters of the mist jet. Important parameters affecting fire suppression and extinguishment include spray cone angle, volumetric flow rate, mist jet speed, operating pressure, water source temperature and water mist particle size.

2.1 Spray cone angle

The spray cone angle is related to the nozzle structure, the nozzle location relative to the fire source and the working pressure. By changing the working pressure, slight changes in the spray cone angle can be achieved. Study [4] deals with the effect of increasing the working pressure on the change of the spray cone angle. The study worked with pressures of 60, 70 and 80 bar, whereupon it was found that by increasing the pressure there are slight changes in the spray cone angle in the range of tenths to lower units of degrees. Study [5] describes the effect of the spray cone angle on fire suppression and extinction. They successively tested different spray cone angles ranging from 50 to 120° on the case of a circular oil pool fire. The experiment showed that spray cone angles of 50, 60 and 70° were not applicable for extinguishing oil when the temperature fluctuated around 200°C during water mist application. This is due to the fact that small spray cone angles affect a smaller area and thus cannot be as effective. At angles of 80 to 110°, it was true that the effectiveness of the water mist increased with increasing angle. With that said, the 110° angle was determined to be the most effective spray cone angle for extinguishing an oil fire with water mist. For the 120° angle, the results differed only slightly from those for the 110° angle. On the other hand, study [6] describes the effect of 60°, 90° and 120° spray cone angle on the extinguishment of an oil pan fire. In this case, the 60° angle worked best, followed by 90°, and the 120° spray cone angle had the worst results. The 60° spray cone angle worked well at both 6 MPa and 10 MPa working pressure. At the same time, it was also best at water flow rates of 2 and 5 litres per minute.

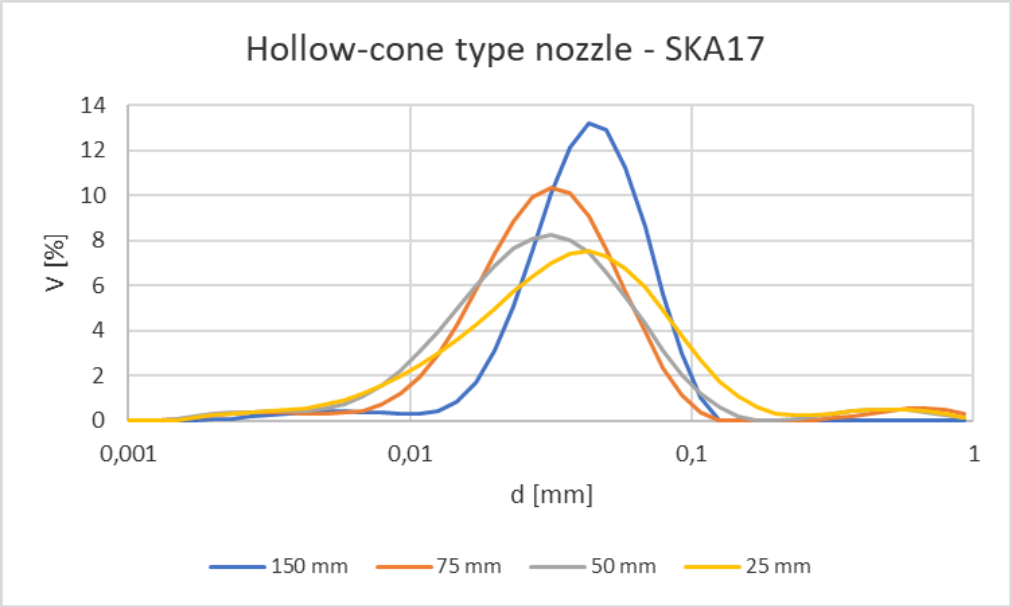
2.2 Droplet size and working pressure

The water mist jet is not a monodisperse system where all droplets are the same size. To quantify the particle size distribution, we most often use the Sauter Mean Diameter (SMD). In practice, we also encounter the Volume Mean Diameter (VMD), Median Mass Diameter or Rosin-Rammler distribution. The smallest and largest droplets make up only a small fraction of all the droplets in a mist jet. [7] Study [8] investigated the effect of water droplet size (40, 80, 120 μm) on the extinguishing efficiency of a 300-kW pool fire of n-heptane. Here it was valid that with increasing diameter there is an increase in time to extinguish the fire. Study [9] compared mist systems and sprinklers in relation to methane fire suppression. The study confirmed that a 1000 μm water mist is more effective than a 1750 and 2000 μm water jet. In addition to the nozzle design, the particle size also depends on the operating pressure. As the pressure increases, the droplet size

decreases and vice versa. With decreasing pressure, larger diameter droplets are produced. Study [10] investigated the effect of working pressure on the change in droplet diameter at different distances from the nozzle orifice at working pressures of 2, 4 and 6 MPa. The largest droplet diameters are achieved at a working pressure of 2 MPa. The smallest diameters are achieved at 6 MPa. The study also focused on improving the extinguishing capability by increasing the working pressure. At a working pressure of 2 MPa, the water mist was not able to extinguish oil fog fires of more than 1 MW. At a working pressure of 6 MPa, the water mist was able to extinguish oil fog fires of up to 1.6 MW. Study [4] investigated the effect of operating pressure on the change in droplet diameter at operating pressures of 2, 4, 6, 8, 10 and 12 MPa. From the results of the study, it can be seen that, here also, with an increase in pressure, the droplet diameters are reduced. Study [11] focused on transformer pool fires with fire outputs of 212.55 kW, 457.14 kW and 747.90 kW. The study found that increasing the working pressure leads to a significant reduction in the time taken to extinguish for all fire intensities. The time taken to extinguish the fire was 4 times lower at 1.4 MPa compared to 0.4 MPa working pressure. The study also confirmed a reduction in droplet diameter as pressure increased. Water mist droplet size also affects the ability of water mist to shield radiant heat. Studies [12] and [13] show that smaller droplets are more effective in shielding radiant heat. Droplet sizes in the order of units and lower tens of micrometres are the most effective. Experiments show that the ideal droplet size is 2 to 25 μm. The influence of particle size is also described in study [14], which looked at the effect of water mist parameters on the shielding of the radiant heat component. This study confirmed that as the droplet diameter decreases, the shielding of the radiant heat component becomes more pronounced. In addition, water flow rate was also found to have an effect on shielding, with the ability to shield radiant heat increasing with increasing flow rate.

Determining particle size distribution and particle velocity is one of the most challenging measurements of water mist parameters. We can use a variety of methods that work on different principles. The most commonly used methods are those based on laser diffraction, the Doppler effect or digital methods. Laser diffraction works on the principle of diffraction phenomena. When laser light hits an obstacle, diffraction effects occur. The diffraction angle is determined by the wavelength of the light and the size of the particle. As the particle size increases, diffraction angles decrease. An example is the SprayTec method. [8][9] The output of the SprayTec device is a graph of the particle size distribution of a given nozzle. The vertical axis shows the volume value in percent and the horizontal axis shows the diameter value in millimetres. The particle size distribution is measured at multiple distances from the nozzle mouth, since the resulting data depend on the distance from the nozzle mouth. An example of the resulting graph is shown in Figure 1, which describes the particle size distribution of a hollow-cone type nozzle (SKA17 is the designation of the nozzle manufacturer). Table 1 describes the comparison of the Sauter mean droplet diameter for different nozzles of the same type at different distances from the nozzle mouth.

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Graph 1 – Particle size distribution of a nozzle with the designation SKA17

Table 1 - Sauter mean diameter of nozzles with the designation SKA16-20

Spraytec	**25 mm**	**50 mm**	**75 mm**	**150 mm**
SKA16	17,93 µm	18,12 µm	20,608 µm	35,72 µm
SKA17	21,89 µm	19,70 µm	21,870 µm	31,46 µm
SKA19	17,46 µm	21,87 µm	22,108 µm	38,51 µm
SKA20	19,85 µm	19,23 µm	21,387 µm	32,91 µm

2.3 Water source temperature

An often-overlooked parameter is the temperature of the mist system's water source. Study [15] proved the positive effect of increasing the source temperature on the cooling effect of water. Study [16] showed faster evaporation of water mist droplets when the water source temperature increases. Only a small fraction of energy is required to heat water compared to the energy required to convert water from a liquid to a gaseous state, thus confirming that higher water temperatures can increase the cooling effect of water. Study [17] describes an experiment in which the effect of water source temperature on diesel and n-heptane fire suppression was investigated. The experiments showed that for n-heptane fire, significantly better results occurred when hot water was used. At a water source temperature of 20 °C and a working pressure of 9 MPa, the time required to extinguish was 54 seconds. At a water temperature of 80 °C and the same working pressure, it was reduced to only 10 seconds. For a diesel fire, the opposite results can be observed. At a water temperature of 20 °C and a working pressure of 9 MPa, the time taken to extinguish was 36 seconds. When the water temperature was increased to 80 °C, the time required to extinguish increased to 70 seconds.

2.4 Spray volume flux

Water flow depends on the spray type, nozzle structure, working pressure and distance from the nozzle. Study [5] describes the effect of water flow rate on extinguishing an oil pan fire at different spray cone angles. The study shows that a water flow rate of 5 litres per minute is more effective than a water flow rate of 2 litres per minute at all spray cone angles (60°, 90°, 120°). The study [5] compared flow rates of 5, 10, 20 and 30 litres per minute. Again, it was shown that the time taken to extinguish a fire decreases as flow rate increases. The most effective flow rate was found to be 20 litres per minute. There was no significant change in the time taken to extinguish the fire when the flow rate was increased. Thus, increasing the water flow rate above 20 litres per minute is not considered effective.

2.5 Spray speed

Spray speed is one of the other important parameters that has an influence on the effectiveness of the water mist. It should be remembered that high velocities may not be effective and, on the contrary, may contribute to fire ignition. Study [5] investigated the effect of spray speed on extinguishing oil fires. The results show that in the range of 5-20 m/s, it is true that the time required to extinguish the fire decreases with increasing speed. On the contrary, the time increased when the speed increased above 20 m/s. The same methods can be used to measure particle velocity as for particle size. Alternatively, methods specifically designed to measure velocity are used, such as Particle Image Velocimetry (PIV).

3. Discussion and results

The individual parameters of water mist have a significant effect on the time required to extinguish or suppress fire. Studies are unable to generally determine which values of spray cone angle are most favourable. This depends on the type of fuel and the size of the fire. For smaller fires, smaller spray cone angles are sufficient. For larger fires, smaller spray cone angles may be ineffective, hence the need to use spray cone angles in excess of 100°. Increasing working pressure significantly affects the capabilities of water mist. By increasing the working pressure, a reduction in the time required to extinguish/suppress a fire can be achieved or larger fires can be extinguished. Therefore, high pressure mist systems are more frequently encountered in practice. Increasing the working pressure results in a reduction of water mist droplets and vice versa. For radiant heat shielding, a droplet size range of 2-25 μm is most advantageous. In terms of size, the most effective diameter values for fire suppression also cannot generally be determined. Again, this depends on the type of fuel. As a general rule, the droplet must not be too large (it would not evaporate completely) or too small (it would evaporate too quickly and would not be able to remove a large amount of heat. For the determination of the SMD, the method chosen in this article is based on the principle of laser diffraction. A total of four nozzles were measured at distances of 25, 50, 75 and 150 mm. As the distance from the nozzle mouth increased, the SMD value increased. The increase in SMD value was not due to volume increase or droplet coupling. It was due to the finest droplets being carried away from the laser measurement beam and thus not included in the final SMD value. As the temperature of the water increases, evaporation occurs more rapidly, and thus the cooling effect is greater. As the flow rate increases, the time required to extinguish decreases. The flow rate cannot be increased indefinitely. If the flow rate is too high, the time will not be reduced and high water demand is not desirable because of excessive

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water damage and increased operating costs. The flow rate of the water mist also cannot be increased excessively. If the flow rate is too high, oxygen will be drawn into the flames, increasing the time required to extinguish the fire.

4. CONCLUSION

Water mist is an effective and efficient extinguishing agent that can be used on many types of fires. Water mist and water in general is an excellent extinguishing agent based on its capabilities. As water evaporates, it removes a large amount of heat from the flames, fuel and surroundings, cooling them. At the same time, the vaporizing water mist expands rapidly and displaces oxygen with combustible gases from the combustion zone. In addition, it is capable of shielding the radiant heat component. In general, the smallest droplets (2-25 μm) are the most suitable for shielding radiant heat. In addition, water mist is able to trap particles from smoke, thus facilitating evacuation and increasing visibility. The effectiveness of water mists depends on their parameters. For the flow rate and speed of water mist, it can be determined that increasing the value reduces the time required to extinguish the fire. However, the value cannot be increased indefinitely and at a certain value there is a breakpoint where, on the contrary, increasing the value of this parameter leads to an increase in the time required to extinguish. Working pressure and droplet size are closely related. The droplet size can be influenced by changing the working pressure. By increasing the working pressure, the water mist droplets become smaller and at a higher working pressure a fire can be extinguished in less time or a fire with a higher output can be extinguished. For droplet size, a single value for droplet diameter cannot generally be established for all types of fire. Different droplet sizes are appropriate for each type of fire. Many different methods can be used to determine droplet size. In this article, a method based on the principle of laser diffraction was selected. A total of four nozzles were measured at 25, 50, 75 and 150 mm and Sauter's mean diameter was determined for these nozzles. A trend can be noticed in the values where the SMD value resulted higher with increasing distance from the nozzle. In some cases, the temperature of the water source leads to a decrease in the time to extinguish, but for other cases the time to extinguish may increase. The type of fire and its dimensions are important for determining the spray cone angle. For smaller fires, large spray cone angles are not appropriate and conversely, for larger fires, small spray cone angles are not appropriate.

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METHODS AND TOOLS FOR STRATEGIC ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

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ABSTRACT

The article deals with methods and tools for strategic environmental impact assessment (EIA) in the context of the CEVYKO project, whose facility capacity is 100,000 t/year of processed mixed, separated and bulky municipal waste. Only category O waste (other waste) will be processed. In the introduction, the basic principles and legal framework of EIA are presented, including their importance for sustainability and environmental protection. Subsequently, the specific methods used in the evaluation of projects with a high environmental impact, such as CEVYKO, are described, including risk analysis, impact modeling and evaluation of alternatives. The article also focuses on data collection and analysis tools that enable accurate predictions of environmental impacts and effective mitigation planning. In the conclusion, the results of the EIA for the CEVYKO project are discussed, including the identified key environmental impacts and proposed measures for their minimization. The study highlights the importance of a comprehensive and integrated approach to EIA, which includes all relevant aspects of waste management and contributes to sustainable development.

Keywords: EIA, CEVYKO, Waste, Analysis, Waste management

INTRODUCTION

The CEVYKO project focuses on the efficient processing of mixed, separated and bulky municipal waste with a facility capacity of 100,000 t/year, while only category O waste (other waste) is processed. [5,6,7,] This project includes advanced waste sorting and separation methods that enable maximum use of recyclable materials and minimization of negative impacts on the environment. The waste is weighed separately using a collection technique via a scale to the so-called daily warehouse. After that, the materials are transferred to the first sorting cabin via a bag opener or crusher by a belt conveyor. Here, the operator manually removes waste that must not enter the technology, such as bulky objects, hazardous waste or glass. Further sorting takes place using a drum sorter, which divides the waste into three basic fractions: sub-sieve fraction (≤ 60 mm), sieve fraction (60-350 mm) and over-sieve fraction (≥ 350 mm). The sub-mesh fraction undergoes metal separation and is then transported to a container, from where it goes on to be further processed into solid alternative fuel (TAP). The 60-350 mm fraction is fed to optical separators that separate the paper and plastic components. The paper is further sorted by optical separators and manually into individual types of recyclable paper, while the non-recyclable remainder goes to TAP

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production. Plastics are sorted by a ballistic sorter into 3D and 2D fractions, with each fraction undergoing further optical sorting and manual sorting. The ≥350 mm fraction is transported to the sorting cabin, where recyclable materials such as cardboard and plastic foil are manually separated. The rest of the material is also used to produce TAP. Bulky waste is pre-crushed and then separated into recyclable raw materials, while the remaining material is used for the production of TAP. The resulting waste for the production of TAP is transported to the technology, where inert material and PVC are removed. Subsequently, the waste is crushed and homogenized, while the quality of TAP is continuously monitored according to the set parameters. TAP is then handed over to customers in suitable energy sources for the production of heat and electricity. The entire processing process takes place in the hall with extraction by a fan and filtration of waste air using a fabric filter. This project illustrates the advanced and integrated approaches to municipal waste treatment that are key to sustainable waste management and environmental protection. [1,2,3,4]

MATERIALS AND METHODS

When dealing with the EIA (Environmental Impact Assessment) process, various methods and tools are used to identify, evaluate and minimize the negative impacts of projects on the environment. The most commonly used methods include:

a) Screening a scoping

Screening is the initial stage of the EIA process, which determines whether an environmental impact assessment is necessary for a given project. This step includes a review of the type and scope of the project and its potential environmental impacts. Scoping is the process of determining the scope and key issues that should be included in an EIA. The main environmental aspects and areas of interest will be identified and will be subjected to a detailed assessment. This step often involves consultation with experts, the public and stakeholders. [4,8,9,10]

b) Data collection and analysis and impact identification and assessment

Data collection and analysis are critical steps that involve gathering relevant information about the state of the environment in the project area. Various methods are used, such as field surveys, air and water quality monitoring, biological surveys, geographic information systems (GIS), and remote sensing. This phase includes the identification and assessment of the project's potential environmental impacts. Various analytical methods are used, such as: Matrix of influences. Identification of relationships between project activities and environmental components. Checklists. Systematic evaluation of individual aspects of the environment. Modeling and simulation. Forecasting the impacts of project activities based on mathematical and computer models (e.g. dispersion models of air pollution, hydrological models). Comparative analyses. Comparison with similar projects and their impacts. [11,13,14,15]

c) EIA report preparation

The EIA report documents all phases of the assessment, including methods used to assess impacts, results of analyses, proposed mitigation measures, and evaluation of alternatives. The report is submitted to the relevant authorities and is subject to public discussion. [12]

d) Decision making

On the basis of the EIA report and public consultations, the competent authorities will decide on the approval or rejection of the project, or set the conditions under which the project can be implemented. Monitoring and follow-up. After project approval, continuous monitoring and follow-up are important to ensure that the project complies with the established conditions and that the mitigation measures are effective. Using these methods and tools in the EIA process helps ensure that projects are planned and implemented with minimal negative impact on the environment and promote sustainable development. [4,8,9,10,11,15]

RESULTS

a) Characteristics of possible impacts and estimation of their size and significance (in terms of probability, duration, frequency and reversibility)

Effects on the living components of nature can be assessed as less significant due to the nature and location of the project. The plan will be implemented in an area marked by anthropogenic activity.

The project is expected to have the following effects:

- On the immission situation in the locality during operation of the project,
- On the noise situation from stationary sources,
- On population and public health.

b) Impact on air quality

The conclusions of the dispersion study are as follows:

Due to the operation of the project, its immediate surroundings may be more significantly affected by immissions of suspended particles. The calculated daily concentrations of particles of the PM10 fraction directly in the area reach values that exceed the immission limit value, outside the area the calculated values drop significantly.

c) PM_{10} emissions

The maximum contribution of daily PM_{10} concentrations in the entire locality was calculated above half the value of the immission limit – 36.3 $\mu g/m^3$, but the maximums are calculated directly at the site area. Significantly lower concentrations, below 10 $\mu g/m^3$, were calculated in more distant locations.

Contributions of daily concentrations from 4.3 to 5.5 $\mu g/m^3$ are calculated in selected profiles of nearby buildings. The period of exceeding the contribution value of 2 $\mu g/m^3$ is calculated a maximum of 3 times per year. Even with the existing immission background (maximum PM_{10} immissions of approx. 46 $\mu g/m^3$), precisely due to the operation of this project, the immission limits should not be exceeded, when the permissible number of exceeding the limit of 50 $\mu g/m^3$ is 35 times per year.

The maximum calculated contribution of the average annual concentration of PM_{10} is 0.94 $\mu g/m^3$ on the campus, and outside the campus it is an order of magnitude lower by tenths of $\mu g/m^3$. In populated localities, the contributions of annual PM_{10} concentrations of 0.024 to 0.037 $\mu g/m^3$ are calculated, i.e. a maximum of approx. 0.1% of the immission limit value (40 $\mu g/m^3$) and the immission background (29.2 $\mu g/m^3$).

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d) $PM_{2.5}$ emissions

The maximum calculated contribution of the average annual concentration of $PM_{2.5}$ is 0.63 µg/m^3 in the area of the project, outside the area in the order of hundredths to tenths of µg/m^3. In populated areas, contributions of annual concentrations of 0.041 to 0.069 µg/m^3 are calculated, i.e. a maximum of approx. 0.3% of the immission limit value (20 µg/m^3) and the immission background (approx. 22.4 µg/m^3).

e) NO_2 immission

The maximum contributions of hourly NO_2 concentrations in the entire location are calculated to be 0.303 µg/m^3, which represents approximately 0.15% of the limit value. Contributions from 0.037 µg/m3 to 0.094 µg/m^3 were calculated in the selected profiles.

The maximum contribution of the average annual NO_2 concentration was calculated to be 0.0027 µg/m^3, in the selected profiles the contributions of the annual NO_2 concentrations are calculated in tens of thousands of µg/m3, at most 0.00079 µg/m^3 (<0.01% of the limit).

f) CO emissions

The maximum calculated contribution of eight-hour CO concentration averages reaches 5.1 µg/m3, i.e. 0.05% of the immission limit value (10,000 µg/m3). At the selected reference points, the calculated values range from 0.4÷ 1.6 µg/m3, i.e. significantly less than 1% of the immission limit value. The impact of the project on CO emissions is minimal, the emission limit will not be exceeded.

g) Benzene immission

The maximum contribution of the average annual concentration of benzene was calculated to be 0.00027 µg/m^3 (<0.1% of the limit), in built-up areas the contributions are calculated up to 0.00007 µg/m^3, i.e. significantly below the immission limit value (5 µg/m^3) .

h) Benzo[a]pyrene immission

The maximum contribution of the average annual concentration of benzo[a]pyrene was calculated to be 0.00071 ng/m^3 (0.07% of the limit), in populated areas contributions up to 0.00023 ng/m^3 are calculated, i.e. significantly below the immission limit value (1 ng /m3).

With the considered immission background of around 2.7 ng/m^3, the effect of the project is immeasurable and the operation of the project will not cause the immission limit for annual concentrations of benzo[a]pyrene to be exceeded.

i) Effect of noise load

To calculate the mathematical model, a total of 4 reference points were chosen at the nearest residential building, at a distance of 2 m from the facade. The calculation is performed excluding the reflection from the adjacent facade.

Table 1 List and location of reference points

Name of the point	Address	Distance from the target	Description
RB 1	Spodní 563/1	About 1,500 m	Family house
RB 2	Důlní 890/7	About 1,300 m	Apartment building
RB 3	Ul. Hořanská 49.8034894N, 18.4636481E	About 950 m	Gardening colony
RB 4	U Pošty 373/3, Havířov	About 1,300 m	Family house

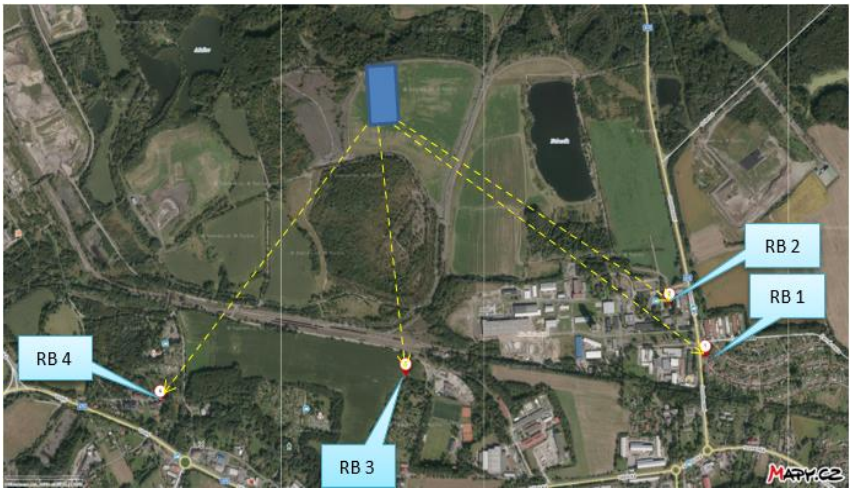


Figure 1 Selected reference points

Table 2 Table of calculation points

TABLE OF CALCULATION POINTS							
RB	Height (m)	DAY			NIGHT		
		Transport (total according to the census of transport without intention)	Transport (total according to the transport census, including the plan)	Difference	Transport (total according to the census of transport without intention)	Transport (total according to the transport census, including the plan)	Difference
		L_{Aeq} [dB]	L_{Aeq} [dB]	[dB]	L_{Aeq} [dB]	L_{Aeq} [dB]	[dB]
1	3,0	58,4	58,4	0	51,5	51,5	0
	6,0	59,5	59,6	+ 0,1	52,7	52,7	0
2	3,0	44,7	44,7	0	37,8	37,8	0
	6,0	46,2	46,3	+ 0,1	39,3	39,3	0
3	3,0	33,8	33,8	0	27,0	27,0	0
4	3,0	32,5	32,6	+ 0,1	25,4	25,4	0
	6,0	35,3	35,4	+ 0,1	28,3	28,3	0
Limit		**68**			**58**		

Table 3 Table of calculation points

TABLE OF CALCULATION POINTS					
RB	Height (m)	DAY			NIGHT
		Stationary resources including intra-campus transport	Measured noise values (level L_{90})	Difference	Stationary resources including intra-campus transport
		L_{Aeq} [dB]	[dB]	[dB]	L_{Aeq} [dB]
1	3,0	23,5	54,6	0	23,5
	6,0	23,7	-	-	23,7
2	3,0	28,4	-	-	28,4
	6,0	28,4	-	-	28,4
3	3,0	35,3	40,3	+ 1,2	35,3
4	3,0	27,5	45,1	+ 0,1	27,5
	6,0	27,5	-	-	27,5
Limit		**50**			**40**

Note on all calculated values: For the HLUK+ program in version 14, the uncertainties of the calculation results are at most 2 dB from the conventionally correct LA_{eq} value for the considered situations.

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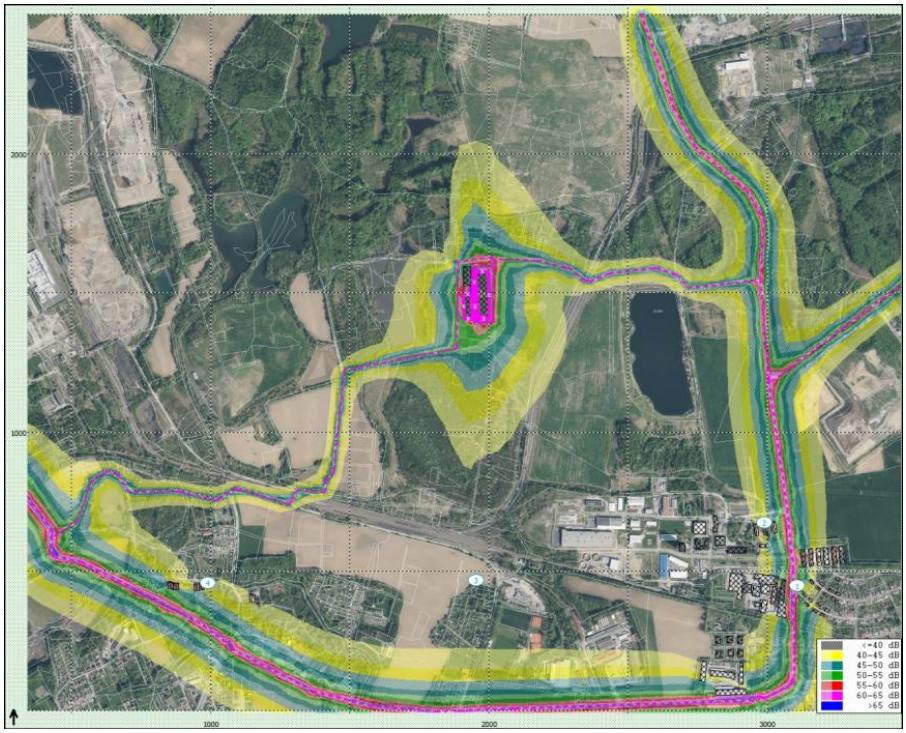


Figure 2. Isophones at a height of 3 m - proposed condition - DAY

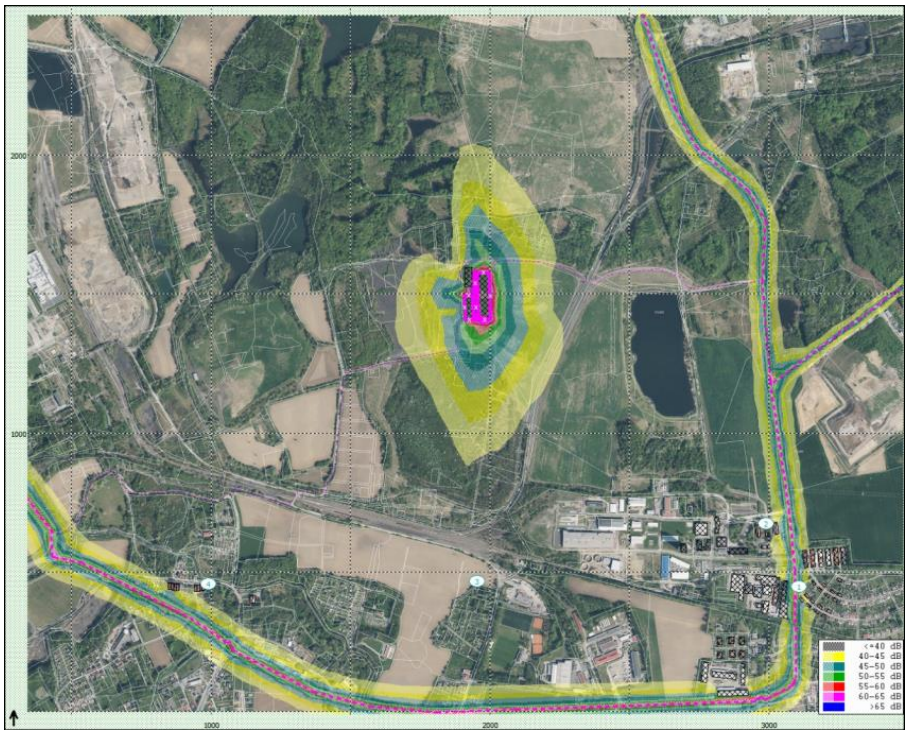


Figure 3 Isophones at a height of 3 m - proposed condition - NIGHT

j) The permissible value for the daytime for noise from the operation of stationary sources in the area is LAeq = 50 dB(A), for the night time it is LAeq = 40 dB(A), the permissible value for the daytime for noise from traffic on roads is LAeq = 68 dB(A), for night time LAeq = 58 dB(A).

The highest calculated values from the operation of stationary noise sources, including campus traffic, were calculated to be a maximum of 35.3 dB(A) for RB 3 in the case of normal production operation during the day and at night. The highest calculated values from road traffic, including associated traffic, were calculated for RB1, namely 59.6 dB(A) during the day, in this case there will be an increase of 0.1 dB compared to the current situation.

k) The following conclusions follow from the assessment of health risks:

The following conclusions emerged from the assessment of the health risks of the impact of immission contributions on the population: The highest annual immission contributions of fractions PM_{10} and $PM_{2.5}$, NO_2, 8-hour CO immission contributions and the maximum hourly NO_2 contributions listed in the dispersion study do not represent a significant health risk for the population.

l) Assessment of the effects of noise on public health

The results of the noise study show that noise contributions from stationary noise sources related to the operation of the project during the day and at night do not represent significant adverse health effects.

The results of the public health impact assessment do not apply to emergency situations and the conclusions of the public health impact assessment are valid only for the input data presented in the dispersion study and in the noise study.

m) Impact on vegetation and greenery

During the implementation of the assessed plan, a situation will not arise that would require technical measures necessary to ensure the migration of animals or the transport of plants to a new, more suitable location. Stable and biologically valuable ecosystems are not created on the area of the construction site under consideration.

n) Impact on water

The location does not fall into any water resource protection zone or CHOPAV, there is no underground or surface water source for public supply of the population. The site is not located in a flood zone. For the construction of the new plant, adjustments to the hydrological regime of the landscape are not considered. The intention will not cause water erosion. Due to the new construction, there will be an increase in paved areas in the area compared to the present. Rainwater will be drained into a rain pit, rainwater from parking and handling areas will be drained through an oil separator.

o) Impact on soil

The entire project is located on an area that was a "brownfield" and is currently ready for use as an industrial zone. The parcels in question do not have an assigned BPEJ and no objects of protection are registered on them. An exemption from the agricultural or forestry fund will not be necessary. The surface of the territory is formed by anthropogenic deposits, the soil cover is minimal. The effects of the project on the soil and rock environment can be characterized as minimal, in the case of human factor failure (failure to comply with the prescribed procedures) as temporary, unimportant effects (if any, the resulting pollution may only be less significant and will be quickly removed).

p) Social, economic consequences

The actual implementation of the project does not have an excessively negative effect on the population in the mentioned areas. The conducted assessment (noise and

dispersion study) found that the project will not have a negative effect on the public health of residents within the scope of the project's influence, the relevant limits will be met. The social and economic consequences will not be negative.

DISCUSSION

The summary of a non-technical nature contains the conclusions of the individual evaluation sub-circles in a concise form. The intention is to build a modern technical facility which, thanks to the optical sorting technology used, will enable the sorting of usable raw materials from SKO and at the same time to sort the secondary raw materials from the separation to a very good quality. Waste for which there is no use on the market of secondary raw materials, but which have energy potential, will be processed into a solid alternative fuel based on waste - the so-called TAP. The intention is to build a modern technical facility which, thanks to the optical sorting technology used, will enable the sorting of usable raw materials from SKO and at the same time to sort the secondary raw materials from the separation to a very good quality. Waste for which there is no use on the market of secondary raw materials, but which have energy potential, will be processed into a solid alternative fuel based on waste - the so-called TAP. These modern facilities are of regional and supra-regional importance, and the capacity options correspond to this, when it is necessary to ensure the supply of SKO from a wider region and to adapt and optimize the logistics of SKO collection to the mentioned facility. As part of the plan, waste with catalog numbers 20 01 01 Paper and cardboard, 20 01 39 Plastics, 20 03 01 Mixed municipal waste, 20 03 07 Bulky waste in a total amount of 100,000 t/year will be processed. Alternatively, other similar types of waste suitable for processing with the given technology can be processed.

CONCLUSION

The CEVYKO project represents a comprehensive system for the processing and sorting of municipal waste, the aim of which is to minimize negative impacts on the environment and maximize the use of recyclable materials. This system includes several key stages and technologies that ensure the efficient processing of waste from its reception to the final production of Solid Alternative Fuel (TAP). Receiving waste and the first stage of sorting. The waste is separately weighed into the CEVYKO facility using collection equipment and is taken over the scale to the so-called daily warehouse. This process enables accurate recording of the amount and type of waste, which is key for subsequent processing. The daily warehouse serves as a temporary storage facility where waste is prepared for further sorting. Drum sorter and division into three basic fractions. Plastics are sorted and the remaining material after separating all recyclable plastics is also led to the production of TAP. Over-sieve fraction (≥ 350 mm): This fraction is transported to the sorting cabin, where recyclable papers (cardboards) and plastic films are manually separated. The rest of the material is transported to TAP production. Bulky waste processing. Selected types of bulky waste are received from suppliers in a separate part of the facility. These wastes are pre-crushed and subsequently undergo separation of secondary raw materials such as metals and plastics. Residual waste is used again to produce TAP, thereby maximizing the use of materials and minimizing the amount of waste that would have to be landfilled. Production of solid alternative fuel (TAP) The waste for the production of TAP from the sorting line and from the bulky waste processing line is transported to the technology for the production of solid alternative fuel. The CEVYKO project represents a modern and

efficient solution for the processing of municipal waste, which combines technological innovation with ecological and economic advantages. Thanks to a comprehensive and integrated approach to waste sorting and processing, the project contributes to sustainable development and environmental protection. This approach could serve as a model for other projects focused on efficient waste management and promoting the circular economy.

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OPPORTUNITIES AND CHALLENGES IN ACHIEVING SUSTAINABLE TOURISM ON REGIONAL LEVEL

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ABSTRACT

Sustainable tourism at the regional level is an approach to tourism development that aims to maximize economic, social, and cultural benefits for local communities while protecting and conserving the surrounding environment and cultural heritage of the region. This concept emphasizes responsible resource management, reducing environmental impact, and promoting social and economic inclusion. By adopting principles of sustainable tourism, the tourism industry can contribute to the conservation and protection of natural and cultural resources in a destination, while also providing sustainable economic and social benefits for local communities. From this perspective, sustainable tourism in protected areas is of particular importance, where it is essential to implement responsible tourism practices and develop appropriate management plans in collaboration with local communities, authorities, and other stakeholders. To address these challenges and capitalize on opportunities, it is essential to develop and implement appropriate management plans, which include measures for environmental conservation, and education. Maintaining a balance between nature and culture conservation and the sustainable and responsible development of tourism is crucial and for this the potential environmental footprint of diverse tourism activities will be analyzed, assessed, and debated for the case study of the Danube Delta Biosphere Reserve in Romania with the goal of shaping sustainable tourism.

Keywords: sustainable tourism, protected areas, Danube Delta Biosphere Reserve, biodiversity, environmental footprint

INTRODUCTION

Nowadays it is to be noticed that humanity environmental consciousness has changed in a positive direction all over the world. This is basically a result of the fact that some decades ago it became clear that human economic activities, especially industrial ones, have besides desired impact on humanity quality of life also undesired environmental impacts [11]. Nevertheless especially after the Conference for Environment in Stockholm in 1972 and after the release of the first report to the Club of Rome „Limits to Growth" [6] it was finally understood that besides wanted impact of technological advance, undesired and negative effects can also appear [5]. Nowadays humanity confronts itself with several global problems, which can be mainly grouped into three categories: world population growth, growth of energy and natural resources consumption and environmental pollution, as to be noticed in Figure 1 [5, 10].

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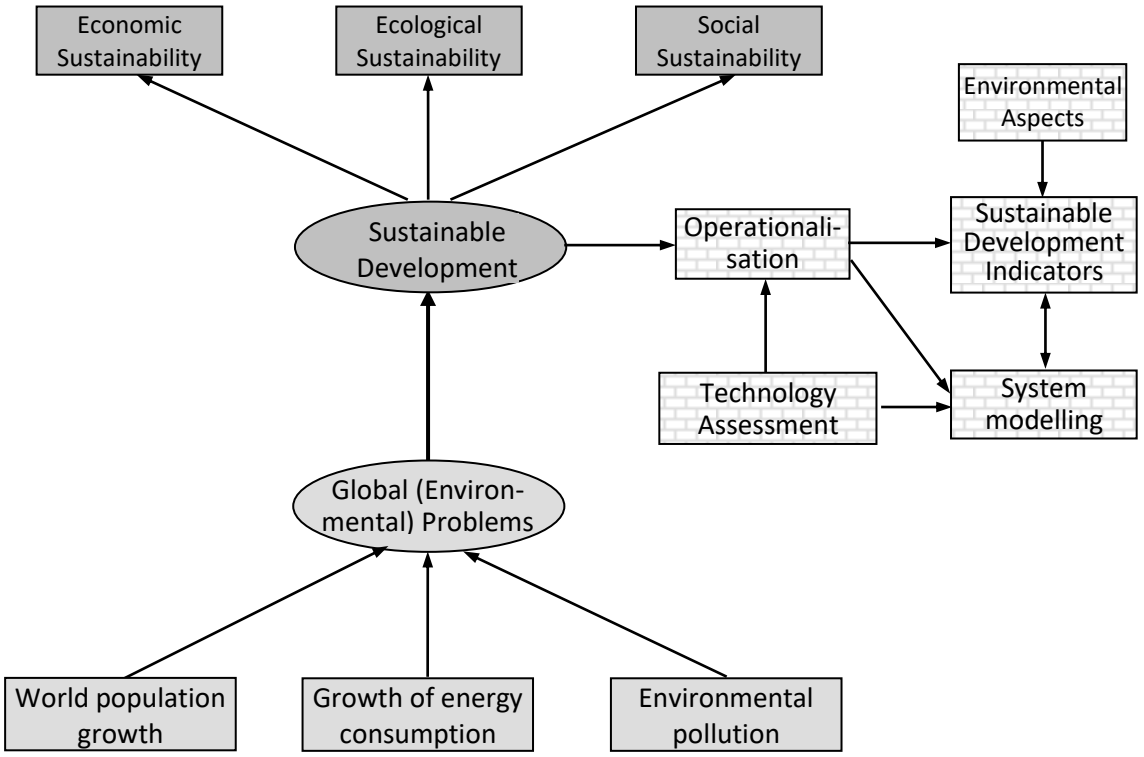


Figure 1: Global (environmental) problems and the concept of sustainable development.

As a result of the global political discussions to try finding best solutions to this noticed challenge the Brundtland Report of the World Council on Environment and Development has been released [4]. The most relevant fact is represented by that the concept of sustainable development was for the first time defined in the Brundtland Report [4]. After its definition the concept of sustainable development was accepted fast on a worldwide level as a possible solution for the complex global environmental, economic, and social problems. Sustainable development was largely debated on the Conference for Environment and Development in Rio de Janeiro 1992 as well as mentioned in the conference closing document „Agenda21“ [12]. Many activities after this time have pointed out that the evolution of technical, social, and environmental systems must be analysed in synergetic relation [5, 10]. At this point several events can be mentioned, for instance, the follow-up “Rio + 10” – Conference in Johannesburg in 2002, the Western Cape Sustainable Development Conference 2005 in Cape Town, South Africa as well as the World Summit on the Information Society, WSIS, which has been held in two phases, first phase 2003 in Geneva, Switzerland, and second phase 2005 in Tunis, Tunisia [15]. Next follow-up Rio-Conferences took place as well, in 2012 the so-called “Rio+20” - Conference in Rio de Janeiro as well as in 2022 the “Rio+30” – Conference, which has been again organized in Rio de Janeiro [13, 14].

The concept of sustainable development has become a widely used term nowadays [12, 13, 14]. Anyway, looking at texts dealing with this topic, the impression arises that there are as many understandings of what it means to be sustainable as users of the term [5]. Nevertheless, to make this concept more understandable rules, strategies and principles of sustainable development have been defined, see [2, 11].

Most debated strategies in this regard are focused on possibilities to achieve sustainable tourism, as being nowadays one of the most carried out free time spending activities of human beings. The vision is to carry out such activities in a successful way, by considering environmental protection-related aspects [1, 2, 3]. Sustainable tourism is a concept that integrates the principles of sustainable development into the tourism sector, aiming to minimize negative environmental impacts and maximize economic and social benefits for local communities [3]. This involves managing resources in such a way that the economic, social, and aesthetic needs of the present are met while ensuring the conservation of cultural and natural heritage for future generations. Sustainable tourism plays an essential role at the regional level, having the potential to generate multiple economic, ecological, and social benefits. This form of tourism focuses on developing an industry that respects and protects the natural and cultural environment while contributing to the economic well-being of local communities. The importance of sustainable tourism at the regional level can be understood through several key aspects [2, 3].

Sustainable tourism significantly contributes to regional economic development. Ecologically, sustainable tourism promotes the protection and conservation of natural resources [3]. It can improve the quality of life for local communities and stimulate investments in infrastructure and public services. By adopting sustainable practices, regions can ensure that tourism development contributes to long-term prosperity while protecting the natural and cultural resources that make these destinations attractive. Thus, sustainable tourism can become a driver of growth and development, harmoniously integrating economic needs with those of the environment and local communities [2, 9].

MATERIALS AND METHODS

The Danube Delta is an exceptionally popular tourist destination due to its spectacular landscapes and unique biodiversity. However, the current state of tourism in the Danube Delta presents both significant opportunities and challenges. The current state of tourism in the Danube Delta is marked by increased interest in ecotourism and nature-based recreational activities. To create a holistic picture, tourism and economic statistics and reports, environmental impact reports, interviews with locals, and current environmental policies and regulations regarding the conservation of the Danube Delta were used. In this context, both positive and negative will be analysed to identify challenges related to sustainable tourism and the implementation of environmental policies that can harmonize this activity in an area with immense natural wealth. To maintain the delicate balance between tourism development and ecological conservation, an integrated approach is essential [2].

OPPORTUNITIES AND POSITIVE ASPECTS

Regarding the opportunities and positive aspects related to tourism activities in the mentioned region, several individual issues should be emphasized as follows [1]:

a. Ecotourism and sustainable tourism-The Danube Delta has experienced growth in ecotourism, with a focus on activities such as bird watching, boat trips, and guided tours

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of the local biodiversity. These forms of tourism have a low environmental impact and contribute to raising awareness about the importance of nature conservation.

b. Revenue for local communities - Tourism generates significant revenue for local communities, providing jobs and stimulating the regional economy. Well-managed tourist activities can support sustainable development and offer viable economic alternatives for the residents of the Delta. The revenue generated by sustainable tourism in the Danube Delta Biosphere Reserve is an important source of economic support for local communities. Ecological tourist activities, such as guided birdwatching tours, boat rides, and eco-friendly guesthouse accommodations, not only attract visitors but also create jobs and stimulate local businesses, including restaurants and artisans [8].

c. Conservation and Education Initiatives - Many tourism projects include educational components, informing visitors about the Delta's ecosystems and the importance of protecting them. These initiatives help promote responsible behavior among tourists.

CHALLENGES AND PROBLEMS

Considering arisen challenges and problems related to tourism activities in the mentioned region, several individual issues should be emphasized as resulted from current analyses carried out on-site as follows [9]:

a. Overtourism - During peak times, the Danube Delta experiences overtourism, leading to natural resource pressures and infrastructure strain. This influx causes water and soil pollution, habitat degradation, and wildlife disturbance. Insufficient tourist infrastructure exacerbates environmental deterioration. Strict regulatory measures and sustainable tourism practices are essential to protect the Delta's ecosystems.

b. Lack of sustainability - The Delta's tourist infrastructure is often underdeveloped or unsustainable, with accommodation and transportation contributing to pollution and habitat destruction if not properly managed.

c. Impact of tourist activities - Motorized boat tours and other activities cause bank erosion, water pollution, and wildlife disturbance. Unsustainable tourism practices degrade the natural environment.

d. Lack of health services - Geographical isolation and limited accessibility in the Danube Delta result in inadequate health services for both residents and visitors. Underdeveloped medical infrastructure and insufficient staffing lead to delays in emergency treatment and poor chronic health management. Investment in healthcare infrastructure and telemedicine is crucial.

e. Insufficient regulation and monitoring - Inadequate implementation and enforcement of environmental regulations allow harmful activities like illegal fishing and uncontrolled tourism, degrading habitats and biodiversity. Strengthening regulatory and monitoring efforts is vital to protect the Delta.

f. Lack of published reports from the side of local authorities regarding state-of-the-art of tourist activities in Danube Delta region

g. Lack of results-oriented projects in the field of designing proper strategies for Sustainable Tourism on regional level applied to Danube Delta region.

RESULTS

The Danube Delta, a UNESCO World Heritage site, is a unique and fragile ecosystem known for its rich biodiversity and pristine natural landscapes [1]. However, the increasing influx of tourists to this region poses significant environmental challenges. Issues related to the environmental footprint of tourism activities in the Danube Delta emerged with the increase in tourist influx to this region as to be remarked in Figure 2.

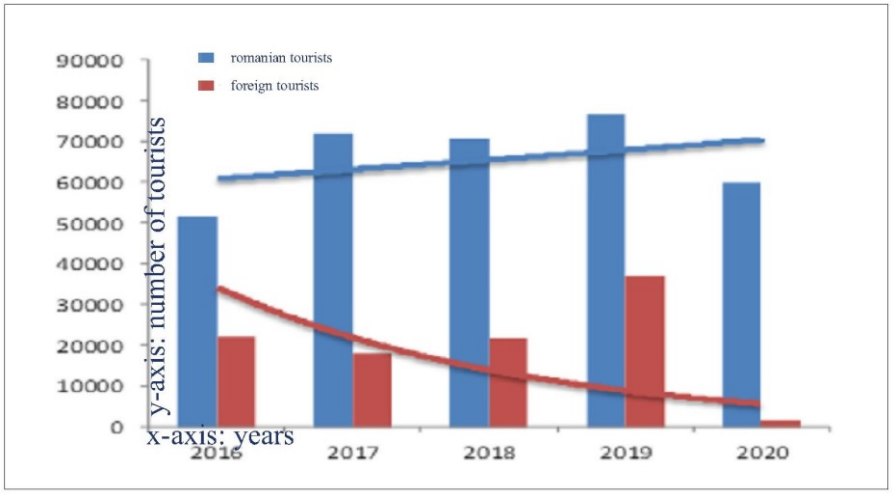


Figure 2: Comparative evolution of the number of tourists in the Danube Delta between 2016 and 2020 [1].

Understanding the environmental footprint of diverse tourism activities in the Danube Delta is crucial for sustainable development, as to be remarked in Figure 3 [1].

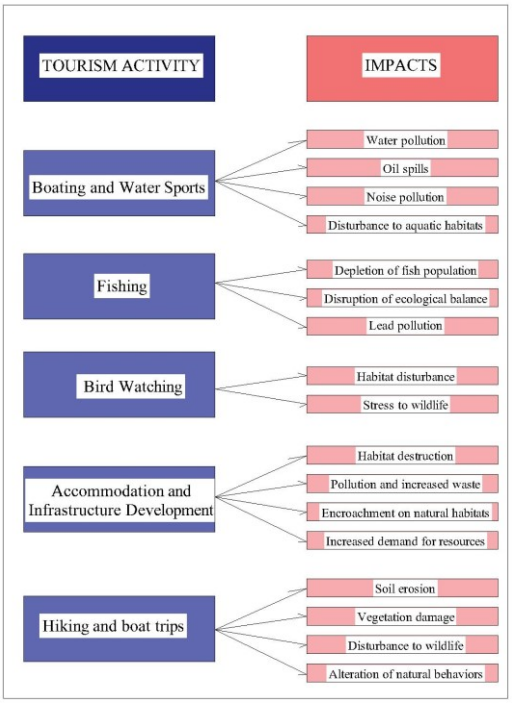


Figure 3: Tourism activities in the Danube Delta and their direct impact on the environment.

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Modeling sustainable tourism in the Danube Delta requires the implementation of well-defined strategies to ensure the protection of fragile ecosystems and the conservation of local cultural heritage [8]. One of these strategies is the development of eco-friendly tourist infrastructure, which includes the use of renewable energy, efficient waste management, and the construction of facilities that minimize environmental impact [1, 2]. Additionally, promoting educational tourism and ecotourism can raise awareness among tourists about the importance of conserving biodiversity and local culture [7, 8]. Involvement of local communities is essential; they must be active partners in the tourism development process, benefiting economically and socially from tourist activities. Training and educating locals in sustainable practices and involving them in tourist guidance can ensure harmonious tourism development that respects both the natural environment and cultural traditions [1, 8]. Furthermore, creating and implementing strict regulations and monitoring policies can prevent environmental degradation and ensure that tourism is conducted sustainably [2, 3, 9]. Thus, through a combination of green infrastructure, education, community involvement, and strict regulations, the Danube Delta can become a model of sustainable tourism as to be remarked in Figure 4 [1, 8].

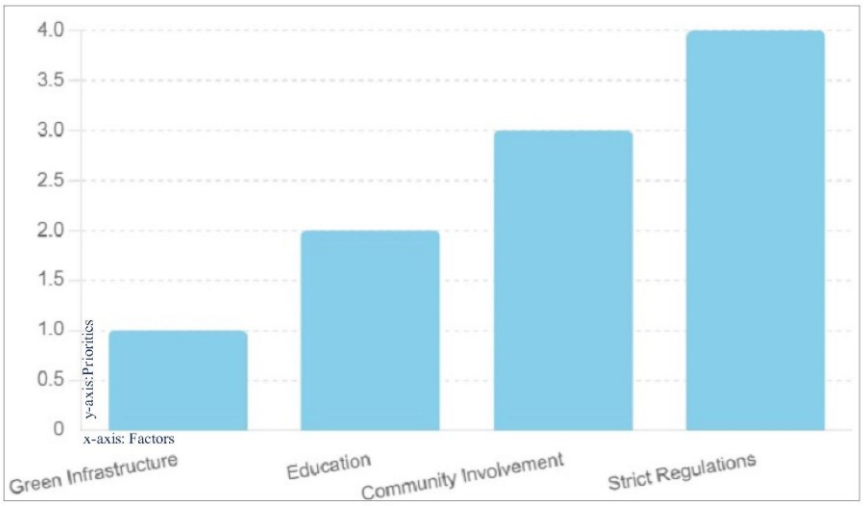


Figure 4: Key factors for sustainable tourism in the Danube Delta.

NEEDED MANAGEMENT TOOLS FOR SUSTAINABLE TOURISM

Connected to mentioned opportunities and positive aspects as well as to debated challenges and problems regarding assuring sustainable tourism activities in Danube Delta region it is of foremost importance to give emphasis to following sections as being integral parts of succeeding in shaping sustainable tourism activities in Danube Delta:

a. Legal and Regulatory Framework, meaning implementing and monitoring environmental legislation, including waste management, emission control, and species protection.

b. Strategic Planning, needing development of a tourism management plan with clear objectives, specific strategies, and performance indicators.

c. Funding Instruments, ensuring financial resources through government programs, European funds, and private sector partnerships.

d. Cooperation and Collaboration, having as direct result facilitating dialogue among authorities, NGOs, local communities, and tourism operators.

e. Monitoring and Evaluation by implementing a specific assessing system of environmental policies and strategies with a direct result in improvements of them.

DISCUSSION

Danube Delta annually attracts a considerable number of tourists interested in its unique landscapes, rich biodiversity, and opportunities for birdwatching and observing other wildlife species. This growth in tourism has generated economic benefits for local communities, providing jobs and stimulating the regional economy. Additionally, education and awareness initiatives regarding environmental conservation should promoted responsible behaviour among tourists, thereby supporting efforts to protect fragile ecosystems. To develop sustainable tourism in Danube Delta, future opportunities and challenges in this field will be explored in detail. The role of technology in contributing to more sustainable tourism should be carefully analysed in the future, including digital platforms that promote eco-friendly destinations and applications for tourists that encourage responsible travel.

CONCLUSION

Sustainable tourism offers significant economic development opportunities for regions, benefiting local communities. It attracts tourists interested in authentic and ecological experiences, stimulating economic growth and diversifying income sources. Job creation in tourism and infrastructure development can enhance residents' quality of life, reduce migration, and increase economic stability. Initial investments in eco-friendly infrastructure and community education can be substantial. Managing tourism's impact on the environment is crucial for maintaining destination attractiveness. Conflicts may arise between tourism development and resource conservation, requiring a balanced approach for success of sustainable tourism. Close collaboration between authorities, private sector, and local communities is essential to overcome challenges and maximize sustainable tourism benefits. Education and awareness are vital for promoting sustainable practices, while strict policies and regulations can protect resources. By adopting clear strategies and involving all stakeholders, sustainable tourism can drive regional development, ensuring long-term benefits for the environment and communities. Sustainable tourism development must consider the environmental footprint of activities, as demonstrated in the Danube Delta Biosphere Reserve case study in Romania, to shape sustainable tourism effectively.

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PARTICIPATION OF PUBLIC ORGANIZATIONS IN THE IMPLEMENTATION OF THE EUROPEAN GREEN DEAL IN UKRAINE

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ABSTRACT

Ukraine actively participated in the implementation of the provisions of the European Green Deal (EGD), seeking to build a "green" economy and a prosperous society. The purpose of this study is to determine the forms and directions of activities of public associations in the implementation of the provisions of the EGD in Ukraine. Influential public organizations involved in the implementation of the European Green Deal are the Center for Environmental Initiatives "Ekodiya" (Kyiv), "Ekoclub" (Rivne), "Ecology. Right. Human", Information Center "Green Dossier", Ukrainian Climate Network, etc. To implement the provisions of the EGD, public associations acted in the following directions: increasing the EU's climate ambition for 2030 and 2050; supplying clean, affordable, and secure energy; mobilizing industry for a clean and circular economy; building and renovating an energy and resource-efficient way; accelerating the shift to sustainable and smart mobility; from "Farm to Fork": designing a fair, healthy and environmentally friendly food system; preserving and restoring ecosystems and biodiversity; a zero pollution ambition for a toxic-free environment. The work uses some general scientific (logical) and special interdisciplinary research methods. Among the general scientific methods used are: analysis, synthesis, induction, and deduction. Special interdisciplinary methods used in history, political science, and sociology are presented: institutional, systemic, and content analysis methods.

Key words: public organizations, European green deal, environmental policy.

INTRODUCTION

The EGD as a framework project, which includes separate programs, is designed to ensure general and comprehensive economic growth, based on an innovative strategy for the development of the main sectors of the economy, while simultaneously reducing the volume of carbon emissions. The main efforts of experts from EU countries are focused on those sectors of the economy that have the greatest impact on climate change. Having identified European integration as a strategic direction of state development, Ukraine actively participated in the implementation of the provisions of the EGD, striving to build a "green" economy and become a full-fledged subject of the new policy.

METHODS OF RESEARCH

The purpose of this study is to determine the forms and directions of activities of public associations in the implementation of EGD provisions in Ukraine. To solve the set goal, the authors use a wide range of sources: agreements and normative legal acts within the framework of the EGD; documents of state programs; publications, booklets, information guides of public organizations; analytical studies of specialized institutions of Ukraine. The work uses some general scientific (logical) and special interdisciplinary research methods. Among the general scientific methods used are: analysis, synthesis, induction, and deduction. Special interdisciplinary methods used in history, political science, and sociology are presented: institutional, systemic, and content analysis methods. The institutional method was focused on the study of such social structures as public organizations, their purpose, and peculiarities of functioning in society and the state. The system method emphasizes the interaction of state authorities, specialized environmental protection agencies, international funds, and public associations. Content analysis was used to study statutory documents, programs, appeals, and materials of information sites of environmental organizations to obtain objective conclusions regarding the implementation of specific provisions of EGD in Ukraine.

DISCUSSION

A. Andrusevich, V. Kravchuk and Z. Kozak began to investigate the implementation of the European Green Deal in Ukraine (Andrusevych et al., 2020), Interesting are the studies of D. Palamarchuk (Palamarchuk, 2021), A. Shevchenko, M. Petrushenko and B. Burkinsky (Shevchenko et al., 2021). It should also be noted the works in which the impact of public environmental organizations on nuclear energy was analyzed [1] and to solve the problem of climate change in Ukraine [2]. On December 11, 2019, the European Commission officially announced the readiness of the document called "European Green Deal" (EGD). EGD is a proposal for a set of various measures designed to make the European Union the first climate-neutral region of the planet by 2050, which involves reducing industrial CO2 emissions to zero. For this, a "road map" of key primary measures has been developed - from radical emission reductions to capital investments in advanced research and innovations aimed at preserving the environment [3]. Taking into account the main provisions of the EGD, we will consider the activities of non-governmental public associations for their implementation in 8 areas.

Increasing the EU's climate ambition for 2030 and 2050

Ecological public organizations have developed a "Road map of climate goals until 2030", the implementation of which should reduce greenhouse gas emissions. Achieving the set goal will make a sufficient contribution to keeping the global temperature increase at the level of +1.5°C. The document describes quantitative targets for energy, buildings, transport, waste, and the general agriculture, forestry, and land use sector [4]. The Eastern Partnership, launched in 2009, became a joint initiative of the EU, its member states, and 6 Eastern European partners: Azerbaijan, Armenia, Belarus, Georgia, Moldova, and Ukraine. The partnership is aimed at strengthening and deepening political and economic relations between the EU and the countries of the region and, among other things, supports the achievement of global policy goals set by the Paris Agreement on climate change, the UN Agenda for Sustainable Development until 2030. Expert working groups and thematic panels also function within the framework of the Eastern Partnership. Thus, Working Group No. 3 "Environment, Climate Change and Energy Security" of the

Ukrainian National Platform of the Eastern Partnership Civil Society Forum developed an analytical document "Environmental and climate sustainability of the Eastern Partnership - assessment of prospects for achievement in Ukraine" [5]. In 2020, the Ukrainian climate network, consisting of public organizations: "Ekoclub", "Ekoltava", "Ekosense", "Ekodiya", "Voice of Nature", "Our Home – Manyava" and "Ukrainian Youth Climate Association", conducted an all-Ukrainian sociological survey "Climate change and climate adaptation". The survey was conducted online throughout the country, including the Autonomous Republic of Crimea, Luhansk, and Donetsk regions. The offline survey was conducted by members of the Ukrainian Climate Network in Kyiv, Poltavska, Zaporizhzhska, Dnipropetrovska, Ivano-Frankivska, and Rivnenska oblast. 3,765 respondents from all over Ukraine took part in the survey [6].

In March 2021, the Ukrainian Climate Network (UCN) supported the global climate strike. Among the requirements submitted to the Cabinet of Ministers: to approve a nationally determined contribution to reducing greenhouse gas emissions by 2030 to the level of 72% from 1990; adopt carbon neutrality by 2050; implement climate education in Ukraine [7, 16]. As part of the implementation of the project "Climate goals 2030 for Zaporizhzhia", the non-governmental organization "Ekosens" prepared an educational and information brochure "Vulnerability to climate change and climate goals of Zaporizhzhia and the region" [8, 22]. Experts from the Public Organization "National Ecological Center of Ukraine" (NECU) took part in the work of the Forum "Increasing climate ambitions: the position of local self-government bodies and youth". The forum was held on February 27, 2020. in the conference hall of the Verkhovna Rada of Ukraine. The first part of the event was organized in the format of a round table with the participation of political, expert, and youth leaders who are concerned with the issues of climate change and mitigating its consequences. Experts and activists have set the goal of making Ukraine carbon-neutral by 2050 [9, 32-33].

Supplying clean, affordable and secure energy

The influence of the fuel and energy complex of Ukraine on the state of the environment is significant. The general level of emissions from power plants in Ukraine is 5-30 times higher than EU standards. In 2020 as part of the project "Supporting the activities of the Ukrainian national platform of the Civil Society Forum of the Eastern Partnership", the "National Environmental Center of Ukraine" public organization implemented the project "Development of renewable energy and creation of balancing capacities – analysis of challenges for the sustainability of the energy system of Ukraine in terms of achieving energy and climate goals". The analysis showed that currently the energy system of Ukraine is overloaded with the basic capacity of nuclear power plants and needs to increase the share of highly maneuverable generation, which is necessary for the development of renewable energy, in particular – solar and wind power plants, which have a variable, non-guaranteed schedule of electricity production [9, 21-23]. The joint work of the "Ecoclub" with territorial communities on the development of local energy and climate initiatives has become promising. This combination became possible primarily thanks to the European program for climate and energy conservation – "The Covenant of Mayors", to which 303 settlements in Ukraine joined. Project participants undertook to take measures to achieve the goal of reducing greenhouse gas emissions by at least 30% by 2050. To fulfill the goals of the "The Covenant of Mayors", the Sustainable Energy and Climate Action Plan (SECAP) was developed – a document that describes in detail the steps that the community must take to save energy and reduce

emissions [10, 17-18]. During September 21-25, 2021, the "Ecoclub" team was in Berlin, where they met with the partner organizations "Energy Partnership of Ukraine and Germany" (DENA), Wechange, DRA, the Representation of the Foundation named after By Heinrich Böll, GermanWatch. During the meetings, they discussed: the working conditions of private solar stations in Ukraine; the development of hydrogen energy based on RES; the development of energy cooperatives in Germany and Ukraine; the need of information campaigns in the field of RES; the impact of land reform on the cultivation of energy crops, etc. [10, 31]. In September 2021, 10 Ukrainian Climate Network organizations took part in the All-Ukrainian climate mobilization: "Ekodiya" in Kyiv, "Ekoclub" in Berlin, PLATO in Lviv etc. Ukraine should develop renewable energy sources and abandon dirty coal and gas, modernize industry, and increase energy efficiency in the housing sector - climate actions in various regions of Ukraine were held with these slogans [7, 16].

Mobilising industry for a clean and circular economy

Achieving a climate-neutral, closed-loop economy requires full mobilization of industry. It takes 25 years – a whole generation – to transform an industrial sector. By 2050, decisions and actions must be taken in the next five years. About half of all greenhouse gas emissions and more than 90% of biodiversity loss and water scarcity are related to the extraction of resources and the processing of materials, fuels, and food. EU industry has begun to shift, but, as before, its share accounts for 20% of greenhouse gas emissions. The process remains too "linear" and depends on the number of new materials that are extracted, sold, and processed into goods and finally disposed of as waste or emissions. Only 12% of the materials used are obtained from secondary raw materials [3]. The GEIPP Ukraine project is part of the Global Eco-Industrial Parks Program implemented by the United Nations Industrial Development Organization (UNIDO) in seven countries with the financial support of Switzerland through the Swiss State Secretariat for Economic Affairs (SECO). The project started in 2020 and will be implemented by the end of 2023. The main beneficiary is the Ministry of Economy of Ukraine. The project aims to demonstrate the practicality and advantages of eco-industrial park approaches in increasing resource efficiency and improving the economic, environmental, and social indicators of the involved enterprises, which, in turn, will contribute to the inclusive and sustainable industrial development of Ukraine [9, 33].

Building and renovating in an energy and resource efficient way

Construction, operation, and repair of buildings require significant amounts of energy and mineral resources (eg, sand, gravel, cement). Buildings also account for 40% of energy consumption. Today, the annual rate of restoration of the building stock ranges from 0.4 to 1.2% in EU member states. This figure will need to be at least doubled to meet the EU's energy efficiency and climate goals. NGO "Ekodiya" has prepared a vision of what strategic priorities are key and should be integrated into the Roadmap for Ukraine's participation in the EDG. The proposed Vision and recommendations are not exhaustive and focus only on those areas in which the organization has the expertise and conducts systematic work [31]. Activists of the public organization "Ekoltava" translated the English-language publication about the construction of energy-passive houses "Earthship" from natural materials [11, 5-6].

Accelerating the shift to sustainable and smart mobility

Ukraine has a developed infrastructure of rail, road, water, and air transport. But today, the level of safety, indicators of the quality and efficiency of passenger and cargo transportation, energy efficiency, and the dynamics of technogenic load on the environment do not meet modern requirements. In December 2020, the EU Sustainable and Smart Mobility Strategy were published. One of the goals of the Strategy, which is part of the European Green Deal package, is to reduce greenhouse gas emissions in the Transport sector. The Mobility Strategy and Action Plan for it are designed for 4 years (starting from 2021) and contain 82 initiatives to transform the EU transport system into a smart, competitive, safe, inclusive, and accessible one. NGO "Ekodiya" has prepared the publication "Together for sustainable mobility!", which examines the goals and points of the EU Sustainable and Smart Mobility Strategy and provides examples of how it can be applied in Ukraine at the local and national levels for employees of cities, regions, and communities [7, 25]. Despite differences in the declared goals of the EU and Ukraine, the key priorities of the Mobility Strategy fully correspond to the goals and objectives of Ukraine in cooperation with the EU. Among the common priorities are reorientation towards high-speed rail transport, multimodal transport, digitization of the transport sector, and load shifting from road freight transport to rail and water transport. The Strategy also provides for the completion of the Trans-European Transport Network (TEN-T), which is possible with the inclusion of Ukrainian roads and inland waterways. According to the 2030 Roadmap for Climate Goals developed by non-governmental organizations, the main trends in the transport sector should be to phase out fossil fuels and reduce the use of motor vehicles in favor of public transport, micro-mobility and rail [4, 51]. At least 50% of transport costs from local budgets should go to public transport and at least 5% to micro-mobility. In 2030, the share of motor vehicle use should decrease to 10%, and the shares of micro-mobility and public transport should increase from today's level. It is necessary to strive to convert all public transport to electricity and increase the number of passenger trips by railway, including the city railway. At least 70% of railway tracks should be electrified, more freight should be transported by rail and water transport as opposed to road [2, 277-285]. Kyiv Cyclists' Association (AVK) U-Cycle held the Veloforum-2021 international conference in Uzhhorod and hubs in Odesa, Berdyansk, and Kramatorsk. A map of the cycling routes of Ukraine has been created. The study "Overview of foreign national cycling strategies" was conducted. Urban school "Streets for People" was organized [7, 26].

From ‘Farm to Fork’: designing a fair, healthy and environmentally-friendly food system.

As part of the implementation of the EGD, the European Commission published the strategy "From farm to fork". The strategy is aimed at reducing the impact of the EU food system on the environment and climate and increasing its sustainability, ensuring food security against climate change and biodiversity loss, as well as ensuring a global transition to competitive sustainability. To determine what the Ukrainian path of agricultural sector transformation should be, the specialists of the "Green Dossier" information center monitored and analyzed the documents and legal acts being developed in the EU for the implementation of the EDG, researched experience, and collected interesting examples from around the world, adapted and clarified this information to the Ukrainian consumer in numerous publications and thematic digests. They also took part in various international events, in writing analytical and positional documents, and held

discussion platforms on the most resonant topics. All this became the basis for the development of the road map "Ukrainian green road from farm to fork: step by step", which consists of two parts - about the possibilities of sustainable agricultural production and about the need to change the usual patterns of consumption [12].

Preserving and restoring ecosystems and biodiversity

Biodiversity is the national wealth of Ukraine, the preservation and tireless use of which is recognized as one of the priorities of state policy in the field of nature management, ecological safety, and environmental protection, an integral condition for improving its condition and ecologically balanced socio-economic development. In May 2020, the European Commission presented the "EU Biodiversity Strategy to 2030: Bringing nature back into our lives". Global climate change, which became one of the main reasons for the development of such an ambitious environmental protection document of the EU, concerns not only Western countries. The impact of global warming on the environment and economy is felt much more by less developed countries and especially agrarian states. In Europe, Ukraine is the leader among such states. NECU, in cooperation with state authorities, actively protects areas with living nature, primarily with unique populations of plants and animals, conducts preparatory work for the creation of new objects of the nature reserve fund, and also monitors compliance with environmental legislation in protected areas [9, 12-14]. Specialists of the organization "Ecology. Right. Human" prepared the manual "Nature Reserve Fund: Green Treasury of the Community" dedicated to the powers of united territorial communities and local self-government bodies regarding management in the field of land use and protection. The guide reveals the aspects of achieving sustainable ecosystems and improving the quality of community living through the proper organization of the protection of particularly valuable nature conservation areas [8, 26]. Forests are ecosystems that are crucial for life on Earth. The stability of the planet's climate and the circulation of clean fresh water depend on them. 8 out of 10 terrestrial species of plants and animals find shelter in forests. In Ukraine, forests occupy only 16% of the country's area, primarily in Polissia and the Carpathians. Because of this, the strategic areas of work for the Public Union "World Wide Fund for Nature-Ukraine" (WWF Ukraine) are the protection of the most valuable forests of natural origin, in particular, primeval forests; implementation of sustainable forestry practices; preventing illegal logging and promoting the creation of a new forest policy of Ukraine [13].

A zero pollution ambition for a toxic-free environment

Creating a non-toxic environment requires additional actions to prevent pollution, as well as measures to clean up and eliminate it. To protect the citizens and ecosystems of Europe, EU countries are trying to better monitor, report, prevent and eliminate pollution of air, water, soil and consumer goods. "The All-Ukrainian Environmental League" (VEL) took part in the round table "Waste minimization in the food system", which was held by the subcommittee on household waste management of the Committee of the Verkhovna Rada of Ukraine on energy and housing and communal services on February 17, 2020 [14]. The Zero Waste Lviv organization held Zero Waste Fest 2021 in Lviv – the most powerful zero waste festival in Ukraine. The key topic of discussions and activities was the rejection of plastic bags. We created a selection of materials for the "Choose reusable" campaign [15].

RESULTS

EGD envisages eight main areas of qualitative modernization of the economy, which contributes to the implementation of the climate agenda: increasing the EU's climate ambition for 2030 and 2050; supplying clean, affordable and secure energy; mobilising industry for a clean and circular economy; building and renovating in an energy and resource efficient way; accelerating the shift to sustainable and smart mobility; from «Farm to Fork»: designing a fair, healthy and environmentally-friendly food system; preserving and restoring ecosystems and biodiversity; a zero pollution ambition for a toxic-free environment. In January 2020, the government of Ukraine declared EGD a priority area of development, striving to become an equal subject of the new policy. During the year, a position document was developed and presented to the partners in the European Commission - the vision and proposals of Ukraine regarding the joint implementation of EGD. An interdepartmental working group on coordination of overcoming the consequences of climate change has been created within the framework of the European Commission's "European Green Course" initiative, which is coordinated by the Deputy Prime Minister for European and Euro-Atlantic Integration Olga Stefanishyna. However, experience shows that modern global projects, to which EGD certainly belongs, cannot be directly implemented by state authorities and environmental protection agencies. It is necessary to involve wide circles of society, which are structured in various public organizations.

CONCLUSION

Therefore, the implementation of EGD in Ukraine has broad prospects for the effective operation of structural sectors of the economy, namely industry, energy, transport, construction, and agriculture. Implementation of EGD in Ukraine is carried out not only by state bodies and relevant ministries but also by public organizations, which act as a connecting link between the government and society and at the same time provide an opportunity for citizens to implement the necessary projects. These structures actively interact at all levels: international, national, regional, and local. Important achievements of public associations include: holding international and all-Ukrainian conferences; implementation of educational campaigns through mass media, distribution of training manuals and information booklets; implementation of sociological research; development of normative and legal documents; organization of mass street actions; participation in international grant projects with the specified problems. The active and multidisciplinary activity of public organizations in implementing the provisions of the EGD will contribute to the gradual construction of a climate-neutral economy in Ukraine and integration into the European ecological and economic space.

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PHILOSOPHICAL ASPECT OF CLIMATE CHANGE IN THE SAKHA REPUBLIC (YAKUTIA)

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ABSTRACT

Climate change has an increasingly significant impact on the lives of people around the world. In this context, of particular interest is the study of the philosophical aspect of climate change in the Sakha Republic (Yakutia). The study is based on a philosophical analysis of climate change, as well as a generalization of the opinions on environmental issues. The main method is a logical-analytical approach to revealing the philosophical context of climate change in the context of Yakutia. A philosophical view of climate change in Yakutia emphasizes not only technical aspects of the changes, but also draws attention to the importance of socio-ecological aspects of this problem. Philosophical analysis allows us to consider the issue of climate change as a socio-ecological phenomenon that requires an integrated approach including ecological consciousness, deep understanding and adoption of appropriate social decisions as climate change causes changes in the mentality and culture of the local population. Rising temperatures, drought, flood, forest fires and other climate changes create new challenges for society and require comprehension at a philosophical level. The philosophical aspect of climate change in Yakutia provides an in-depth analysis of the problem that allows us to consider climate change as a complex socio-ecological phenomenon that requires an integrated approach that includes eco-philosophical aspects. It emphasizes the need to integrate climate aspects into social consciousness of the local population of the region and make it eco-philosophical one.

Keywords: climate change, Sakha Republic (Yakutia), eco-philosophy, socio-ecological phenomenon, environment

INTRODUCTION

Among the problems of a universal human scale, global environmental problems, including the problem of global climate change, occupy an important place. The solution of these problems determines the further prospects for the development of civilization. The socio-ecological choice that humanity has to make, from the very beginning revealed its systemic, interdisciplinary and activity-oriented nature. There is a search for an optimal alternative in the relationship between society and nature that will help overcome the environmental crisis.

Global climate is a complex characteristic of the biosphere; its changes reflect the state of interaction between society and nature. A manifestation of the contradictions between humanity and nature, the ever-increasing gap between ethical tasks and real human

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behavior is the global environmental crisis. A special case of it is anthropogenic climate change.

This problem has important socio-philosophical aspects, and the results of the analysis of them will allow us to consider climate change systematically, implementing an interdisciplinary approach that is called an eco-philosophical approach. This approach should be implemented on the basis of a worldview that would reflect, first of all, universal human values, the ability to rise above egoistic interests in the name of overcoming common hazards.

Indeed, despite the extreme importance and complexity of the relationship between man and nature, an attempt at a truly holistic study of them is being made only now within the framework of such a direction of philosophical knowledge as eco-philosophy.

MATERIALS AND METHODS

The theoretical basis for considering the climate problem is the concept of the formation of the noosphere, that considers it as a manifestation of material, energy and information contradictions in the "man - society - nature" system, and also contains the noospheric paradigm of the transition of civilization from eco-catastrophe to sustainable development.

The methodological basis of this study is a systematic approach. A special place in the work also occupy general scientific methods of scientific knowledge.

The study is based on a philosophical analysis of climate change, as well as generalization of the researchers' opinions involved in environmental issues, and issues of global climate and socio-development. The main method is a logical-analytical approach to revealing the philosophical context of climate change in the context of Yakutia. All these made it possible to approach the problem under consideration in interconnection, feasibility and comprehensiveness.

RESULTS

Since the second half of the twentieth century, numerous international and domestic observations have recorded changes in climate, that together confirm the paradigm of global climate change [1, 2, 3, 4, 5]. Domestic observations show that the average annual temperature across whole the country is growing more than 2.5 times faster than the global temperature, at a rate of 0.45°C per 10 years, and especially rapidly in the polar region, where the growth rate reaches 0.8°C per 10 years. The results of annual studies by Roshydromet on climate features showed that 2021 was one of the warmest year since 1936; the average annual air temperature anomaly averaged over the territory of whole the country was +1.69°C.

Climate change occurs not only on a global scale, but also, above all, at the regional level. The Sakha Republic (Yakutia) belongs to the regions where climate change occurs noticeably faster than the average on the planet. According to research of the Institute of Permafrost Studies, the average temperature of urban areas in Yakutsk has changed since 1960 from -8°C to -4°C in 2007. According to the map of linear trends in changes in average annual soil temperature, the temperature of permafrost in the Yakutsk region increases by an average of 0.03°C per year. The degradation of permafrost threatens changes in topography, destruction of buildings and damage to

roads. In 2016, a team of scientists from George Washington University from the USA made a forecast of changes in the load-bearing capacity of a pile foundation by 2050. According to their forecast, the critical point in the Yakutsk region will be reached by 2040 [5].

Climate change in Yakutia provokes rising temperatures in summer and winter, drought and forest fires in summer time. During 3 summer periods, from 2021 to 2023, there was nearly no rain in the central territory of Yakutia. The average temperature here reached 36 degrees above zero in July during this period.

For instance, in the central part of the republic, June 2021 became the hottest and the second most deficient in precipitation in 150 years of observation. During the month, with temperatures reaching plus 35-40 degrees, less than 2 mm of precipitation fell, with the norm being 37 mm.

Due to dry and hot weather, forest fires rage since the beginning of June. Yakutia is one of the most fire-prone regions of the country. The total forest area in the region is 256.1 million hectares (83.4% of the territory of the Republic).

In 2021, the most catastrophic fire period, there were more than 1000 fires in the Republic; in total, 9.3 million hectares (including the burned area) were damaged by fire, most part of which were forests.

Due to dense smoke and reduced visibility, transport links in the Republic were disrupted: the Yakutsk airport stopped operating, and ferry traffic on the Lena River was stopped. Rospotrebnadzor took air measurements and found out that in Yakutsk, due to fires, the maximum permissible concentration (MPC) of pollutants was over-exceeded. Work to extinguish fires was complicated by high temperatures and windy weather.

Experts say the region is warming faster than almost any other part of the world. Forest fires in Yakutia could threaten to accelerate global warming by releasing large amounts of gases that cause the greenhouse effect. Forest fires in Yakutia are largely provoked by record high air temperatures for summer in this northern part. For instance, a temperature of 38°C in the Yakut town of Verkhoyansk on 20 June 2020 was recognized as a new Arctic temperature record by the World Meteorological Organization [6].

According to Mark Parrington, a leading specialist at the atmospheric observation service at the European Center for Medium-Range Weather Forecasts, in 2020 the amount of carbon dioxide released due to fires in Yakutia was approximately the same as from fuel consumption in Mexico for the entire 2018 [7]. Continuation of such a trend could accelerate climate change through the release of huge amounts of greenhouse gases. The consequences of the fires could be felt far beyond the borders of Yakutia.

Rising temperatures, drought, flood, forest fires and other climate changes create new challenges for society and require comprehension at a philosophical level. A philosophical aspect of climate change in Yakutia should emphasize not only technical aspects of the changes, but also draw attention to the importance of socio-ecological aspects of this problem. Philosophical analysis allows us to consider the issue of climate change as a socio-ecological phenomenon that requires an integrated approach that includes ecological consciousness, deep understanding and adoption of appropriate social decisions as climate change causes changes in the mentality and culture of the

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local population. It emphasizes the need to integrate climate aspects into the social consciousness of the local population of the region and make it eco-philosophical one.

DISCUSSION

The problem of man's relationship to nature, the ethical aspects of his relationship with the outside world, the attempt to create a harmonious society living in unity with the environment has worried and continues to worry humanity throughout its existence. Thus, this issue can be traced in the works of such famous thinkers such as Pythagoras, Heraclitus, Seneca, Augustine, Kant and many others.

It is reflected not only in philosophical and scientific works, but also in political and religious concepts, ideological and economic doctrines.

At present, philosophy can and should help solve the current problem. After all, over the centuries it has formed and is forming a new human consciousness that must destroy the previous attitudes of society and overcome the contradictions between man and nature.

Despite the extreme complexity of the relationship between man and nature, an attempt to study them holistically is currently being undertaken within the framework of such a direction of philosophical knowledge as eco-philosophy.

Ecological philosophy has appeared quite recently, in the 20th century, and is closely related to the so-called deep ecology developed by the philosophers A. Næss [8] and the F. Guattari [9]. By ecosophy A. Næss [8] meant the philosophy of ecological harmony or balance. Like any “sophia”, it contains norms, rules, postulates, priorities and hypotheses regarding co-state of affairs in the Universe. The areas of interest of ecosophy, according to him, are variable and include not only facts of pollution, resources, population, but also value priorities. F.Guattari [9] developed his approach to understanding eco-philosophy based on three main parts: environmental ecology, social ecology and mental ecology associated with psychology. He correlated the ecology of the environment with the “social ecology of the mind.” Based on his ideas, without certain changes in the social and material sphere of human society, fundamental changes in people's consciousness are impossible.

Currently, eco-philosophy can be defined as a field of philosophical knowledge that explores the philosophical problems of interaction between living organisms and systems, between themselves and their environment. Following philosophy, eco-philosophy as the main subject of its research highlights the interaction between man and the environment. So, starting from the defining ecology as a science about the interaction of living organisms and their communities between themselves and the environment, we can note the similarities between the subjects of study of philosophy and ecology, at the junction between which lies the problematic field of eco-philosophy.

Thus, eco-philosophy includes both philosophical and environmental issues in the form of identifying aspects or phenomena of interaction of complex systems. Ecological philosophy comes from the biosocial nature of man himself. All components of it should not oppose each other, but interact with each other, forming one system.

Based on this approach, the interpretation of natural and animal as something negative becomes less pronounced and comes understanding the need for interaction between these two systems.

As a result, eco-philosophy is aimed at identifying general patterns of interaction between living organisms, including humans, among themselves, and at the study of formation of complex socio-natural systems, their development and functioning.

Thus, eco-philosophy acquires a clearly defined focus on finding ways to overcome the ongoing crisis in the interaction between society and nature through co-evolutionary approach, that is, the joint evolution of nature and human society.

It is necessary to note the applied significance of formation of a new environmental worldview, since a worldview is what a person bases his actions on, forms his way of life and in this aspect the worldview also has practical character. For society as a whole, this applied nature of eco-philosophy is gradually realized through the eco-philosophical paradigm.

In modern society, environmental problems are of particular importance, and this is connected not only, or rather, not so much with environmental pollution, but to a greater extent with the crisis of modern civilization, the crisis of spirituality, morality, and modern culture as a whole. Most countries live according to the logic of a consumer capitalist society. The cornerstone of such society is the prevalence of economic gain and the cult of the sphere of consumption. Transnational corporations, through the media, are growing new consumers for themselves, regardless of the increasing risks.

In fact, new times were marked by technological determinism that ensured the preservation of the dominance of utilitarian consumer environmental consciousness. But, when a real threat looms over humanity in the form of global environmental problems, the world community again is turning to the philosophical problems of the relationship between nature and society (including the problem of ecological consciousness).The idea of reorienting ecological consciousness from utilitarian-consumer goals to noospheric ones is emerging.

According to it a man should be considered in unity with nature, since he is part of it. The ideas about the noosphere, as well as the co-evolutionary theory, play a major role in the development of the theory of ecological consciousness [10; 11]. In the environmental ethics, the noosphere is considered as a product of the co-evolution of nature and society.

It is worth noting the ideas of the Club of Rome. From the point of view of this Club the integrity of new morality is given by a person himself, by culture of a society and by values of culture. Nature, man, society, and technics are considered as the center of ethical ideas, and nature is understood as the main basis of existence.

From this perspective, the fiftieth anniversary report of the Club of Rome, dedicated to the issue of a radical change in the existing paradigm of the development of civilization, seems extremely interesting [12]. The changes proposed and described directly in the report itself concern all aspects of the functioning of human society.

Existing problems can be traced both in the political (the rise of authoritarian and fundamentalist sentiments), social (demographic problems) and economic spheres (the crisis of capitalism, the dominance of financial speculation), environmental sphere (the destruction of the planet as a whole) and, most importantly, in the philosophical sphere and worldview (primitive materialism and simplified perception of the world).

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Actually, the second part of the report is devoted to ideological issues. The rejection of a simplified, fragmented perception of the world, reductionism and anthropocentrism in favor of a holistic, syncretic perception of reality is reflected within the framework of the philosophical concept of the "New Enlightenment". A society professing it, from the point of view of the authors of the report, would be open to development, but would value stability and care about its future. The central categories of the "New Enlightenment" will be such concepts as "synergy", "interaction", "compromise", and "balance" [12].

Thus, achieving balance is necessary in the following areas of human functioning: in the relationship between man and nature (ecological self-awareness); between short-term and long-term perspective; between individualism and collectivism, between development and stability, between equality and fair social reward, etc. Thus, the worldview concept of the "New Enlightenment" can become the very answer, a way out of the current crisis situation, the solution of which is seen exclusively within the framework of a philosophical approach.

Let us emphasize once again that the uniqueness of the philosophical approach lies in its focus on the formation of a holistic and complex worldview, a worldview that will make it possible to coordinate the vector of development of individuals, regions (such as the Sakha Republic (Yakutia)), countries, and humanity as a whole. At the same time, many aspects of the problems discussed in the article can converge in a new direction of philosophy – ecological philosophy.

CONCLUSION

One of the most pressing problems of the modern world is the problem of building harmonious relationships within the "man-society-nature" system, capable of preventing a whole range of serious anthropo-, socio- and bio-oriented consequences. Undoubtedly, solving the environmental problem can be considered as an imperative for the survival of humanity. All other, primarily global, problems of our time are directly dependent on the stability and sustainability of it.

As a result, in the current situation, the role of such fundamental, ideologically significant areas of knowledge as ecology and philosophy is increasing, as well as the special interdisciplinary field emerging at the intersection of these disciplines and their joint interests - environmental philosophy or eco-philosophy. Such environmental philosophy allows us to correctly pose environmental problems, understand them more deeply and comprehensively, and develop the best environmental strategy.

Eco-philosophy sets the task of changing not only society, but also implementing environmental education. It's about formation of new morality, of environmental consciousness as a set of opinions, knowledge and beliefs that form the "society - nature" system. At the present stage, philosophy can help solve environmental problems in the Sakha Republic (Yakutia) in various directions, since it forces the formation of a new social consciousness focused on the need to overcome environmental contradictions associated with the cultural structures of the past and the one-sidedness of man's practical interests in his relationship to nature.

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POLLUTION ASSESSMENT OF THE RIVERS FLOWING THROUGH LARGE BULGARIAN CITIES. A COMPARATIVE STUDY

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ABSTRACT

This research compares the water quality in four river bodies passing through different cities in Bulgaria. An eco-chemical approach was applied including physicochemical and analytical measurements, as well as calculation of different pollution indices and the distribution of the element species as an indicator of their bioavailability. The results from analytical measurements and calculated pollution indices show that all the studied water bodies were polluted regarding P-PO_4^{3-}, N-NH_4^+, Mn, and Pb. The highest values were measured in the Struma River, which is the result of both natural origin, due to the presence of coal mines, and the unsustainable management of mining and metallurgy activities in the past. The second most polluted is the Iskar River near Sofia city, mainly a consequence of the increased population in recent years. Thermodynamically calculated species of trace metals show that free Mn^{2+} ions dominate in all rivers being highest in Struma river. They are dangerous for aquatic fauna as free metal ions easily interact with ligands of organic compounds found in the bloodstream and/or within organs. Free ions are also calculated for Zn, but it is less dangerous because its content is significantly less. It was found only at single stations in the Maritsa and Danube rivers. Cu and Pb are potentially the riskiest elements for plants as their dominant organometallic species are easily accumulated by them. Regarding Al, its dominant hydroxy species are a prerequisite for the precipitation of $Al(OH)_3$ and the self-purification of waters.

Keywords: Bulgarian Rivers, Pollution indices, Thermodynamic modeling, Chemical species

INTRODUCTION

Growing urbanization and population density are causing environmental problems related to both increased disposals of construction and household waste and insufficient capacity of sewage systems and treatment plants. All this leads to a decrease in the quality of the urban ecosystem, a sensitive part of which is the rivers flowing through the cities.

The dominant literature data concerning studies on river systems are primarily related to monitoring analysis of their physicochemical and chemical indicators, use of several coefficients for risk assessment and statistical models to clarify the influence of various factors on the ecological status of the studied objects [1-8]. Monitoring studies of rivers in Bulgaria are regularly conducted by the Ministry of Environment and Water and the Executive Environment Agency. The annual reports for the period 1997-2021 show a

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tendency to improve water quality, but there is still a significant number of risky water bodies, such as the rivers Iskar, Topolnitsa, Luda Yana, Tundzha, Maritsa, etc. [5]. Analogously to world practices, scientific researches published by Bulgarian scientists are related to water monitoring studies and assessment using statistical models and pollution coefficients [6-8].

In our previous work, we demonstrated a complex approach for assessment of the water-soil-plant ecosystem, including the analysis of the chemical composition of water and aqueous soil extracts and the application of various thermodynamic mathematical methods for the evaluation of chemical species in them. Based on this approach we established a relationship between the chemical species of trace metals and their bioaccumulation from the uncultivated vegetation [9,10].

This research aims to compare the water quality of rivers passing through different cities in Bulgaria. An eco-chemical approach was applied. It includes physicochemical and analytical measurements (in the period 2020-2021), calculation of different pollution indices, and thermodynamic modeling of chemical species of the elements as an indicator of their bioavailability. Parts of four rivers were studied, namely, the Iskar River passing through Sofia city (1282253 residents), the Struma River passing through Pernik city (70285 residents), the Maritsa River passing through Plovdiv city (346893 residents), and the Bulgarian part of the Danube River passing through Silistra city (40498 residents). The threshold pollution indices of $P\text{-}PO_4$, $N\text{-}NO_3$, $N\text{-}NO_2$, $N\text{-}NH_4$, Al, Mn, Cu, Zn and Pb were calculated and evaluated. Ion-interaction and Stockholm Humic models were applied for thermodynamic calculations of inorganic and organic chemical species.

MATERIALS AND METHODS

Sampling and preservation

The study areas with sampling stations are shown in Fig. 1.

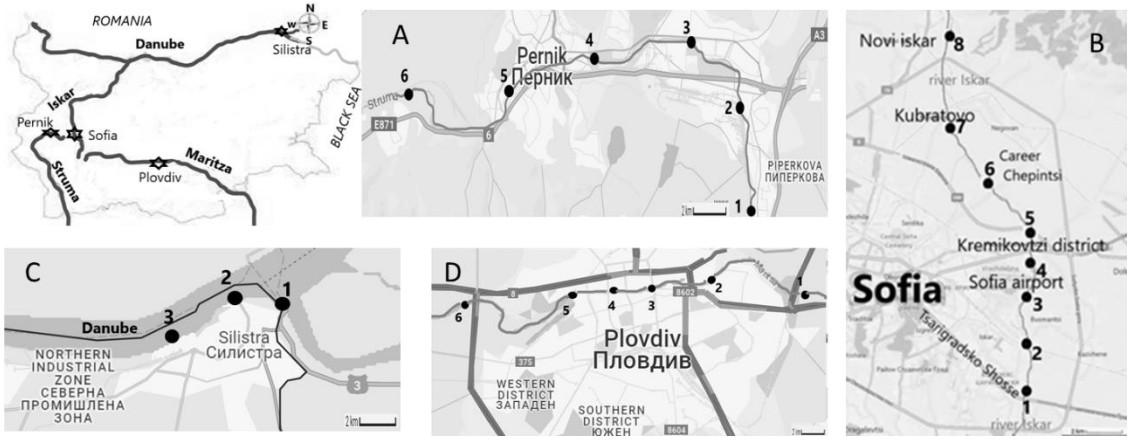


Fig. 1 Study areas with sampling stations. A – Pernik city; B – Sofia city; C – Silistra city and D – Plovdiv city.

Water samples (approximate volume of 1.5 L) were collected from the upper surface layer (0 - 20 cm) of the water basins. Each sample consisted of 3 sub-samples collected at a distance of 3 - 5 m from each other. They were filtered through 0.45 μm Millipore (Millipore, Bedford, MA, USA) membrane filters. Filtrates for dissolved organic carbon (DOC) determination were preserved frozen in glass containers until analysis. Filtrates

for ICP-OES (inductively coupled plasma optical emission spectrometry) analysis were acidified with 65 % HNO_3 p.a. (Merck, Darmstadt, Germany) to pH < 2.0 and were stored in polyethylene bottles at 4°C.

Measurements and chemical analysis

Physicochemical characteristics (temperature, pH and dissolved oxygen) of the water samples were measured *in situ* by a portable Multi 340i-WTW equipment (WTW, Weilheim, Germany) using a series of calibrated temperature–compensated electrodes.

Alkalinity and nutrients (PO_4^{3-}, NO_2^-, NO_3^- and NH_4^+) were determined *in situ*, while Cl^- and SO_4^{2-} ions and dissolved organic carbon (DOC), *ex situ*, all of them spectrophotometrically (portable NOVA, Merck, NJ, USA).

Major elements (K, Ca, Mg) and potentially toxic metals (Al, Fe, Mn, Co, Ni, Cu, Zn, and Pb) were determined by ICP-OES (PRODIGY 7, Teledyne Leeman Labs, USA). Certified Reference Material (Multielement standard solution V for ICP), SIGMA-ALDRICH, Lot: BCCB7069 was used for quality assurance purposes.

The CO_3^{2-} content was calculated from the alkalinity value and the concentration of Na - by ion equivalent balance.

Coefficient for pollution assessment

To assess the pollution, the single threshold indices of pollution of an individual element (C_f) were calculated according to the formula $C_f = C/C_{MAC}$, where C is the total concentration of the component and C_{MAC} is the maximum allowed concentration (MAC). The integrated threshold pollution indices $P_w = \sum C_{fn}/n$ (n - the number of components) were calculated as well [11].

Thermodynamic modeling of chemical species

The distribution of dissolved chemical species in water bodies was calculated using the Visual Minteq computer program, Version 3.1 [12]. The classical ion-association model [13] was applied for calculating the inorganic chemical species and the Stockholm Humic Model (SHM) [12] accounting for the complexation reactions of potentially toxic metals with organic matter. The ion-association model is based on the extended Debye-Hückel theory and applies to solutions with ionic strength below 0.1. The Stockholm Humic Model is a discrete ligand model, assuming that natural organic substances, presented in the natural solution, have a variety of functional groups able to bind metal cations. All required parameters for both models are included in the program databases.

Experimental data for the total concentrations of major and potentially toxic metals, nutrients, DOC and pH were used as input data. In case the analytical results of a given element were below its detection limit, the latter was used for the modeling. The following assumptions were made to calculate the species concentrations and their ratios: (1) in the ion-association model a thermodynamic equilibrium was assumed only for complex formation processes; (2) in the Stockholm Humic Model, DOC was only assigned to fulvic acids which are soluble in water; (3) Mn^{6+} and Mn^{7+} ions were not considered in the calculations, since they are not stable in natural waters [14]; (4) redox processes were evaluated with the inclusion of all redox pairs that may exist in the systems studied, namely O^0/O^{2-}, N^{3+}/N^{5+}, N^{3-}/N^{5+}, Mn^{2+}/Mn^{3+}, Cu^+/Cu^{2+}. The results showed domination of the O^0/O^{2-} couple. In all cases, insignificant amounts of Mn^{3+} and Cu^+ ions were detected. For this reason, only the Mn^{2+} and Cu^{2+} ions were considered.

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RESULTS

The results showed that pH and the concentration of the main ions (Na, K, Mg, Ca, Cl-, SO_4^{2-}, CO_3^{2-}) in the studied water bodies are within the limits characteristic of the river systems [15]. It was established that, pH in the Struma, Iskar and Maritza rivers varies over a wider range (7.31 - 8.59) than in the Danube River (8.43-8.73). Regarding the concentration of the main ions, we found that their maximum values in the Struma River exceeded between 2 and 10 times the concentration in the other three rivers.

In terms of nutrients (PO_4^{3-}, NO_2^-, NO_3^- and NH_4^+), values significantly exceeding the maximum permissible according to the Bulgarian legislation, Ordinance 4/2012 for "moderate condition" of surface waters were registered. The calculated single threshold pollution indices (Fig. 2a) are highest in the Struma River in the region of Pernik for all four investigated ions. Next are those in the Iskar River, in the area of the Sofia city. In the Maritsa and Danube rivers, only phosphorus shows concentrations higher than MAC, whose maximum and average values exceed even those in the Struma and Iskar rivers.

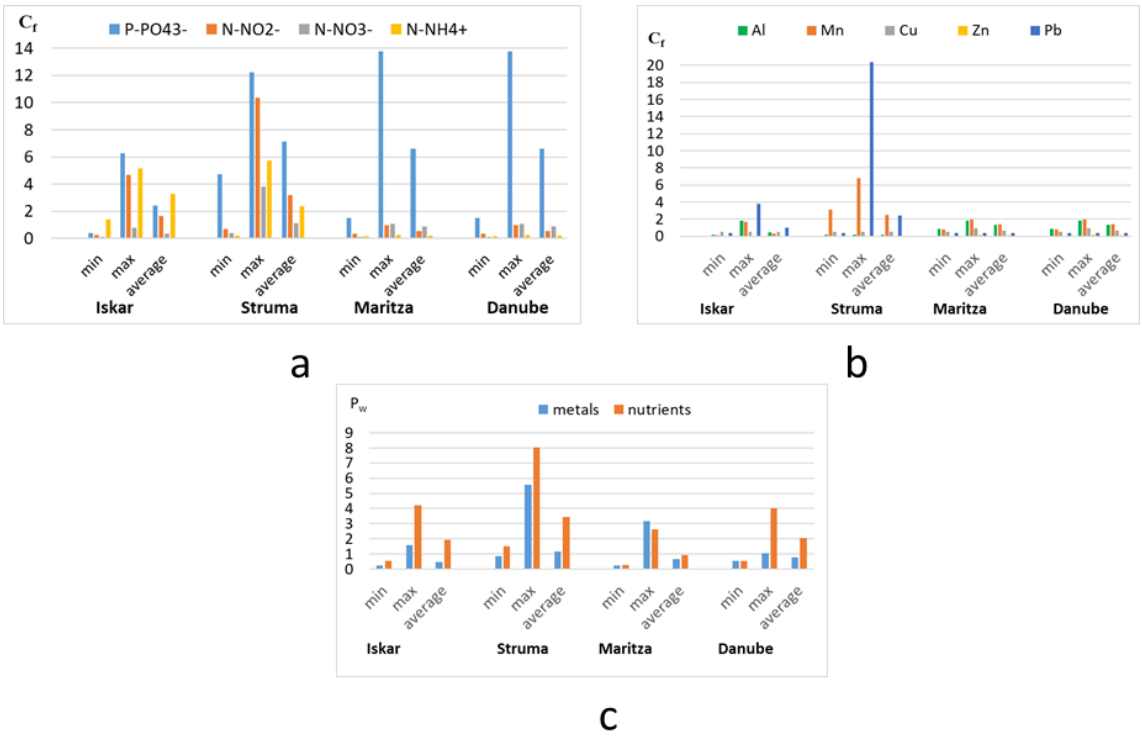


Fig. 2 Pollution indices (C_f and P_w), calculated using minimal, maximal and average measured values. (a) C_f of nutrients; (b) C_f of metals; (c) P_w

Maximum single threshold pollution indices (Fig. 2b) of Mn and especially of Pb in the Struma River exceed about 5 times those in the Iskar River and up to 10 times those in the Danube and Maritsa rivers. The indices calculated for the other studied elements are similar, as for Cu and Zn being below 1 for the four rivers so that the water is clean concerning them.

Integrated threshold pollution indices P_w (Fig. 2c) show higher pollution with nutrients than with potentially toxic metals, and only in Maritsa river the dependence of the maximum P_w is reversed.

Thermodynamically calculated species distribution of Al, Mn, Zn, Cu and Pb (Fig. 3) show similarity in the type of their dominant species between individual river systems,

but significant differences depending on the nature of the element. The dominant chemical species for Al are hydroxy inorganic (20-99%) and organic (30-80%) complexes, for Mn – free ions (50-85%)) and carbonate (5-45%) complexes, and for Zn, Cu and Pb – organic species (60-100%). For Mn, 2-10% sulfate complexes – 1-8% organic species were also calculated. In the case of Zn, 5-20% free ions were also calculated. In waters with high pH – hydroxy (up to 15%) and carbonate (up to 10%) species were also appeared.

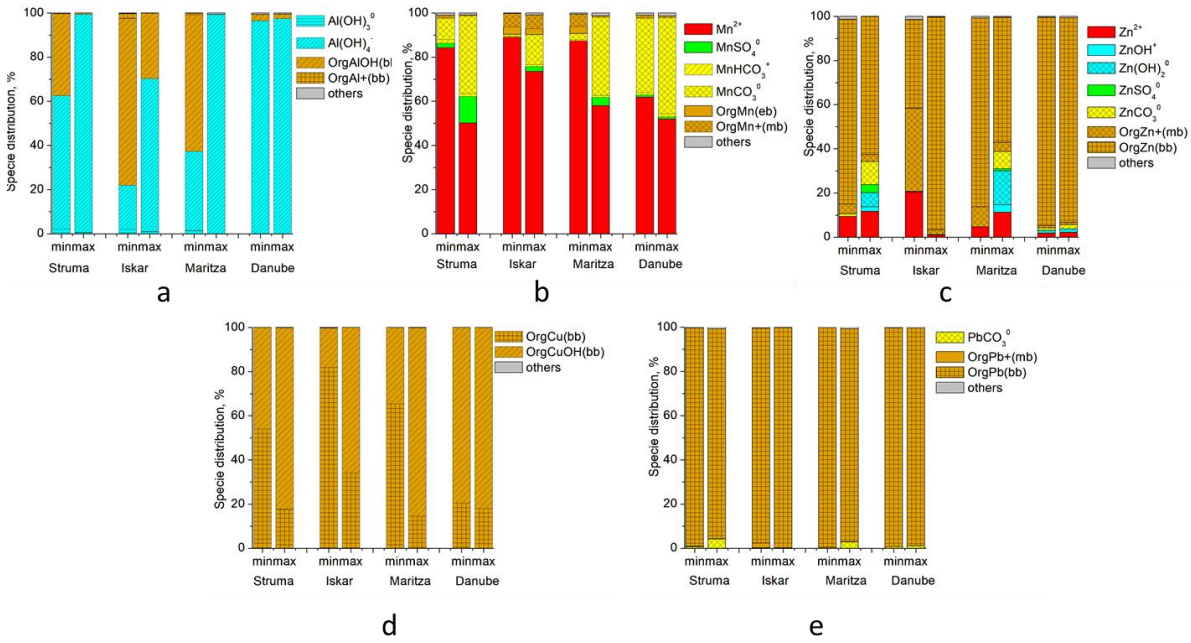


Fig. 3 Thermodynamically calculated species distribution of Al (a), Mn (b), Zn (c), Cu (d), and Pb (e) using minimal, maximal, and average measured concentrations.

The differences in the concentrations of the species calculated with the minimum and maximum measured values are due to the differences in the measured pH. A higher pH leads to an increase in hydroxy and carbonate inorganic species, as well as bidentately bonded organic species.

DISCUSSION

In the last two decades, the urbanization processes in Bulgaria have become more and more intense. Economic and social factors are a prerequisite for the migration of a large part of the population from villages to cities and from smaller to larger cities. Sofia, the capital of Bulgaria, and Plovdiv, the second largest city, are experiencing significant population growth and urbanization due to economic opportunities, tourist destinations, educational institutions, and infrastructure development. In contrast, the number of Pernik citizens has been decreasing in recent years due to a decline in coal mining and processing industries, which are the main livelihoods of the population. Silistra is located in northeastern Bulgaria, near the border with Romania, and the population density is characterized by more stability but also a slight decline.

Our research showed that the highest concentrations of PO_4^{3-}, NO_2^-, NO_3^- and NH_4^+ ions were measured in the waters of the Struma River and this is mainly due to agricultural runoff from the cultivated lands before the Pernik. High values of the four indicators were

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also measured in the waters of the Iskar River. Bearing in mind that the city of Sofia is located at the foot of the Vitosha mountain, from where the Iskar River springs, and that the average content of NH_4^+ ions is the highest, it can be assumed that the pollution is the result of the increased population of the city. In the investigated sections of the Maritsa and Danube rivers, only the content of PO_4^{3-} ions exceeded many times the maximum permissible concentration. For the Maritza River, this is the result of both agricultural and domestic pollution. For the Danube River, one of Europe's major river systems, the reasons are complex and cannot be limited only within Bulgaria.

Regarding the potentially toxic metals, the high content of Mn and especially Pb in the water bodies of the Struma River is the result of both natural origin, due to the presence of coal mines, and the unsustainable management of mining and metallurgy activities in the area in the past. The increased values of Al, Mn, and especially Pb in the Iskar River near Sofia are rather the result of increased human activity. The trends for the concentration of studied metals in the rivers Maritsa, near Plovdiv, and Danube, near Silistra, are similar and lower than in Struma and Iskar rivers.

The results of thermodynamic calculations allow for a more complete assessment of water pollution in addition to chemical analyses for quantitative content of the studied metals and calculated criteria since the toxicity and bioavailability of the elements is determined not only by their total content but also by their species in which they are present in the ecosystem. Representatives of flora and fauna in an ecosystem have different mechanisms for the assimilation of metal ions. In animals and humans, this occurs through inhalation, ingestion of food and liquids, or through the skin. In plant species, absorption and accumulation take place primarily through the root system. Based on the conclusions of our previous studies [9, 10] and the thermodynamic calculations of the chemical species of the metals studied in this work, it can be concluded that free Mn^{2+} ions dominate in all rivers being highest in Struma River. They are dangerous for aquatic fauna as free metal ions easily interact with ligands of organic compounds found in the bloodstream and/or within organs. Free ions are also calculated for Zn, but it is less dangerous because its content is significantly less. It was found only at single stations in the Maritza and Danube rivers. Cu and Pb are potentially the riskiest elements for plants as their dominant organometallic species are easily accumulated by them. Regarding Al, its dominant hydroxy species are a prerequisite for the precipitation of $Al(OH)_3$ and the self-purification of waters.

CONCLUSION

This study examines the differences in water quality across four river systems that flow through several Bulgarian cities. Physicochemical and analytical measurements, the computation of threshold pollution indices of an individual element and as well integrated threshold pollution indices and the calculated distribution of element species as a measure of their bioavailability were all part of the eco-chemical strategy that was used. Based on analytical measurements and derived pollution indices, all the water bodies under study were found to have high levels of pollution in terms of PO_4^{3-}, NH_4^+, Mn^{2+}, and Pb^{2+}. High values of NO_2^- ions were also measured in the waters of Struma and Iskar rivers These results mostly indicate contamination from domestic and agricultural sources. The integrated threshold pollution indices of Struma River are the highest, which may be attributed to both its natural origin—coal mines—and the previous, unsustainable management of the region's mining and metallurgical operations. The Iskar River is the

second most contaminated due to the increased population of the city. Pollution in the Maritsa River near Plovdiv and the Danube, near Silistra, are similar but lower than those in the Struma and Iskar rivers. They result from both agricultural and domestic pollution. For the Danube River, one of Europe's major river systems, the reasons are complex and cannot be limited to Bulgaria only.

Based on thermodynamic estimates of the chemical species of the metals investigated in this paper, free Mn^{2+} ions predominate in all rivers, with the Struma River having the largest concentration. Since free metal ions easily interact with ligands of organic substances found in blood and/or inside organs, we believe that it is Mn^{2+} ions that pose a threat to aquatic life. Zn^{2+} free ions are also computed, but since it has a much lower concentration, it is less hazardous. It was only discovered at a few sites along the Danube and Maritsa rivers. Given how easily plants may acquire the major organometallic species of Cu and Pb, these elements may pose the most damage to plants. Concerning Al, the precipitation of $Al(OH)_3$ and the self-purification process need the presence of its dominating hydroxy species.

ACKNOWLEDGEMENTS

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PRELIMINARY RESULTS OF DIGITAL IMAGES ANALYSIS OF THE TECHNICAL FLUIDS SURFACE BASED ON RGB-TECHNIQUE

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ABSTRACT

The research objective was to develop a methodology for determining the total suspended solids concentration in wastewater based on the color indexes analysis. Determining the structure and properties of natural objects by processing its digital images has become widespread in soil science, since the soil colour is determined by its chemical and mineralogical composition. The material presented in the research can be considered as the initial steps in the development of soil science methods as applied to research objective.

Based on the RGB-technique for processing digital images of the liquids surface contaminated with suspended solids, the authors tried to quantitatively describe digital indexes depending on the contamination level.

At the first stage, a forecast of unknown concentration values was made. Under normal illumination conditions (about 300 lux), based on five known concentration values, approximation functions were plotted for the colour indexes SI (saturation) and CI (coloration). Two unknown concentration values were forecasted: for the exponential function through the SI-index – 210.1 and 150.5 mg/l, and through the CI-index – 235.8 and 158.8 mg/l; for a linear function through the SI-index – 250.6 and 200.1 mg/l, and through the CI-index – 267.3 and 208.2 mg/l. The unknown experimental concentrations were 237 and 158 mg/L, respectively.

At the second stage, the effect of illumination was studied on samples of apatite-nepheline factory wastewater. For two illumination ranges (300-335 lux) and (290-394 lux), as well as 7 concentration values for color indexes SI and CI, linear approximation functions were plotted in the index-concentration axes.

Keywords: wastewater, total suspended solids, colour indexes, RGB-technique, illumination level

INTRODUCTION

Traditionally, the concentration of total suspended solids (TSS) in liquid phase is determined by nephelometric, turbidimetric and gravimetric methods of analysis [1]. However, all types of analysis require water sampling, which is not always feasible in-situ. In some cases, for example, during an emergency discharge of heavily polluted industrial waters, careful monitoring of their dilution process and the TSS concentration reduction before flowing into water bodies is required. For this reason, it is topical to find a way to remotely determine the TSS concentration.

The research objective was to develop a methodology for determining the TSS concentration in wastewater based on the colour indexes analysis, that will make it

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possible to determine its concentration remotely. Using an established methodological approach [2], the authors, based on the RGB method (and partly Lab method) for processing digital images of the surface of liquids contaminated with impurities of various natures with different concentrations, tried to quantitatively describe digital indexes (brightness, saturation, hue, coloration, redness) [3] depending on the pollution level (and vice versa).

$$BI = \sqrt{\{(R^2 + G^2 + B^2)/3\}}$$
$$SI = (R - B)/(R + B)$$
$$HI = (2 * R - G - B)/(G - B)$$
$$CI = (R - G)/(R + G)$$
$$RI = R^2/(B * G^3)$$

A description of the color model can be found on the websites [4, 5]. The work makes an attempt to extend the approach of Russian soil scientists [6, 7], who note that the color of the soil is determined by its chemical and mineralogical composition, as well as the presence of components capable of absorbing or scattering radiation at different lengths waves and intensity.

MATERIALS AND METHODS

On a laboratory scale, an attempt was made to develop an approach that makes it possible to determine the TSS concentration in a technical fluid by processing digital images. During the research, the mining enterprise contaminated wastewater samples were poured into plastic cups with a volume of 100 ml (d – 5.5 cm), diluting it with distilled water to various suspended solids concentrations – 396, 297, 186, 99, 40 mg/l. The experimental samples surface was photographed at a height of 5 cm using a camera with the following characteristics: 12 MP, f/1.6 aperture, image formats – HEIF and JPEG. As in the research [2], image processing consisted of averaging RGB indicators over a large number of pixels in a program developed by K.A. Malodushev. The program makes it possible to count the number and colour of pixels in a photo image and display information about the image in the format of RGB and Lab colour models. The program is written according to the principles of object-oriented programming.

The research can be divided into two stages. At the first stage, the values of color indexes – brightness, saturation, hue, coloration, redness – were calculated for each experimental sample at 300 lux illumination. An attempt was also made to determine the unknown TSS concentration, followed by turbidimetric method verification using the HI98713-02 device (Hanna Instruments Inc., Italy). The second stage was aimed at studying the illumination influence on the accuracy of determining the total suspended solids concentration during image processing. This series was carried out both for the above contaminated wastewater and for standardized test solutions. Test solutions were prepared as follows. Tailings of apatite-nepheline ores enrichment were grinded in an agate mortar to a particle size of <50 microns, and then mixed with distilled water to obtain solutions with a given TSS concentration – 500, 1000, 1500, 2000, 2500 mg/l. Mineral composition of suspended solids: nepheline (65%), feldspars (18%), richterite (5%), sodalite (5%), muscovite (4%), apatite (3%). Chemical composition of suspended solids: SiO_2 – 43.09; Al_2O_3 – 19.42; Fe_2O_3 – 9.59; MnO – 0.20; MgO – 1.17; CaO – 4.95; Na_2O – 9.15; K_2O – 5.40; TiO_2 – 3.93; P_2O_5 – 1.52; S – 0.05; LOI – 1.01.

RESULTS

First series of the research

At the first stage, an attempt was made to forecast unknown TSS concentration values (Table 1). For the first liquid under normal illumination conditions (about 300 lux), five known concentration values (+ two measurements were unknown) were initially calculated, and then approximation functions were plotted for the color indexes SI (saturation) and CI (coloration) in the «index-concentration» axes: exponential (Fig. 1a, 1b) with a high reliability coefficient (0.997) and linear (Fig. 1c, 1d) with a lower reliability coefficient (0.9).

Table 1 – Initial data (TSS concentration, photo) and calculated values of color indexes and unknown concentrations, determined by exponential and linear approximations.

C_{TSS}, mg/l	Photo	Calculation indexes		Exponential dependence, mg/l		Linear dependence, mg/l	
		SI	CI	SI	CI	SI	CI
396		0.0144	-0.0072				
297		-0.0035	-0.0144				
186		-0.0302	-0.025				
99		-0.0782	-0.0465				
40		-0.1263	-0.0697				
xx2		-0.0253	-0.0207	**210.1**	**235.8**	**250.6**	**267.3**
xx1		-0.0462	-0.0317	**150.5**	**158.8**	**200.1**	**208.2**

Using the approximating functions, two unknown concentration values were forecasted:
for the exponential function through the SI-index – 210.1 and 150.5 mg/l, and through the CI-index 235,8 and 158.8 mg/l;
for a linear function through the SI-index – 250.6 and 200.1 mg/l, and through the CI-index 267.3 and 208.2 mg/l. The actual TSS concentrations were 237 and 158 mg/l, respectively.
Therefore, when describing experimental points through an exponential function, for the CI-index there is an error of 0.5%, and for the SI-index – 5-11%.

The transition to linear approximation functions, which speeds up data processing and analysis, significantly increases the forecast error: for the CI-index there is an error of 13-32%, and for the SI-index – 6-27%. It seems that using the described approach it is possible to fairly accurately forecast unknown concentration values through the CI-index.

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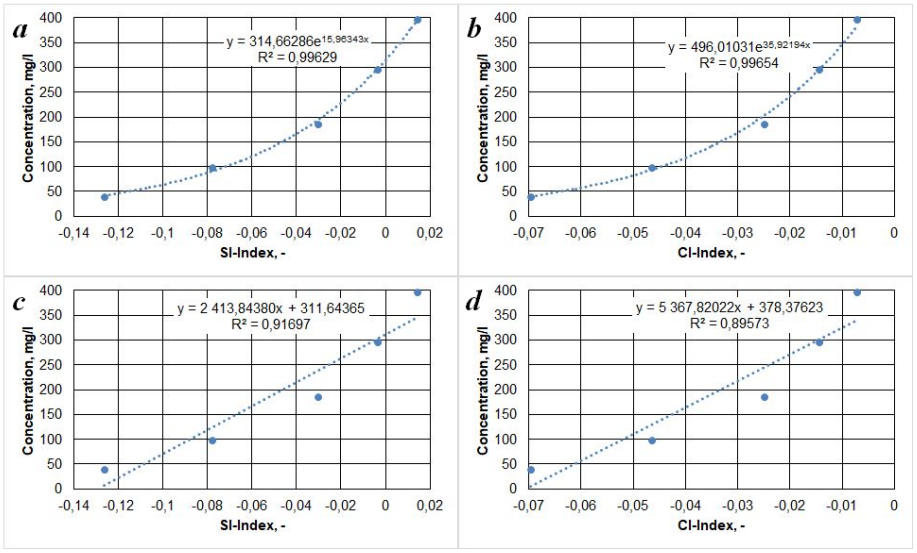


Figure 1. Graphic representation of the results in «concentration – index» coordinates for exponential approximation for SI (*a*) and CI (*b*) indexes, as well as for linear approximation for SI (*c*) and CI (*d*) indexes.

Thus, within the framework of the experiment performed, the result looks quite logical, which allowed us to conclude that it is possible to move further by adopting the SI and CI indexes. Moreover, the latter makes it possible to obtain concentration values quite close to the experimental ones. During the preparation and conduct of the experiment, it was noted and also found in a number of publications indicating that there is a certain influence of illumination on the results obtained. For this reason, that effect was further studied, but in the simplest linear approximation.

Second series of the research

In this series of experiments, liquids contaminated with various impurities were used. Initially, the liquid was studied, as in the first series of studies, for two illumination options 1 and 2 (without clearly determination). A light sheet was placed nearby as a reference for the purpose of applying the Lab technique. The processing results for 3 RGB color indexes and 2 illumination options are presented in Table 2. Graphs (and trends) of two color indexes SI and CI and two illumination options are shown in Fig. 2.

Table 2 – Calculated values of some color indexes for two illumination options.

C_{TSS}, mg/l	Illumination option 1 (Ligth_1)				Illumination option 2 (Ligth_2)			
	Photo	BI	SI	CI	Photo	BI	SI	CI
99		148.6	0.0286	-0.001		119.9	0.0657	0.0113
186		152.8	0.0524	0.0067		110.6	0.0959	0.0155
297		147.3	0.0736	0.0127		114.0	0.1118	0.0244
396		139.5	0.0978	0.0194		106.4	0.1359	0.0263
Reference		186.8	-0.0214	-0.0084		198.1	0.0188	0.003

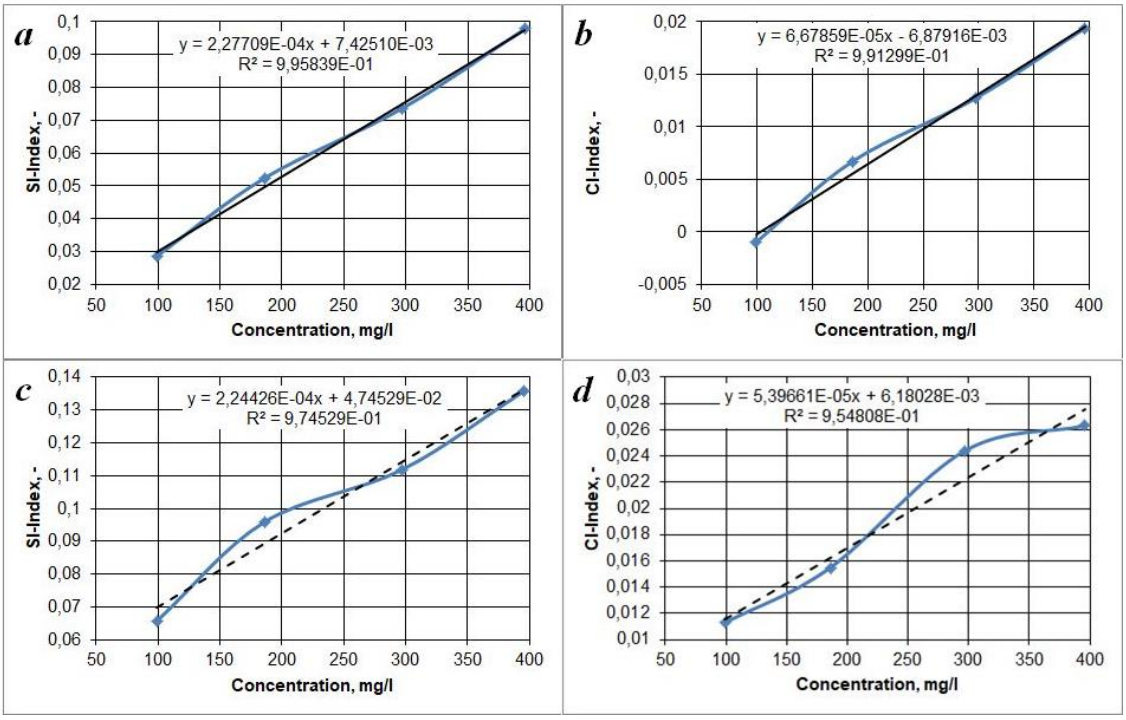


Figure 2. Graphs (and trends) of two color indexes SI (*a*) and CI (*b*) for illumination option 1 (Light_1), graphs (and trends) of two color indexes SI (*c*) and CI (*d*) for illumination option 2 (Light_2).

As can be seen in the presented graphs in Fig. 2, following the illumination there is a change in the ranges of index values.

If in the illumination option Ligth_1 the values of the SI and CI indexes fell within the ranges of 0.03-0.10 and -0.001-0.02, respectively, then in the illumination option Ligth_2 similar ranges are 0.06-0.14 and 0.01-0.026, also respectively.

The results of using the Lab method are presented in Table 3 (calculated values of the ΔE parameter and in Fig. 3, which shows graphs (and trends) of the calculated ΔE values depending on the impurity concentration for both illumination options (Ligth_1 and Ligth_2).

Table 3 – Calculated values of the ΔE parameter for two illumination options.

C_{TSS}, mg/l	ΔE_L1	ΔE_L2
99	15.03	29.193
186	15.13	32.914
297	18.044	31.841
396	21.509	35.029

https://doi.org/10.5593/sgem2024/5.1/s20.27

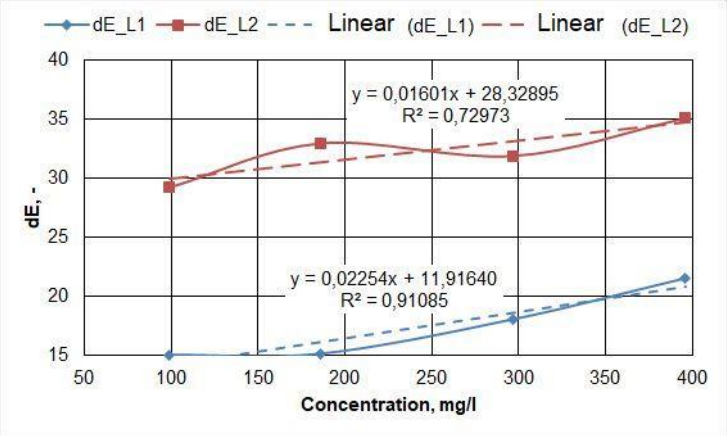


Figure 3. Graphs (and trends) of the ΔE indicator dependence on the TSS concentration for 2 illumination options.

For the same liquid under two illumination ranges (300 – 335 lux) and (290 – 394 lux) and 7 concentration values for the calculated color indexes SI and CI, linear approximation functions were plotted in the same index-concentration axes. Concentration values [mg/l]: 40, 79, 158, 198, 237, 317, 396. Below are the averaged analytical dependences of the color indexes SI and CI on concentration.

$$SI(C) = 0.00030 \cdot C - 0.08639 \text{ (range 300-335 lux)}$$
$$CI(C) = 0.00011 \cdot C - 0.04530 \text{ (range 300-335 lux)}$$
$$SI(C) = 0.00033 \cdot C + 0.00109 \text{ (range 290-394 lux)}$$
$$CI(C) = 0.00011 \cdot C - 0.00853 \text{ (range 290-394 lux)}$$

For this type of liquid, the slope of the graphs of the obtained functions (average values 0.00033 for the SI index and 0.00011 for the CI index) varied slightly depending on the illumination. There was a shift in the graphs along the vertical axis: with increasing illumination, the graphs are located lower. A similar situation was observed for the second liquid (natural water body). Under conditions of illumination range (215 – 404 lux) and 7 concentration values, linear approximation functions and their averaged linear function were plotted for the calculated values of the color indices SI and CI (Fig. 4). Concentration values [mg/l]: 11.6, 23.3, 46.5, 58.2, 69.8, 87.7, 116.4. Below are the averaged analytical dependences of the color index on concentration.

$$SI(C) = 0.00074 \cdot C - 0.00733 \text{ (range 215-404 lux)}$$
$$CI(C) = 0.00023 \cdot C - 0.01119 \text{ (range 215-404 lux)}$$

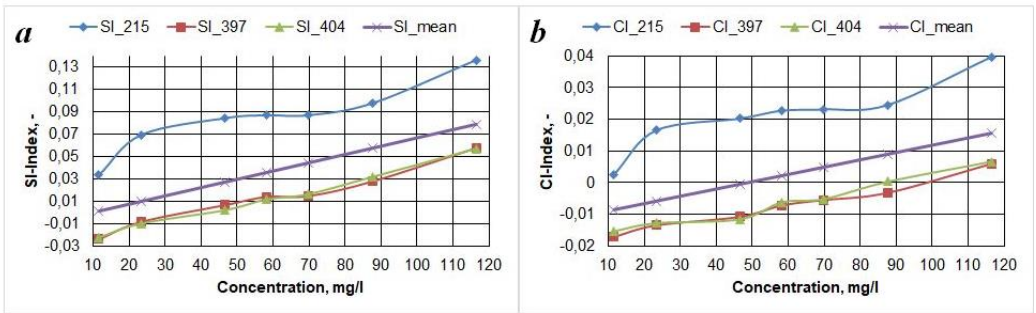


Figure 4. Graphs (and trends) of two colour indexes SI (*a*) and CI (*b*) in «index – concentration» coordinates for linear approximation of the natural water body.

The slope of the graphs of the obtained functions varied slightly depending on the illumination (average values 0.00074 for the SI index and 0.00023 for the CI index). There was only a shift of the graphs along the vertical axis: with increasing illumination,

the graphs are located lower. In subsequent experiments, model solutions were used, prepared in accordance with the procedure described in the «Materials and Methods» section. For such a liquid, under conditions of illumination range (88-240 lux) and (89-286 lux) and 5 concentration values, attempts to construct linear approximations for the calculated color indexes SI and CI turned out to be unsuccessful – the reliability coefficients are low. The results (in the form of graphs) with increasing illumination are also difficult to describe: with the first increase, first downward, and with further increase upward. It appears that this type of pollution is characterized by a very high sensitivity to light. At the same time, it was noted that the calculated color index RI looks more suitable for this liquid (the reliability of the linear approximation is higher, the arrangement of the graphs (see Fig. 5) is more «dense»). Below is the averaged analytical dependence of the color index on concentration.

$$RI(C) = 1.0925 \cdot 10^{-8} \cdot C + 4.2978 \cdot 10^{-5}$$ (range 88-286 lux)

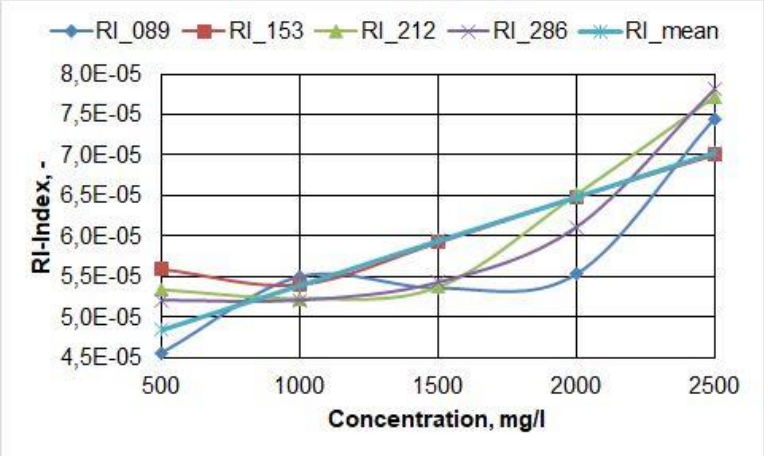


Figure 5. Graphic representation of the results of the test solutions analysis in «index – concentration» coordinates for linear approximation.

It seems that a serious drawback of the approach under study is the fact that repeatability of the output result was not observed at similar illumination values: 88 (89) lux and 150 (153) lux. An increase in concentration smooths out the differences. The results obtained are encouraging. The authors believe that it is, in principle, possible to achieve stable results, which means that the proposed method has some promise. Additionally, an attempt was made to obtain images of a liquid with a fixed impurity concentration and a fixed illumination value, using another digital camera. The results of this experiment are shown in Table 4.

Table 4 – Calculated RGB values at fixed impurity concentrations and illumination values using another digital device.

№	Photo	Results
1		Number of pixels = 31320; RGB = 191.2004; 189.2341; 170.8014
2		Number of pixels = 37036; RGB = 191.4751; 189.7798; 170.5849
3		Number of pixels = 29225; RGB = 191.2166; 189.0737; 170.6392

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CONCLUSION

The results of digital photographs analysis of the surface of liquids contaminated with impurities of various natures and different concentrations are presented. A previously tested RGB technique was used to quantitatively describe digital indexes (brightness, saturation, hue, colour, redness) depending on the pollution level. Under normal illumination conditions (about 300 lux), based on 5 known concentration values (+ 2 measurements were unknown), approximation functions were plotted for the colour indices SI and CI in the index-concentration axes: exponential and linear with confidence coefficients of 0.997 and 0.900, respectively. Two unknown concentration values were forecasted, the values of which, when using the CI-index, have an error from the experiment at the level of 0.5%, and for the SI index – 5-11%. Using samples of wastewater from an apatite-nepheline factory with a high total suspended solids concentration, as well as natural body water, the influence of illumination on the results of the analysis of digital photographs was studied. High sensitivity of the images to the level of illumination was noted. A shift in the graphs of the approximation functions of digital indices along the vertical axis is predicted: with increasing illumination, the graphs are located lower. The use of another digital device made it possible to achieve a certain stability in the results of image processing. Research is underway.

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PRIORITY AIR POLLUTANTS AS GLOBAL RISK FACTORS FOR PUBLIC HEALTH (ON THE EXAMPLE OF KAZAN)

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ABSTRACT

The results of our study revealed regional peculiarities, which showed an excess of the share of PM10 compared to PM2.5 in the rank distribution and high concentration of soot in the level of impact on public health. It was found that the distribution in terms of contribution to the total risk value (HQ) of the main pollutants is highest in all three zones: carbon (soot), nitrogen dioxide (NO2), suspended solids (PM), where the main share is suspended particles up to 10 microns (PM10). Among the studied zones, zone 1 is the most polluted zone in terms of the impact of atmospheric air chemicals on human health. The share contribution of chemical substances showed that the first rank of influence on the occurrence of negative effects on adolescent health is carbon (soot), which accounted for 35.9% in zone 1, in zones 2 and 3 - respectively 26% and 36.9%. nitrogen dioxide accounted for 17.9%-19.4%, the distribution of suspended particles PM10 by area ranged from 13.9%-21.8%. Comparison of the total hazard quotients of the studied population groups revealed an excess of this indicator both in adolescents and adults. They are characterised as high (HQ >3): 4.12-5.48 for adolescents, 3.0-3.91 for adults. The main critical organs exposed to the impact of pollutants in the territory of Kazan turned out to be respiratory organs, systemic impact, on teeth, impact on mortality and blood system.

Keywords: air pollution, health risk assessment, particulate matter, PM10, non-carcinogenic risk

INTRODUCTION

Air pollution is one of the most acute environmental problems of our time, significantly affecting human health. Rapid urbanisation and industrialisation, accompanied by increasing emissions of harmful substances into the atmosphere, worsen air quality, especially in large cities and industrial areas. In a number of large industrial cities, the contribution of environmental factors to the deterioration of health is in the range of 40-60% [1]. At the same time, it is established that the priority role in the formation of unfavourable impact of the habitat belongs to atmospheric air pollution [2].

Numerous scientific studies both in Russia and abroad have proved the negative impact of atmospheric air pollution on mortality and morbidity of various respiratory,

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cardiovascular, neurological diseases, malignant neoplasms of the population [2-4]. The increasing role of environmental pollution in shaping the quality of life of the population is noted in works related to the identification of factors that determine the conditions and comfort of the human living environment [5, 6].

Polluted atmosphere is one of the main problems of urban and suburbanised areas in the territory of the Republic of Tatarstan, in particular, the city of Kazan. The city of Kazan is a large industrial and cultural centre with a high level of intensive development of the industrial sector, transport congestion and urbanisation, which contribute to the formation of a large number of emissions into the atmospheric air, which leads to an increased risk to public health [7].

Children and adolescents are thought to be more susceptible to the effects of air pollution than adults, due to underdeveloped lungs and defence systems, and due to increased lung ventilation and a higher degree of physical activity there is an increased exposure to the body [8]. Thus, we identified adolescents 14-18 years of age as a population for further study.

Purpose of the study: to assess the health risk of adolescents and adults due to chemicals in atmospheric air.

MATERIALS AND METHODS

To assess the chemical composition of atmospheric air, we used the data of socio-hygienic monitoring and the results of laboratory tests for 2015-2021, performed on the basis of accredited testing laboratories of FBUZ "Centre of Hygiene and Epidemiology in the Republic of Tatarstan". The assessment was carried out in three monitoring points in Kazan: zone 1 - Gorkovskoye Shosse, zone 2 - Prospekt Pobedy, zone 3 - Tatarstan Street.

Non-carcinogenic risk assessment for adolescents and adults was carried out according to R 2.1.10.3968-23 "Guidelines for health risk assessment of the population at exposure to chemical substances". Calculation of average daily doses for adolescents (mass 50 kg) and adults (mass 70 kg) was carried out using standard exposure factors. [9, 10]. The hazard quotient HQ was determined by the ratio of the potential daily dose of a substance to the safe exposure level.

Non-carcinogenic risk assessment (HQ) and identification of critical organs/systems used reference concentrations for chronic inhalation exposures from Guideline 2.1.10.3968-23. The total hazard index (HI), which characterises the risk of non-carcinogenic effects in combined exposures, was calculated as the sum of HQs for individual substances with simultaneous ingestion of several substances by the same pathway

HQ values in the range from 0.11 to 1.0 and HI values from 1.1 to 3.0 were taken as an acceptable level of non-carcinogenic effects; HQ values from 1.1-3 and HI values from 3.1-6 were taken as alarming.

Statistical analysis of the obtained data was implemented in Windows 11 operating system using standard application packages Excel.

RESULTS

When non-carcinogenic hazard quotients (HQ) for individual substances were calculated and analysed, it was found that carbon (soot), nitrogen dioxide, PM10 and formaldehyde took the leading positions in terms of contribution to the total risk (Table 1).

Table 1 - Results of assessment of the total risk of non-carcinogenic effects of chemical substances polluting atmospheric air for adolescents and adults by zones of Kazan.

Substance	Hazard quotients (HQ)					
	Zone 1		Zone 2		Zone 3	
	Adolescents	Adults	Adolescents	Adults	Adolescents	Adults
Nitrogen dioxide (calculated as NO2)	0,98	0,70	0,74	0,53	0,91	0,65
Sulphur dioxide	0,13	0,09	0,11	0,08	0,00	0,00
Carbon dioxide	0,40	0,29	0,36	0,26	0,43	0,31
Carbon(soot)	1,97	1,40	1,07	0,76	1,73	1,24
Particulate matter (PM10)	0,84	0,60	0,90	0,64	0,65	0,47
Particulate matter (PM2,5)	0,42	0,30	0,45	0,32	0,28	0,20
Formaldehyde	0,74	0,53	0,49	0,35	0,69	0,49
Total risk	5,48	3,91	4,12	2,94	4,69	3,36

When comparing the total hazard quotients of the studied population groups, this indicator was found to be exceeded in both adolescents and adults. They are characterised as high (HQ >3): 4.98-14.74 for adolescents, 3.56-10.53 for adults. (Table 1).

Ranking of the main chemical substances by their contribution to the total hazard quotient showed that for adolescents in the first zone the risk level corresponds to the alarming (HQ - 1.1-3) due to carbon (soot) emissions - the contribution to the total risk is 1.97 (35.9%), in the second and third zones the contribution of soot to the total risk was equal to 1.07 (26.0%) and 1.73 (36.9%). In the first zone the main contribution to the total risk for adolescents is made, in addition to carbon (soot), by NO2 - 0.98 (17.9%), PM10 - 0.84 (15.3%), in the second zone - PM10 - 0.9 (21.8%) NO2 -0.74 (18.0%), in the third zone - NO2 - 0.91 (19.4%), formaldehyde - 0.69 (14.7%). For the

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adult population, a similar trend persists: the main contribution to the total risk was made in the first zone by soot - 1.4, NO2 - 0.70, PM - 0.6, PM10 - 0.6, in the second zone - soot - 0.76, PM10 - 0.64, PM -0.62, NO2 -0.53, in the third zone - soot - 1.24, NO2 -0.65 and formaldehyde - 0.49.

Table 2 - Total hazard indices for individual organs and systems for the studied populations at the monitoring points.

Critical organs/systems	Hazard indices (HI)					
	Zone 1		Zone 2		Zone 3	
	Adolescents	Adults	Adolescents	Adults	Adolescents	Adults
Respiratory organs	5,08	3,63	3,76	2,69	4,26	3,04
Central nervous system	0,40	0,29	0,36	0,26	0,43	0,31
Mortality	1,71	1,22	2,32	1,66	1,37	0,98
Cardiovascular system	1,25	0,89	1,26	0,90	1,09	0,78
Blood system	1,38	0,99	1,12	0,80	1,34	0,96
Immune system	0,01	0,00	0,02	0,01	0,69	0,00
Intrauterine development	1,25	0,89	1,28	0,91	1,09	0,78
Systemic	1,97	1,40	1,07	0,76	1,73	1,24
Teeth	1,97	1,40	1,07	0,76	1,73	1,24

The greatest toxicological load from exposure to polluted atmospheric air is experienced by several critical organs and systems. First of all, respiratory organs in all 3 zones are more exposed to the effects of pollutants: HI=3.76-5.08 for adolescents is characterised as an alarming risk level (HI=3.1-6), HI=2.69-5.08 for adults - for the second zone an acceptable risk level is calculated, for zones 1 and 3 - alarming. The hazard indices for the development of non-carcinogenic effects for the remaining zones correspond to permissible levels (HI=1.1-3.0) or minimal (1.0 or less). The second highest risk of noncarcinogenic effects for zones 1 and 3 is for dental and systemic exposure (HI = 1.73-1.97 for adolescents and HI = 1.24-1.4 for adults), and for zone 2 is for mortality (HI = 2.32 and HI = 1.66 for adolescents and adults, respectively). There is also a high mortality risk in residential zones 1 and 3, with HI = 1.37-1.71 for adolescents and HI = 0.98-1.22 for adults. For the blood system, the risk for adolescents corresponds to the acceptable risk - 1.12-1.38 for adolescents and 0.8-0.99 for adults (Table 2).

DISCUSSION

In a recently published study on the global burden of disease, fine PM air pollution ranks eighth among the leading risk factors for non-communicable diseases, and may contribute to up to 4.2 million premature deaths globally each year [11].

In a large number of studies on the composition of air pollutants, PM2,5 has been shown to be the major contributor to pollution [12]. However, a scientific team of Spanish researchers found that for Northern Spain, background concentrations of PM10 predominate over PM2.5, as in our study [13].

We identified regional peculiarities that showed an excess of the share of PM10 compared to PM2.5 in the ranking distribution and high soot concentrations in terms of health effects.

CONCLUSION

In this study, we analysed air pollution in the study metropolitan area, where high non-carcinogenic risk was found in zone 1 for adolescents and adults. A significant part of the exposure leading to these health effects is due to the higher density of human activities in these zones and air emissions from motor vehicles (presence of trunk highways). The distribution in terms of contribution to the total hazard quotient (HQ) of the main pollutants was found to be highest in all three zones: carbon (soot), nitrogen dioxide (NO2) and suspended particulate matter up to 10 μm (PM 10).

In view of the fact that hazard ratios of non-carcinogenic risk in all three areas are characterised as high (unacceptable for the population), it is necessary to urgently carry out health improvement and other actions to reduce the risk. These actions include reduction of emissions from motor transport and industrial enterprises, landscaping and creation of green areas, air quality monitoring and control, development and implementation of environmental norms and standards.

Thus, the conducted research allowed to establish regularities and regional peculiarities of atmospheric air pollution. Currently, on the basis of administrative policy, socio-hygienic monitoring it is necessary to purposefully plan sanitary and hygienic measures to prevent and eliminate the harmful effects of environmental factors on the health of the population in order to reduce and minimise the levels of risk to the health of adolescents and adults.

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REGULATING CARBON INTENSITY IN FERROUS METALLURGY: NEW APPROACHES BASED ON THE PRINCIPLES OF BEST AVAILABLE TECHNIQUES

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ABSTRACT

The article describes the approaches to development of an effective regulatory mechanism to manage carbon intensity of Russian resource-intensive industries. The authors focus their attention on the ferrous metallurgy industry as the top emitter of greenhouse gases (GHG) and the second-largest consumer of energy among Russian industrial sectors. Resource consumption wise this sector is well-studies and regulated by the Best Available Techniques (BAT). Establishing the interrelation between carbon intensity indicators and resource consumption metrics, as well as operating costs per unit of consumed resource, forms the basis for developing a comparative analysis (benchmarking) system. This system relies on specialised indicators outlined in the Reference Documents on the Best Available Techniques (BREF). The authors suggest using the BAT concept for devising an approach to ascertain the acceptable level of greenhouse gas emissions and incentivise modernisation through industry-specific indicative carbon intensity parameters in the sector. Such parameters are substantiated for the ferrous metallurgy of the Russian Federation. The article evaluates the anticipated economic impact for both the government and the ferrous metallurgy industry stemming from the adoption of the proposed approaches to regulating carbon intensity in the sector. The practical implementation of the proposed methodology is poised to mitigate the financial burdens associated with the introduction of Carbon Border Adjustment Mechanisms (CBAM) around various economies.

Keywords: ferrous metallurgy, carbon intensity, decarbonisation, Best Available Techniques, indicative carbon intensity parameters

INTRODUCTION

The Strategy for the Development of the Russian Federation with Low Greenhouse Gas Emissions until 2050 outlines targets for achieving climate neutrality no later than 2060. The key industrial development objective is to ensure sustainability in the context of the global energy transition. In Russia, industrial development focuses on enhancing resource and energy efficiency [1], implementing Best Available Techniques (BAT), exploring alternative energy sources, and transitioning to a circular economy [2].

Among industrial sectors, ferrous metallurgy is the top emitter of greenhouse gases (GHG) and the second-largest consumer of energy. It accounts for approximately 8% of

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global final energy consumption and 7% of GHG emissions (measured in CO_2-eq), including emissions from fuel combustion. The steelmaking sector is the largest industrial consumer of coal, which is used to produce the coke and energy needed to make steel from iron ore.

According to experts, substantial decarbonisation of ferrous metallurgy is necessary to align with climate objectives and facilitate the Fourth Energy Transition, aiming for a minimum 30% reduction in GHG emissions by 2050. Further impetus for emission reduction comes from the trend toward establishing global carbon intensity standards for imported products, such as the Carbon Border Adjustment Mechanisms [3, 4].

Decarbonisation efforts should primarily focus on implementing cost-effective projects aimed at improving resource efficiency. Developing a regulatory framework and facilitating investment in projects geared toward reducing carbon intensity, especially through technological modernization based on BAT principles, becomes particularly important. The study aims at establishing new approaches to regulating carbon intensity in ferrous metallurgy based on the principles of Best Available Techniques.

MATERIALS AND METHODS

The methodological framework of this study draws upon general approaches used in research, including empirical and theoretical methods of management, economic analysis and synthesis, economic and mathematical modelling, and benchmarking. Data for the analysis was derived from a range of sources, including government statistics, official reports from Russian and international analytical bodies, strategic documents at both state and industry levels, and relevant scientific literature. The reliability and validity of our assertions, conclusions, and recommendations are substantiated through comprehensive data analysis encompassing sources such as regulatory documents, analytical reviews, technological standards, scientific articles, and monographs and modern research methodologies such as deduction, induction, generalization, synthesis, comparative and factor analysis, expert assessments, and statistical techniques employed for processing information from various industrial sectors.

RESULTS

Clarifying strategic priorities for sustainable industrial development amid the energy transition

The transition toward a low-carbon economy in the current era of the Fourth Energy Transition is characterized not only by technological imperatives and the necessity to improve production efficiency but also by a fundamentally new imperative – the necessity to reduce the environmental impact on the planet by curbing anthropogenic greenhouse gas emissions and thereby mitigating climate change [5].

This study identifies several key strategic priorities shaping the sustainable development of industrial systems amidst the Fourth Energy Transition:

– the need to curtail anthropogenic GHG emissions at the industrial system level, aiming to reduce the costs associated with adapting to climate change and mitigating potential expenses linked to the gradual enforcement of Carbon Border Adjustment Mechanisms by various nations for carbon-intensive imports [6];

– the growing necessity to ensure the economic and energy security of numerous countries, driven by current geopolitical dynamics and constrained by dwindling fossil fuel reserves, energy inefficiencies in economies, infrastructural deterioration, and limited access to up-to-date technologies for implementing new projects [7];

– the need to reconceptualize the outcomes of industrial modernization by fostering the formation of new job opportunities, enhancing environmental and safety standards, and cutting operational costs through higher resource and environmental efficiency in production [8];

– shifts in public perception concerning environmental and climate issues and the objectives of sustainable development in industrial sectors, emphasizing the use of green technologies, which necessitates raising public awareness regarding processes aimed at reducing carbon intensity in industry and engaging social groups in making economic and management decisions [9].

Sustainable industrial development within the energy transition context can be interpreted as a multifaceted process encompassing transformations in domains such as technology, resources, and management [2]. These transformations reflect corporate capacity to maintain economic efficiency while addressing societal needs, fulfilling international commitments, and fostering national economic growth through resource efficiency, which also entails reducing production carbon intensity and curtailing adverse environmental impacts.

While the sustainable development discourse, particularly the climate agenda, is most prominent in Western markets, burgeoning initiatives in this domain are evident in Eastern regions as well [10]. This scenario poses a challenge for Russia's key economic sectors, including those oriented toward exports, as they are carbon-intensive. Addressing this challenge necessitates the formulation of a regulatory mechanism for managing industrial carbon intensity, aligned with international paradigms. Such a mechanism can be based on the proposed classification of instruments operational in different countries and regions.

An industry-focused framework for comparative carbon intensity analysis in ferrous metallurgy

Amidst the energy transition, priority should be given to fostering sustainable development within carbon-intensive industries, which are major contributors to the gross domestic product. Examples include ferrous metallurgy, aluminium, chemicals, non-metallic minerals, and pulp and paper industries. Over the past decade, Russia has been evaluating the national industry and its resource and technological standing while transitioning toward technologically regulated entities, guided by BAT principles.

This involves conducting comparative analyses of pollutant emissions and resource consumption indicators in BAT application domains, establishing both emissions indicators and targeted resource efficiency metrics.

In ferrous metallurgy, carbon intensity metrics depend on resource consumption indicators and economic efficiency benchmarks, such as costs per unit of resource consumed. This underscores the feasibility of formulating a comparative analysis system for greenhouse gas emissions based on specialized indicators delineated in Reference Documents on Best Available Techniques.

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Our case study illustrates the correlation between parameters such as carbon intensity, specific electricity, natural gas, and concentrate consumption, and specific resource costs in pellet production (Figure 1).

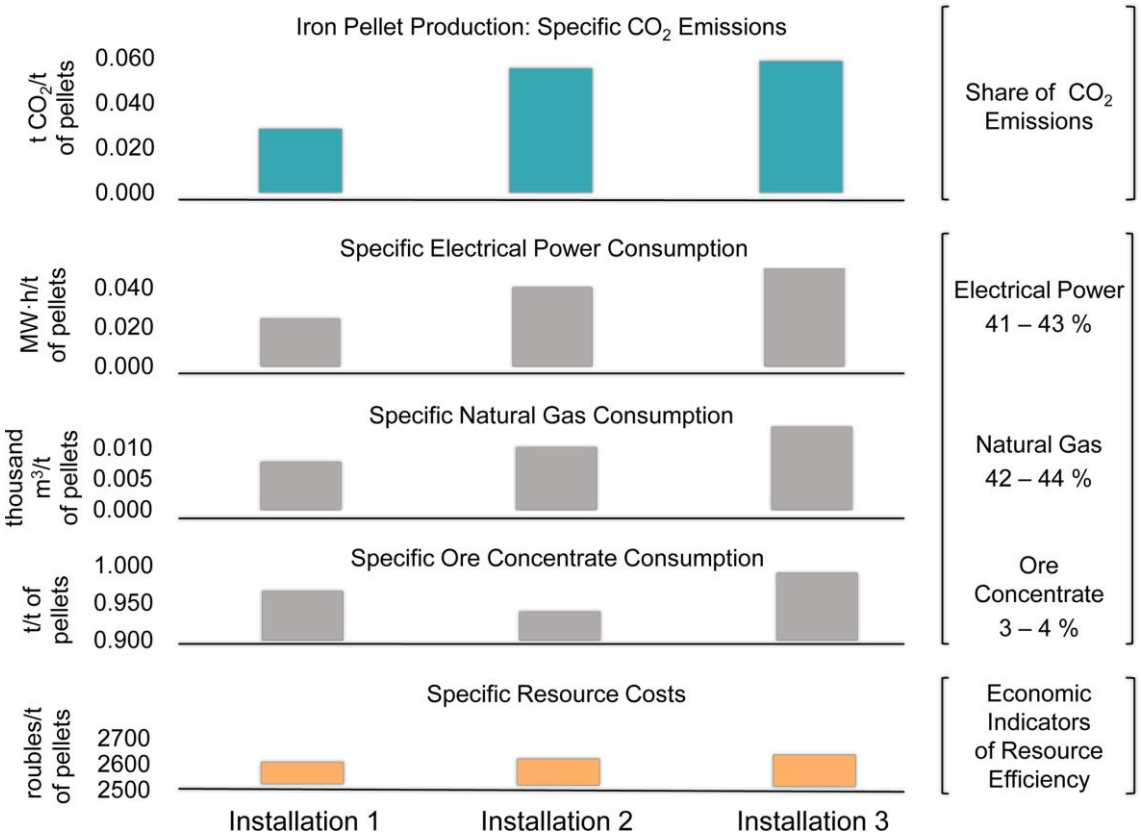


Figure 1. Resource efficiency and carbon intensity of the selected installations producing iron pellets

A national industry benchmarking system should be based on standardized benchmarks enabling the following: 1) appraising the carbon intensity of modernization projects, and 2) quantifying high-carbon industries' deviation from permissible greenhouse gas emissions. This framework can inform requirements regarding carbon emission trading.

Within the study, the author devised an approach to ascertain the acceptable level of greenhouse gas emissions and incentivize modernization through industry-specific indicative carbon intensity parameters (ICIPs). This concept encapsulates a spectrum of carbon intensity values derived from a comparative analysis of production processes' carbon intensity within the industry, factoring in (1) the number of installations, (2) employed technologies, and (3) the technological and carbon intensity levels achieved by each installation.

ICIPs emerge from data processing, analysis, and emission calculations based on primary data on material and energy mixes obtained from Russian iron producers. The upper and lower limits of the ICIPs are computed considering targets set at industry and national levels.

Broadly, the upper limit delineates areas of production processes with the highest carbon intensity, warranting the application of specialized regulatory tools. These tools,

mandated by legislation to curtail greenhouse gas emissions, may encompass legislative restrictions, taxes, or quotas.

The lower limit signifies the least carbon-intensive production within the industry, serving as a benchmark for green projects vying for specific government support measures (Figure 2).

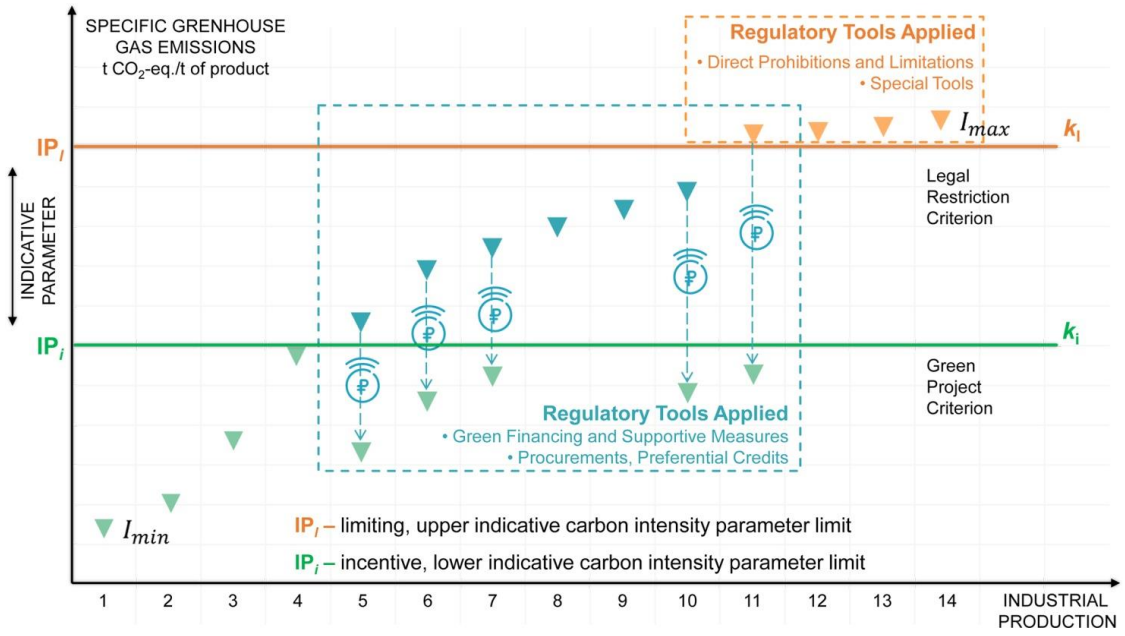


Figure 2. Industry-specific indicative carbon intensity parameters: key principles

The approach proposed in the article is grounded in synthesizing empirical data on the carbon intensity of production processes.

The upper ICIP limit (IP_l) is calculated as follows:

$$IP_l = I_{max} - (I_{max} - I_{min}) \times k_l, \quad (1)$$

where I_{max} is the highest carbon intensity from a production process in the industry, I_{min} is the lowest carbon intensity from a production process in the industry, and k_l is the limiting coefficient.

The lower ICIP limit (IP_i) is calculated as follows:

$$IP_i = I_{max} - (I_{max} - I_{min}) \times k_i, \quad (2)$$

where I_{max} is the highest carbon intensity from a production process in the industry, I_{min} is the lowest carbon intensity from a production process in the industry, and k_i is the incentive coefficient.

The value of the limiting coefficient (k_l) is chosen based on the Strategy for the Development of the Russian Federation with Low Greenhouse Gas Emissions until 2050 to ensure that the Strategy's upper-level goals and indicators are met. The upper and lower limits in this study were found using $k_i = 0.4$ and $k_l = 0.15$ for ferrous metallurgy.

The k_i value considers the Strategy's targets for 2030; it is expected that the carbon intensity of the production process in the steel sector will slightly decrease (by 6%) and gross CO_2 emissions will peak in 2030 if production grows. From 2030 to 2050, both

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carbon intensity and gross emissions in the sector are expected to go down, which will necessitate revised coefficients and updated ICIP values.

As an example, Figure 3 presents carbon intensity values for electric arc furnace steelmaking.

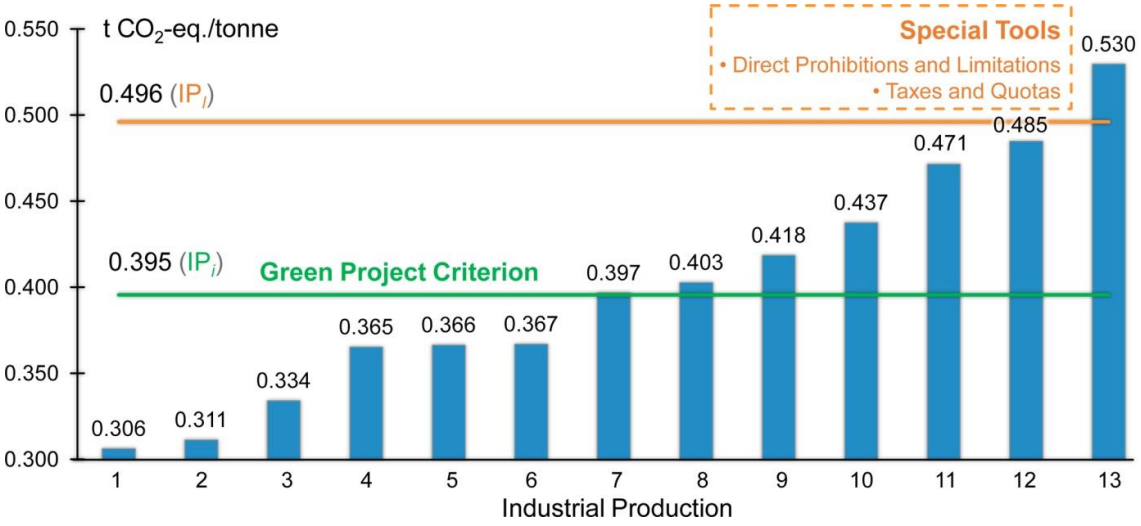


Figure 3. Comparative analysis of carbon intensity for electric arc furnace steelmaking

The comparative analysis of the industrial installations indicates the need for using regulatory measures such as bans, restrictions, cap-and-trade systems, or carbon taxes targeted at Installation 13 as one of its facilities demonstrates carbon intensity exceeding the upper ICIP limit. Eligibility criteria for the government support eligibility criteria are currently set at a level achievable only through upgrading, currently unmet by half of economic entities.

DISCUSSION

Gradual decarbonisation of ferrous metallurgy through carbon pricing

This part of the study aims to determine the carbon pricing mechanism that incentivizes businesses to invest in decarbonisation through upgrading their resources and technologies.

The carbon price (*CP*), applicable when the upper ICIP limit for the industry is surpassed, is calculated as follows:

$$CP = E_t \times Y_t, \tag{3}$$

where E_t is the number of emissions (in tons) more than the upper ICIP limit (IP_l) for the reporting year (calculated according to (1)), and Y_t is the price per one ton of CO_2 (if the upper ICIP limit is exceeded).

E_t is calculated as follows:

$$E_t = (P_f - IP_l) \times M, \tag{4}$$

where P_f is the carbon intensity in the reporting year (t CO_2-eq/t of product), IP_l is the upper (limiting) ICIP value (t CO_2-eq/t of product), and M is annual emissions (t).

Then the cost of reducing CO_2 emissions to the upper ICIP limit (P_t) is calculated as follows:

$$P_t = E_t \times I_t, \quad (5)$$

where E_t is the amount of emissions (in tons) in excess of the upper ICIP value (IP_l) for the reporting year, and I_t is the cost of reducing specific CO_2 emissions (per ton).

Then the cost of reducing CO_2 emissions to the lower ICIP limit (P_s) is calculated as follows:

$$P_s = E_s \times I_t, \quad (6)$$

Where E_s is the amount of emissions (in tons) in excess of the lower ICIP limit (IP_i) for the reporting year (calculated according to (7)), and I_t is the cost of reducing CO_2 emissions (per ton).

The amount of emissions (in tons) in excess of the lower ICIP value (IP_i) is calculated as follows:

$$E_s = (P_f - IP_i) \times M, \quad (7)$$

Where P_f is the carbon intensity in the reporting year (t CO_2-eq/t of product), IP_i is the lower ICIP value (t CO_2-eq/t of product), and M is annual emissions (t).

These calculations are made for each production stage in the sector, with the results being aggregated to determine the costs of achieving the upper and lower ICIP limits and the price for exceeding the upper limit. The results for all production stages in ferrous metallurgy are shown in Table 1.

Table 1. The price for exceeding the upper ICIP value (IP_l) and the costs of reducing greenhouse gas emissions to the upper (P_t) and lower (P_s) ICIP values: calculation results

Production stage	Installations	The price for exceeding the upper ICIP limit (*PT*), thousand RUB	The cost of reducing GHG emissions to the upper ICIP limit (P_t), thousand RUB	The cost of reducing GHG emissions to the lower ICIP limit (P_s), thousand RUB
Coke	6	141.081	655.376	9830.643
Sinter	8	64.549	426.718	6400.769
Pellets	6	30.431	201.519	3022.788
Cast iron	7	107.615	1010.141	15152.122
Direct reduced iron	2	0	0	0
Basic oxygen furnace steelmaking	6	35.039	368.508	5527.620
Electric arc furnace steelmaking	13	13.769	270.923	4063.851
Total	48	392.485	2933.186	43997.794

The carbon price is set at 1,000 RUB per ton of CO_2-eq. This price is currently enforced in the Sakhalin region as part of an experiment to curb emissions. Considering expert evaluations and pilot project implementations, the cost of reducing emissions per ton of CO_2-eq is estimated at 15,000 roubles. Notably, our analysis reveals that the emission reduction costs (P_t and P_s) are higher than the current carbon price (*PT*) by one or two orders of magnitude, respectively.

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We also found the effective carbon price aimed at achieving the upper ICIP value (Y_{et}) using the formula:

$$Y_{et} = (P_t / PT) \times Y_t \quad (8)$$

The effective carbon price denotes the price at which it becomes more advantageous for businesses to undertake projects aimed at reducing greenhouse gas emissions than to pay the carbon price for exceeding the upper ICIP limit. Based on the calculation results, it can be inferred that the effective carbon price necessary to meet the Strategy's targets should be significantly higher than the current price established in the Sakhalin region, reaching approximately 15,000 RUB per ton of CO_2-eq.

It is worth noting that the relative gross reduction by each individual production stage will be marginal upon reaching the upper ICIP limit. For instance, it will amount to only 2.25% of the current emissions level in coke production.

Likewise, we calculate the carbon price for 1 ton of CO_2-eq that will stimulate more substantial industrial upgrades (Y_{es}), factoring in the cost of reducing emissions to the lower ICIP limit. This calculation follows the formula:

$$Y_{es} = (P_s / PT) \times Y_t \quad (9)$$

In this scenario, the effective carbon price should be approximately an order of magnitude higher, reaching around 112,000 RUB per ton of CO_2-eq.

An alternative to such a substantial increase could involve tightening the Strategy's target indicators. This would necessitate recalibrating ICIP values in the industry using the proposed organizational and economic regulatory mechanism. Such recalibration would establish more ambitious requirements for green projects [11] and increase the number of economic entities obliged to pay fees for greenhouse gas emissions.

A more effective approach would be to update the Strategy's indicators, distributing the financial burden for surpassing established thresholds across a larger number of businesses. This strategy would stimulate more significant and uniform decarbonisation of the industry.

Considering the above, expectations for a substantial increase in the carbon price in near future may be unrealistic. This notion is supported by the experience of gradual price increases for carbon emissions and discharges of pollutants in Russia, which have not fundamentally reduced environmental pollution. Moreover, the essence of the “polluter pays” principle aims to incentivize investment in production upgrades and the development of innovative technologies [9].

Therefore, it is necessary to demonstrate flexibility in employing restrictive and incentive instruments, including government support measures for low-carbon investment projects. Implementing such projects will progressively reduce the carbon intensity of iron and steel production processes, alleviating costs for exporting companies faced with the introduction of CBAM by various importing countries.

For instance, based on export volumes in 2020, the anticipated costs for ferrous metallurgy in the EU could reach up to 100 million euros per year at a rate of 53.5 euros per ton of CO_2-eq. This equates to approximately 10 billion RUB per year at the current EUR exchange rate. The organizational and economic mechanism devised as part of our research could help retain a portion of this sum in Russia's budget by levying emissions

fees within the country. These funds could be earmarked for targeted government support for low-carbon projects [11].

CONCLUSION

The global energy transition within the industrial sector is advocated to be perceived as a qualitative structural transformation and consistent technological evolution aimed at improving resource efficiency and the competitive edge of industrial producers while enhancing their economic viability. Priorities in the domain of sustainable industrial development should revolve around resource and technological modernization, alongside the reduction of carbon intensity in production [12].

Establishing the interrelation between carbon intensity indicators and resource consumption metrics, as well as operating costs per unit of consumed resource, forms the basis for developing a comparative analysis system. This system relies on specialised indicators outlined in the Reference Documents on the Best Available Techniques [2]. For the operational landscape of ferrous metallurgy and its production processes, a framework for comparative analysis has been devised. It is rooted in Indicative Carbon Intensity Parameters, incorporating the connections between resource use, carbon intensity, and the economic facets of resource consumption.

An evaluation was conducted on the anticipated economic impact for both the government and the ferrous metallurgy industry stemming from the adoption of the proposed approaches to regulating carbon intensity in the sector. The effective carbon price for surpassing the established threshold ICIP values, along with the potential costs incurred by exporters of ferrous metallurgy products, were found. The practical implementation of the proposed methodology is poised to mitigate the financial burdens associated with the introduction of Carbon Border Adjustment Mechanisms, channelling corporate resources toward production upgrades.

A promising avenue for further research could involve the expansion and replication of the principles, methodologies, and tools devised during the study of carbon intensity regulation approaches in ferrous metallurgy to encompass other industries. Concurrently, it is important to develop decarbonisation scenarios for industries, assessing the costs associated with technological, organizational, and economic solutions, including carbon dioxide capture, utilization, and storage technologies [13].

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REGULATION OF THE MINERALIZATION AND HUMUFICATION PROCESSES IN NITISOLS FERRALIC AND HUMIC CAMBISOLS BY INTEGRATING ^{14}C-MODIFIED TEA (*Tea Sinensis*) BIOMASS

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ABSTRACT

This work delves into the process of phenolic oxidation products rdistribution in Nitisols Ferralic and Humic Cambisols, which were modified by (^{14}C) introduced tea biomass. Metabolites derived from tea biomass were found to interact with humic and fulvic acids and form covalent bonds with them.

The study of quantitative aspects of the inclusion of phenolic substances in the chemical composition of humic and fulvic acids reveals that humic acids incorporate a significantly greater amount of the radioactive tracer (^{14}C) compared to fulvic acids. By applying the formula derived by us ($D_{CaCO_3 + MgCO_3} = \frac{\mathbf{1{,}45\ Hz}}{\mathbf{6{,}5 - pH}}$) it becomes feasible to determine the soil microliming dosage required to expedite the processes of mineralization and humification of tea plant manure and other residues rich in polyphenolic substances.

Furthermore, it is recommended to apply manganese-based microfertilizers to the soil prior to pruning tea bushes. These agrochemical measures are crucial in optimizing the mineralization of phenolic substances, neutralizing their toxic effects, enhancing the intensity of the humification process, and ultimately increasing soil fertility.

Keywords: soil, tea biomass, humus, microfertilizers, microliming

1. INTRODUCTION

Utilization of extremely toxic pollutants for humans and the environment - phenol and its derivatives - is one of the most important challenges of our time.
Polyphenols originate from plant residues (fallen leaves, shoots, withered parts) and products of mining, chemical processing of industrial enterprises and/or their wastes. It has been found that phenolic compounds in soils decompose slowly but deeper compared to other organic matter [2], [5], [8], [7], [10].
According to some researchers, plant polyphenols affect the soil genesis properties, nutrient cycling, organic matter degradation, mineralization rate, nitrogen (N) availability and humus formation [6], [9]. Soil organic carbon stability is regulated by increased supply of nitrogen (N) and phosphorus (P) [4]. Meanwhile, it is expected that increasing soil pH by liming will promote soil organic carbon accumulation [14].

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The decomposition of tea biomass occurs in Nitisols Ferralic as well as Humic Cambisols, one of the important conditions for its activation is the participation of Mn ions. The mineralization process is active during the first 40 days after the application of manganese sludge and/or $MnSO_4$ to the soil. As the mineralization of tea biomass becomes more intense, the magnitude of the surface reaction of the soil decreases [10].

2 PROCEDURE FOR PAPER SUBMISSION

Our objective was to get involved in the humification of metabolites produced during mineralization of tea cuts rich in phenolic compounds (dried and fallen biomass) in Nitisols Ferralic and Humic Cambisols, to investigate the results of the migration and to determine the potential for optimization.

The experiments were carried out by us with ^{14}C-labeled radioactive tea (Tea Sinensis) plants biomass and according to the developed versions [10].

To isolate humic and fulvic acids from the soils of the study versions, we used the accelerated pyrophosphate method [12], which allowed us to avoid destruction of the preparations.

Humic acids were obtained by us by acidification of the initial solution to pH, and fulvic acids were obtained by the Forsythe method on activated carbon. The obtained preparations were repeatedly re-sedimented and dialyzed against distilled water. The radioactivity of the preparations was measured six times using Ract-Beta-2 scintillation counter and metals in humic and fulvic acid preparations were determined using Perkin Elmer-305B atomic adsorption spectrometer.

3 RESULTS AND ANALYSIS

We studied further redistribution of phenolic oxidation products in soils. For this purpose, humic and fulvic acids were isolated from the study soils, the isolated preparations were purified by methods of multiple re-sedimentation and electrodialysis, after which their radioactivity was determined.

The presented Table 1 shows that humic and fulvic acids isolated from both Nitisols Ferralic and Humic Cambisols contain radioactive carbon (^{14}C). Preparation purification methods suggest that transformed metabolites (residues) of tea biomass interact with humic and fulvic acids and form covalent bonds with them.

Incorporation of the products of mineralization of (^{14}C)-labeled tea biomass into humus content. Radioactivity per 100 mg of the preparation is 10^6 becquerels.

Table 1

№	Test options	Nitisols Ferralic soils		Humic Cambisols	
		Humic acid	Fulvic acid	Humic acid	Fulvic acid
1	Soil+ Tea biomass (reference)	1,44 ± 0,01	0,49 ± 0,02	1,07 ± 0,009	0,17 ± 0,001
2	Reference + Manganese sludge	1,93 ± 0,016	0,52 ± 0,022	1,67 ± 0,015	0,19 ± 0,001
3	Reference + $MnSO_4$	2,28 ± 0,017	0,53 ± 0,022	1,74 ± 0,015	0,21 ± 0,013
4	Reference + $MgCO_3$	3,08 ± 0,019	0,55 ± 0,025	3,0 ± 0,02	0,47 ± 0,02
5	Reference + Manganese sludge + $MgCO_3$	3,86 ± 0,025	0,58 ± 0,02	3,33 ± 0,021	0,51 ± 0,026
6	Reference + $MnSO_4$ + $MgCO_3$	4,66 ± 0,03	0,6 ± 0,03	4,43 ± 0,027	0,54 ± 0,027

When studying the quantitative aspects of phenolic substances inclusion in the chemical composition of humic and fulvic acids, the following results are obtained.

Effect of tea biomass application on the content of iron and manganese forms in red earth soil (Nitisols Ferralic)

Table 2

№	Test option	Fe %		Mn %	
		Total	Mobile	Total	Mobile
1	Soil+Tea biomass (Reference)	11,62 ± 0,08	3,49 ± 0,02	0,13 ± 9,1×10^{-4}	0,011 ± 7,5×10^{-5}
2	Reference + Manganese sludge	11,66 ± 0,081	3,51 ± 0,03	0,132 ± 9,2×10^{-4}	0,014 ± 9,8×10^{-5}
3	Reference + $MnSO_4$	11,67 ± 0,082	3,52 ± 0,03	0,132 ± 9,2×10^{-4}	0,019 ± 13,3×10^{-5}
4	Reference + $MgCO_3$	11,65 ± 0,082	3,46 ± 0,027	0,13 ± 9,1×10^{-4}	0,007 ± 4,6×10^{-5}
5	Reference + Manganese sludge + $MgCO_3$	11,60 ± 0,081	3,48 ± 0,029	0,132 ± 9,2×10^{-4}	0,023 ± 16,1×10^{-5}
6	Reference + $MnSO_4$ + $MgCO_3$	11,69 ± 0,082	3,53 ± 0,031	0,132 ± 9,2×10^{-4}	0,023 ± 16,1×10^{-5}

Humic acids bind much more radioactive label (^{14}C) than fulvic acids. The observed difference in the content of radioactive label content of humic and fulvic acids can be explained by the fact that compared to humic acids, fulvic acids have predominantly aliphatic structures with a lower ability to bind phenolic substances. Chemical analysis of the studied soil samples showed that mobile and common forms of Fe as well as common forms of Mn change insignificantly for all variants of the test for both soils (Tables №2; №3).

Effect of tea biomass application on the content of iron and manganese forms in black soil (Humic Cambisols)

Table 3

№	Test option	Fe %		Mn %	
		Total	Mobile	Total	Mobile
1	Soil+Tea biomass (Reference)	8,65 ± 0,06	2,5 ± 0,02	0,18 ± 1,2×10^{-3}	0,019 ± 1,31×10^{-4}
2	Reference + Manganese sludge	8,71 ± 0,061	2,61 ± 0,02	0,182 ± 1,24×10^{-3}	0,022 ± 1,4×10^{-4}
3	Reference + $MnSO_4$	8,73 ± 0,062	2,62 ± 0,023	0,182 ± 1,25×10^{-3}	0,027 ± 1,8×10^{-4}
4	Reference + $MgCO_3$	8,64 ± 0,057	2,47 ± 0,017	0,18 ±1,22×10^{-3}	0,014 ± 1,8×10^{-4}
5	Reference + Manganese sludge + $MgCO_3$	8,70 ± 0,06	2,62 ± 0,022	0,182 ± 1,26×10^{-3}	0,029 ± 2,1×10^{-4}
6	Reference + $MnSO_4$ + $MgCO_3$	8,62 ± 0,059	2,4 ± 0,015	0,182 ± 1,27×10^{-3}	0,012 ± 8,4×10^{-5}

The mobile form of Mn for red soil tested in the fifth and sixth variants (Reference + Manganese sludge + $MgCO_3$; Reference + $MnSO_4$ + $MgCO_3$) is about 3 times more as compared to the fourth variant (Reference + $MgCO_3$) and twice as more than for black soil. In our opinion, this is due to the chemical activity of the products formed during mineralization. In our published work [10], we noted that the active presence of Mn in the process of tea biomass mineralization was ascertained. At the same time, there are data reported in the scientific literature that polyvalent metals also participate in the transformation of phenolic substances [3], [11]. Based on our studies, it was found that after electrodialysis in humic acids, ash content for red earth soil (Nitisols Ferralic) was 6.3-6.8%, and 3.5-4.6% for humic Cambisols (Table 4).

Content of some chemical elements in humic acids isolated from soils incubated with (^{14}C)-labeled tea biomass

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Table 4

Soil type	Options	Content of ash elements, %					Ash content of the preparation %
		Fe	Mg	Ca	Mn	Cu	
Nitisols Ferralic soils	1. Soil+Tea biomass (Reference)	3,8 ± 0,03	0,56 ± 0,004	0,03 ± 1,8×10^{-4}	0,09 ± 5,8×10^{-4}	0,04 ± 2,5×10^{-4}	6,3 ± 0,04
	6. Reference + $MnSO_4$ + $MgCO_3$	4,3 ± 0,04	0,71 ± 0,005	0,04 ± 2,5×10^{-4}	0,01 ± 6,2×10^{-4}	0,05 ± 2,6×10^{-4}	6,8 ± 0,05
Humic Cambisols	1. Soil+Tea biomass (Reference)	0,71 ± 0,005	0,67 ± 0,007	0,04 ± 2,7×10^{-4}	0,12 ± 6,3×10^{-4}	0,02 ± 1,2×10^{-4}	3,5 ± 0,03
	6. Reference + $MnSO_4$ + $MgCO_3$	1,2 ± 0,008	1,06 ± 0,008	0,04 ± 3,3×10^{-4}	0,14 ± 6,5×10^{-4}	0,15 ± 6,7×10^{-4}	4,6 ± 0,03

It is worth noting that when comparing the reference variant (Soil+Tea biomass) with the experiment variant (Reference + $MnSO_4$ + $MgCO_3$) the total ash content of humic preparation increases. The content of iron, copper and manganese significantly increases in it what is explained by the formation of chelates with phenolic compounds, and in the experimental variant, the increase in Mg content is due to the fact that due to the $MgCO_3$ liming in the soil in the soil increases its total content and, accordingly, the interaction of Mg with humic acid.

Our studies [10] showed that mineralization of tea biomass in red and black soils in the reference variant proceeds with low intensity, which is due to the acid reaction of soils and low redox potential. Under these conditions, polyvalent metals involved in the oxidation of phenolic substances are in a passive state (reduced forms) and/or leached into the lower soil layers. The mineralization process can be activated by soil microliming and application of manganese-free microfertilizers as confirmed by our results [10], according to which this effect continues especially actively during the first 40 days and then significantly decreases. This is due to the gradual withdrawal of manganese from the processes. On the basis of the above, we can propose to apply the necessary amount of manganese microfertilizers in the soil immediately before pruning of the tea bush when developing a practical recommendation.

It is known from scientific literature [1], [13] that liming with $CaCO_3$ leads to a decrease in the quantity and quality of tea leaf yield. According to our estimation, the increase in pH caused by the application of physiologically acidic fertilizers under tea crop should be compensated by microliming. In our experiments, the method of microliming eiyh the amount of $CaCO_3$ + $MgCO_3$ mixture resulting in a pH decrease by only one unit was used. At this time, in both study soil taxa (Nitisols Ferralic and Humic Cambisols) soluble forms of manganese decrease slightly and iron is formed relatively more [10]. The above changes cannot disturb the balance of redox processes in the soil, but only shift it towards

oxidative processes what is justified for these soils (prone to hydromorphic and/or permicidal moisture regime).

A formula was developed to determine the microliming doses:

$$\mathbf{D}CaCO_3 + MgCO_3 = \frac{\mathbf{1{,}45\ Hz}}{\mathbf{6{,}5-pH}}$$

where $\mathbf{D}CaCO_3 + MgCO_3$ is $CaCO_3 + MgCO_3$ (with 4:1 ratio) is the amount reducing pH by one unit per ton ha; pH is the pH of the soil to lime; Hz is the hydrolytic acidity of the soil to lime; 6,5 – is the value of pH obtained by the soil when a full dose of liming si applied; 1,45 is the conversion factor of $CaCO_3$ and $MgCO_3$ mixture. In the numerator of this formula shows the full dose of liming, which when applied to the soil lowers the value of pH to 6.5 with practical results: pH will be reduced to 6,5. To calculate pH unit, this value must be divided by the difference between 6.5 and the pH in the soil.

Based on the results of our research, we believe that it is possible to develop agrotechnical measures aimed at optimizing the mineralization of tea biomass rich in phenolic compounds, which will not only neutralize their toxic effect, but also increase the amount of humic acids and improve soil fertility. Such activities include operations such as microliming with a mixture of $CaCO_3 + MgCO_3$ and/or fertilizers containing these components and the application of microfertilizers containing manganese.

4 CONCLUSIONS

1. The activity of the mineralization process of tea biomass rich in polyphenolic compounds can be increased by microliming Nitisols Ferralic and Humic Cambisols and applying manganese-free microfertilizers;

2. In the process of mineralization, transformation products of phenolic substances connect humic and fulvic acids by covalent bonds;

3. Manganese ions added to accelerate the process of biomass mineralization are bound by humic and fulvic acids;

4. The doses of microliming required to accelerate the mineralization and humification process of phenolic-rich tea plant prunings and other residues can be calculated using the formula deduced by us ($\mathbf{D}CaCO_3 + MgCO_3 = \frac{\mathbf{1{,}45\ Hz}}{\mathbf{6{,}5-pH}}$). At the same time, manganese microfertilizer should be applied to the soil before pruning the tea bush.

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RISK ASSESSMENT OF CHEMICAL SUBSTANCES IN THE ATMOSPHERIC AIR AS INDICATOR OF THE ROAD TRAFFIC IMPACT ON THE CHILDREN'S HEALTH IN THE CITY OF KAZAN

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ABSTRACT

Assessment of non-carcinogenic risk for the child population health from chemical substances taken with the motor vehicle exhaust gases in 4 districts of the city of Kazan based on the monitoring data from FSFHI "The Center of Hygiene and Epidemiology in the Republic of Tatarstan" for the period from 2015 to 2021 was carried out. The average annual concentrations of chemical substances exceeded the allowable level of standards (MAC) from 2.32 to 9.96 of MAC in all zones. The value of the total daily dose on the inhalation route of the substances' intake with atmospheric air (I) made 1.09 – 10.33 mg/(kg x day) depending on the zone. An unacceptable level of non-carcinogenic risk (HI>3.0) was determined in all zones. In zones 2 and 4, the major impact on the RS was made by soot (HI 13.1), in zone 1 – by complex intake of all fractions of suspended particulate matters, with maximal level of PM 2,5 (HI =5.98), in zone 3 – by intake of PM 10 (HI 7.83). Black carbon (BC) was found to be an important indicator, as well as PM 2,5 and PM 10, for assessing the road traffic impact on the air quality and health. The children living in zones 2 and 4 are most vulnerable to non-carcinogenic risk as far as the respiratory system, which is formed due to complex intake of BC, PM 10 and PM 2,5. Transition to a complex assessment of risk from chemical substances with the account of contribution of certain substances is an important decision in determining the priority actions for minimizing the children's health risk at regional level.

Keywords: air pollution, non-carcinogenic risk, contribution of chemicals, road transportation, children.

INTRODUCTION

The results of numerous modern studies show that motor vehicle transport is the priority source of impact on the population health and the atmospheric air pollution in the city's residential areas [1]. Combination of unfavorable meteorological, transport and urban planning conditions within the city limits forms high air pollution with hazardous pollutants, which are evolved with vehicle exhaust gases. Particulate matters PM 10 and PM 2,5 , which pose a serious threat to the population health due to their ability to

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adsorb toxic and carcinogenic substances on their surface, and due to their micro-dimensions, to enter the human blood system, increasing the risk of brochopulmonary, cardiovascular and oncological diseases, are among the most hazardous toxicants entering the air during the vehicles' operation. Children, due to their age peculiarities and toxicokinetic mechanisms, are most exposed to environmental chemical factors [2]. The methodology of the population health risk assessment allows ranking the areas according to the levels of the habitat pollution with the account of the health hazard and is used when taking the most effective measures to minimize negative consequences of the chemicals' effect [3]. The atmospheric air quality is a pressing issue for the population of the city of Kazan as well, because it is exposed to the atmospheric pollutants, the percentage of which exceeds regional standards and air quality standards established by WHO.

MATERIALS AND METHODS

The risk assessment procedure was performed according to algorithms and criteria given in Guidelines R 2.1.10.3968-23 [4] based on the research findings of "The Center of Hygiene and Epidemiology in RT (Tatarstan)" for the period from 2015 to 2021. Monitoring of atmospheric air is carried out at research points, where control of the motor vehicle chemical emissions, being on the list of Russian and international priority pollutants, is performed. The calculation of daily doses on chronic inhalation intake (I) was carried out at the level of upper 95-th % confidence limit of average annual concentrations of chemical substances at the following monitoring points: zone 1 – Model'naya str., Privolzhsky district; zone 2 – the Gorky Highway (Gorkovskoye shosse), Kirovsky district; zone 3 – Victory Avenue (Prospect Pobedy), Privolzhsky district; zone 4 – the Siberian Highway (Sibirsky tract), Sovetsky district according to formula:

$I = [(Ca \times Tout \times Vout) + (Ch \times Tin \times Vin)] \times EF \times ED/(AT \times BW \times 365)$ (1), where Ca – substance concentration in the atmospheric air, mg/m; Ch - substance concentration in the indoor air, mg/m 3 (1,0*Ca); Tout - the time spent outdoors, 8 hours /day; Tin - the time spent indoors, 16 hours /day; Vout – breathing rate outdoors, 1.4 m 3 hour; Vin - breathing rate indoors, 0.63 m 3 /hour; EF – exposure frequency, 350 days/year; ED – exposure duration, 6 years; BW – body weight, 15 kg; Exposure averaging period, children: 6 years. Subject for research: children aged from 3 to 7 years old living in these districts. The risk was assessed according to the hazard quotient of developing non-carcinogenic effects (HQ) for certain substances, where HQ = 0.11-1.0, it being acceptable. When assessing the total effect of the substances with unidirectional effect the level of HI=3.0 was used as an acceptable one, provided that the hazard quotient (HQ) exceeded 1.0 in none of the pollution components. To reveal differences between the zones, the Kolmogorov- Smirnov nonparametric test at the value of ($p<0.05$) was used.

Aim of the work – to assess non-carcinogenic health risk for the child population living in certain zones of the city of Kazan.

RESULTS

Kazan is one of the largest industrial, financial and shopping centers of Russia with the developed infrastructure and intensive motor vehicle traffic. The selected zones differ in the volume of traffic load and architectural and planning conception of the city districts, and this fact specifies the peculiarities of the level of the atmospheric air pollution [5]. Analysis of average annual concentrations of chemical substances in all zones showed the exceedance of allowable levels given in standards (MAC): BC (from 2.32 to 9.96 of MAC), suspended solids (from 4.3 to 5.5 of MAC), suspended solids PM_{10} (from 4.4 to 5.75 of MAC), suspended solids $PM_{2.5}$ (from 4.0 to 6.3 of MAC) (Tab. 1).

Table 1. Average annual concentrations of the substances under analysis (95 %) in the city zones (the years 2015 - 2021), mg/m^3.

Substances	MAC mg/m^3	zone 1 [a]C mg/m^3	zone 2 [a]C mg/m^3	zone 3 [a]C mg/m^3	zone 4 [a]C mg/m^3
NO calculated with reference to NO_2	0.06	0.05	0.056	0.041	-
Black carbon (BC)	0.025	0.058	0.249	0.109	0.24
PM	0.075	0.322	0.374	0.414	0.336
PM10	0.04	0.176	0.219	0.23	0.195
PM2,5	0.025	0.1	0.113	0.126	0.112
Nitrogen dioxide (NO2)	0.04	0.094	0.24	0.118	0.264
Sulphur Dioxide	3.0	-	6.385	4.18	6.322
Formaldehyde	0.003	-	0.015	0.01	0.014
Benzo(a)pyrene	0.000001	-	-	-	-
Benzol	0.005	-	0.0006	-	-

[a]C – substance concentration (mg/m^3)

Minimal values in the zones exceed the intermediate target indicator of WHO for given substances as well [5]. If during the year the substance concentration was registered at the level under the method detection limit in more than 95 % of samples, it was excluded from the risk assessment. The maximum exceedance of MAC was revealed in zones 2 and 3, which were characterized by high truck traffic load. Significant differences were found between all substances: in zone 4 (Sibirsky tract), in the level of nitrogen dioxide (in terms of NO_2) with all the rest districts: the p-val comparison in the zones «4-3» and «4-1» made $p < 0.005$, and between zones «4-2» with confidence level of $p < 0.025$. The concentrations of TSP in zone 2 (Gorkovskoye shosse) significantly exceed the level of this indicator in zone 1 (Model'naya str.): p-val ($p<0.025$). The average annual values of (95% Perc) carbon (soot) with confidence of $p<0.025$ are higher in zone 2 (Gorkovskoye shosse), than in zone 3 (Prospect Pobedy), p-val $p<0.005$. The excess concentration level of $PM_{2,5}$ in zone 3 (Prospect Pobedy) compared with zone 1 (Model'naya str.) made: p-val $p<0.025$. There are no significant differences between the rest districts.

The maximum value of the total exposure (I) on the inhalation effect of substances with the atmospheric air in 95 %, was identified in zones 2 and 4: 10.8 - 10.33 mg/(kg x day), correspondingly; the minimum value was determined in zone 1 - 1.09 mg/(kg x day)). The major contribution to the total daily dose in zones 2-4 was made by CO_2 (from 79.9% to 84.5%). Zone 1 differed from them, here the exposure was formed by 40% due to the intake of PM: 21.8 % - PM_{10}, 12.5% - $PM_{2,5}$ and 11.7%. – nitrogen

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dioxide. Chronic exposure of the population to the aerotechnogenic pollutions in all zones was characterized by an unacceptable level of non-carcinohenic risk (HI=3.0) as far as suspended solids, BC, formaldehyde and nitrogen dioxide. The maximum total risk was registered in the 2nd zone: HI =53.5 (Tab. 2).

Table 2. Indices of total risk of non-carcinogenic effects from chemical substances polluting the atmospheric air for the child population of the city of Kazan by city zones, (95 %)

Zones	1	%	2	%	3	%	4	%
TSP	5.85	22.31	6.8	13.7	7.5	18.6	6.1	13.1
NO_2	1.70	12.35	1.90	15.29	1.40	10.07	8.98	12.64
NO calculated with reference to NO_2	-	4.39	-	2.38	-	2.34	-	-
Carbon oxide	-	-	2.89	5.42	1.89	4.7	2.86	6.05
Black carbon	1.58	12.26	6.77	25.4	2.98	14.94	6.54	27.65
TSP	5.85	22.62	6.79	12.73	7.52	18.83	6.10	12.87
PM10	4.78	23.14	5.96	13.97	6.26	19.61	5.32	14.05
PM2,5	9.10	21.12	10.28	11.5	11.50	17.2	10.18	12.90
Formaldehyde	-	-	6.86	12.8	4.85	12.16	6.54	13.81
Benzol	-	-	0.02	0.32	-	-	-	-
Phenol	-	4.08	-	-	-	-	-	
HI	25.8	100	53.5	100	39.95	100	47.36	100

The major contribution to the value of total risk (HI) in zones 1, 3 is made by suspended solid fractions (55.7% - 66.9%) in total. The percentage of soot and nitrogen dioxide makes from 10 to 14%. A specific feature of zones 2 and 4, apart from the availability of suspended particulate matters, is high contribution of soot (25.4% - 27.7%) and formaldehyde (12.8 % - 13.8%). When assessing the total impact on the same organs and systems, the hazard quotient (HQ) exceeded 1.0 in all pollution components. This being the case and according to [6] in zone 1 (Model′naya str.), the risk for the respiratory system (RS) and mortality is determined by the complex intake of all suspended solid fractions, with maximum level of $PM_{2,5}$ (HI =5.98), and this corresponds to the alert level criterion; in zone 2, the risk for RS is formed due to the availability of BC (13.56), the risk of premature mortality and cardiovascular diseases – by the fraction of PM_{10} (HI =7.46) (Tab. 3).

Table 3. Risk indicators from the general toxic action of chemical substances in the atmospheric air on the bodily organs and systems, (HI)

Systems	zone 1	zone 2	zone 3	zone 4
RS	5.98	13.56	7.83	13.1
Mortality	5.98	7.46	7.83	6.66
CVS	5.98	7.46	7.83	6.66

The general toxic action of PM_{10} (HI 7.83) in zone 3 is responsible for the RS, mortality and cardiovascular diseases. In zone 4, BC (HI 13.1) has a major effect on the RS, and PM_{10} (HI 6.66) – on mortality. Based on the results of the analysis of complex

intake of chemical substances, a high non-carcinogenic risk (HI more than 6.0) for the respiratory system, the cardiovascular system and mortality caused by association of suspended solid fractions, soot, formaldehyde and nitrogen dioxide for the child population of the city of Kazan is formed in the 2nd, 3rd and 4th zones of the city, and the alert risk -in the 1st zone (HI = 3.1-6.0). The main uncertainties having effect on the findings of our research are as follows: application of standard exposure factors, which do not take into account regional climatic peculiarities, and that fact can decrease considerably the time of children's staying outdoors in autumn and winter periods.

DISCUSSION

The obtained results confirm that air pollution is responsible for a range of adverse health outcomes, affecting multiple organs and systems of the human body [7, 8]. A high level of non-carcinogenic risk for the respiratory system (HI 5.98 - 13.56), the cardiovascular system (HI 5.98 - 7.83), and mortality (HI 5.98 - 7.83) due to association of the fractions of suspended particulate matters, soot, the intake of formaldehyde and nitrogen dioxide was identified in children in all zones. Rice [9] showed that even low levels of air pollution including $PM_{2,5}$ and soot affected the children′s respiratory health, and measures on improving air quality could be insufficient for provision of their normal lung function. According to the results of research, living or attending schools by the sides of the roads with high traffic density exposes children to the impact of higher levels of air pollutants emitted by motor vehicles, and increases the incidence of asthma and dyspnea in children [10]. Granulometric and chemical composition of the road dust is important in assessing the city atmospheric pollution with particles of various diameter, because vehicle traffic brings to blowing them off the roadbed, and this fact results in the intake of about 37% of PM_{10}, 15% of $PM_{2,5}$ and 3% of PM_1 of the total motor vehicle emissions [11]. Our research shows that black carbon (BC) is an important indicator, as well as $PM_{2,5}$ and PM_{10}, for assessment of the road traffic′s impact on the air quality and health. Thus, in zones 2 and 4 with maximal level of the total hazard quotient, the contribution of BC to the risk formation makes 25.4% and 27.7%, correspondingly, at the total proportion of $PM_{2,5}$ and PM_{10} equal to 16.2% and 15.5%. And these zones are characterized by intensive traffic of heavy diesel- powered vehicles. The findings of Taheri [12] showed a direct contribution of the park of diesel vehicles to fresh BC and mass fraction of BC in $PM_{2,5}$, where about 17% of the total mass of $PM_{2,5}$ were identified as BC. Therefore, PM_{10} and $PM_{2,5}$ can be suitable indicators when considering the impact of the road dust resuspending, whereas black carbon is a more sensitive indicator of the exhaust gas emissions from the vehicle diesel engines when assessing the road traffic impact on the air quality. Epidemiologic data show that associations with NO_2 indicate the impact of other air pollutants, mainly of PM or other components of a complex mixture of the air pollutants associated with the road traffic, on the human health, rather than an adverse effect of NO_2 itself [13]. The given situation is registered in our research in zones 2 (Gorkovskoye shosse) and 4

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(Sibirsky tract) with maximal values of NO_2, where children are more vulnerable to non-carcinogenic risk for RS, which is formed due to high soot concentrations, and the risk of premature death and cardiovascular diseases – due to the PM_{10} fraction. However, during the ecological-geochemical assessments of the transport effect on the population health and the environment one should pay attention not only to the large highways, but to the inter-block streets with light traffic flow, where the increase of the $PM_{2,5}$ and PM_{10} concentrations and their enrichment with heavy metals and BC due to the low wind speed takes place, thereby intensifying the air pollution in the residential areas as well [14].

CONCLUSION

An unacceptable level of non-carcinogenic risk (HI>3.0) was determined in all zones. Exceedance of average annual levels of PM2,5 and PM10 concentrations recommended in a new edition of WHO on the air quality by a factor of 20 and 11.7 correspondingly was established. The children living in zones 2 and 4 are most vulnerable to non-carcinogenic risk as far as the respiratory system, which is formed due to complex intake of soot, PM10 and PM2,5. The significance of the city territory ranking on the basis of quantitative assessments of the risk of the air pollution impact on the population health increases, because according to the research findings all districts of the city of Kazan are classified as polluted ones. To provide a strong foundation for quality management of the air with several pollutants, the transition to a complex assessment of the chemicals' effect with the account of contribution of certain compounds or their combination, which are apparently the leading factors, being responsible for the impact on the children's health, is required at the regional level. Transition to a complex assessment of risk from the chemicals entering with the motor vehicle emissions reflects the specificity of the atmospheric air quality in the regional level territories. It is an important supporting tool in taking the priority actions for minimizing the population health risk. The long-term trend of the motor vehicle contribution as a major source of the atmospheric air pollution, evaluated on the observation data, is required for objective quantitative assessment.

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SPATIO-TEMPORAL ANALYSIS OF EUTROPHICATION AND HABITAT LOSS IN COAS3TAL LAKES: A CASE STUDY FROM THE KAMCHIYA-SHKORPILOVTSI SECTOR, BULGARIAN BLACK SEA COAST

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ABSTRACT

The study presents the first comprehensive spatio-temporal analysis of eutrophication and the consequent loss of sensitive aquatic habitats in the transitional water bodies along the Kamchiya-Shkorpilovtsi sector of the Bulgarian Black Sea coast. The research focuses on the Maznia Azmak Lake, an old Kamchiya riverbed integral to the Kamchia Nature Reserve and two Natura 2000 protected areas. The primary objective was to assess the scale and rate of eutrophication and its impact on aquatic habitats, employing modern methodologies such as drone surveys, high-precision GPS geodetic measurements, and bathymetric investigations. Data was gathered from 2019 to 2023, including key physicochemical parameters (pH, dissolved oxygen, conductivity, temperature, chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen, and phosphorus). Results indicate that Maznia Azmak Lake exhibited stable pH levels (7.8-8.3) and increasing conductivity (up to 964 µS/cm), with dissolved oxygen levels varying significantly (4.8-9.3 mg/l). The lake's COD and BOD values suggested moderate organic pollution, with nutrient levels remaining low. Seasonal salinity variations were observed, correlating with low summer water levels and sea wave activity. The macrophyte analysis revealed a heterogeneous mix of species with minimal helophyte dominance. Popovo Blato Lake demonstrated low dissolved oxygen levels and high conductivity (peaking at 992 µS/cm), with COD reaching 40.6 ml O2/l in September 2023, indicating severe organic pollution. Conversely, Petrovo Blato Lake had variable dissolved oxygen and high conductivity, with low nutrient levels, though occasional COD and BOD peaks suggested episodic pollution events. The mouth of the Fandakliyska River, showing stable pH and conductivity, had relatively higher dissolved oxygen levels, pointing to better overall water quality compared to the lakes. This area's episodic pollution events were reflected in variable COD and BOD values. The results underscore the critical need for ongoing monitoring and targeted interventions to mitigate pollution and preserve these vulnerable aquatic habitats. This pioneering study contributes valuable baseline data and insights into the eutrophication processes affecting the Bulgarian Black Sea coast, emphasizing the importance of preserving these ecosystems for their biodiversity and ecological services.

Keywords: eutrophication, aquatic habitats, coastal lakes, GIS analysis, Bulgarian Black Sea coast

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INTRODUCTION

Environmental changes resulting from human activities profoundly impact the delicate balance of ecosystems within inland waters, seas, and oceans. Transitional waters, such as estuaries, lagoons, and the hygrophilous forests found along the Bulgarian Black Sea coast, are particularly susceptible to these changes. These ecosystems are exceptionally vulnerable to pollution and alterations in hydrological patterns [1].

Among these ecosystems, the longnose type's mixed lowland and riparian forests are significant components of the intrazonal vegetation found in Bulgaria's river valleys. These forests experience periodic flooding and, in some instances, exceedingly high humidity levels. The soils underlying these forests can alternate between being well-drained during dry periods and remaining moist during inundations. The dominant tree species vary depending on the water regime, although they often belong to the genera Fraxinus, Ulmus, or Quercus. The surrounding zonal vegetation strongly influences the ground cover, characterized by a diverse array of plant species. These mixed lowland forests, found along riverbanks and in dense thickets, are classified within the Populetea albae class of the Fraxinetalia and Populetalia orders, as well as the Alno-Quercion roboris and Alnion incanae alliances [2]. In essence, these ecosystems represent critical habitats supporting a rich biodiversity but are also at significant risk due to human-induced environmental changes. Protecting and conserving these ecosystems is essential for their intrinsic value and the numerous ecological services they provide. Efforts to mitigate anthropogenic impacts and preserve the integrity of these ecosystems are imperative for the well-being of both local and global environments.

The primary objective is to comprehensively analyze the spatio-temporal changes, scale, and rate of eutrophication occurring in the wetlands and coastal lakes within the Kamchiya-Shkorpilovtsi coastal sector. Additionally, this analysis aims to assess the consequent loss of sensitive aquatic habitats, which are crucial for conservation efforts.

SURVEY AREA

A highly modified coastal lake called Maznia azmak, an old Kamchiya riverbed, was chosen as a study area. It is located in the river's lower reaches, adjacent to its mouth of the estuarine type. The research site is an integral part of Kamchia Nature Reserve and two Natura 2000 protected areas, i.e., BG0002045 Komplex Kamchia (Birds Directive) and BG0000116 Kamchia (Habitats Directive) [3].

The study area covers part of the dense forest south of the Kamchia River, including the wetland in it, namely the so-called Maznia azmak (Fig. 1).

DATA AND METHODS

Indicators used. The requirement to use aquatic macrophytes as one of the biological quality elements in water monitoring was set in 2000 in the Water Framework Directive of the European Union. Numerous water status assessment systems based on aquatic macrophytes have been developed and implemented in Europe [6],[7],[8],[9].

Combining modern bathymetric surveys and assessment of the environmental status, including the analysis of basic physicochemical parameters, allows for a comprehensive analysis of the population parameters of ichthyofauna in brackish waters.

Field research. The field studies conducted during 2023-2024 within the framework of the "Conservation of Dunes along the Bulgarian Coastline" project employed a comprehensive approach integrating drone surveys, geodetic measurements using high-precision GPS, and bathymetric investigations [10].

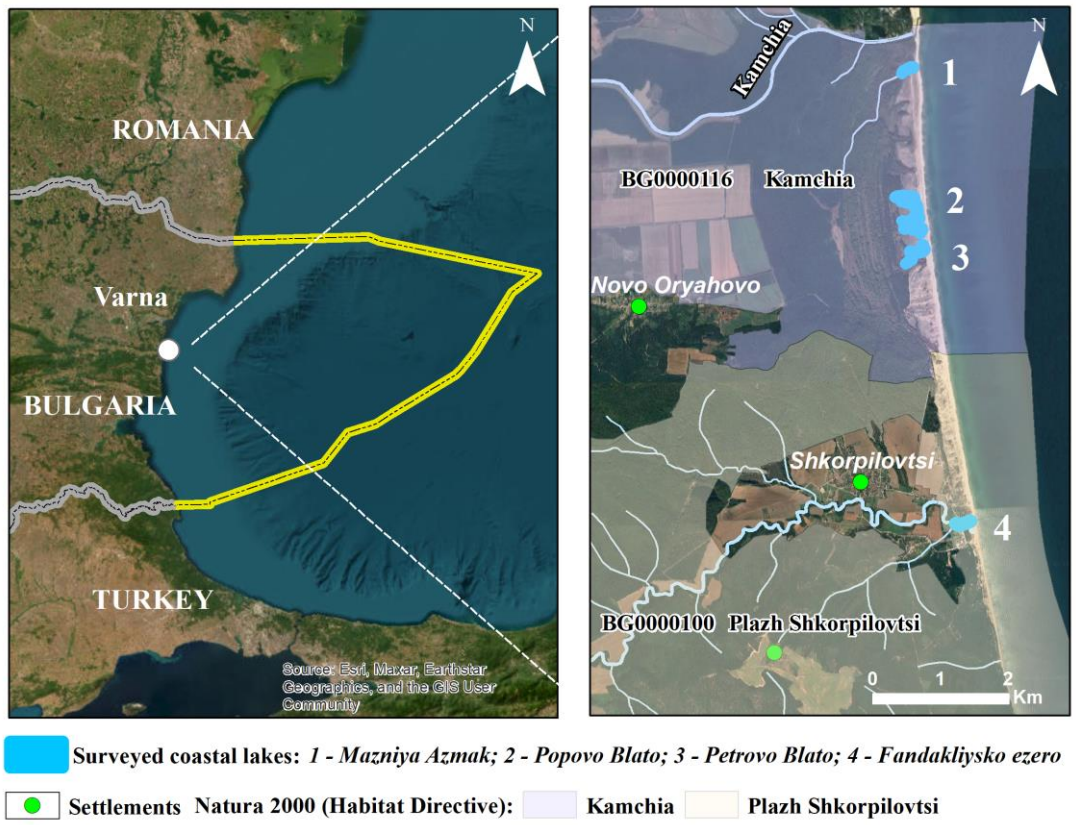


Fig. 1. Location of surveyed wetlands - coastal lakes at Kamchiya-Shkorpilovtsi coastal sector, Bulgarian Black Sea Coast

Drone Surveys and Geodetic Measurements. Drone imagery was utilized to capture high-resolution aerial views of the study areas. These images provided valuable data for assessing dune morphology, vegetation cover, and coastal dynamics. Geodetic measurements were performed using high-precision GPS equipment to accurately determine key points' coordinates and elevation profiles within the study sites [12],[13]. The Survey appy drones DJI Phantom IV RTK Quadcopter and Vertical take-off and landing system (VTOLS) WingtraOne for mapping the Bulgarian Black Sea coastal zone is based on the UAS approach [11]. This implies the use of reference and control geodetic points. The control measurements were made with an RTK GPS receiver called HiTarget V90Plus, which provided high enough coordinate accuracy through a certified RTK network in Bulgaria. The achieved horizontal accuracy of 2 cm and height accuracy of 3 cm guarantee high spatial reliability of the conducted surveys. In such specialized studies, the specific nature of UAVs requires optimal hydrometeorological conditions (sufficient sunlight, purity and low turbidity of seawater and wind speed below 5 m/s.

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Bathymetric Surveys. In lakes, bathymetric surveys were conducted using a flat-bottomed inflatable boat equipped with GPS technology. This approach enabled the mapping of submerged features and the precision measurement of water depths. Additionally, in the Skorpilovtsi Marsh, highly accurate bathymetric surveys were carried out using a single-beam echo sounder mounted on a boat. These surveys provided detailed depth profiles crucial for understanding the hydrological dynamics of the marsh ecosystem [10],[11].

Integration of Previous Bathymetric Data. Furthermore, to enhance the comprehensiveness of the bathymetric data, information from previous surveys was integrated into the analysis. This inclusion allowed for a comparative assessment of changes in water depth and sediment distribution over time, contributing to a more holistic understanding of the studied environments [10],[11]..

Data processing. The flight data were processed using the software Agisoft Photoscan Professional, Pix4Dmapper, and Global Mapper, which allowed for the comparability of results and the isolation of statistical errors through analysis and interpretation of the obtained data [10],[11].

Physical and chemical measurements. The physicochemical parameters were sampled with standardized equipment for analysis of water samples HQ30D.99.000000: HQ30D Digital portable multimeter, equipped for measuring pH and dissolved oxygen (optical technology).

RESULTS AND DISCUSSION

The results present the physicochemical parameters of four water bodies (Mazniya Azmak Lake, Popovo Blato Lake, Petrovo Blato Lake, and the mouth of the Fandakliyska River) over a five-year period from 2019 to 2023. The data includes measurements of pH, dissolved oxygen, conductivity, temperature, chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen, and total phosphorus. These indicators were classified according to their state as per Regulation № H-4 of September 14, 2012.

Table 1. Physicochemical indicators of the environment for 2019 - 2023 and their state classification according to regulation № H-4 of September 14, 2012, on the characterization of surface waters.

Area	Year	Month	pH	Dissolved oxygen [O_2 mg/l]	Conduc-tivity [µS/cm]	Tempera-ture [°C]	COD [ml O_2/l]	BOD [mg O_2/l]	Total nitrogen [mg/l]	Total phos-phorus [mg/l]
Mazniya azmak lake	2019	4	7.8	6.3	563	11.8	4.17	2.9	1.21	0.21
		9	8.1	8.6	786	21.3	6.2	5.11	4.1	1.03
	2020	4	8	5.9	601	10.4	5.13	3.1	2.01	0.25
		9	8.3	9.1	844	20.8	7.14	5.6	3.6	0.98
	2021	4	7.9	7.3	614	13.6	5.26	3.3	1.98	1.56
		9	8.1	6.4	781	18.6	5.64	1.3	1.7	0.562
	2022	4	8.1	6.5	801	13.4	6.13	2.6	<0.5	<0.01
		9	8	4.8	836	19.1	4.28	1.2	<0.5	<0.01
	2023	4	7.8	6.4	964	14.2	7.45	2.9	<0.5	<0.01

Area	Year	Month	pH	Dissolved oxygen [O_2 mg/l]	Conduc-tivity [µS/cm]	Tempera-ture [°C]	COD [ml O_2/l]	BOD [mg O_2/l]	Total nitrogen [mg/l]	Total phos-phorus [mg/l]
		9	7.9	9.3	878	19.4	6.55	1.1	<0.5	<0.01
Popovo blato lake	2019	4	8.1	4.12	864	10.2	27.3	4.8	0.9	0.364
		9	7.9	3.27	992	18.6	30.8	5.9	1.2	0.459
	2020	4	7.6	5.21	624	12.5	16.8	3.5	<0.5	<0.01
		9	8.1	2.98	848	19.1	28.2	5.9	<0.5	<0.01
	2021	4	8.1	6.1	933	8.8	26.6	6.1	<0.5	<0.01
		9	8.1	4.2	965	20.1	31.1	6.4	1.1	<0.01
	2022	4	7.8	5.9	765	11.1	22.5	5.2	<0.5	0.118
		9	8	3.2	644	21.1	12.1	4.8	<0.5	<0.01
	2023	4	8	4.8	820	8.4	28.8	5.2	0.8	0.016
		9	8	2.7	835	19.6	40.6	6.1	<0.5	<0.01
Petrovo blato lake	2019	4	8	5.6	625	10.4	26.2	5.2	<0.5	0.022
		9	7.6	4.2	705	19.8	31.1	4.4	0.9	<0.01
	2020	4	8	6.1	642	11.6	28.4	5.1	<0.5	<0.01
		9	7.9	4.3	732	19.3	29.5	4.4	1.3	0.034
	2021	4	7.9	7.1	822	9.1	30.6	5.5	<0.5	<0.01
		9	7.9	2.4	865	19.8	26.4	3.3	<0.5	<0.01
	2022	4	8	2.2	799	10.9	18.5	3.2	0.6	0.062
		9	8	7.3	843	20.9	20	1.8	0.7	<0.01
	2023	4	8	3.1	865	8.8	19.9	1.9	<0.5	<0.01
		9	7.8	4.5	781	19.8	32.2	4.6	1.1	<0.01
The mouth of the Fundakliyska river	2019	4	8.1	6.4	640	7.4	12.7	3.1	0.8	0.137
		9	8.1	5.8	592	18.4	6.6	1.3	0.8	<0.01
	2020	4	8.1	6.8	662	10.4	24.7	5.1	<0.5	0.166
		9	8.1	7.3	541	19.2	8.3	2	<0.5	0.459
	2021	4	8	6.4	625	11.6	21.1	3.3	0.7	0.028
		9	8	8.1	578	19.6	16.8	4.6	<0.5	<0.01
	2022	4	8	5.6	712	12.2	30.2	5.2	1	<0.01
		9	8.1	8.8	764	18.4	27.7	5.4	<0.5	0.027
	2023	4	8	6.2	689	10.6	8.2	1.3	1.2	<0.01
		9	8.1	7.6	656	20.1	9.3	2.1	<0.5	<0.01

*blue – “very good” condition; green – “good” condition; yellow – “moderate” condition

Mazniya Azmak coastal lake

The pH levels in Mazniya Azmak Lake remained generally stable, ranging between 7.8 and 8.3 over the five-year period. Dissolved oxygen levels varied from 4.8 to 9.3 mg/l, with lower values recorded in 2022 and a noticeable increase in 2023. Conductivity showed a trend of increasing, reaching a peak of 964 µS/cm in April 2023. The water temperature ranged from 10.4°C to 21.3°C, showing expected seasonal variations. The chemical oxygen demand (COD) and biological oxygen demand (BOD) showed moderate values, with occasional peaks in COD, such as 7.45 ml O2/l in April 2023.

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Both total nitrogen and phosphorus levels were generally low, with total phosphorus dropping below detectable levels in 2022 and 2023.

Mazniya Azmak Lake showed stable pH levels and a general increase in conductivity over the years, suggesting a gradual accumulation of dissolved salts or pollutants. The dissolved oxygen levels were adequate for most of the period but exhibited lower values in 2022, which could indicate episodic stress on aquatic life. The moderate COD and BOD values and low nutrient levels suggest that organic pollution is present but not at critical levels. The occasional peaks in COD, such as in April 2023, could be attributed to seasonal agricultural runoff or localized pollution events. The classification of most indicators as "good" or "very good" reflects the relatively stable condition of this lake.

During the monitoring measurements, salt intrusion was established due to low water levels and the strong influence of sea wave activity. This phenomenon was observed only in the low summer water of 2020. Despite its proximity to the sea, the observed wetland has the nature of standing water [12],[13]. The main physicochemical parameters of the environment for the period 2019-2021 are listed in Table 1. The data analysis on the physicochemical indicators showed that after the summer season, there was an increase in nutrients, as well as an increase in electrical conductivity and salinity during the summer season of observation periods. Conditions varied from almost constantly fresh to strong seasonal salinity within 2-5 ‰ for the period 2020-2023.

Research on macrophytic vegetation found highly heterogeneous types with large variability of macrophytic overgrowing. Helophytes never dominated against the water mirror (usually ≤2% coverage). The following helophytes were often abundant: *Juncus effusus, Lycopus europaeus, Persicaria hydropiper.* According to Kohler (1978) [14]. the total abundance of macrophytes did not exceed 3. Total coverage most often 1 ÷ 5% (according to EN14184: 2003). Other typical species were *Ruppia maritima, Nymphaea alba, Potamogeton pectinatus, Lemna minor, Lemna gibba, Typha angustifolia, Typha latifolia, Phragmites communs, Myriophyllum spp., Carex spp., Scirpus spp., Shoenoplectus litoralis, Enteromorpha spp., Cladophora spp.*

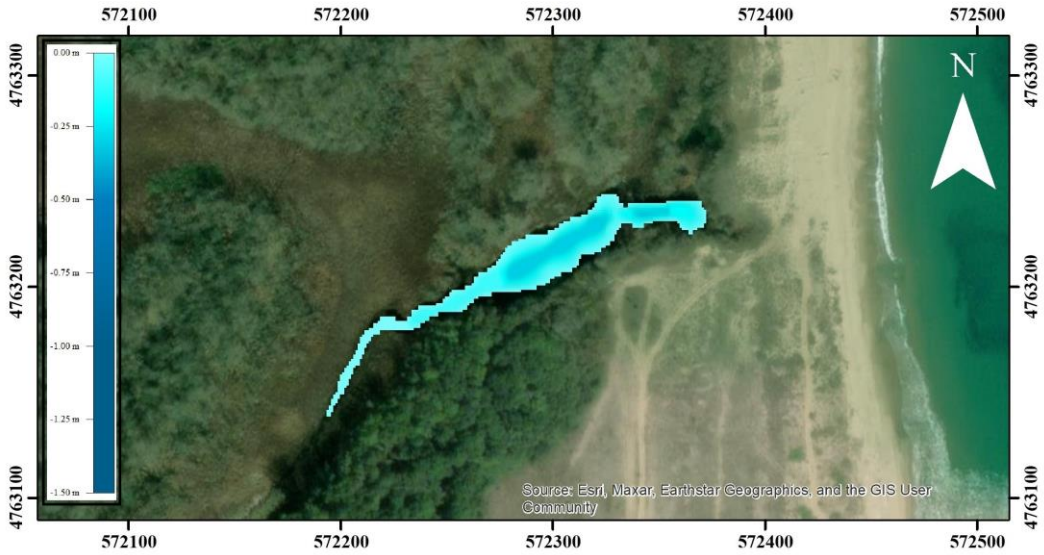


Fig. 2. Digital bathymetric model of the water area of the Mazniya Azmak coastal lake (for location, see №1 on Fig.1)

Popovo Blato coastal lake

The pH levels in Popovo Blato Lake remained mostly around 8.0. Dissolved oxygen levels were consistently low, often falling below 5 mg/l. Conductivity was high, peaking at 992 µS/cm in September 2019. The temperature ranged from 8.4°C to 21.1°C. The COD values were high, notably reaching 40.6 ml O2/l in September 2023. BOD levels were also high, often exceeding 5 mg/l. Total nitrogen and phosphorus were typically low, with phosphorus often falling below detectable levels.

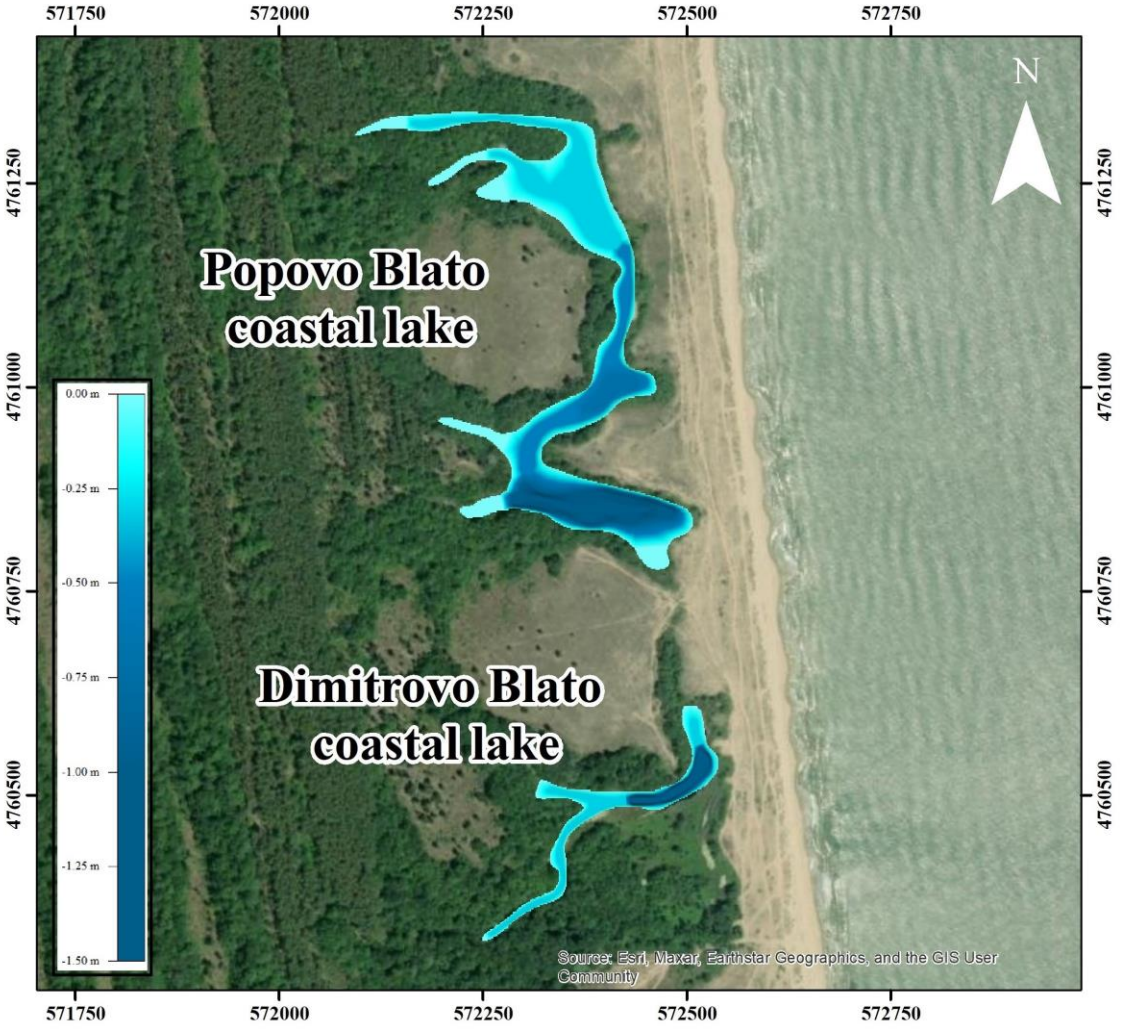


Fig. 3. Digital bathymetric model of the Popovo Blato and Dimitrovo Blato coastal lakes (for location, see №2-3 on Fig.1)

Popovo Blato Lake exhibited consistently low dissolved oxygen levels and high conductivity, indicating significant pollution stress. The high COD and BOD values throughout the period suggest substantial organic pollution, likely from agricultural runoff, wastewater discharge, or other anthropogenic sources. The low nutrient levels, with occasional detectable nitrogen, imply that nutrient pollution is not as severe as organic pollution. The high COD values, peaking at 40.6 ml O2/l in September 2023, highlight this lake's critical need for pollution control measures. The frequent classification of indicators as “moderate” underscores the ongoing environmental challenges faced by Popovo Blato Lake.

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Petrovo Blato coastal lake

The pH levels in Petrovo Blato Lake were around 8.0, with minor fluctuations. Dissolved oxygen levels were generally low, varying from 2.2 to 7.3 mg/l. Conductivity was variable but high, peaking at 865 µS/cm. Seasonal temperature variations were observed, ranging from 8.8°C to 20.9°C. The COD values were high, peaking at 32.2 ml O2/l in September 2023. BOD levels were generally moderate to high. Total nitrogen levels were often below 0.5 mg/l, and phosphorus levels were generally low.

Petrovo Blato Lake showed variable dissolved oxygen levels, often on the lower side, which can stress aquatic organisms. The high and variable conductivity points to fluctuating pollution levels, potentially from episodic sources. The consistently high COD values indicate significant organic pollution, similar to Popovo Blato Lake, but with slightly better-dissolved oxygen levels. The low nutrient levels suggest that nutrient pollution is not a major concern. However, the occasional peaks in COD and BOD indicate periods of higher pollution, requiring targeted interventions. The classification of indicators as "good" or "moderate" reflects a mixed environmental state, with ongoing pollution issues.

The mouth of Fandakliyska Reive - "Fandakliysko ezero" coastal lake

The mouth of the Fundakliyska River is a slow-flowing river with a predominant fine substrate (sand, organic substrate). Helophytes dominate the water table (typically ≤50% cover). A highly heterogeneous type with significant variability regarding macrophyte growths. Varies from typically macrophytes riparian reaches (with helophytes dominating) to no macrophytes in heavily shaded gallery forests.

For most small Black Sea rivers, indicator species are the small river mullet (*Petroleuciscus borysthenicus*), the monkey goby (*Neogobius fluviatilis*), and the three-needle stickleback (*Gasterosteus aculeatus*). Sometimes, species of the Mugilidae family also enter this river.

The pH levels at the mouth of the Fundakliyska River remained consistently around 8.0 to 8.1. Dissolved oxygen levels varied from 5.6 to 8.8 mg/l. Conductivity levels were generally stable, around 540-764 µS/cm. There were seasonal temperature variations ranging from 7.4°C to 20.1°C. The COD values were variable, with peaks up to 30.2 ml O2/l. BOD levels showed moderate values, with occasional peaks. Both total nitrogen and phosphorus levels were low, with phosphorus often falling below detectable levels.

The mouth of the Fundakliyska River exhibited stable pH and conductivity levels, indicating a relatively consistent water quality. The dissolved oxygen levels were generally higher compared to the other water bodies, suggesting better conditions for aquatic life. The COD and BOD values were variable, with occasional peaks pointing to episodic pollution events. The low nutrient levels, with phosphorus often undetectable, suggest minimal nutrient pollution. The classification of indicators as "very good" or "good" indicates a relatively healthy state, with some periods of moderate pollution that need monitoring.

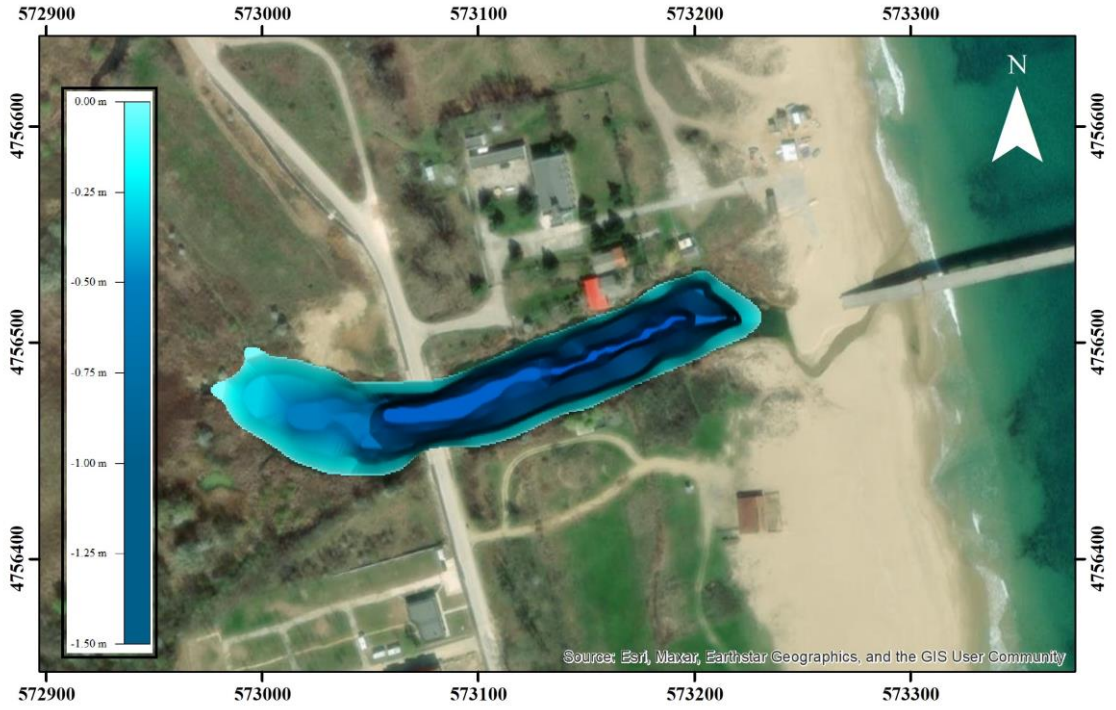


Fig. 4. Digital bathymetric model of the "Fandakliysko ezero" coastal lake on the mouth of Fandakliyska River at Shkorpilovtsi Village

Of the macrozoobenthos, Oligochaeta never dominate (<50 numbers); *Stylodrilus heringianus, Lumbriculus variegates, Pristina rosea;* Hirudinea: Erpobdella, etc.; Mollusca: Radix, Galba, Limnaea, Bythinia (in some cases massive), *Ancylus fluviatilis, Acroloxus lacustris, Planorbis planorbis, Theodoxus fluviatilis, Theodoxus danubualis, Physella acuta*, Sphaerium, Unionidae, etc.; Crustacea: *Potamon ibericum* (crooked crayfish), Gammarus (sometimes abundant), *Asellus aquaticus* (<50 pieces/m^2); Ephemeroptera: Baetis (usually dominated) Caenis, *Seratella ignita*, Heptagenia, Ecdyonurus, Paraleptophlebia, etc.; Odonata: *Platycnemis pennipes, Brachytron pretense, Gomphus vulgatissimus, Onychogomphus forcipatus*, Aeschna, Coenagrion; Trichoptera: Hydropsyche (usually well represented), *Helicopsyche bacescui* (good indicator), Mystacides (Leptoceridae), Hydroptila, Rhyacophila, etc.; Megaloptera: Sialis sp.; Diptera: Tanytarsini (Chironomidae), Simuliidae (some species), Tabanidae, Ceratopogonidae, Athericidae. Most indices (BI, PETI) do not reach maximum values for this specific type of Black Sea river. BI≤3.5; It works with shortened scales that adapt to this type. Extremely high variability within the type. Frequent droughts determine the structure of the MZB communities.

DISCUSSION

The key differences between the lakes highlight the varying sources and levels of pollution: Mazniya Azmak Lake and the mouth of the Fundakliyska River generally had better-dissolved oxygen levels, with values reaching up to 9.3 mg/l, while Popovo Blato Lake and Petrovo Blato Lake exhibited lower levels, with Popovo Blato Lake as low as 2.7 mg/l, indicating potential stress on aquatic life. Popovo Blato Lake consistently

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showed higher conductivity values, peaking at 992 µS/cm, indicating greater pollution or mineral content, with Mazniya Azmak Lake showing an increasing trend, reaching 964 µS/cm in 2023. Popovo Blato Lake had the highest COD and BOD values, reflecting higher organic pollution, with COD up to 40.6 ml O2/l and BOD up to 6.4 mg O2/l. Petrovo Blato Lake also showed high COD values, with a maximum of 32.2 ml O2/l, while Mazniya Azmak Lake and the mouth of the Fundakliyska River exhibited moderate levels. Nutrient levels were generally low across all lakes, with Mazniya Azmak Lake and Petrovo Blato Lake often having undetectable total phosphorus levels (<0.01 mg/l), suggesting nutrient pollution is not significant, though Popovo Blato Lake occasionally had detectable nitrogen levels, up to 1.2 mg/l.

CONCLUSION

This study provides a critical spatio-temporal analysis of eutrophication and habitat loss in the Kamchiya-Shkorpilovtsi coastal lakes along the Bulgarian Black Sea coast. For the first time, detailed mapping of Maznia azmak, Popovo Blato, Dimitrovo Blato, and Fandakliysko ezero reveals significant ecological deterioration due to eutrophication. Findings highlight increased aquatic vegetation and pollution, particularly in Popovo Blato, which exhibited the highest organic pollution levels. This research underscores the urgent need for targeted conservation and pollution control measures to protect these vulnerable ecosystems, emphasizing their importance for biodiversity and the pressing need to mitigate anthropogenic impacts.

AUTHOR CONTRIBUTIONS

RB and BP: Conceptualization, Methodology, Software; RB and BP: Data curation, Writing- Original draft preparation; RB and BP: Visualization, Investigation; RB and BP: Software, Validation.: RB and BP: Writing-Reviewing and Editing

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BLUE-GREEN INFRASTRUCTURE OF METROPOLITAN AREAS: CHANGES, TRENDS, ENVIRONMENTAL POTENTIAL

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ABSTRACT

The blue-green infrastructure is a network of interconnected natural areas. Its development is particularly important for heavily urbanized areas, which are prevalent in metropolitan regions. Metropolises are densely populated urban areas. In the article focusing on the Górnośląsko-Zagłębiowska Metropolis (GZM), utilizing the Urban Atlas database, Geographic Information Systems (GIS), and remote sensing tools (Based on Sentinel 2 satellite imagery), an analysis of changes in blue-green infrastructure objects was conducted for the years 2006, 2012, 2018 and 2023. The results indicated a gradual decrease in green areas in favor of dense residential development (mainly in the center of GZM). However, the largest share of GZM areas (especially its outskirts) consists of forests, meadows and pastures. To a small extent, the share of urban greenery has increased in the subsequent years under study. The results showed that the methods used allow for an effective analysis of changes in land cover with blue-green infrastructure and the need to develop it for the purposes of increasing retention and reducing the negative effects of climate change.

Keywords: The blue-green infrastructure, Green Metropolis, GIS, Urban Atlas, Remote sensing, Retention

INTRODUCTION

The term 'green infrastructure' was introduced into the legal system by the document Adaptation to climate change: a European framework for action, adopted in 2009 by the European Commission. This White Paper, as the publication was called, was dedicated to enhancing the Community's adaptive capacity in the face of climate change affecting Member States. The publication suggests that the most effective strategies will make use of nature's capacity to mitigate and control the effects of climate change, rather than simply relying on technical solutions. The section on impact assessment argues for an approach that includes green infrastructure [1].

The concept of blue-green infrastructure (BGI) includes the same components, but emphasises the equivalence and interdependence of green and water structures [2]. The

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concepts of blue-green urban networks (blue-green grids) [3] are oriented towards the protection, planning and design of green and water structures in conjunction with the landscaping of the city and a system of multifunctional public spaces. Still, their objectives also include biodiversity enhancement, stormwater runoff management and climate change adaptation. It is also defined as a network of interconnected natural and semi-natural areas, particularly those developed in wetlands and areas covered by inland surface waters [4].

These areas, through e.g. water retention, mitigate the effects of climate change on areas of large cities or clusters of cities. An essential process is to reduce the rate of heating of urban surfaces within the so-called urban heat island (UHI), to improve oxygen conditions (especially in areas of poor aeration), to neutralise urban runoff and to support biodiversity [1], [4], [5]. The development of blue-green infrastructure, in areas of dense urban development, effectively influences water retention, which in urban sealed areas mitigates the effects of urban flash floods threatening urban residents.

In order to reduce the negative impacts of progressive climate change in metropolitan areas solutions using nature-based patterns are being sought, in line with the idea of Nature-based Solutions (NbS).

Therefore, the aim of this research was: to identify trends in changes occurring in the development of blue-green infrastructure in Poland in the Upper Silesian and Zagłębie Metropolitan Area (pol. Górnośląsko-Zagłębiowska Metropolia, abbrev. GZM) in the years 2006 - 2018 and to indicate the directions of its development with historical and existing potential.

STUDY AREA

The Upper Silesian and Zagłębie Metropolis (GZM) was selected as the study area (Fig. 1). The metropolis consists of 41 cities and communes with a total area of 250 000 ha, home to 2.1 million inhabitants, and 270,000 companies and enterprises. The GZM is located in southern Poland within the Katowice Upland [6]. In the 20th century, the cities comprising today's metropolis had a predominantly industrial function, forming the core of the Upper Silesian Industrial District. At present, as a result of socio-economic transformations, the areas of the Upper Silesian Industrial Region are still characterised by dense urban development with extensive post-industrial areas (subsidence troughs, post-mining waste heaps resulting from underground exploitation of coal and other raw materials and their processing. It is also an area of developed transport with the Katowice International Airport, the European Sośnica motorway junction of the E75 and E40 roads and a well-developed network of railway infrastructure.

The hydrography of the Metropolis is unique in that the first-order water body separating the basins of the country's largest rivers, the Oder and Vistula, runs through its capital (the city of Katowice). Although there are no natural water bodies, [7] defines the area as the Upper Silesian Anthropogenic Lake District. This term was used due to the fact that there are more than 2,000 water bodies in the study area, created during more than 100 years of deep mining of minerals, mainly coal.

The vegetation cover of the GMZ consists of forests, parks, green spaces, street greenery, agricultural land and unused areas with spontaneously developing biodiversity.

The amount of natural areas in the GZM is increased by the forest communities of the Forest Protection Belt (pol. Leśny Pas Ochronny, abbrev. LPO), established in the 1960s and 1970s around the then Upper Silesian Industrial District (pol. Górnośląski Okręg Przemysłowy, abbrev. GOP).

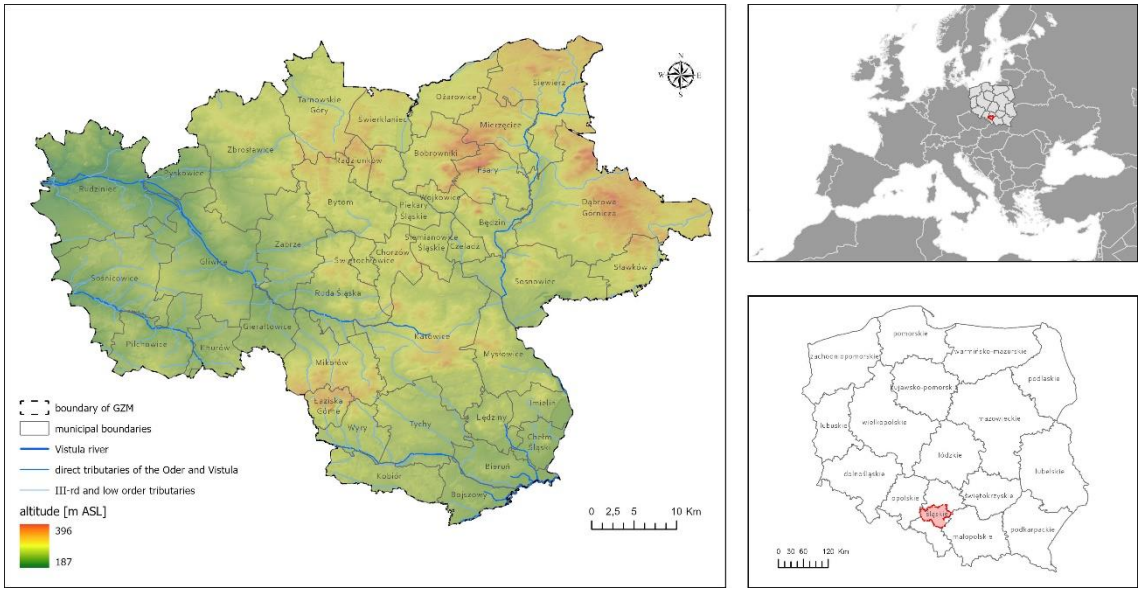


Fig. 1: Study area and its location on the background of Poland and Europe.

Due to the above-described landscape complexity as a result of dynamic changes in relief and hydrography, and bearing in mind the current needs for transformation of the expanding metropolitan areas in the era of climate change, the Upper Silesian and Zagłębie Metropolitan Area was chosen as a model for determining trends and identifying GBI potential.

MATERIALS AND METHODS

1. Data and methods

Research into identifying changes to blue-green infrastructure was carried out using geo-information tools, including MapInfo 2019.3 and ArcGIS Pro 3.2 software (including ESRI Living Atlas resources). Historical maps were obtained from the Polish State Archives and then georeferenced.

The main research material was the Urban Atlas (and Urban Atlas Change) database, developed within the Copernicus programme (part of the European Union space programme). To meet the objectives, land cover and land use data were downloaded for the years 2006, 2012 and 2018 for the functional area "Katowice", which includes the area of GZM excluding the city of Tarnowskie Góry (located in the northern part of the metropolis).

A satellite image taken as part of the Sentinel L2A mission in 2023 (under <10% cloud cover) was used to analyse the current land cover of surface water and vegetation. The ground resolution of the image was 10 m. Information on water-covered areas was extracted based on the Normalised Differential Water Index (NDWI), calculated from the formula: (GREEN-NIR)/(GREEN+NIR) [8]. For Normalized Difference Water Index (NDWI) values, areas covered by water are those for which its value is >0.

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Vegetation area data, on the other hand, were derived from the Normalized Difference Vegetation Index (NDVI), calculated using the formula: (NIR-RED)/(NIR+RED). NDVI values range in rank from -1 to 1, where values above 0.6 correspond to very healthy vegetation [9].

2. Historical maps

As a first step, archival cartographic material was queried. Historical maps created before the development of uniform cartographic techniques (1636-1748) are non-cartometric. Due to the impossibility of giving them proper georeferencing, the information extracted from them is burdened with a very large error in the area of land use elements and therefore could not be the basis for a detailed analysis with the adopted methods. Although the historical maps were not used in the presented study, they formed the basis for the study. As an example, Fig. 2 shows the visible decrease of GBI objects, i.e., areas of water reservoirs, riverbeds or forests and low greenery, in one of the communes (Bojszowy), located in the southern part of the GZM. The topographic images clearly show a decrease in forest areas, agricultural land and water objects over the centuries.

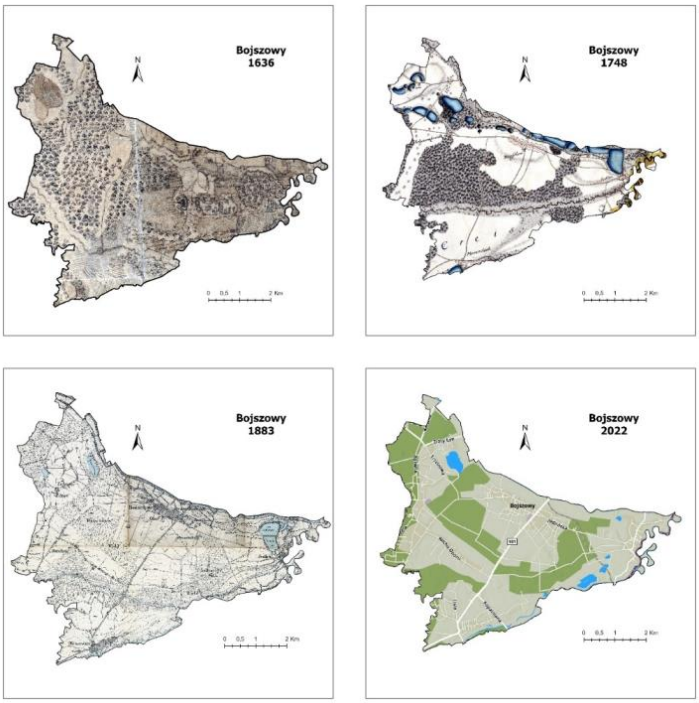


Fig. 2: Changes to GBI areas on historical and topographic maps - example of Bojszowy municipality (own study)

RESULTS AND DISCUSSION

The results of the analysis of Urban Atlas data (Katowice sheet) showed that more than 80,000 ha (32%) of arable land, together with meadows, pastures and wetlands, and 70,000 ha (28%) of forests, mostly of an economic nature, were identified in the GMZ in 2018 (Fig. 3). The proportion of forest in the GMZ was similar to the rate of metropolitan areas in Europe, which ranged from 25 to 55% for Central Europe. Built-up areas accounted for about 30,000 ha (12%) while urban greenery occupied just under 5,000 ha (2%) (Fig. 3).

Between 2006 and 2018, the area of arable fields, meadows and pastures and forests decreased by 4,636 ha (2.6%) and water by 98 ha (2%) (Fig. 3). Forests, arable land with pastures are the dominant component of green infrastructure in the study area, occupying 179,786 ha of land. With decreasing GBI acreage, however, the share of built-up, industrial and communication land increases (Fig. 3) from 23.3% to 25.2% of the GZM area. Between 2012 and 2018, as much as 51% of agricultural land and 7% of greenfield land was developed. The newly developed built-up areas have a discontinuous development character. The area of continuous development remains unchanged at 6460 ha (i.e., 2.6% of the area of the GMZ). Despite changes in the employment structure, services now dominate in the GZM, there is still a high proportion of industry. This is evident in the increasing share of industrial areas (from 7.8% to 8.4% of the area of the GZM), with the structure of industry differing from that which prevailed in the 20th century. The halt in the development of the coal and metallurgical industries is evidenced by the unchanged area of post-mining waste dumps (Fig. 4), amounting to 1.68% of the GZM area. More than 17% of artificial areas have been converted to arable land and meadows and pastures.

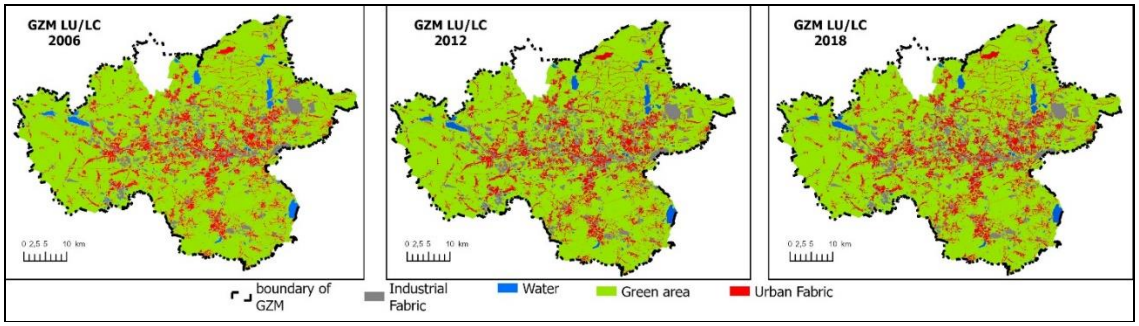


Fig. 3: Land types in the GZM area in 2006, 2012, 2018.

As shown above, the share of natural surfaces in the Upper Silesian and Zagłębie Metropolitan area has been decreasing in favour of artificial surfaces for centuries. This situation has not changed in the past two decades either (Fig. 4). [10] using the example of the Dhaka Metropolitan Area, forecast a further increase in the share of built-up areas and a decrease in the areas occupied by waterbodies and areas covered with greenery. The authors point out that with an ever-increasing population and increased demand for services, there is a continuous increase in the area of construction sites, residential areas and industrial and commercial facilities. [11] on the other hand, in her study observes a trend associated with a decrease in the share of agricultural land in large Polish cities, with a slight increase in the area of green areas.

In the 1980s, in response to the effects of long-term environmental degradation, the concept of sustainable urban development was formulated [12]. Among other things, the United Nations defines sustainable development as one that meets the needs of people today without compromising the ability of future generations to meet their needs. It requires a concerted effort to create optimal living conditions - a reality that is resilient to the consequences of disasters - for all people in the world and for the planet as a whole. To achieve sustainable development, coherence is needed between three key elements: economic growth, social inclusion and environmental protection. For this purpose, it becomes essential to promote the integrated and sustainable management of natural resources and ecosystems, and this also means that any further land development

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or sealing should be limited in favour of areas with a high retention capacity. Despite the intensive land development of the GZM, there are still many potential sites that can be restored to their natural state.

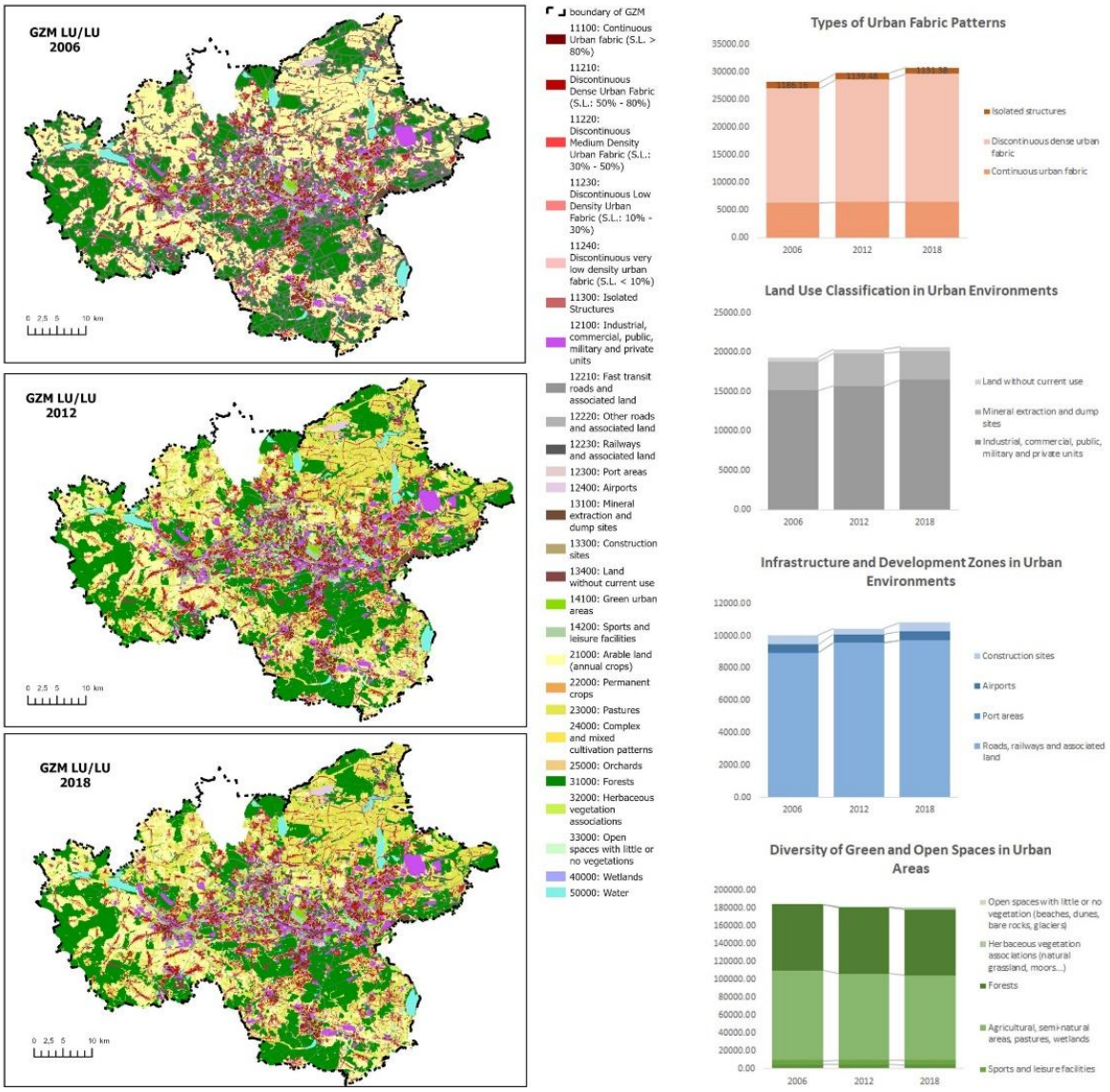


Fig. 4: Methods of using the GZM area according to the Urban Atlas classification in 2006, 2012, 2018.

Table 1 shows the conversion of built-up land to areas of blue-green infrastructure. Between 2012 and 2018, 170.8 ha (0.07%) of built-up/industrial/unused land was converted to grassland. In contrast, 1,036 ha of post-mining areas and dumps became sites of herbaceous vegetation, e.g. grassland, peatland or wetlands or pasture (Table 1).

Table 1: Summary of land-use changes in the GZM in 2006, 2012 and 2018

Land cover type that has been changed (designated as unfavourable for the purposes of the study)	Changes between 2006 and 2012			Changes between 2012 and 2018		
	Total area that has changed from 2006 to 2012 [ha]	The type of land cover that has been present since 2012 and its area [ha]		Total area that has changed from 2012 to 2018 [ha]	The type of land cover that has been present since 2018 and its area [ha]	
Construction sites	40	Arable land (annual crops)	35.93	191.75	Pastures	**170.84**
		Pastures	2.14		Herbaceous vegetation associations (natural grassland. moors...)	9.88
		Water	1.39		Green urban areas	6.59
		Green urban areas	0.54		Arable land (annual crops)	4.44
Continuous and discontinuous urban fabric	2.09	Green urban areas	2.09	0.96	Green urban areas	0.96
Industrial. commercial. public. military and private units	0			21.97	Herbaceous vegetation associations (natural grassland. moors...)	**21.97**
Land without current use	0			1.98	Green urban areas	1.24
					Pastures	0.74
Mineral extraction and dump sites	41.56	Arable land (annual crops)	24.54	1036.31	Herbaceous vegetation associations (natural grassland. moors...)	**547.92**
		Forests	11.11		Pastures	**436.31**
		Water	3.48		Wetlands	28.83
		Green urban areas	1.7		Water	17.73
		Pastures	0.74		Arable land (annual crops)	3.72
					Green urban areas	1.8
Roads and associated land	0.76	Pastures	0.65	0.13	Pastures	0.08
		Arable land (annual crops)	0.11		Forests	0.05

Source: Urban Atlas changes 2006 - 2012 and 2012 - 2018 (own study)

In the GZM, the area for which the NDVI value was 0.6 or higher (indicating high chlorophyll content) amounted to 65 180 ha, representing 26% of the analysed area. The presence of vegetation was also identified in the central part of the GZM, in its most densely built-up part (Fig. 5). Green infrastructure consists of both wooded areas and elements of managed greenery, as well as areas where spontaneous succession processes occur [13]. This so-called 'fourth nature' introduces solutions that are closer to nature and thus more sustainable, able to adapt urban and metropolitan areas to changing

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environmental conditions [14]. There are areas where green infrastructure does not exist, hence it is worth considering its introduction in the form of, for example, greening the roofs and walls of buildings [1].

On the day the image was taken, the surface water area was 8 356 ha (3.27% of the GZM area), which confirms the presence of small water-filled holes throughout the metropolitan area (Fig. 5). The smallest objects were most densely located in the centre of the GZM On the other hand, large water bodies are located close to the borders of the GZM (both in the northern, southern, western and eastern parts of the GZM). Such a distribution of hydrographic facilities favours the development of retention and, in particular, the improvement of small retention conditions in the most densely built-up areas. Also based on historical materials, in order to improve the retention capacity of the GZM area, it is possible to restore some of the reservoirs that existed in these areas in the 18th and 19th centuries.

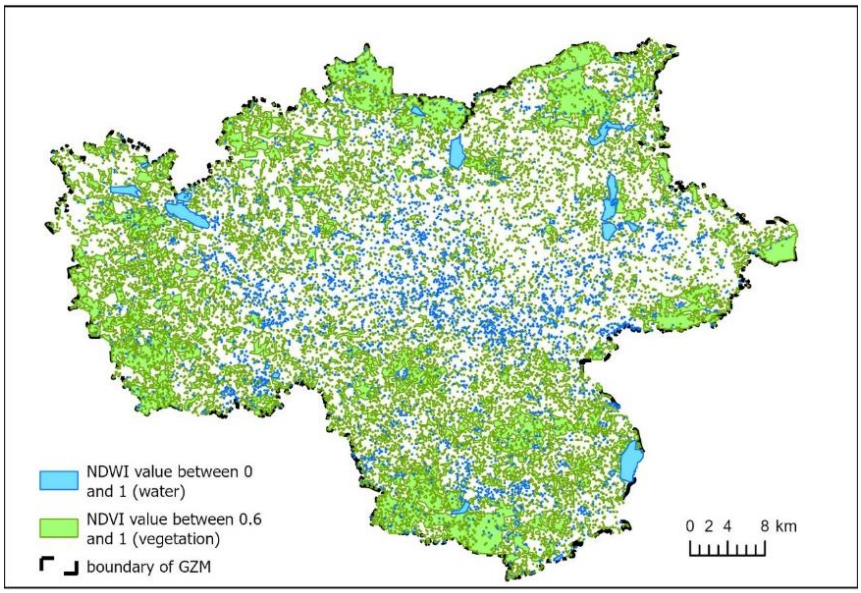


Fig. 5: Areas of healthy vegetation and surface water occurrence in the GZM based on NDWI and NDVI indices calculated from imagery taken on 28.12.2023

CONCLUSIONS

The GZM area is characterised by a decreasing share of agricultural land and forests in favour of residential and service development areas. The dominant trend is to reduce the share of green areas (mainly meadows and pastures) in favour of new developments, in which the share of biologically active area, which supports e.g. water retention and improves the quality of life of residents, is marginalised. The share of forest areas decrease in favour of discontinuous development, which is due to the location of new housing estates, among others, in the protection border site of the GMZ. In contrast, the proportion of surface water areas remains unchanged. In addition, large retention facilities are located on the outskirts of the metropolis, which helps, among other things, to mitigate climate change (increasing humidity) and obviously improve retention.

The results of the research carried out show that some land-use changes in European metropolises, including the GZM, contribute to the development of BGI areas.

However, this phenomenon does not occur to a sufficient degree to effectively mitigate the effects of UHI.

A response to the negative trends of land-use change in metropolitan areas may be to restore selected areas to their "natural" state, prior to industrialisation and intensive urbanisation. Where this is not possible, the development of nature-based solutions is a desirable action. One such action is the restoration of originally existing features (e.g. hydrographic features) that have disappeared as a result of expansive land development.

It has also been shown that satellite imagery processed using geo-information science (GIS) tools can be used to qualitatively and quantitatively assess and monitor changes in the surface of blue-green infrastructure components.

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THE BULGARIAN TICHA RESERVOIR FUNCTION IN 2017-2023 PERIOD

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ABSTRACT

The sustainable water management is a process based on a brief knowledge about the water resources availability. The water lack or excess in the form of droughts or flooding, and/or improper water use can cause serious disruptions in the water management process with negative effects on the water supply, economy, and the human and ecosystems well-being. To minimize the negative consequences a specialized research is needed. It requires a complex study that allows objectively detecting of critical aspects in the water management process.

In help of water managers and professionals in the area this material is presenting the results of investigation about the Ticha reservoir. Ticha is one of the complex and significant dams in Bulgaria. Its water is used for multiple purposes: for water supply, irrigation, electricity production, for provision of water for ensuring the required minimum river flow for the healthy function of aquatic ecosystems. But several times recently signals alarmed for very low reservoir state with critical impact on the water use. This provoke this special study of the Ticha`s reservoir performance for the 2017-2023 period, observing in details the reservoir specificities, hydrograph, the established water intakes and water use in accordance to the hydrological situation. The obtained results serve to diagnose the critical events and leading to them reasons. This analysis and obtained results can support the sustainable management of the Ticha reservoir and the decision makers in the field.

Keywords: water management, drought, Ticha, reservoir state, Ticha water crisis

INTRODUCTION

The flexible and prudent use of water resources is a basic prerequisite for sustainable water management. It requires a good knowledge about the water availability and its proper redistribution with regard to the particular needs. For this purpose in practice are used various solutions. One uses the artificial reservoirs for water supply. Their operation closely depends of complex aspects that assume the particular climatological, geomorphological, hydrological and economy factors, balanced by the adopted water management procedures. But in some cases the occurrences of untypical events, associated with serious water lack or excess, resulting from droughts or water inundations, and/or improper water use, cause serious disruptions in the entire water management process. Such episodes require a proper investigation to understand well the main reason of happening and to prevent from such future events by “learning from the past”. In order to better understand the functioning of the reservoirs, this approach was used for one of the significant water reservoirs in Bulgaria – the Ticha reservoir. Recently, it has been alerted several times about the very low state of the reservoir, which has had a critical impact on the water use [1, 2, 3]. In order to account for what happened, a study was made specifically of the operation of the Ticha dam. It covers the

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period 2017-2022, with an analysis of the operation of the dam and its condition in relation to the established water intakes and water use, in accordance with the particular hydrological situation. The obtained results serve to diagnose the critical events that occurred during the period and the reasons that caused them. This analysis and the results obtained can support the sustainable management of the Ticha reservoir, and help the process of preventing future adverse events.

MATERIALS AND METHODS

The evaluation of the functioning of any dam is a complex process that requires a proper assessment of the data and information related to the factors forming the balance of its inflow and outflow, to prevent and avoid any risky hazards [4]. Such assessment is of importance for the water management of the particular reservoir evaluation, emphasizing the importance of local climate, geomorphological, hydrological and environmental factors, and the specific water use. Presented aspects are processed using various geomatics and data processing tools. This research was carried our according to the developed authors methodology for the reservoirs state function observation [5]. It was conducted using Microsoft Excel and ArcMap.

The Ticha reservoir is one of the Complex and significant dams in Bulgaria [6]. It is situated in the north-eastern part of Bulgaria, in Shumen Province, Varbitsa Municipality – Fig. 1. It lies along the river valley of Golyama Kamchija river before the Preslav gorge [7]. It is located to the north of the Stara Planina mountain foots (the Balkan Mountains) in the Danube plain. The nearest town is Veliki Preslav, which is less than 10 km from the spillway of the dam. Nearest settlements are also Varbitsa town (18km), and Shumen (40km) – the tenth-largest city in Bulgaria and administrative and economic center of Shumen Province.

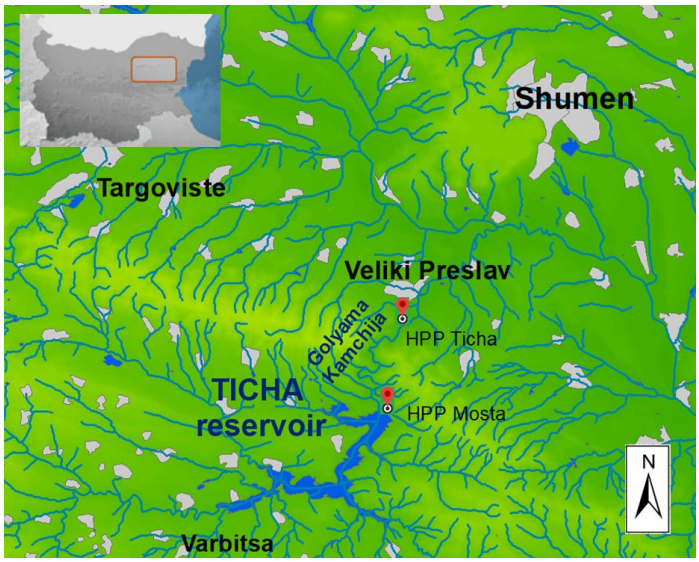


Fig. 1 Ticha reservoir location

This is one of the largest reservoirs in Bulgaria. When the dam was created the villages and lands of Vinitsa and Staroselska reminded below its water level. For this reason the previous name of the reservoir was Vinitsa. There have been settlements in this area since ancient times. Probably for this along the valley of Kamchija river the largest density of Thracian burial mound necropolises has been recorded in North-Eastern

Bulgaria. A considerable number of them can be found near the shores of Ticha dam. This gives additional value to the development of tourism in the area. Fishing is also popular there. The southern part of the reservoir offers good conditions for fishing. The northern part is a water supply area.

The beginning of the intensive development of irrigation in this area was at the end of the fifties of the 20th century with the construction of several dams for irrigation purposes. Subsequently, large dams in the area were also built. One of them is the Ticha reservoir. It has been in operation since 1973, being included in the structure of large irrigation systems, to cover the highest of the irrigation needs. They are connected to the exclusive use of the extremely fertile land in the area, used for growing of fruit and vegetable production. Subsequently it became the main source for domestic and industrial water supply in the area. It became the main supplier for three cities - Shumen and Veliki Preslav, in Shumen Province and Targoviste, in Targoviste Province, and the small settlements in the presented regions. For optimal use of the water two hydroelectric power plants were built in the area. One of them is the hydroelectric power plant "Mosta" (HPP Mosta), the other is – the small hydroelectric power plant "Ticha" (HPP Ticha). They produce electricity according to the approved and agreed schedules between the National Electricity Company – Bulgaria (NEK EAD), Irrigation systems EAD (Napoitelni Sisitemi EAD) and the Ministry of Environment and Water (MOEW) of Bulgaria. They also process water to release water volumes for prevention against overflowing during heavy rainfall and protect flooding in the area. To ensure the ecologically healthy conditions in Golyama Kamchija river after the dam the HPP "Mosta" provide the needed and legally regulated minimum permissible flow.

The climate in the area is temperal continental [8]. The location of the reservoir and its catchment further influence local climate features. The Ticha reservoir is situated in the Danube plain, down the Balkan Mountains. The climate of the mountainous regions differs sharply from that of the lowlands. During the cold half-year, Stara Planina mountain plays the role of a significant barrier against the cold winds from the northern parts of Bulgaria. During the warm half-year, the transfer of air masses is often from the northwest. Accordingly, during this part of the year, the greatest precipitation falls on the northern and northwestern slopes of the Balkan Mountains and the places near it. The maximum rainfall is in summer – mainly in June, partly also in May. In the mountains, throughout the year, temperatures remain significantly lower and precipitation is greater. In the Danube plain winters are cold.

The Ticha reservoir lies along the Golyama Kamchija river. The former name of this river is Ticha, named the reservoir nowadays. It is one of the largest in Bulgaria. It has the largest reservoir perimeter – over 100 km. The reservoir has a maximum length of 14 km, and a maximum width of 1 km. The surface area is 1.870 ha. The dam overflowed in July 2005 and July 2010, threatening the surrounding villages and land. Due to this, the water level of the reservoir is closely monitored and maintained to prevent flooding.

RESULTS AND DISCUSSION

In December 2019 [1] and August 2020 [2, 3] various national media spread information about the drying up of the Ticha reservoir. Ticha supply with domestic and industrial water the settlements Shumen, Turgoviste and Veliki Preslav and the nearest villages, supplying also the agricultural lands in the area with irrigation water. For this

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reason such information is quite worrying. The Minister of Environment and Water (MOEW) in September 2020 commented on public the problems with dams and possible solutions [2]. As a result, the pre-arranged schedule for water use from the reservoir has been altered, with amendments and restrictions on water withdrawals. Similar changes have been made many times in the dam`s managing process. To understand better the recent operation of the Ticha dam, this material briefly presents the results of a study investigating the functioning of the dam for the period 2017-2023.

The Ticha reservoir is part of the Complex and Significant Dams of Bulgaria according to the Bulgarian Water Act [6]. Its annual and monthly management is carried out according to specially prepared schedules, approved by the Minister of Environment and Water. On the base of the registered reservoir state at the end of the month (considered as available water volume in the reservoir at the beginning of the new month) and the preliminary established water intakes and planed repairs for the next month the monthly management schedule for the reservoir is prepared. When drawing up the monthly schedule, after assessing the expected estimated inflow, if it is necessary are set conditions so that a certain maximum volume will be not exceeded, by setting additional conditions for action in the presence of a corresponding inflow and volume. A similar procedure is performed in case of a minimum inflow into the reservoir expectation. The implementation of the presented procedures provides a real impact on the registered reservoir volume. Figure 2 shows the change in the monthly volume of the reservoir for the period 2017-2023. In the study: the total volue of the reservoir is 311.800 mln. m^3; the total available volume of the reservoir is connected to the daily recharge and outflow; the dead volume is 40 mln. m^3; the useful conservation volume represents the difference of the total available and the dead volume.

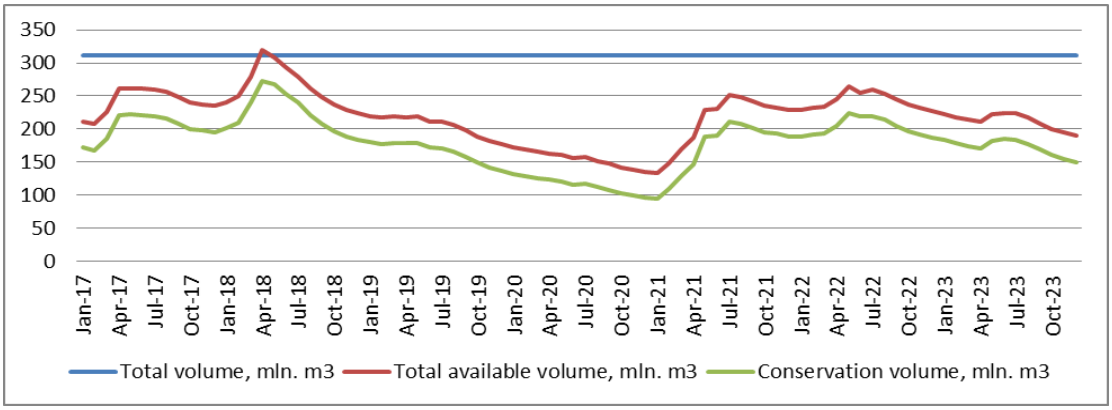


Fig. 2 Ticha reservoir state for the period 2017-2023

The results obtained show that at the registered reservoir state there is a clearly recorded period of sustained decrease in the reservoir volume in the period April 2018 to January 2021. The reported period covers the episodes with a public alarm to the decreased reservoir state. Despite the public problem recognition from the Minister of Environment and Water in September 2020, the reservoir volume continues to decrease until the beginning of 2021, when a smooth increase is noticed. This can be explained with the specifics of the reservoir recharge. From a hydrological point of view, the minimum of the Golyama Kamchija river is in September, which can be connected with the minimum natural feeding of the reservoir in this period. The reduced recharge and permanent water intakes can be connected to the reduction in the reservoir volume until January 2021. From hydrological view point, with regard to the particular Ticha

reservoir specifics, the maximum rainfall in the area is observed in April-May. This is a prerequisite for restoring of the dam.

The water used from Ticha reservoir is strictly regulated. The approved water abstractions are used with priority for water supply, but are used also for irrigation, to ensure the aquatic ecosystems wellbeing, and for electricity production. Generally, the water for water supply is directed to the water supply systems of Shumen and Veliki Preslav, and separately to Targoviste. After the identified shortage of water in the Ticha reservoir in 2020 the eco-ministry noticed the water supply operators, water users and operating companies managing the Complex and significant dams in Bulgaria with a filling rate of less than 50%, to take actions to limit water withdrawal for other purposes in order to ensure drinking domestic water supply and taking measures for water supply from alternative surface and underground water sources. This also applies to irrigation water, reducing the permitted water volumes for irrigation purposes. To ensure the aquatic ecosystems healthy function in rivers a minimum permissible flow in the rivers was required. At that time regarding the Bulgarian Water Act [6] it must be equal to 10 percent from the mean annual discharge, determined regarding information for a representative time period, but not less than minimum monthly water discharge (natural runoff) with 95 percent probability of exceeding. The water required to ensure the minimum permissible outflow after the dam is passed through the HPP "Mosta". For HPP "Ticha", water volumes discharged from the HPP "Mosta" and the "Vinitsa" main irrigation canel can be supplied. The supply of water for electricity production is within the permitted limits and it is carried out in agreement with the Bulgarian National Electricity Company (NEK EAD) and Energo-Pro Bulgaria AD. The average branches water use for 2023 is presented in Fig. 3.

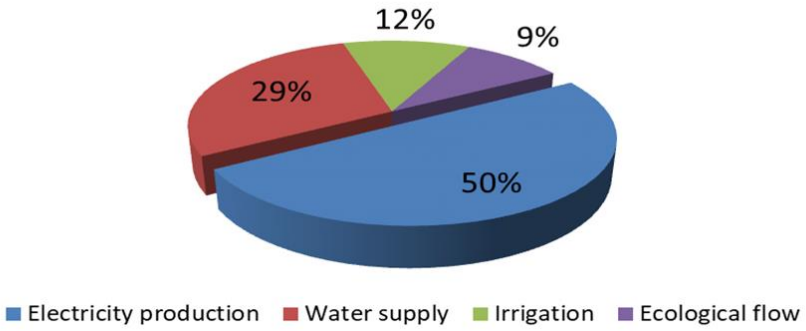


Fig. 3 The Ticha reservoir withdrawal share by branches

To observe better the reservoir function of importance is also to have good impressions about the authorized water use. It is a main factor for the reservoirs outflow and its dynamics predetermine in a great term the particular state of the reservoirs. It is a significant factor that can practically be adjusted to achieve target results in both directions – emptying or preserving water volumes. A study of the dynamics of water use was carried out for the Ticha reservoir for the period 2017-2023. The results are presented on Fig. 4.

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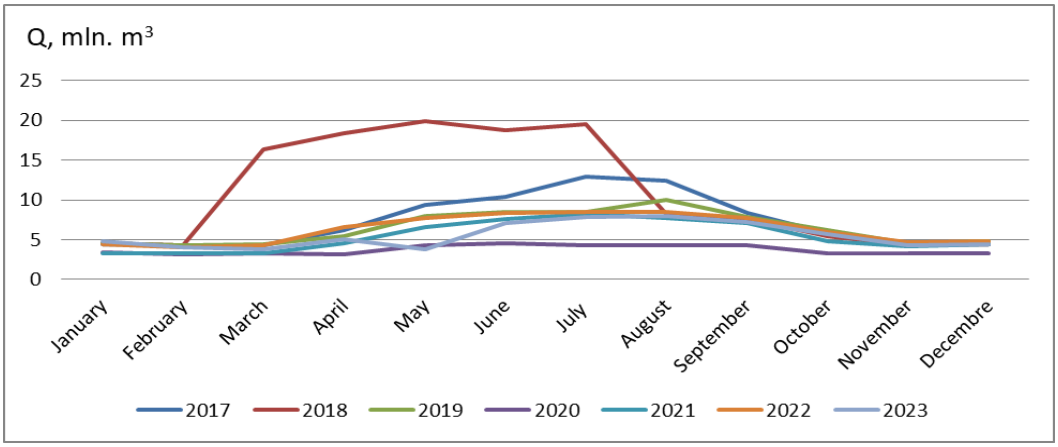


Fig. 4 Annual variation of the water intake from the Ticha reservoir

The results show relatively constant water consumption over the years. An exception is noted for 2018, when a significant release of water volumes took place in March. The results are presented in Figure 5.

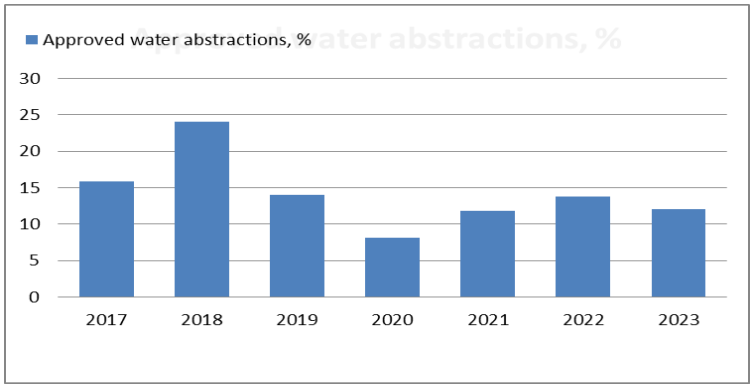


Fig. 5 Approved water abstractions for the period 2017-2023, %

Upon further analysis it is noticed that at this point the actual condition of the reservoir exceeds that predicted to maintain the volume of the reservoir, thus posing a potential overflow hazard. In order to release these risky volumes, it is permitted to release water through the both hydro power plants, which reaches the prescribed upper limit for water volumes in the reservoir. Accounting the local conditions, the release of such a volume in March is not untenable, taking into account that the period April-May is related to the expected spring flow maximums and the reservoir recharge. This release of volumes is reasonable, as at the beginning of April, an excess of the Ticha state was reported again. In the following months, the release of volumes from the Ticha reservoir is according the requests from the users, approved by MOEW. At the beginning of 2019, no significant filling of the reservoir volume was registered. During the following period no changes in the water intake from the reservoir were imposed. In January 2020, in connection with the low volume of the reservoir, it was recommended that the water supply companies to take action to include alternative water sources to ensure the water supply. Due to the low volume in the following period the water intake from the Ticha reservoir was limited. Based on an analysis carried out in April 2020, it was found that the incoming inflow is significantly less than the consumption, which is why the water use from the reservoir was severely reduced. The significantly reduced water use is in effect for drinking water supply, but to a greater extent it also affects water for

irrigation, provision of minimum permissible flow in the river after the dam, and for electricity production. The measures undertaken have yielded results and in 2021 the water condition of the Ticha reservoir has been restored to its usual operating limits. In 2022 and 2023, no significant problems in the operation of the reservoir were reported either.

CONCLUSION

Ticha is one of the Complex and significant dams in Bulgaria. It is of vital importance for the water supply of the settlements Shumen, Turgoviste and Veliki Preslav and the nearest villages. It is of extreme importance in the region also because it provides the necessary water for irrigation of the agricultural land in the area, it is used for electricity production, and to ensure the healthy functioning of the aquatic ecosystems in the Golyama Kamchija river after the dam. The conducted research established that in the period 2017-2023 a significant crisis was registered regarding the Ticha reservoir state. It is associated with a long-term critically low water volume in the reservoir, associated with reduced recharge. At the beginning of 2019 and 2020, no significant filling of the reservoir volume was registered, which led to strong restrictions in the water supply. But despite the insignificant recharge of the reservoir during these periods, the needs of water for domestic and irrigation water supply were met. Taking into account the increasing signals about drought and illegal water intakes, we can recommended an additional hydrological study to establish the reasons for the decrease in the inflow to the Ticha reservoir. Such study can be a part of the required by the Bulgarian and EC main regulations, connected to the National Drought Management Plans preparation.

ACKNOWLEDGEMENTS

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THE DYNAMICS OF NITROGEN AND PHOSPHORUS CONCENTRATIONS IN AGRICULTURAL RUNOFF AT THE LEVEL OF EXPERIMENTAL PLOTS: CASE STUDY IN LATVIA

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ABSTRACT

Excessive input of nitrogen and phosphorus into water systems causes eutrophication. Efforts to reduce nitrogen and phosphorus losses from agriculture in the Baltic Sea region are crucial. The aim of the study is to assess the impact of nitrogen application rates in the form of mineral fertilizer on concentrations of Ntot, NO3-N, Ptot, and PO4-P (mg L-1) in runoff at the level of experimental fields. This study analyzed data from October 2014 to April 2022 collected from the Mellupite monitoring station, where experimental plots were set up with the application of different amount of nitrogen, expressed as nitrogen rate per hectare of cultivated agricultural land, ranging from 0 kg ha-1 to 240 kg ha-1. The average value of Ntot concentration at the level of experimental plots ranged from the lowest value observed in the experimental plots with the nitrogen application rate of 0 kg ha-1 (7.3 mg L-1) to the highest average value observed in the experimental plots with the application rate of 180 kg ha-1 (12.9 mg L-1). The lowest average value of Ptot concentration was observed in the experimental plots with 240 kg ha-1 of N applied in the fertilizer (0.036 mg L-1), while the highest average concentration value was observed in the experimental plots with the nitrogen application rate of 60 kg ha-1 (0.097 mg L-1). During the study period, the highest NO3-N concentration values were observed in 2021/2022 when winter rapeseed was grown (9.9 mg L-1 N0, 13.6 mg L-1 N60, 12.4 mg L-1 N120, 14.3 mg L-1 N180). Kruskal-Wallis tests indicate that the experimental plot with 0 kg ha-1 showed statistically significantly lower Ntot concentration (p-value <0.001) and the plot with 60 kg ha-1 showed statistically significantly higher Ptot concentration (p-value <0.0001).

Keywords: Baltic Sea, eutrophication, nutrient pollution, experimental plots, agricultural runoff

INTRODUCTION

Eutrophication caused by excessive nutrient delivery into watercourses leads to algal blooms, oxygen reduction, and habitat degradation with negative impacts on marine ecosystems [1]. A number of rules and initiatives have been put in place to prevent nutrient pollution from agriculture in countries surrounding the Baltic Sea. According to the HELCOM Baltic Sea Action Plan, nitrate nitrogen from agricultural sources is the

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main source of diffuse pollution of surface waters, mainly due to increased emissions of nutrients [2]. Elevated levels of nitrogen and phosphorus in agricultural runoff can stimulate algal blooms. These blooms can produce toxins harmful to aquatic organisms and humans, disrupt food chains, and impair water quality. Eutrophication caused by agricultural runoff can lead to biodiversity loss in aquatic ecosystems [3]. The leaching of nutrients is affected by the physical, chemical, and biological properties of the soil [4]. Various natural factors impact the quality of agricultural runoff, such as the average air temperature [5], the average annual rainfall resulting in significant nitrogen leaching [6], runoff impacts, where phosphorus compounds can enter drainage systems and watercourses, the effect of soil texture, where soils with high organic matter content can mineralize significant amounts of nitrogen [7], and the impact of the mean surface slope. There is a significant positive correlation between the angle and the total phosphorus concentration when the surface slope was <15°, whereas the increase in total phosphorus concentrations slowed down as the surface slope increased [8]. Particular attention should be paid to the impact of anthropogenic factors on the quality of agricultural runoff such as the impact of land use patterns, with the increase of agricultural land in the catchment area, increased concentrations of N_{tot}, NO_3-N, P_{tot}, and PO_4-P are observed. On the other hand, increased losses of N_{tot}, NO_3-N, P_{tot}, and PO_4-P [9] are caused by crop share [10], drainage rate, where drainage can be significant for N_{tot} (89%) and P_{tot} (76%) loss-enhancing runoff component [11], the impact of applied nitrogen-containing mineral fertiliser [4] and the impact of the average number of animal units (livestock farming). As forest and natural areas decrease in the catchment area, Singh et al. (2008) found that areas with high animal density were susceptible to contamination of surface water by nutrients [12]. One of the main functions of river ecosystems is water treatment, especially in areas with intensive agricultural activity [13]. Monitoring of discharge from agricultural drainage is carried out to assess the quality of agricultural runoff. The study specifically examines the impact of experimental plots on surface waters by looking at different application rates of nitrogen per hectare of arable land including 0 kg, 60 kg, 120 kg, 180 kg, and 240 kg.

MATERIALS AND METHODS

The Mellupite monitoring station, where the experimental plots are located, is situated in the western part of the country, in the Vadakste plain of the Central Latvian lowlands. This station lies in the south of Saldus county next to the Mellupite stream (also known as Melnupe or Melnupite), a tributary on the left bank of the Zana River. The Zana River, in turn, is a tributary on the right bank of the Venta River. The total catchment area of Mellupite is 21.37 km², while the catchment area at the monitoring station is 9 km² [14]. The Mellupite monitoring station characterizes moderately intensive agricultural production conditions in Latvia. The predominant soil in the basin is peat podzol (classified as Stagnic Luvisol by FAO) with a pH ranging from 6.7 to 7.0 [15]. Sixteen experimental plots (see Fig. 1) covering a total area of 1.92 hectares have been established in the research area. Agricultural crops are cultivated on these fields. Land management practices, except for the application rates of nitrogen, are determined by the landowner's choice (the Kaudzites farm), thus representing a typical mode of land management used in agriculture. During the research period from October 2014 to April 2022, winter wheat and winter rapeseed dominated the crop rotation. The experimental plots were divided based on five rates of applied nitrogen in the form of mineral fertilizer. Flow measurements from tile drain systems are conducted separately for each

plot. Measurements are made with mechanical counters, the measuring structure is tipping buckets. The collection of water samples is carried out in an automatic proportional to the flow rate.

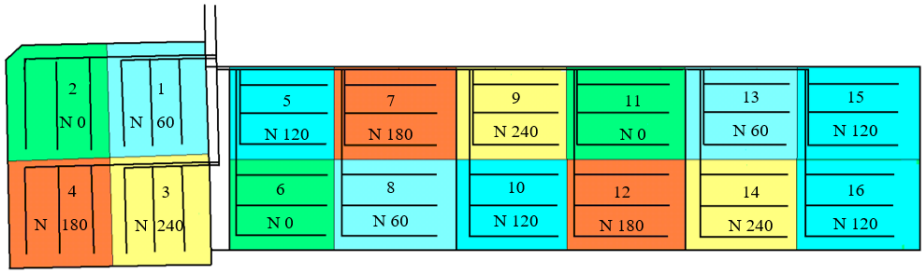


Figure 1. Scheme of arrangement of experimental plots with plot number and rate of applied nitrogen (N) in the form mineral fertilizer (N kg ha^{-1})

For the purposes of the study, the chemical composition of water samples collected monthly is determined according to the amount of fertiliser applied. Water samples from plots with equal rates of nitrogen fertiliser have been mixed together and analysed in the laboratory as one water sample (Table 1).

Table 1. Distribution of water samples depending on the applied fertilizer dose.

No	Water sample labeling	Nitrogen application rate	
		Nitrates Directive reporting designation	Explanation
1	MA	N0	0 kg ha^{-1} of N
2	MB	N60	60 kg ha^{-1} of N
3	MC	N120	120 kg ha^{-1} of N
4	MD	N180	180 kg ha^{-1} of N
5	ME	N240	240 kg ha^{-1} of N

Descriptive statistics are used in the study, followed by multiple pairwise comparisons using the Steel-Dwass-Critchlow-Fligner procedure for a two-tailed test, and Kruskal-Wallis tests are conducted.

RESULTS

The values of long-term average N_{tot} and NO_3-N concentrations (mg L^{-1}) at the level of experimental plots from the study period from 2014 to 2022 are summarized in Table 2. Evaluating the average N_{tot} concentration values at the level of experimental plots, the lowest value was observed in experimental plot MA (7.3 mg L^{-1}), and the highest average value was observed in experimental plot MD (12.9 mg L^{-1})

Table 2. Long-term average values of N_{tot} and NO_3-N concentrations (mg L^{-1}) at the research level of experimental plots (2014-2022).

No	Water sample labeling	NO_3-N, mg L^{-1}			N_{tot}, mg L^{-1}		
		Min	Max	Avg.	Min	Max	Avg.
1	MA	1.7	17.8	7.0	1.9	18.8	7.3
2	MB	2.7	29.9	9.7	2.9	30.5	10.2
3	MC	2.9	23.9	10.2	3.2	24.4	10.6
4	MD	4.0	28.7	11.8	4.0	29.8	12.2
5	ME	2.8	27.1	12.5	2.9	28.7	12.9

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The lowest average value of NO_3-N concentrations was observed in experimental plot MA (7.0 mg L^{-1}), and the highest average value was observed in experimental plot ME (12.5 mg L^{-1}). The long-term average values of P_{tot} and PO_4-P concentrations (mg L^{-1}) at the research level of the experimental plots during the research period from 2014 to 2022 are summarized in Table 3.

Table 3. Long-term average values of P_{tot} and PO_4-P concentrations (mg L^{-1}) at the research level of experimental plots (2014-2022).

No	Water sample labeling	PO_4-P, mg L^{-1}			P_{tot}, mg L^{-1}		
		Min	Max	Avg.	Min	Max	Avg.
1	MA	0.001	0.228	0.056	0.004	0.252	0.068
2	MB	0.004	0.213	0.085	0.003	0.264	0.097
3	MC	0.001	0.230	0.028	0.003	0.237	0.037
4	MD	0.001	0.131	0.042	0.002	0.149	0.049
5	ME	0.001	0.147	0.028	0.002	0.165	0.036

At the level of the lowest average P_{tot} concentration values, observed in the experimental plots MC and ME (0.037 mg L^{-1} and 0.036 mg L^{-1}), while the highest average concentration values were observed in the experimental plot MB (0.097 mg L^{-1}). Similar trends are observed in PO_4-P in the long-term analysis of concentration values; respectively, the average lowest PO_4-P concentration values were observed in the experimental plots MC and ME (0.028 mg L^{-1}), while the highest average concentration values were observed in the experimental plot MB (0.085 mg L^{-1}). Figure 2 shows the relationship between nitrogen application rate (kg ha^{-1}), NO_3-N concentration (mg L^{-1}), and crops at the research level of the experimental plots.

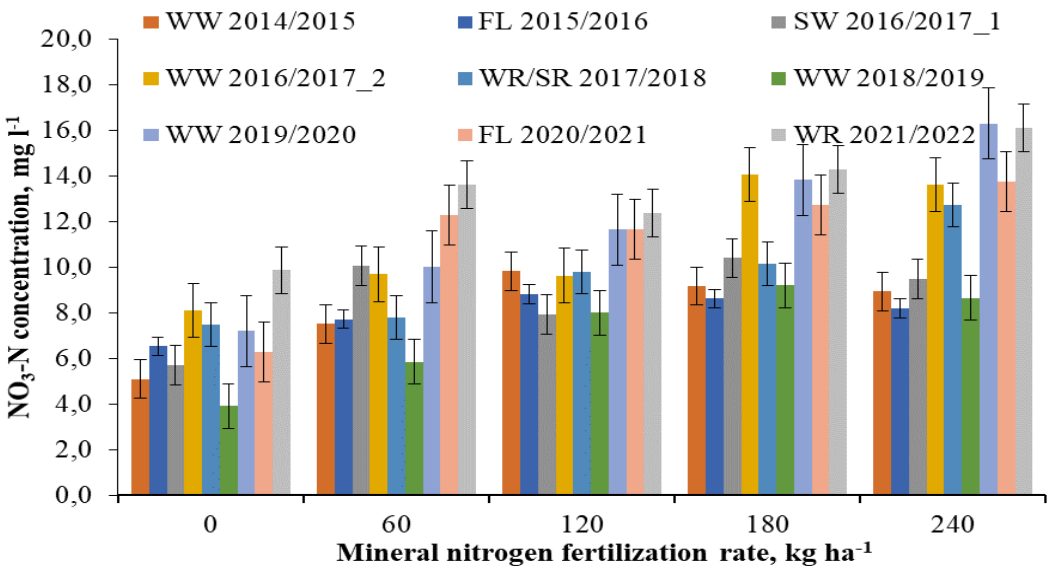


Figure 2. Relationship between nitrogen application rate (kg ha^{-1}), NO_3-N concentration (mg L^{-1}), and crops at the research level of the experimental fields *(WW, winter wheat; FL, fallow land; WR, winter rapeseed; SR, spring rapeseed; SW, summer wheat).*

Evaluating the nitrogen application rates in the form of mineral fertilizers (kg ha^{-1}), NO_3-N concentration (mg L^{-1}), and the relationship between crops at the research level of the experimental fields, during the study period, the highest NO_3-N concentration values were observed in 2021/2022 when winter rapeseed was grown (9.9 mg L^{-1} N0,

13.6 mg L^{-1} N60, 12.4 mg L^{-1} N120, 14.3 mg L^{-1} N180), while at N240 – winter wheat in 2019/2020 (16.3 mg L^{-1}). The lowest values of NO_3-N concentrations were observed in 2018/2019 when winter wheat was grown (3.9 mg L^{-1} N0, 5.9 mg L^{-1} N60), in 2016/2017 when summer wheat was grown (7.9 mg L^{-1} N120), as well as in 2015/2016 when fallow land was left (8.6 mg L^{-1} N180, 8.2 mg L^{-1} N240). Figure 3 shows the relationship between nitrogen application rate (kg ha^{-1}), PO_4-P concentration (mg L^{-1}), and crops at the research level of the experimental fields.

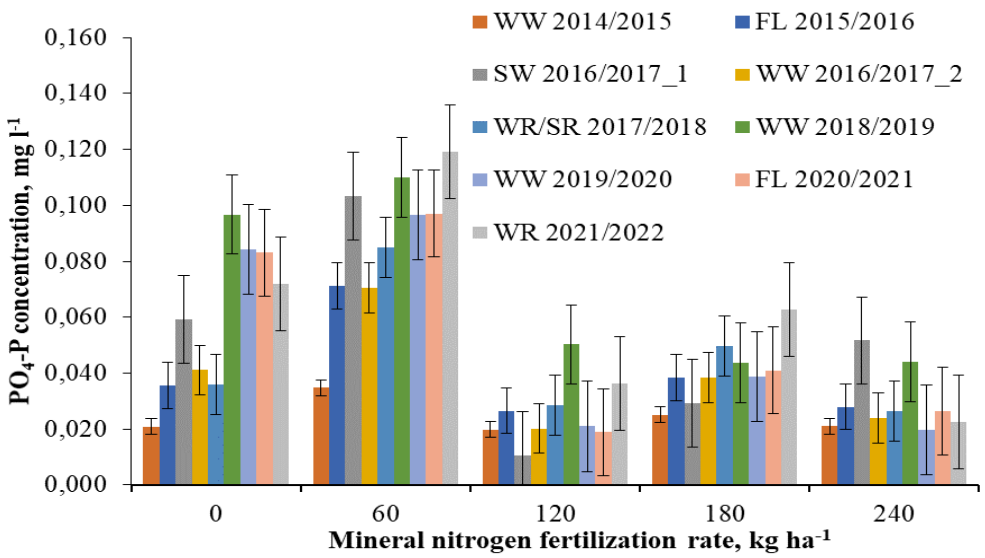


Figure 3. Relationship between nitrogen application rate (kg ha^{-1}), PO_4-P concentrations (mg L^{-1}), and crops at the research level of experimental plots *(WW, winter wheat; FL, fallow land; WR, winter rapeseed; SR, spring rapeseed; SW, summer wheat).*

Evaluating the nitrogen application rates of mineral fertilizers (kg ha^{-1}), the concentration of PO_4-P (mg L^{-1}) and the relationship between crops at the research level of the experimental fields during the research period the highest values of PO_4-P concentrations were observed in 2021/2022, when winter crops were grown including winter rapeseed (0.07 mg L^{-1} N0, 0.12 mg L^{-1} N60, 0.06 mg L^{-1} N180) and winter wheat at N120 PO_4-P concentrations in 2018/2019 (0.05 mg L^{-1}), while at N240 – spring wheat in 2016/2017 (0.05 mg L^{-1}). The lowest values of PO_4-P concentrations were observed in 2016/2017, when summer wheat was grown (0.01 mg L^{-1} N120), in 2014/2015, when winter wheat was grown (0.02 mg L^{-1} was at N0, N240), as well as when growing winter wheat in 2019/2020 (0.02 mg L^{-1} N240).

Table 4. Multiple pairwise comparisons (PO_4-P mg/l) using the Steel-Dwass-Critchlow-Fligner procedure/ Two-tailed test of yearly average values.

PO_4-P mg/l					
Sample	**Frequency**	**Sum of ranks**	**Mean of ranks**	**Groups**	
N120	9	100.50	11.17	A	
N240	9	128.50	14.28	A	
N180	9	211.00	23.44	A	
N0	9	255.00	28.33	A	B
N60	9	340.00	37.79		B

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Steel-Dwass-Critchlow-Fligner procedure/ Two-tailed test of annual average showed two groups in PO_4-P annual average measurements (see Table 4).

Table 5. Multiple pairwise comparisons (NO_3-N mg/l) using the Steel-Dwass-Critchlow-Fligner procedure/ Two-tailed test of yearly average values.

NO_3-N mg/l					
N0	9	73.00	8.11	A	
N60	9	188.00	20.89	A	B
N120	9	217.00	24.11		B
N240	9	277.00	30.78		B
N180	9	280.00	31.11		B

Steel-Dwass-Critchlow-Fligner procedure/ Two-tailed test of annual average showed two groups in NO_3-N annual average measurements (see Table 5). Kruskal-Wallis tests indicate that the experimental plot with 0 kg ha^{-1} of N application rate showed statistically significantly lower N_{tot} concentration (p-value <0.001) and the plot with 60 kg ha^{-1} showed statistically significantly higher P_{tot} concentration (p-value <0.0001).

DISCUSSION

During the summer period as the hydrological activity decreases NO_3-N leaching decreases, such dynamics of NO_3-N leaching can be observed regardless of whether winter or summer crops are sown because during the time period at risk the crops cannot absorb the NO_3-N in the soil solution [16], also in our study, a very high risk of NO_3-N leaching was observed for various crops, for example, during the study period, the highest values of NO_3-N concentrations were observed when winter rapeseed was grown at 14.3 mg L^{-1} N180. Rudzianskaite and Miseviciene (2005) concluded that in the research objects, the concentration of NO_3-N in the runoff from perennial grasslands was 2.4 – 3.6 times lower than in the runoff from arable lands [17], in 2015/2016, when the fallow was left with very high concentrations, which could indicate the negative effect of fallow on water quality, the concentrations were 8.6 mg L^{-1} N180 and 8.2 mg L^{-1} N240. The study by Dimanta (2012) shows (the study was also conducted at the monitoring station Mellupite) that in the years when agricultural crops - winter rapeseed and winter wheat - were on the experimental plots, higher concentrations of nutrients were observed in drain waters (N_{tot} 10.5 mg L^{-1}, NO_3- N 9.3 mg L^{-1}, P_{tot} 0.131 mg L^{-1}), while the lowest N_{tot} and P_{tot} concentrations were observed during clover and oat vegetation (N_{tot} 7.5 mg L^{-1}, NO_3-N 7.0 mg L^{-1}, P_{tot} 0.046 mg L^{-1}) [18], these obtained results can be compared well with the obtained results in our study, where NO_3-N concentrations reached up to 14.3 mg L^{-1} in plots with winter rapeseed. Since 2018, when Valujeva et al. (2020) did not consider water quality as an issue in Latvia due to the annual average nitrate concentration in surface water bodies not exceeding the EU Nitrate Directive standards of 11.3 mg nitrate-N per L, a decline in water quality has been observed. For instance, in trial fields of FL 2020/2021 and WR 2021/2022, the EU Nitrate Directive standard has been exceeded at rates of both 60 kg per ha and 120, 180, and 240 kg per ha. [19]. The leaching of nutrients should be considered in relation with other affecting factors, not only by examining the crop, soil management practices, or weather effects, but also by considering other environmental factors. Moreover, soil moisture plays an important role in regulating the production and release of N_2O emissions from soil. For instance, research by Valujeva et al. (2023) indicates that crop

rotation involving winter crops in reduced tillage systems has demonstrated the highest N_2O emissions from soil compared to other crops in conventional or reduced tillage systems [20].

CONCLUSION

The annual average N_{tot} concentration at the experimental field study level between 2014 and 2022 ranged from 7.3 mg L^{-1} to 12.9 mg L^{-1}. Similarly, the annual mean P_{tot} concentration at the experimental field study level during the same period ranged from 0.001 mg L^{-1} to 0.230 mg L^{-1}. Application rates of mineral fertilizer have shown significant impacts on the concentrations of N_{tot} and NO_3-N observed in collected water samples with higher applications rates of nitrogen leading to increased concentrations of nitrogen compounds. According to the Kruskal-Wallis test results, the experimental plot with 0 kg ha^{-1} showed statistically significantly lower concentrations of total nitrogen (p-value < 0.001), while the plot with 60 kg ha^{-1} demonstrated statistically significantly higher concentrations of total phosphorus (p-value < 0.0001).
The leaching of nutrients should be considered in relation with factors beyond crop, soil management or weather effects; other environmental factors should also be taken into account.

ACKNOWLEDGEMENTS

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THE FORMATION OF TWO-TIERED ANTHROPOGENIC LANDSCAPES AND ITS IMPACT ON THE ENVIRONMENTAL SAFETY OF THE KRYVI RIH LANDSCAPE TECHNICAL SYSTEM

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ABSTRACT

The mining industry of Ukraine plays an important role in the industrial sector, as the country has significant resources of natural raw materials, which contributes to the development of mining. However, this industry causes serious environmental and social consequences. The long-term operation of mining enterprises in Ukrainian regions causes serious pollution of the atmosphere, soil and water resources, as well as the destruction of the natural landscape. This leads to the degradation of natural resources and deterioration of the quality of life of local residents. The article analyzes the impact of mining and residential landscapes using as example the Kryvyi Rih landscape-technical system. Essential attention is paid to landscapes, which are key in the formation of this system. The impact of technogenesis on these landscapes was studied and the two-tiered nature of mining and residential landscapes was revealed. It was established that this process led to the transformation of natural landscapes into anthropogenic ones, as well as to the formation of surface and underground layers that determine the structure of the Kryvyi Rih landscape-technical system. This work indicates the need to improve the methods of determining the environmental risk of mining activities and emphasizes the importance of preserving natural resources and the health of local communities in the context of the development of the mining industry in Ukraine.

Keywords : ecology, ecological safety, mining complex, two-tiered, anthropogenic landscape, Kryvyi Rih landscape and technical system.

INTRODUCTION

Complex environmental conditions arising in territories dominated by mining companies require improvement of methods for determining the environmental risk of the activities of these enterprises.

As an important element of economic transformation, the mining complex actively contributes to changing the balance between matter, structure and energy on Earth. Natural changes in the relief and the constituents of its sediments are a condition for the emergence of environmental and nature conservation problems. The scale and speed of extraction of raw materials threaten human existence (expansion of built-up areas,

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settlement of surfaces, use of land for landfills, violation of the water balance of surface and underground waters, mineralization above the permissible level, etc.).

The Kryvyi Rih landscape -technical system is not exception here, and the current state of the Kryvyi Rih landscape-technical system has been completely changed due to the influence of the mining industry. Along the extension of the iron ore deposits of the Kryvorizka structure, iron ore was mined and production waste was stored, which led to the complete destruction of the background northern steppe landscapes here in the past, the Saksahan and Inhulets riverbeds. Instead, anthropogenic, mainly mining landscapes were formed and developed, which now occupy almost 40,000 hectares and are of significant importance in the functioning of the modern Kryvyi Rih landscape and technical system, which directly affect the ecological state of the territory.

MATERIALS AND METHODS

Research methods. In the process of work, general scientific and special research methods were used: analytical, comparative and statistical, generalization, historical, statistical and comparative methods and anthropogenic landscape forecasting

RESULTS

Today, in Ukraine, the amount of waste from the mining complex exceeds 20 billion tons, occupying an area of more than 150,000 hectares. In this way, hundreds of large, medium and small man-made deposits of various minerals, suitable for industrial development, have been developed in Ukraine [4]. The mining complexes formed in Ukraine are characterized by a complex internal structure. Their features depend on the method of development, mining technology, topography, hydrological regime and soils of the developed areas. These are mainly landscape territories of mining complexes, in the structure of which three types are distinguished: quarry-dumping, peat-swamp wastelands and terricone-pseudokarst.

The Kryvyi Rih landscape and technical system is a unique system that houses five mining and beneficiation plants: Southern, Northern, Novokryvorizkyi, Central and Inhuletskyi [6]. The areas of anthropogenic landscapes of the KLTS are constantly growing, in terms of percentage, agricultural landscapes occupy the largest area (61.2% of the area of the region), residential landscapes - 13.1%, industrial landscapes - 11.5%, water management landscapes - 8.1%, forestry landscapes - 3 .5%, transport landscapes - 2%, others - 0.6% [6].

The history of the formation of two-tiered mining landscapes of the Kryvyi Rih landscape-technical system (the KLTS) begins with artisanal development and development of natural resources (IV century BC - XVII century). Natural conditions, in particular the climate of the post-glacial period, contributed to the active settlement of the territory of Right Bank Ukraine by early people (40-35 thousand years ago - IV century BC) [7]. In the Neolithic and Eneolithic eras, fine-grained quartzite was mined on the territory of the KLTS, which was used as a substitute for flint. There are also known finds of limestone steles with the remains of ritual drawings, which were applied with ocher and marmot. And during the time of the catacomb culture (XV-XIII centuries BC), mining was active on the territory of the KLTS, this is evidenced by the fact that in the 1960s of the XX century, the remains of a Bronze Age workshop were found on the right bank of the Saksahan River, where from fragments of amphibolite were made pestles, round

stones for work. In the period of the V century B.C. - the middle of the 1st millennium AD Scythian tribes inhabited the territories of the KLTS, who were the first to find deposits of iron ore. The Scythian tribes smelted iron and made weapons, as evidenced by finds found in Dubova Balka and Pivdenna Chervona Balka [7]. In the 9th century A.D. the territory of the KLTS was the "Wild Steppe", where mainly Turkic nomadic tribes roamed. There are no data on the use of KLTS iron ores. In the 18th century - the first half of the 20th century the stage of the initial industrial development of iron ores on the territory of the KLTS begins. At this stage the development of the surface and underground levels of the mining landscapes of the KLTS begins.

The active stage of iron ore development on the territory of the Kryvyi Rih landscape-technical system began in 1881. O.M. Paul began the industrial development of iron ore deposits in the Saksahan ore field. At this stage, the open method of developing useful raw materials with a slight thickness of overburden rocks - up to 9 m - prevailed. The dumps were low, but wide, with a slope angle of 6-8°. The depth of the quarries did not exceed 40 m. However, after the purchase of 21 thousand hectares of land for mines in 1895-1897, their number increased significantly [7].

During the late XIX - early 20th century at the first mines of the KLTS, open mining of the upper horizons of rich ore - 55% and more iron content was carried out. The manual labor of workers was used with typical tools: picks, sledgehammers, picking shovels, handcarts [5]. The development of iron ore deposits led to the emergence of working villages consisting of barracks for workers and primitive infrastructure, later the settlements expanded. The increase of such settlements, their convergence with each other and mutual integration led to their unification into one system, which led to the development of two-tiered urban landscapes of the KLTS. The use of the underground method of iron ore extraction began in 1898. At the same time, the area of mining developments grew - from 800 hectares in 1934 to 2,700 hectares in the middle of the 20th century. The depth of the quarries reached 90 m, the height of the dumps was from 12 to 25 m [7]. In 1935, the first culverts were formed above the underground workings.

The third stage of development of the KLTS begins in the second half of the 20th century - the beginning of the XXI century. This stage is the most influential on the landscape structure of the KLTS. In the 50s and 60s of the 20th century, mining and beneficiation plants appear, which will turn later into powerful mining complexes [6]. Together with the technical development of means of mining operations, the morphometric characteristics of quarries and dumps are also increasing. The formation of the Kryvyi Rih landscape-technical system continues up to this days. As a result of the active action of the mining industry, among the anthropogenic landscapes of the KLTS, the background ones are residential and mining, on which two-tieredness is observed.

On the territory of Ukraine, two-tiered anthropogenic landscapes are also found in the Donetsk, Lviv -Volyn coal basins, in the Kryvyi Rih landscape-technical system, which is the largest one not only in Ukraine, but also in Europe

The concept of two-tieredness is currently rather weakly studied, but it is observed in anthropogenic landscapes. It is possible to draw through the lines between two-tieredness and altitudinal differentiation, but these concepts are quite different [8]. Altitudinal differentiation is determined by the diversity and change with altitude of climatic factors and their effect on the vegetation cover, and the two-tieredness arises as a result of the

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action of all landscape-creating factors: lithogenic, climatic, hydrological, hydrogeological soil, and plant.

With the development of mining technical progress, there is a general trend of a significant increase in the volume of open (quarry) development of deposits, and as a result, quarry and tailings complexes are formed and the surface layer of the KLTS. [9]. Dumps - belong to one of the main forms of anthropogenic relief and are formed due to the following stages: storage of overburden on the earth's surface, storage on the earth's surface of by-products of mineral enrichment - slurries; storage of overburden, slurries and household waste in spent quarries and mine hoppers .

In the analysis of altitudinal differentiation on the territory of the KLTS occupied by mining developments increased up to 2.1 -2.7 times. As a result, a unique for the steppe zone of Ukraine, a low-mountain mining landscape was formed with altitudinal difference of up to 620-650 m, that is, a surface layer and underground workings to a depth of more than 1200 m - an underground layer [8] Mining landscapes are classified according to the classification into quarry - dump and mine landscape complexes, quarry and dump complexes are represented by a quarry and a dump, which are unequally related to each other. The mine type of mining landscapes was formed as a result of the closed¨ development of iron ore deposits and is divided into two subcategories: mine-fall and mine-sediment types of terrain. According to V. L. Kazakov, residential landscapes are divided into two subtypes: non-residential (cemetery) and residential. Service landscapes include domestic, administrative, scientific, educational and commercial subtypes.

Currently, on the territory of the KLTS, on the surface layer of mining landscapes, the largest quarries are operating - the SGZK quarry (more than 400 m), one of the largest reclaimed dumps - Burshchitskyi (110 m), flooded reclaimed quarries - Zhovtnevyi (110 m), Karachunivskyi (250 m), the largest sludge storage facility - Voykivskyi. The underground tier of mining landscapes is divided into mines (trunks, crossdrifts, stoop roads, blind shafts), tunnels and sinkholes. The deepest mines: Gvardiiska mine (1190 m), Kryvorizka mine (1580 m). The expansion of production, expressed in the emergence of a plant with a full metallurgical cycle "Kryvorizhstal", currently renamed " ArcelorMittal Kryvyi Rig", a number of mining enterprises and auxiliary industries prevented the development of the population. The development of iron ore deposits led to the emergence of working villages consisting of barracks for workers and primitive infrastructure, later the settlements expanded. The increase of such settlements, their convergence and mutual integration led to their unification into one system, which led to the development of " two-tiered " urban landscapes of the KLTS [9].

Due to this, the KLTS has a clearly expressed submeridional altitudinal zonation, the so-called two-tieredness, not only with quarries, dumps and mines, but also with a residential landscape. The largest older lane is the western one, which corresponds to 1-2 storey buildings of the end of the 19th century - the 30s of the 20th century, where there were existing and abandoned mining enterprises next to each other. The middle strip of 2-5 storey buildings of 1950-1960, where a number of enterprises of the residential landscape are concentrated in the modern structure of KLTS: various spheres of economy and socio-cultural, educational, business institutions. The eastern strip is a 9-16-story building with a minimum number of enterprises [9]. The settlement landscape of the KLTS also consists of surface and underground layers. The surface layer is characterized by residential buildings (high-rise residential buildings, industrial enterprises, various

shopping centers, cultural and artistic buildings, etc.). The underground layer of the residential landscape includes high-speed trams, which moves along overhead and underground lines, such type of tram traffic characteristic only on the territory of KLTS.

Therefore, in the mining industry, landscape protection is a complex system of measures to prevent or reduce the direct and indirect impact of mining on the landscape [4]. Further uncontrolled development of the economic complex and its impact on natural objects may lead to irreversible changes in the human habitat in the near future. The biggest changes occur in the upper layers of the lithosphere, atmosphere and hydrosphere, changing or destroying the basis of the production landscape and soil cover.

Today, all environmental problems affect the interests and needs of all inhabitants of the planet and are universal and global in nature. As a result of our preliminary analysis of scientific sources, we identified five main types of violations that have a negative impact on the environment. Figure 1 shows them in more detail.

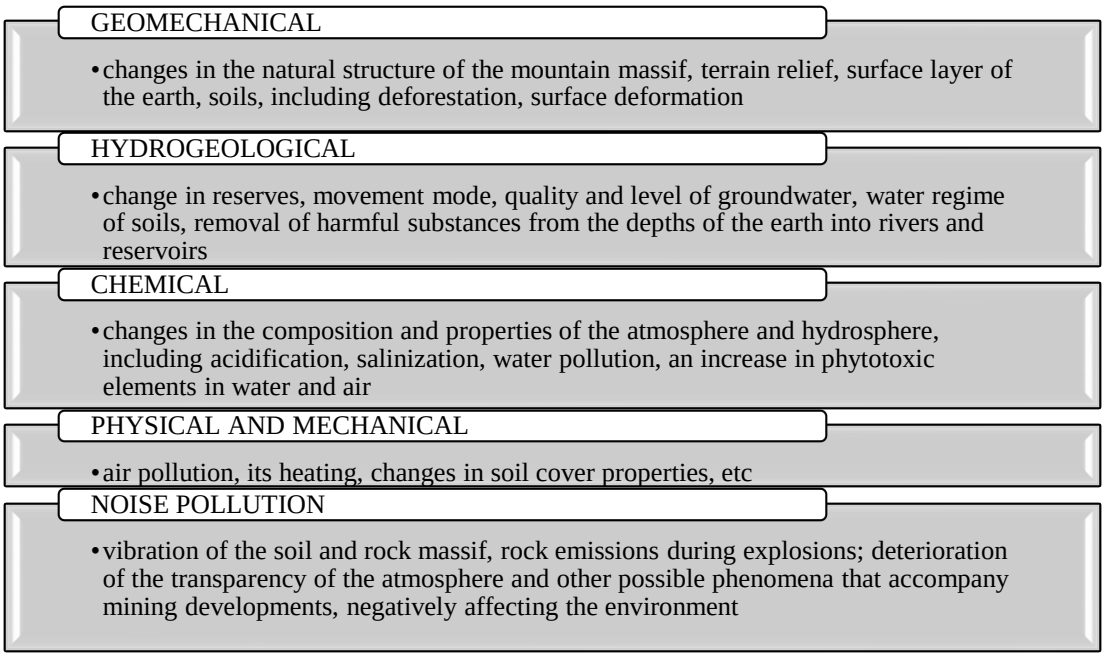


Fig. 1. Main types of environmental violations

There are many reasons for this state, among them: the connection between the sphere of expression and the degree of environmental impact of processes and products that are the result of manual labor and human will, compared to natural processes occurring in nature; mining and industrial complexes are responsible for a significant part of environmental pollution.

The impact of mineral extraction on the natural environment begins with geological studies. Taking into account the types we have highlighted, the disturbance of soil hydrology can lead to a decrease in the productivity of agricultural lands adjacent to mining concessions. A deep funnel is formed around the quarry, as a result of which the inflow of water solutions into the soil layer is reduced with all consequences. Therefore, the zone of active influence of the quarry extends from 5 to 15 kilometers.

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In a radius of 1.5-2 kilometers near the quarry, for the reason of soil alkalinity to pH = 8, productivity decreases by 30-50%, and the content of harmful metal impurities increases by 2-3 times, which leads to a decrease in gas and dust emissions, and this in turn queue leads to water supply restriction. Air pollution in the mining industry is caused mainly by dust and gases generated during explosions, as well as emissions of natural gas from mines and quarries. According to estimates, an average of about 8 million tons of natural gas is released as a result of explosions worldwide every year , which is much less than natural gas emissions, since more than 90 million tons of methane are released into the atmosphere from coal mines alone [4, 5].

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Vast agricultural areas are laid waste, soils and forests are destroyed, basic hydrological conditions are altered, productivity is reduced, and even the topography of the region and the movement of air currents are changing. Exploitation of the subsoil leads to the creation of large areas of artificial mining landscape, characterized by surface accumulations of mine bodies (pits, workings, sludge deposits) and negative relief - quarries, areas with subsidence of the surface above mine shafts, etc. [5]. In these areas, the entire surface is rebuilt, the composition of natural vegetation is drastically reduced, the biological productivity of the land decreases, and groundwater is depleted. Conversely, low-lying areas in plain areas are often flooded, making them economically inaccessible. Harmful gases and mineralized water extracted from mines and quarries and entering surface waters are an important source of environmental pollution, and the accumulation of rocks on the surface becomes an active source of fine dust.

In Ukraine, the largest mining activity is carried out by Kryvorizhzhia. There are about 18,000 hectares of disturbed soil, among of which approximately 12,000 hectares are rock dumps and sediments. Modern mining techniques, including mound construction and pollution control, open up underground mineral deposits by carving production spaces into the rock. To protect the fertile soil layer, earthworks, fire prevention works, leveling and landscaping of the territory (Lviv -Volyn Basin) are necessary [5]. Significant subsidence of the Earth's surface is associated with intensive extraction of groundwater, oil and gas, which is often accompanied by structural deformations, regional flooding and coastal flooding. Pumping out groundwater lowers the water level in the surrounding areas, which leads to the death of forests and a decrease in soil fertility. Deforestation and disturbance of vegetation occurs in open-pit mining areas, during the storage of minerals and surface dumps, during the construction of roads, and during the construction of maintenance buildings for mining companies. Surface disturbance occurs during the mining of minerals in quarries, during the construction of mine shafts and overhead structures, as well as during the mining of minerals underground as a result of surface subsidence. As the rock recedes, the surface drops. The depression formed is filled with water, this phenomenon was observed during the development of Carpathian potash.

Mining has both positive and negative impacts on people and communities. Negative impact on the population living in mining areas, manifested by the release of dust and other substances, as well as a minor impact on the standard of living, including noise, vibration, temperature, vehicles, emissions, etc. due to harmful effects on life, etc. [5]. On the positive side, industry is often the center of a local community and can contribute to local and regional economic prosperity. Of all the available methods, open pit mining is the most convenient. For example, the Zhytomyr region is one of the richest territories in mineral deposits, surface and dead deposits, it is advisable to study during the period of open mining of indigenous rocks. Deposits of mechanical and facing stone in Zhytomyr region, in particular labradorite, granite and gabbro, are almost universal. The region has large reserves of stone that is in good condition for processing and processing in large quantities. In the process of open-pit mining, a significant part of agricultural land is used for the extraction of minerals in quarries, mining landfills, construction of industrial zones, construction of communications, etc. The area under the landfill significantly exceeds the area of the quarry area. Open pit mining has a negative impact on the environment , as shown in Figure 2 .

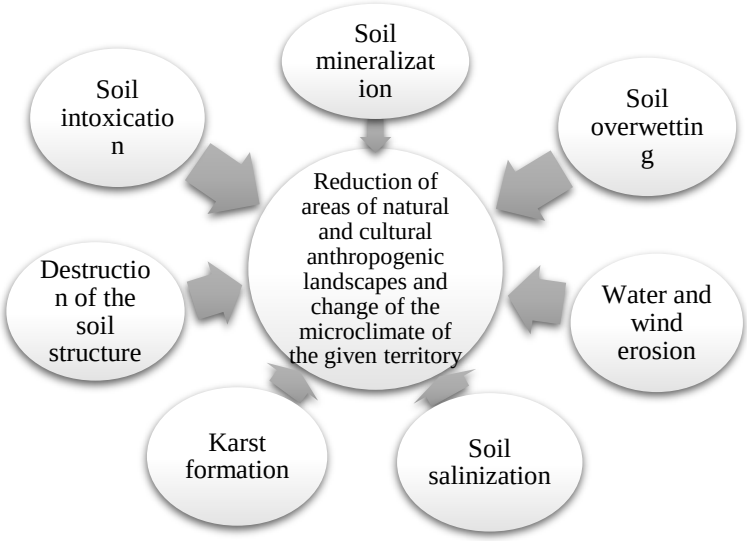


Fig. 2. Environmental consequences of open mining for landscapes

The impact of open mineral development on hydrosphere objects is expressed in the pollution of surface and underground waters by products of explosive decay, fuel and lubricating oils, salty mineralized waters, etc. During open pit mining, large-scale explosions pollute the air with a mixture of dust and gases. In addition, many heavy processing equipment, most of which are equipped with internal combustion engines, are used in quarries and landfills and are a strong source of air pollution, releasing large amounts of dust into the air. According to the classification of air pollution sources adopted in the EU, the mining industry causes air pollution with gaseous substances and mineral dust.

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DISCUSSION

The works of foreign and domestic scientists, such as Mirza Z., Mahmood A. [1], Surenda R. [2], Suresh B., Sunil R. [3], Bosak P.V., Stokalyuk O.V., Koroleva O.G., Popovych V.V. [4], Ivanova V.M. [5], Maksimova N.M. are devoted to the problems of environmental safety. However, in our opinion, it is relevant to analyze the level of ecological danger of the mining industry for the development and search of optimal forms of environmentalization of the mining complex and the assessment of the formation of two-tiered anthropogenic landscapes and their impact on the ecological safety of the Kryvyi Rih landscape-technical system .

CONCLUSION

Taking this into account, we propose to consider priority measures in the direction of maintaining environmental safety, appropriate adjustment (development) of environmental strategy, methods, etc. The Kryvyi Rih landscape-technical system has a two-tiered structure for the reason of mining industry, which has changed the completely natural landscapes of the system, the scale of which reaches more than 40,000 hectares. Therefore, in order to solve the ecological danger in the mining areas of the Kryvyi Rih landscape and technical system, it is necessary to carry out: development of the environmental passport of the mining area; implementation and monitoring of environmental management of the mining district; ensuring the environmental safety of tericons (mine rocks) of the mining district: prevention of emergency emissions (discharges), elimination of the consequences of environmental pollution as a result of possible accidents and disasters; minimization of the ecological danger of the mining district to the environment (phytomelioration reproduction, bioplateau, reclamation of tericons, etc.).

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THE HUMAN IMPACT ON THE STRUCTURE OF THE RIPARIAN VEGETATION IN THE RURAL AREA

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ABSTRACT

Riparian vegetation of water streams represents dynamic ecosystem, which meets various functions. Since it forms a buffer zone between the aquatic and terrestrial ecosystems, it is of great importance in the ecological stability of landscape. Its importance is even higher nowadays when the effect of human activities on the environment is much stronger than in the past. The structure and quality of the vegetation comprising the riparian zone plays an important role in its ability to provide various ecosystem functions such as filtration of the sediment being transported by the surface runoff due to water erosion. This study investigated the impact of human activities on the structure and biodiversity of riparian vegetation in a rural area of the Sadówka watercourse in Poland, focusing on the effects of channelization and embankment on the riparian vegetation ecosystem functions. The canopy density at 11 selected sites along the river was estimated in 2008 as a global degree of canopy cover (GDCC). The mean GDCC in the upper part of the watercourse was 54 % and it occasionally reached up to 68%. Several rural settlements are in the middle part of the stream, what affected the GDCC ranging from 19 up to 68%. In this area also most of the regulated embarked sections of the watercourse are located. The lowest part of the river channel still shows its natural state with the mean GDCC of 66% besides the area is intensively used for agriculture. There are several sections of regulated flow, however the embankment is of mainly natural – grassy type. Human modifications to the channel, such as artificial embankments and regulation, had a negative impact on the structure and biodiversity of the riparian vegetation, with the most natural sections exhibiting the highest GDCC and biodiversity. The degree of human impact varied along the length of the watercourse. Understanding the impact of human activities on riparian vegetation is crucial for maintaining ecological stability and mitigating the effects of erosion and flooding.

Keywords: riparian vegetation, monitoring, natural channel, regulated channel, canopy cover

INTRODUCTION

Riparian vegetation is a unique vegetation zone that acts as a buffer between aquatic and terrestrial ecosystems alongside rivers and streams. This zone plays a critical role in maintaining the ecological stability of landscapes and provides various ecosystem services such as provision of bioremediation, water flow regulation, pollination, seed dispersal, nursery habitats, pest control, disease control, decomposition, water treatment, global climate regulation, local air temperature regulation [1]. The implementation of these functions depends on the site characteristics, spatial and species composition of vegetation, its health and structure. For example, herbaceous layer is the most efficient at filtrating the sediment from surface runoff, however its effect in protection of riverbanks

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against erosion is low. On the other hand, shrub layer can efficiently mitigate the processes of bank erosion, but its contribution to filtration of surface runoff is lower [2]. Kowalska et al. [1] highlighted the importance of riparian hardwood forests in Poland as multiservice hotspots, providing crucial ecological functions and regulating services. Their research indicates that these forests have a higher potential for regulating services compared to other forest ecosystems. However, alterations in the natural water regime, such as the absence of flooding and artificial drainage, can negatively impact water-related regulating services and overall ecosystem stability, potentially facilitating invasions of alien species. Interestingly, the study also found that drier mesophilous forests can offer more favorable habitats for wild pollinators.

Worldwide, riparian ecosystems are under severe threats due to agricultural activities, urbanization, river flow alteration, overexploitation, climate change, pollution, and biological invasion [3]. Human activities, particularly in rural areas, have significantly modified riparian zones through agricultural practices, land development, and channelization. These alterations can change vegetation cover, affecting the ecological functions of riparian buffers. Channelization, which involves straightening, deepening, and embanking streams, can reduce sinuosity, increase water flow and erosion, and decrease habitat complexity. Consequently, species biodiversity, density, and quality of riparian vegetation may decline. Comprehending these impacts is essential for creating strategies to minimize negative effects and enhance ecosystem resilience [4].

The assessment of riparian condition is perquisite for making, implementing and tracking the riparian management projects. Riparian quality is high when riparian vegetation consists of forested areas. On the other hand, riparian quality is low when land is lacking woody vegetation along river corridors [3]. The various morphometric parameters of the vegetation (e.g., number of individuals, canopy density and height) can be studied by field measurements and remote sensing methods. Bombino et al. [5] identified embanked and control sites within homogeneous riparian zones. Transects were divided into sample areas in both embanked and control sub-reaches. Vegetation parameters, including species number, canopy cover, height, type, biological forms, and ecological groups, were surveyed. Two new parameters, global canopy cover and weighted canopy height, were introduced to provide a comprehensive view of vegetation development. Fehérváry and Kiss [6] proposed a method combining machine learning and statistical analysis of LiDAR data to quickly and repeatedly survey vegetation density over large areas. This method can calculate 3D vegetation density as an input for various models. Although it requires significant financial investment and expertise, LiDAR-based surveys are becoming more cost-effective and accessible, making this method increasingly viable for future use in science and management.

This study investigates the impact of human activities, particularly channel modifications, on the structure and biodiversity of riparian vegetation in a rural area of the Sadówka watercourse in Poland**.**

MATERIALS AND METHODS

The Sadówka catchment located in the southwestern part of Poland (Figure 1) covers as area of 43.2 km^2. This intensively cultivated basin is characterized by agricultural fields (57%), forests (30%), pastures (9%), and residential areas (3%). The Sadówka River, 13.5 km long, originates in Nagórnik village and flows through Sady Górne and Sady Dolne

before joining the Nysa Szalona River in Wolbromek. The riparian vegetation, spanning 0.48 km², follows the river course and according to the Computer-based National Protection System of Poland (https://wody.isok.gov.pl/hydroportal.html) the channel is prone to river floods in its last 290 meters. The river has three tributaries, which were not studied in this research. The settlement pattern in this area is predominantly linear, leading to channelization in specific parts. Except for natural, non-regulated reaches outside of villages, the river is regulated, with 7% of its channel embanked on one or both riverbanks. This management is evident in Sady Górne, where 4.5% of the channel length is embanked on one side and 1.6% on both sides. Because of this reason the river channel was divided into Upper (site A-D), Mid (site E-H) and Lower (site I-K) part of the channel (Figure 1).

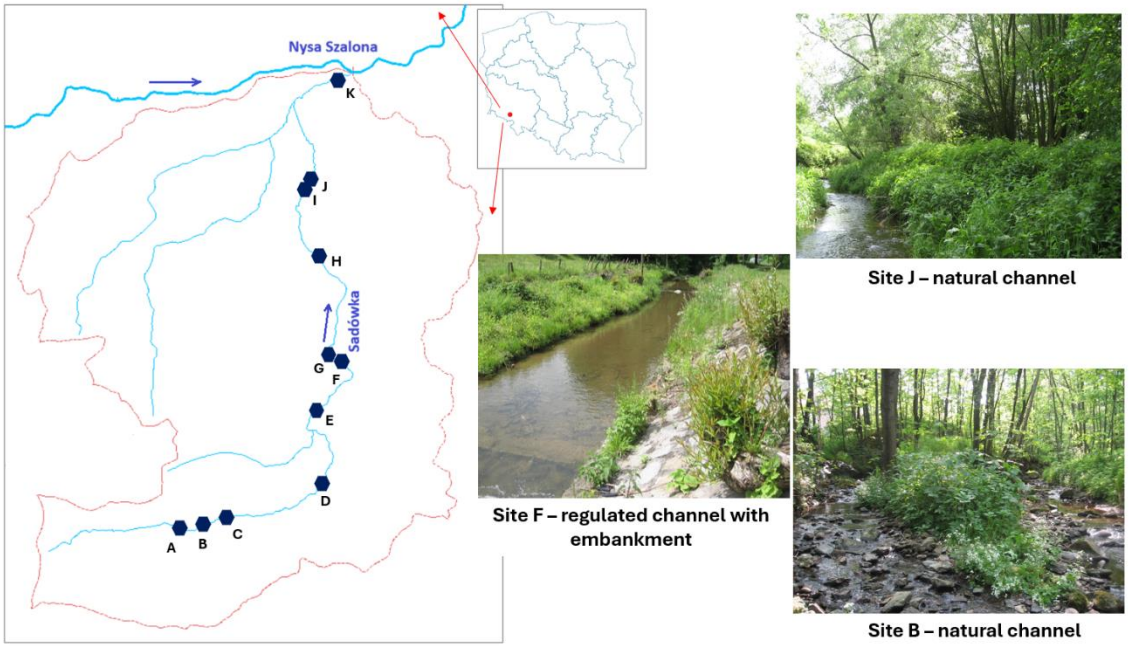


Figure 1 Sadówka River catchment with 11 study sites (A-K). Smaller insert shows the position of the catchment within Poland. Images of site B, F and J were given as examples of the riparian zone in the Upper, Mid and Lower part of the river channel, respectively.

Fieldwork was conducted in May-July 2008 as a part of bigger study [7]. During the first inspection of the study area 11 benchmark reaches (A – K) were selected along the river channel and then described in detail. Vegetation at these reaches was mapped in tree, shrub and herbaceous layer. Using the observation on the canopy coverage of three vegetation layers, global degree of canopy cover (GDCC) was estimated [5]. Position of mapped vegetation elements as well as position of the watercourse, banks, contact surface area with riparian zone, bank and riverbed embankment were plotted in a local positioning system on millimetre paper and then digitalized in GIS and then evaluated.

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RESULTS

The minimum GDCC of 0.19 was observed in site F in the Mid part of the channel. The maximum values of 0.68 were identified at site B in the Upper part and site G in the Mid part of the channel. The mean GDCC was 0.54, 0.39 and 0.66 in the Upper, Mid and Lower part of the river, respectively. Usually, the GDCC was at least partially related to channel type and its level of embankments (Table 1). The exception was site G with both banks regulated, where the wide strip of vegetation outside of the channel resulted in the high GDCC. This was affected by the local landuse. Although the value of GDCC is mainly affected by the representation of three layer in the locality, the natural sites in the Lower part with high coverage in all evaluated vegetation layers resulted in the highest GDCC.

Table 1 Channel embankment types and canopy coverage along the Sadówka River.

	V	Channel type	Riparian vegetation structure – fraction of coverage (-)			GDCC (-)
			trees	shrubs	herbs	
A	yes	one bank partly or fully regulated (embankment)	0.58	0.20	0.85	0.50
B	no	natural. unregulated	0.98	0.20	0.75	0.68
C	no	natural, unregulated	0.35	0.50	0.70	0.46
D	yes	regulated but no embankment	0.40	0.65	0.70	0.53
E	yes	both banks fully regulated	0.25	0.40	0.92	0.41
F	no	both banks fully regulated	0.03	0.03	1.00	0.19
G	yes	both banks fully regulated	0.65	0.60	0.90	0.68
H	yes	regulated but no embankment, natural look	0.07	0.25	1.00	0.28
I	no	natural, unregulated	0.68	0.60	0.96	0.70
J	no	natural, unregulated	0.72	0.56	0.97	0.71
K	no	natural, unregulated	0.60	0.30	0.97	0.56

Note: V – presence of the channel section in the residential area

The Mid part of the river had more regulated sections with artificial embankments, which affected the GDCC and biodiversity. In contrast, the Lower part of the river still showed a more natural state with higher GDCC of 56-71%, because it was mainly out of inhabited areas with sufficient width of riparian zone. The shrub vegetation at site J had a cover of 56% and played an important soil protection function due to the increased occurrence of bank erosion caused by the meandering of the stream.

The species abundance and structure were significantly affected by the human impact, both directly and indirectly. The tree layer was characterized by the presence of several

species including *Acer platanoides, Acer pseudoplatanus, Salix fragilis and Salix caprea* (Figure 2). Other species identified were *Fraxinus excelsior, Quercus robur, Alnus glutinosa, Cerasus avium, Tilia platyphyllos, Betula pendula, Ulmus montana, Alnus glutinosa, Alnus incana* and *Padus racemosa.* Notably, activities introduced non-native species, such as fruit trees (plum trees) and ornamental trees (*Picea excelsa*), into the riparian vegetation. The shrub layer was primarilly composed of *Sambucus nigra*. Other abundant species were *Euonymus europaeus, Swida sanguinea* and *Rubus caesius*. At some locations additional species were identified: *Crataegus leavigata* and *Prunus spinosa*. At site F was exceptional in lacking a shrub layer entirely. The herbaceous layer depending on the site's position along the stream and the time of field mapping. Most of the sites hosted *Urtica dioica*, *Galium aparine* and *Aegopodium podagraria*. In the natural sites downstream, additional species were observed, such as *Scrophularia umbosa*, *Epilobium roseum*, and *Impatiens parviflora*. In the calm waters, *Lemna minor* was also found.

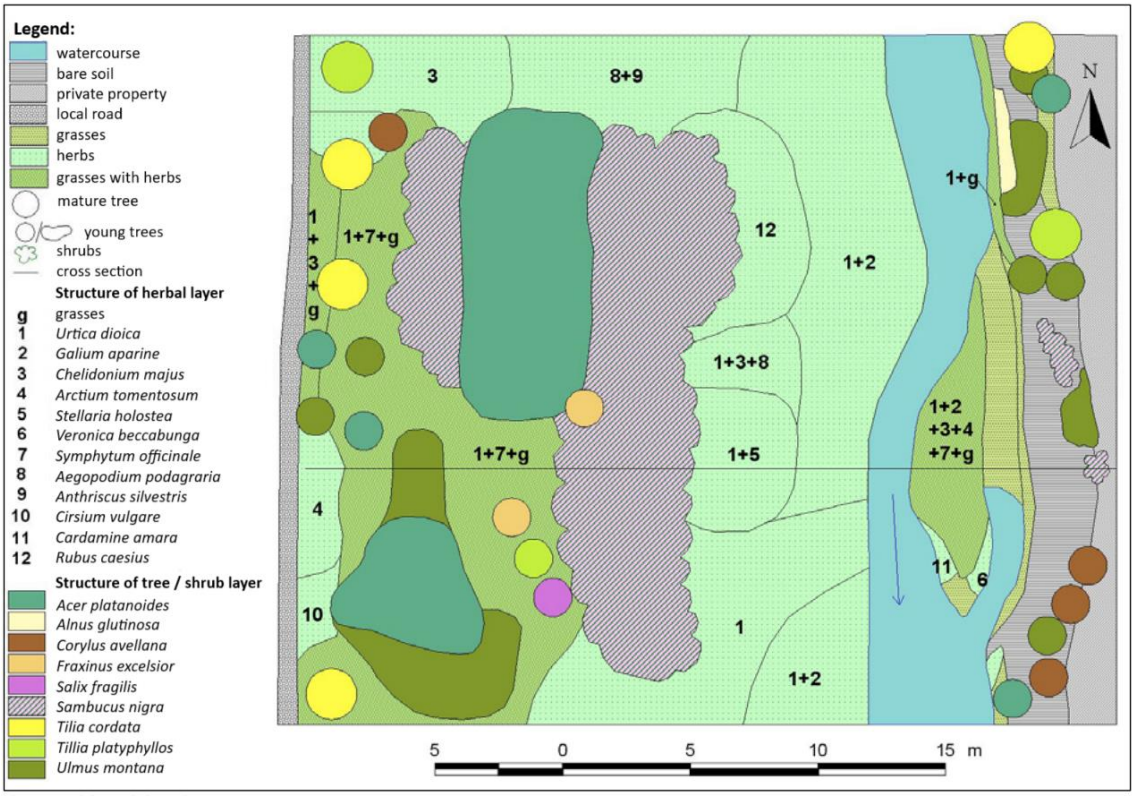


Figure 2 The diagram of the riparian vegetation structure and most abundant species representation – example for site D

DISCUSSION

The study identified a diverse riparian vegetation community composed of tree, shrub and herbaceous species, with the composition varying along the length of the Sadówka watercourse. In summary, our study clearly demonstrates that human modifications to the channel, such as artificial embankments and regulation, had a negative impact on the structure and biodiversity of the riparian vegetation, with the most natural sections exhibiting the highest GDCC and biodiversity. The degree of human impact varied along

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the length of the watercourse. Brinson et al. [4] highlighted that channelization and embankment (such as rip rap) can cause such significant changes as an effect of human intervention in the area. Hower, it should be noted that there were some other factors affecting the species distribution such as the speed of the flow (affected by channelization, longitudinal slope, width and species distribution of vegetation) and landuse upstream and within the reach. Adamska [8] in her study conducted in Lower Silesia concluded that many evaluated riparian buffers zones were limited and could not function properly. Some transects of selected rivers that were located within rural area and drainage agriculture lands can possibly suffer because of the livestock grazing and crop production. The sections in the vicinity of the cities may be exposed to the anthropopressure. She observed that only sections with inclusion of conservation practices like Natura 2000 could be assessed as optimal and good zones.

CONCLUSION

On one hand, channel regulation offers significant advantages in terms of flood control, enhanced land use, and predictable water flow. These benefits are crucial for the safety and economic stability of rural areas, where agriculture and development depend on reliable water management. Effective flood control protects communities and agricultural lands from the destructive impacts of flooding, ensuring that these areas remain productive and habitable. However, these benefits come at a cost. As our study confirmed, channelization often results in a loss of habitat complexity, which is essential for supporting a diverse range of species. The uniformity introduced by regulated channels diminishes the ecological richness of riparian zones, leading to a decline in species diversity. Furthermore, increased water flow speed due to straightened and deepened channels accelerates erosion, undermining the stability of stream banks and causing potential damage to adjacent lands. Reduced vegetation density, a direct consequence of physical alterations, compromises the natural growth patterns and health of riparian plants, weakening the zone's ability to perform critical ecological functions. Nevertheless, the threats posed by continued human activities and climate change remain a concern. These factors can exacerbate the degradation of riparian zones, making it increasingly difficult to maintain their ecological functions. By promoting sustainable management practices, it is possible to achieve a balance between human needs and environmental health. Such practices ensure that land use and water management do not come at the expense of ecological stability. Additionally, efforts to conserve biodiversity within riparian zones can contribute to broader conservation goals, preserving essential ecosystems for future generations.

ACKNOWLEDGEMENTS

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IMPORTANCE OF INHABITANTS' EMERGENCY PREPAREDNESS WITH REGARD TO THEIR QUALITY OF LIFE

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ABSTRACT

We are currently facing various forms of emergencies that affect the quality of life of the inhabitants. Their impacts can have a significant impact on physical, psychological and social health and can negatively affect people's quality of life. Preparedness and training are crucial not only for public authorities, but also for the inhabitants, in order to minimize the consequences of various crisis situations. Quality of life indicators include the quality of housing, which includes the factor of safety. In the context of security, it is important to focus attention, among other things, on the views of inhabitants and how emergencies affect their quality of life. This can help to ensure an improved quality of life for people who find themselves in or threatened by these situations. When public authorities and the inhabitants work together and coordinate, the negative impact of emergencies can be reduced, thereby ensuring safety and security for the inhabitants. The aim of this paper is to find out the impact of emergencies on the quality of life of the inhabitants. A questionnaire survey of inhabitants was used to determine the impact, and the information obtained was then analyzed and statistically evaluated. This allowed to propose solutions to improve the inhabitants' preparedness for emergencies and at the same time to improve their quality of life.

Keywords: quality of life, civil protection, crisis management, citizens, emergency event

INTRODUCTION

Quality of life can be defined as the result of the interaction of economic, social, health and environmental conditions that relate to human and social development. Veenhoven writes about different qualities in the Four Qualities of Life scheme. Most theories focused on the quality of life can be included in this scheme. Veenhoven's distinction is based on two dichotomies: life chances versus life outcomes versus external qualities. The difference between chances and outcomes means that having options for a good life does not mean a good life itself, lived. Potential and reality are interconnected but do not mean the same thing [1].

Masaam claims that the quality of a person's life depends on the exogenous (objective) factors of the individual and on the endogenous (subjective) perception of these factors.

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The subjective quality of life is related to the internal psychological mechanism causing a feeling of satisfaction or pleasure from life. In connection with this dimension, the terms individual or personal quality of life, subjective well-being or life satisfaction are associated. Other terms are used for the objective dimension, e.g. urban or community quality of life, quality of place and environmental quality of life. Masaam says that quality of life is a multifaceted concept where it is important to combine these dimensions to provide a complete picture of a person's quality of life. [2] According to Myers, the objective dimensions of the quality of life are the rewards and influences of the surrounding environment and life circumstances on a person's life, which are divided into social, economic and environmental. The subjective dimension is represented by the sum of the individual's subjective inputs, e.g. opinions, attitude, individual value system, ability to adapt, ways of perceiving the surrounding environment, etc. [3]. Quality of life indicators used by the Statistical Office of the Slovak Republic are based on the concept of the European Statistical System. The indicators ensure the measurement of the quality of life of the inhabitants from 9 dimensions: Material living conditions; Productivity; Health; Education, Physical and economic security; Leisure and social relations; Natural and living conditions; Governance and Human Rights; Total life experience [4].

As part of the quality of life, we mainly focus on safety. One of the basic human needs is security. Securing citizens is becoming more and more difficult, especially due to the increase in greater influences acting on them. Maintaining a state of security is necessary for the functioning of the state, organizations, institutions as well as for human existence. One of the most important tasks facing the entire society is increasing the level of safety of citizens. The level of security of an individual or a company is formed by various factors that influence the activities and processes that are necessary for the fulfilment of goals. Safety can be affected by various factors such as ecological, technical or technological [5,6]. For each person, the word security means something different, but for organizations there are precisely defined laws. One way to effectively manage safety and identify areas for safety improvement is to use performance indicators in a given area. Performance can be defined as the way in which something or someone works and thereby achieves set goals. Performance measurement is important for the organization, it quantitatively lets the management know at what level the organization is functioning, whether goals are set, whether individual parties are satisfied, whether the organization has processes under control and where improvement is needed. Stimulation and optimization methods are used for measurement, evaluation and partly also for process improvement. Security influences the quality of life, making it essential to tackle threats impacting residents [7,8]. Among these threats are extraordinary events, which also warrant careful attention.

The importance of the population's preparedness for emergencies is rising. Factors such as increasing population density, heightened dangers from anthropogenic events and accidents, the growing frequency of emergencies, and urban expansion necessitate risk analysis strategies in urban areas, considering hazard, exposure, and vulnerability factors [9,10]. Concurrently, it is essential to ensure that citizens can respond appropriately to new emergencies. According to Pirlon (2020), local authorities must implement necessary changes to address future challenges by reducing the vulnerability of both people and the urban environment [11].

MATERIALS AND METHODS

Analysis is one of the basic methods. The exact meaning of the word analysis is a method of investigation. Analysis is the process of separating a more complex whole into simpler parts. It is an examination of relationships, properties, and factors, proceeding from the whole to the parts. The aim of analysis is to gain knowledge of the system, identify deficiencies, and determine the necessary changes. The opposite procedure to analysis is synthesis, a process where one proceeds from the simplest concepts to the more complex ones. Synthesis results in the creation of new units. These methods were used in the theoretical part of the investigated issue. The comparison method was used when comparing individual results. The article also utilized induction and deduction. Induction can be defined as a cognitive procedure in which an individual search for regularity, rules, and principles that follow from certain statements or facts. Deduction can be defined as a means of logical analysis or a thought process, where a statement is formed based on several other statements. Induction and deduction were used for partial summaries of individual parts and results. One of the methods used to determine the satisfaction with the residents' quality of life was a questionnaire survey. This method was employed to assess the current perception of extraordinary events concerning the quality of life.

The questionnaire targeted undergraduate students of the Faculty of Safety Engineering at the University of Žilina. After collection, the data were evaluated based on individual questions. 181 respondents took part in the survey, of which 7 respondents filled out the questionnaire incorrectly. Therefore, 174 responses from respondents were taken into account. The results were processed and presented mainly in graphic form. Based on the evaluated data and survey results, options were proposed to improve the quality of life for the residents. The methodical process of work processing outlines individual steps necessary to achieve the goal. To solve a specific issue, it was important to study professional literature. Based on the collected information, the current state of the problem at home and abroad was analysed. A questionnaire was created to determine satisfaction with the quality of life. The method of analysis was used for partial objectives. The methods of induction and deduction were used in the summaries of important parts and in the conclusion. Descriptive statistics were also utilized, which were useful when sorting respondents according to departments, gender, subject completion, and other factors. The methods used served as tools for meeting the goals and were also useful in proposing improvements to the quality of life for residents.

RESULTS

Security as part of the quality of life is an important influence on a person. The following question is focused on safety and whether respondents feel safe in their municipality. From Figure 1, it follows that 41%, which is 71 out of 174 respondents, feel safe in their village or town; 44% feel somewhat safe; 10% feel somewhat unsafe; 2% feel very unsafe; and 3% of respondents cannot assess how they feel in the municipality.

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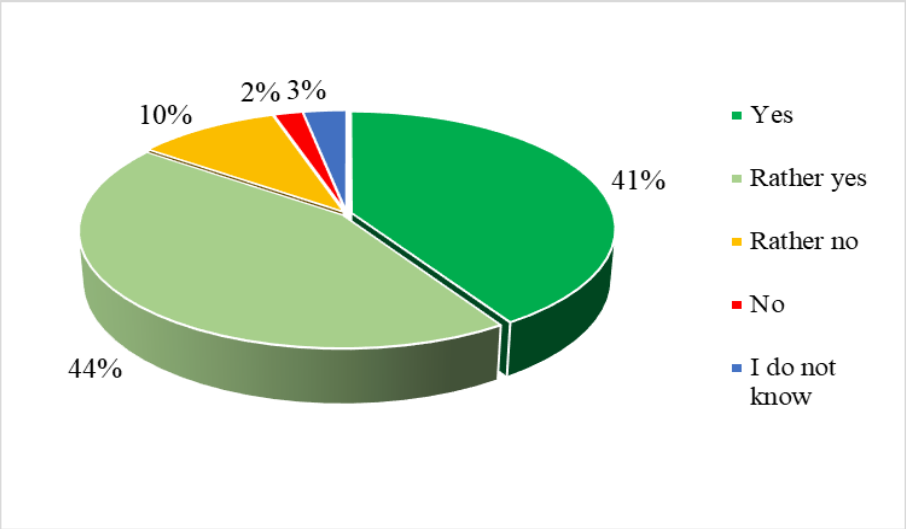


Figure 1 Feeling of safety in the municipality where you live

In the following question, the aim was to find out how respondents perceive security in relation to quality of life and, therefore, how security affects quality of life. Respondents rated the importance of safety on a scale of 1 to 5 with 1 having the least impact and 5 having the greatest impact.

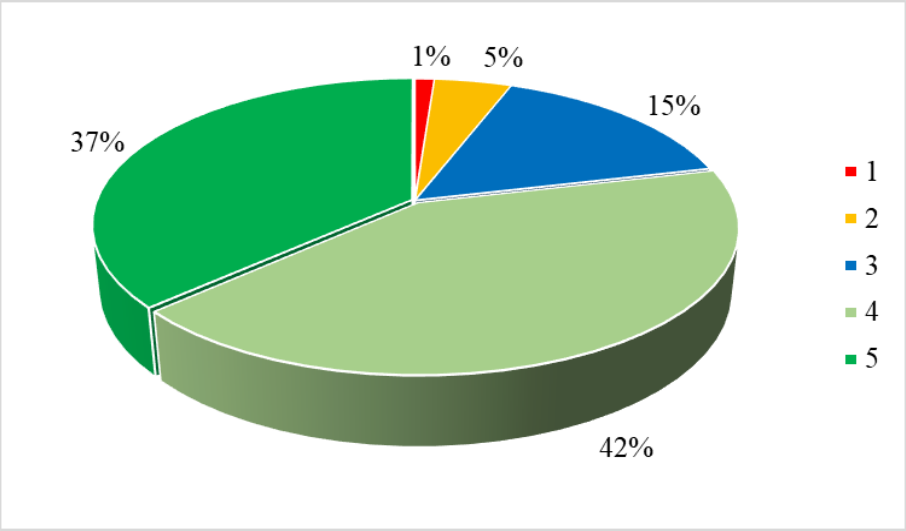


Figure 2 The impact of security on quality of life

Two respondents indicated the number 1, which means that security has the least impact on quality of life. Eight respondents indicated the value 2, 27 respondents indicated the option 3, the highest number of respondents, namely 73, indicated the value 4, and 64 respondents indicated the value 5, which means that security has the greatest impact on quality of life. The following question focuses on whether respondents think that appropriate awareness of civil protection and emergency events such as procedures and recommendations can improve their quality of life in terms of security.

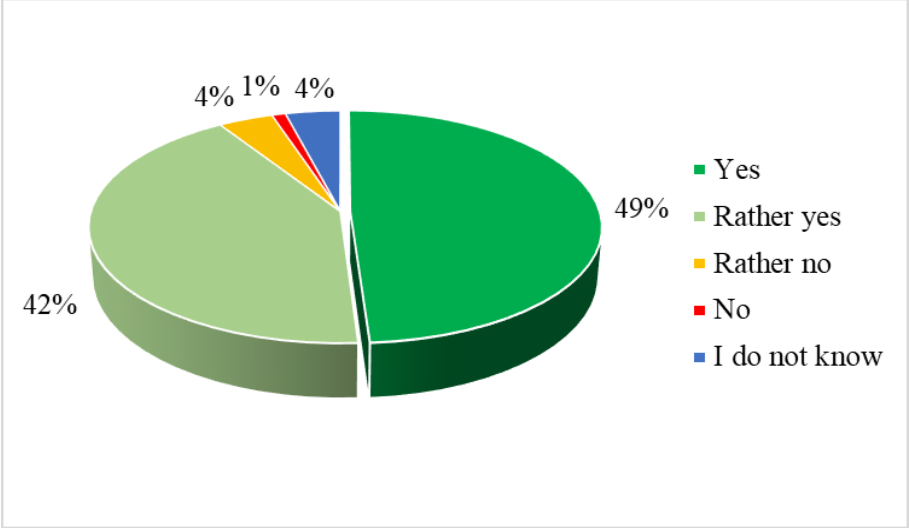


Figure 3 The importance of awareness on the issue of emergency events

Figure 3 shows that the majority of respondents think that appropriate awareness of the issue can improve their quality of life in terms of safety. Up to 49% of respondents answered yes, 42% of respondents answered rather yes, 4% of respondents do not know how to judge and 5% of respondents think that appropriate information will not improve their quality of life in terms of security. The task of the respondents in the following question was to choose from the set options in which way they would like to be educated about how to increase their security with regard to emergency events. For this question, respondents were asked to mark more than one answer. The options that the respondents could choose from are lectures, a website, videos, Facebook, Instagram, within the local newspaper, available book publications, information leaflets, courses or others.

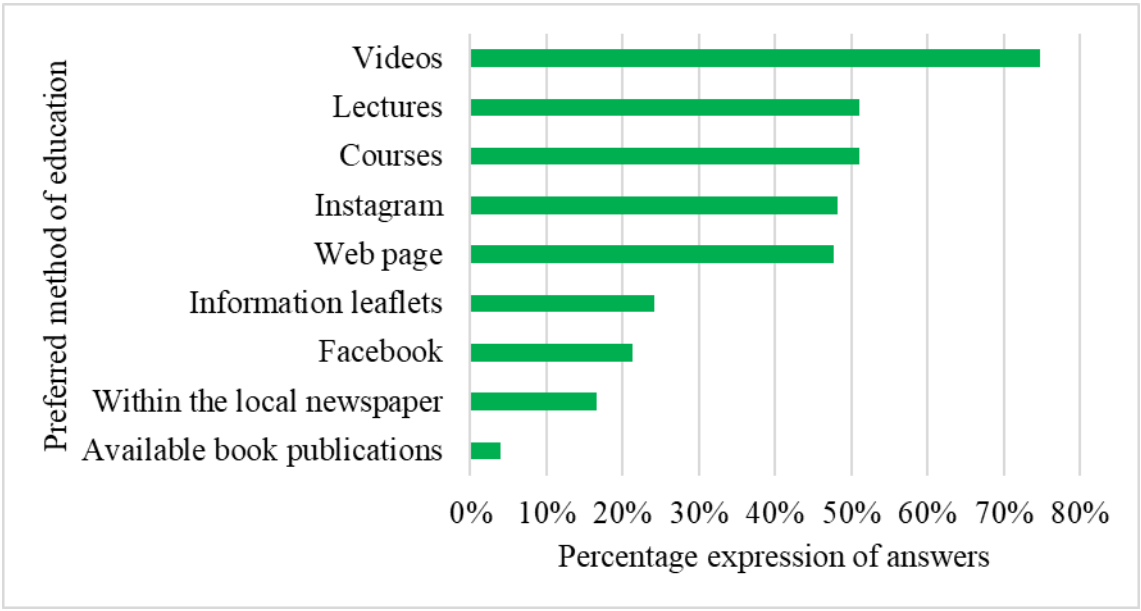


Figure 4 An appropriate method of education about emergency events

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The responses of the respondents to how they would like to be informed about the issue are shown in Figure 4. The most respondents agreed that they would like to be informed using videos, up to 130 students, the second highest number of votes were given to courses and lectures by 89 students, the Internet page 83 students, Facebook 37 students, Instagram 84 students, 29 respondents voted for information in local newspapers, 7 respondents voted for available book publications and 42 respondents chose information leaflets.

DISCUSSION

On the basis of the survey, it is possible to adopt proposals to improve the quality of life of residents with an emphasis on safety and emergency situations. The first proposal is educational videos focused on behavior in the event of an emergency. The aim of the first video will be to communicate to residents what precautions they should take before leaving the apartment or house in the event of an evacuation. The individual procedures will be shown on the video. Other videos will focus on specific emergencies and how residents are coping. The videos will show procedures that should be performed and also those that should not be performed. The videos will be published in the online space and also presented at life and health protection courses. The second proposal is one-day courses. As part of the courses, students will get more information about the protection of civil aviation, learn the principles of behavior during various types of emergency events, and based on the analysis of the territory, it is possible to identify and carry out activities to reduce this risk. They learn or recall first aid principles and get basic information about shelters in their surroundings and evacuation procedures. Part of the course will take place in the form of lectures and the other part in the form of practical exercises. The third proposal to improve the quality of life of residents with regard to emergencies is the creation of an Instagram profile that will be dedicated to the issue of civil protection. The purpose of the profile will be to provide information and procedures on how to behave in the event of an emergency and other necessary information. The content of the profile will include basic terminology, items to be included in evacuation luggage and procedures for how to behave in emergency situations. The profile will be public, which means that individuals will be able to view individual procedures.

Another proposal will be the lectures themselves. The lectures will be held either individually or as part of the courses. The content of the lectures will be an explanation of the issue, definition of emergencies, general principles of behavior in the event of danger, warning the population (warning signals), principles of first aid, contents of evacuation luggage, principles of behavior in individual types of emergencies and basic information about the location of shelters in the vicinity. The practical part of the lectures will follow the theoretical part, and in this part he will be able to try, for example, how to pack evacuation luggage. The proposals also include the need to create a universal website. The website will be concise, clear, and residents will be able to quickly and easily find information on the given issue. The content of the website will include information on civil protection, warning sounds, contents of evacuation baggage, designated emergencies, procedures for behavior in the event of an emergency and emergency telephone numbers. The content of the website will also include knowledge quizzes, where individuals can test their knowledge in the given issue, engaging videos and other interesting things about the issue, because the website was as interesting and engaging as possible.

Since disaster risks are closely tied to social vulnerability, impact assessments must be viewed from a societal perspective. Studies on the socio-psychological aspects of emergency management shed light on the non-technical and rational-analytical factors influencing individual and community preparedness, emergency decisions, warnings, and evacuation responses. The involvement of the local population is crucial for local disaster risk reduction because, despite socio-economic limitations, residents have the capability to respond to, recover from, and manage emergencies [12-14].

CONCLUSION

Knowledge of emergency events and preparedness for them can save the lives and health of residents and minimize damage to property. Therefore, it is crucial to bring this issue to the forefront and educate residents about it. Understanding how to respond to extraordinary events can significantly reduce the negative impact on individuals and communities. In the context of emergency events, learning from past incidents is vital. This includes not only events that have occurred within the territory of the Slovak Republic but also those in other countries. By analyzing and understanding these events, residents can be better prepared for similar situations. For example, examining responses to natural disasters, industrial accidents, and other emergencies can provide valuable insights into effective strategies and common pitfalls. To prevent panic during emergencies, it is essential that residents are well-informed about the procedures they need to follow. Clear communication and education about emergency protocols can ensure that people know what to do and how to act in critical situations. The survey indicates that people are interested in being informed and want to know how to react correctly in the event of an emergency. This interest underscores the importance of proactive education and information dissemination by local authorities and emergency services. The quality of life is influenced by a wide range of indicators, including safety and security. It is necessary to statistically monitor the impact of extraordinary events on the quality of life of the inhabitants. This involves collecting and analyzing data on how such events affect various aspects of life, including physical and mental health, economic stability, and overall well-being. Monitoring the impact of emergency events allows for a better understanding of their effects on residents. This information is crucial for developing and implementing measures to improve the quality of life. For instance, if data shows a high level of stress and anxiety among residents following an emergency, targeted mental health support and community resilience programs can be introduced. Similarly, if property damage is a significant concern, improving building codes and infrastructure resilience can be prioritized.

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THE INFLUENCE OF *CITRUS X CLEMENTINE* LEAVES EXTRACT ON THE CORROSION OF CARBON STEEL

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ABSTRACT

Carbon steel is one of the most common alloys employed in a multitude of industries. However, it has low corrosion resistance and some methods were used in order to enhance the anticorrosion properties, such as modifying the composition of the steel by further alloying, deposition of protective layers on the substrate or modifying the aggressive media by adding corrosion inhibitors.
This paper presents the results of adding an environmental friendly extract (*Citrus x clementine)* in the aggressive media on the corrosion of steel. Methods such as open circuit potential, electrochemical impedance spectroscopy and polarisation for corrosion (Tafel) were employed in order to determine the influence of the *Citrus x clementine* leaves extract on the corrosion rate of steel in 3.5%NaCl. The results presented in this paper provide useful information on the stability of carbon steel in the modified aggressive media and on the polarisation resistance and corrosion rate of carbon steel in 3.5% NaCl, and in 3.5% NaCl modified with *Citrus x clementine* extract in concentrations from 50µL - 600µL.

Keywords: green inhibitors, corrosion of steel, inhibitor efficiency

INTRODUCTION

Carbon steel is an alloy with a multitude of uses in industry due to its properties such as mechanical resistance. However, it has low corrosion resistance and the improvement of anticorrosion properties is required in most cases [1,2].
Corrosion of metallic materials, such as steel, has gained an increased interest in the recent decades and various methods to improve metal protection are being tested. Among these methods, one may mention modifying the composition of the steel by further alloying, cathodic protection, protective coatings and the use of corrosion inhibitors. The use of corrosion inhibitors is a practical and efficient option. The addition of small quantities of a specific substance in the corrosive media can reduce the corrosion rate. The main advantages of this method derive from the inhibition mechanism and the diversity of sources from which the inhibitors can be obtained. In this regard, various plant extracts (garlic, lemon verbena leaves extract, Rosa canina fruit extract) have been proven to be an efficient and environmental friendly alternative and improve corrosion resistance of some metallic substrates such as steel [3-6].
This paper presents the effect of a *Citrus x clementine* leaves alcoholic extract on the corrosion properties of carbon steel. The effect of modifying the composition of the

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aggressive media (3.5%NaCl) with the *Citrus x clementine* leaves extract was characterized by means of open circuit potential monitoring, electrochemical impedance spectroscopy and polarisation for corrosion (Tafel).

MATERIALS AND METHODS

Natural extracts from *Citrus x clementine* leaves were obtained using ethanol. The following steps were performed: drying of the leaves at room temperature for 30 days, crushing of leaves and sieving through a 150-µm sieve. The natural extract was obtained by mixing 2 grams of dried and sieved leaves with 10 mL of 99.6% ethanol (ChimReactiv, Romania). The prepared solution was stirred for 30 minutes, hermetically closed and kept in the dark for 7 days at room temperature. On the 7th day after the preparation of the extraction mixture, it was filtered on filter paper, the filtrate obtained being the natural extract used as a corrosion inhibitor (C_Alc) (figure 1).



Figure 1. Extracts from *Citrus x clementine* leaves

The samples subjected to the corrosion process are carbon steel strips with an active area of $1cm^2$.

The methods used to investigate the inhibitory effect of natural extracts on carbon steel were open circuit potential monitoring (OCP), electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization. Electrochemical tests were performed in a cell with three electrodes: a reference electrode (Ag/AgCl, KCl sat.), a platinum electrode ($9cm^2$) and the working electrode (a steel plate, $1cm^2$), in 50 mL 3.5 % sodium chloride solution. The obtained extracts were added to the electrolyte solution in amounts of 50 (C_Alc50), 75(C_Alc75), 100(C_Alc100), 150(C_Alc150), 200(C_Alc200), 250(C_Alc250), 300(C_Alc300), 400(C_Alc400) and 600µL(C_Alc600). The cell is connected to a VoltaLab 40 PGZ301 potentiostat, interfaced with a VoltaMaster 4.0 software.

The open circuit potential was measured for 10 minutes at the beginning of the test sequences to determine the stability of the steel in the electrolyte solution used (without inhibitor and with inhibitor, respectively). The electrochemical impedance spectroscopy was carried out by applying a 10 mV sinusoidal potential perturbation and scanning a frequency range between 100 kHz and 100 mHz with a measurement rate of 10 measurements/decade. The potentiodynamic polarisation measurements were performed by scanning the potential between -0.85 and 0V, with a scan rate of 2 mV/second.

RESULTS

For the analysed samples, the open circuit potential varies in a range of potential from -570 to -400mV. An example of the variation curves of the open circuit potential for the

carbon steel sample in a 3.5%NaCl (blank) and for two samples analysed in media of 3.5%NaCl modified with 100µL (C_Alc75) and, respectively, with 200µL (C_Alc200) is presented in figure 2.

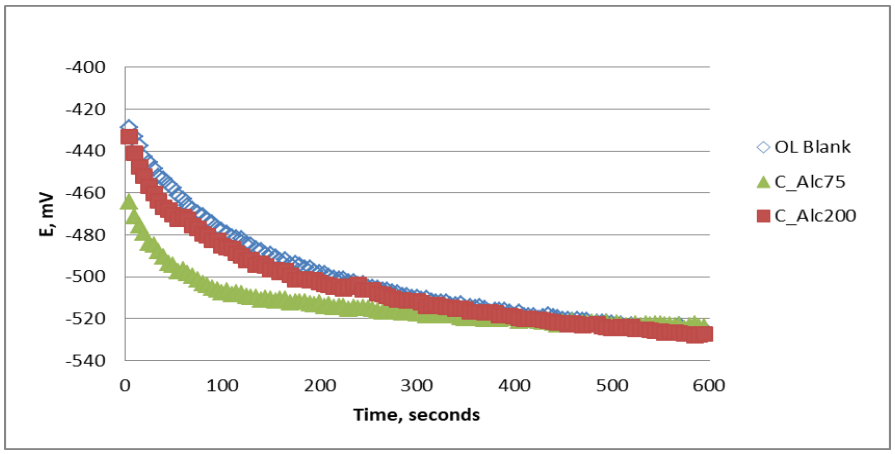


Figure 2. The OCP monitoring registered for carbon steel samples in 3.5%NaCl solution and in the modified aggressive media with *Citrus x clementine* leaves alcoholic extract

The results achieved from the electrochemical impedance spectroscopy, namely the polarisation resistance (R_p) and the correlation coefficient of the circular regression (R^2) are presented in table 1. In figure 3, due to an overlap of the circular trend, are presented three examples of the registered Nyquist diagrams for the carbon steel sample in a 3.5%NaCl (blank) and for two samples analysed in media of 3.5%NaCl modified with 100µL (C_Alc100) and, respectively, with 300µL (C_Alc300).

Table 1. The values of R_2, C, R^2 achieved from the electrochemical impedance spectroscopy for the corrosion of carbon steel in a 3.5% NaCl solution and in the modified NaCl with *Citrus x clementine* leaves alcoholic extract

Sample	R_2, kohm·cm²	R^2
OL	0.831	0.999
C-Alc50	1.348	1
C-Alc75	1.231	1
C-Alc100	1.377	1
C-Alc150	0.885	1
C-Alc200	1.089	1
C-Alc250	1.298	1
C-Alc300	1.228	1
C-Alc400	1.346	0.998
C-Alc600	1.307	0.999

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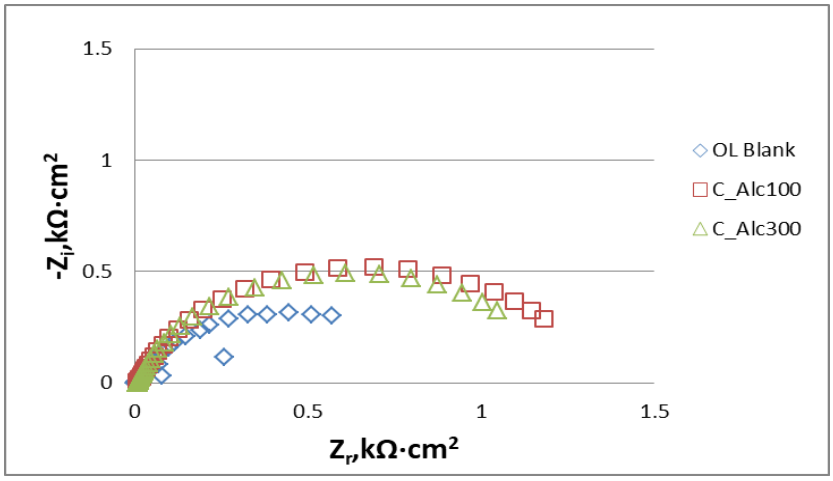


Figure 3. The Nyquist plots registered for the carbon steel sample (blank) in 3.5%NaCl and for the 3.5% NaCl modified with 100µL (C_Alc100) and, respectively, with 300µL (C_Alc300) *Citrus x clementine* leaves alcoholic extract

The results achieved from the potentiodynamic polarisation, namely the corrosion potential (E_{cor}), current density (i_{cor}), polarisation resistance (R_{pT}), anodic slope (β_a), cathodic slope (β_c), corrosion rate (v_{cor}) are presented in table 2. In figure 4, is presented the Tafel diagram for all the carbon steel samples tested in a 3.5%NaCl (blank) and for all samples analysed in media of 3.5%NaCl modified with *Citrus x clementine* leaves alcoholic extract.

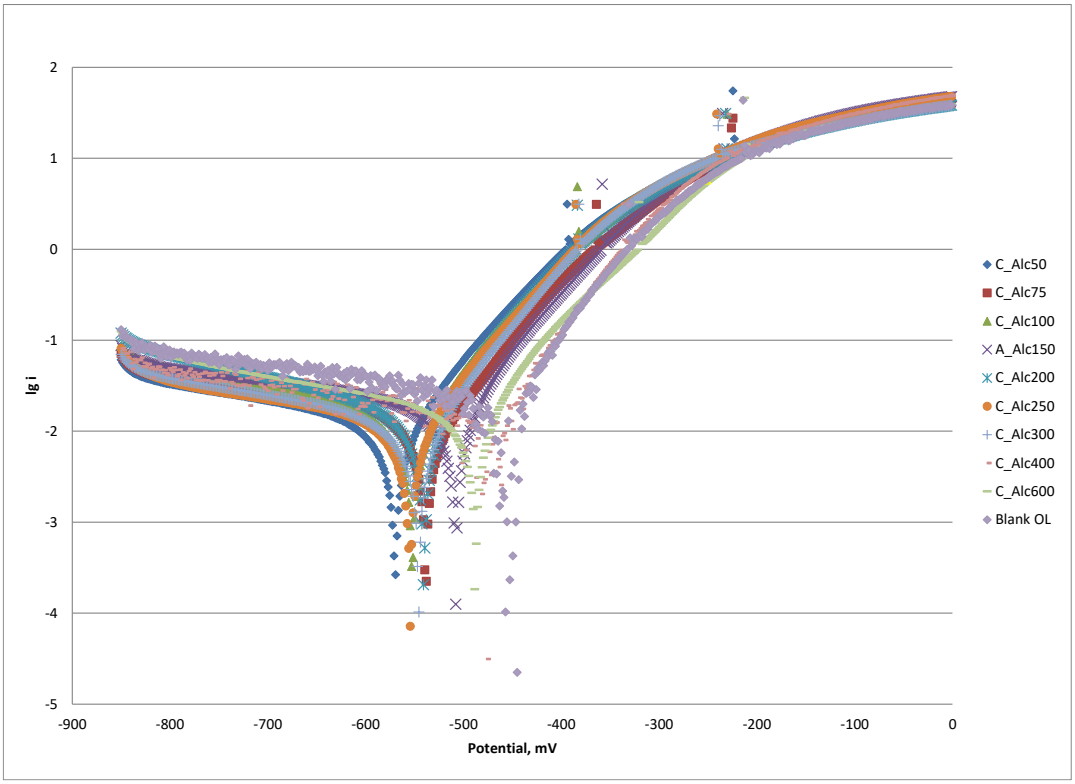


Figure 4. The Tafel plots registered for the carbon steel sample (blank) in 3.5%NaCl and for the 3.5% NaCl modified with *Citrus x clementine* leaves alcoholic extract

Table 2. The values of $E_{cor,}$ i_{cor}, R_p, β_a, β_c, v_{cor} obtained from the potentiodynamic polarisation curves for the corrosion of carbon steel in a 3.5% NaCl solution and in the modified NaCl solution with added *Citrus x clementine* leaves alcoholic extract

Sample	$E_{cor,}$ mV	$i_{cor,}$ µA·cm^{-2}	$R_{pT,}$ kohm·cm^2	β_a, mV	β_c, mV	$v_{cor,}$ µm/Year
OL	-467.9	3.4693	2.54	12.5	-17.7	40.18
C-Alc50	-573.7	1.4925	2.79	17.3	-30.2	17.29
C-Alc75	-542.3	1.7423	2.37	18.0	-29.0	20.18
C-Alc100	-557.3	1.8056	2.28	17.1	-30.2	20.92
C-Alc150	-512.9	2.4790	1.83	14.4	-33.7	28.72
C-Alc200	-545.3	1.9908	2.04	17.3	-29.7	23.06
C-Alc250	-558.5	1.5660	2.70	16.3	-30.8	18.14
C-Alc300	-549.7	1.4192	2.91	17.0	-30.1	16.44
C-Alc400	-479.7	1.8596	2.17	18.0	-22.6	21.54
C-Alc600	-492.9	2.1052	1.91	22.0	-27.7	24.39

DISCUSSION

The open circuit potential monitoring showed that all investigated carbon steel samples are stable in the 3.5%NaCl blank solution and in the modified solutions. For all the carbon steel samples analyzed in the 3.5%NaCl with added *Citrus x clementine* leaves extract the potential decreases versus time for the first 300 seconds and for the next 300 seconds it remains stable in time.

The electrochemical impedance spectroscopy results provide information about the polarisation resistance (R_p) and the capacitance (C) of the carbon steel samples in the studied aggressive media. One may see an increase in the polarisation resistance registered for the samples tested in the media with *Citrus x clementine* leaves alcoholic extract media, save for the sample C-Alc150 (an amount of 150 µL leaves alcoholic extract was added in the 3.5% NaCl), where the increase in the R_p was only 54Ω. The highest value of the polarization resistance was 1.377kΩ·cm², registered for the 3.5% NaCl with 100µL *Citrus x clementine* leaves alcoholic extract.

The Tafel plots, presented in figure 4, show the effect of the *Citrus x clementine* leaves alcoholic extract on the corrosion potential, current density, anodic slope, cathodic slope, and steel sample corrosion rates. The corrosion potential (E_{cor}) shifts to more electronegative values for the investigated carbon steel samples in 3.5% NaCl with the added *Citrus x clementine* leaves alcoholic extract.

The differences noticed in the values of the polarization resistance from electrochemical impedance spectroscopy and the ones obtained from the potentiodynamic polarisation may be due to the fact that the potentiodynamic polarisation is a kinetic technique, while electrochemical impedance spectroscopy is a non-destructive one. That is the reason why one will report to the values of the polarization resistance achieved from the electrochemical impedance spectroscopy rather than the ones from the potentiodynamic polarization.

The values of the current density and corrosion rate provided by the potentiodynamic polarization, show that the *Citrus x clementine* leaves alcoholic extract has a significant impact of the corrosion properties of the carbon steel, namely, the lower the corrosion

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rate and corrosion current density are, the better the corrosion resistance is. Both the current densities and corrosion rates decrease for all the tested carbon steel samples in the modified solutions. The anodic and cathodic slopes show the type of inhibition mechanism, that is the variations in these values may indicate if the inhibitor is either an anodic or a cathodic one.

CONCLUSION

In this paper, the effect of a *Citrus x clementine* leaves alcoholic extract on the corrosion rate of carbon steel substrates in a 3.5% NaCl aggressive media was investigated. Methods such as open circuit potential, electrochemical impedance spectroscopy and potentiodynamic polarisation showed improved characteristics of the analysed carbon steel substrates in the modified aggressive media with *Citrus x clementine* leaves alcoholic extract added in various concentrations.

The open circuit potential showed a high stability of the carbon steel substrates in all aggressive media, with and without the inhibiting extract tested.

The electrochemical impedance spectroscopy showed increased values of the polarisation resistance for all samples analysed in NaCl solution with the leaves extract, the highest value of that resistance being recorded for a concentration of the extract added of 100μL in 50mL of 3.5%NaCl. For a concentration of the *Citrus x clementine* leaves alcoholic of 150 μL, the polarisation resistance showed a very small increase confirmed by the potentiodynamic polarisation, which showed the highest corrosion rate from the carbon steel substrates analysed in the NaCl solution with that extract.

The potentiodynamic polarisation provided representative information on the corrosion rate of the analysed samples, namely an improvement of the values of the corrosion rate from 59.15 μm/Y for the blank sample to a minimum value of 16.4415 μm/Y for the carbon steel sample in a 3.5%NaCl modified with 300 μL of *Citrus x clementine* leaves alcoholic extract.

In conclusion, the *Citrus x clementine* leaves alcoholic extract presents a high potential to be used as an environmental friendly biodegradable natural inhibitor.

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THE INFLUENCE OF IRRIGATION ON DENDROMETRIC CHANGES OF *JUGLANS REGIA* L. UNDER CONDITIONS OF CLIMATE CHANGE

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ABSTRACT

Climate change is a very serious threat, and its consequences affect many different aspects of our lives. In Slovakia, we will also have to get used to the faster onset of warm and dry weather in the spring. The year, from a temperature point of view, ended as the 2nd warmest since 1931. Statistically very significant (annual) deviations occurred in the entire territory of Slovakia, so we characterize it in terms of temperature as strongly to extremely above normal. We monitored the influence of climatic conditions on the dendrometric changes of 9-year-old royal walnut (*Juglans Regia* L.) in Nové Zámky (Slovakia). The research took place in the spring and summer months of 2023 (April 1 - July 31, 2023) and trees were compared a) non-irrigated (only with natural precipitation) and b) irrigated (irrigation dose of 30 mm after the soil water potential drops below 80 kPa). Dendrometric changes were recorded with a DD-S device (Ecomatik) in hourly intervals. Parameters such as temperature, precipitation and soil moisture in 20 cm were also recorded. From the results, in the observed period the growth of branches in the irrigated variant is 3.66 mm, while in the non-irrigated variant it is only 1.24 mm. Although there is a greater increase in the diameter of the branches in the irrigated variant, in the summer (July), when the average daily temperature is also higher, the daily fluctuation of the diameters is higher than in the non-irrigated variant, which is caused by higher evapotranspiration. Based on these results, it is possible to set the optimal use of irrigation in the future based on the needs of plants and not only according to the soil water potential.

Keywords: climate change, irrigation, walnut

INTRODUCTION

The World Meteorological Organization (WMO) has officially confirmed that 2023 is by a huge margin the warmest year on record. The average annual global temperature is close to 1.5°C above pre-industrial levels, which is symbolic because the Paris Agreement on climate change aims to limit long-term temperature increases (averaged over decades rather than individual years) to a maximum of 1.5°C above the pre-industrial level. Global temperature reached new record highs in every month from June

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to December 2023. July and August were the absolute warmest months globally in the history of measurements [1]. Climate change affects millions of people, especially the most vulnerable, as it increases the frequency of extreme weather events that cause reduced crop yields and population displacement. Several major global constraints to crop production are currently identified: climate change, rapid population growth, increasing demand for food, decreasing biodiversity, shrinking agricultural and arable land, increasing demand for agricultural inputs, and other multiple factors simultaneously affecting crop production and productivity [2-4].

The walnut genus (*Juglans* spp.) contains some of the most economically and ecologically valuable trees species in America, Europe, and Asia. Of the 20 species found worldwide, black walnut (*Juglans nigra* L.) and English walnut (*Juglans regia* L.) are the most abundant species of the genus and most represented in the literature. In recent years, a growing number of reports were published on physiological responses of walnut species to environmental factors, such as water, temperature, and nutrients. Many of these studies were conducted to address climate change issues [5].

The aim of this paper is to evaluate the development of dendrometric changes of walnut (*Juglans regia* L.) irrigated and non-irrigated variants during the growing season in 2023.

MATERIALS AND METHODS

The experiment was carried out in the period 1.4. - 31.7.2023 in a 12.31 ha walnut orchard in a rural area near the town of Nové Zámky, Slovakia (Figure 1). This location on the Danube Lowland is characterized by an average annual temperature of 9.8 °C and an annual rainfall of 523 mm [6].

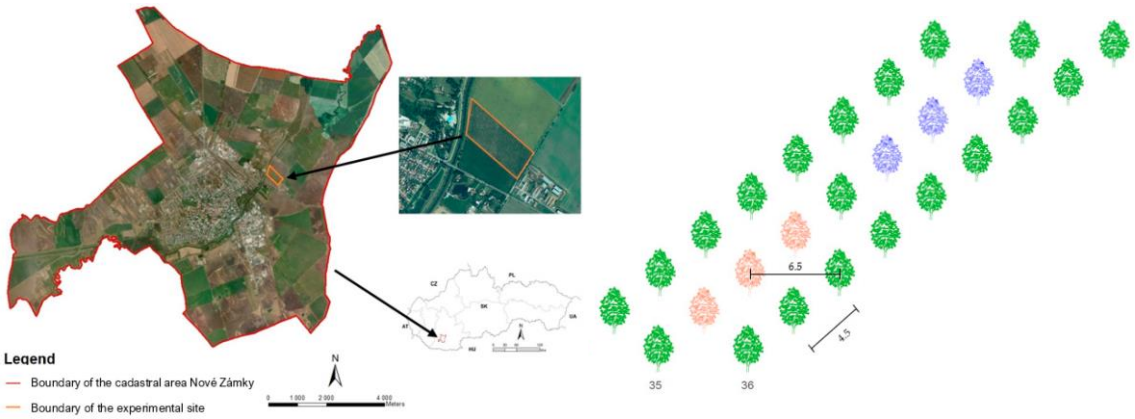


Figure 1 Experimental location and experimental scheme (red trees – non-irrigared, blue trees – irrigated) [7]

The experiment took place in the centre of the orchard on irrigated and non-irrigated variants. The irrigated trees (blue in Figure 1) were irrigated with an irrigation rate of 30 mm by micro-sprinkler when the water potential in the soil fell below 80 kPa and by

natural precipitation. Non-irrigated trees (red in Figure 1) received water only in the form of precipitation.

Dendrometric data were measured with DD-S series dendrometers (Ecomatik). Electronic dendrometers are used to continuously record changes in the size of different parts of plants (e.g. trunk, branch, root and fruit of trees, as well as herbaceous plants). The micrometer-accurate dendrometer data obtained provides valuable information on vitality and growth dynamics, as well as on the water status of the plant. The resolution of readings is 0.2 µm (Dendrometer logger DL18) [8]. The raw data were calculated to mm according to equation [6-8]:

$$mm = \text{raw data} \times 4{,}4$$

Meteorological data were measured by a station located in a walnut orchard. For our needs, we mainly used average daily temperatures and daily rainfall totals.

Soil moisture was measured with SMT100 sensors (Truebner) at a depth of 20 cm from the surface. The TrueLog100 datalogger was set to take measurements at hourly intervals and these data were processed into daily soil moisture averages.

RESULTS

Research on dendromertic changes took place from 1.4. until 31.7.2023 (Figure 2) on irrigated walnuts (blue curve) and non-irrigated walnuts (orange curve). Since the beginning of the measurements, the diameters of the branches in both variants have not changed significantly, except for a few days at the beginning of April, when on some days the temperature drops to 0 °C (in some hours, not daily averages) and there was a shrinkage of the branches by 0.4 mm (irrigated walnuts) and by 0.3 mm (non-irrigated walnuts). A significant increase in branch diameters begins for both variants in the last decade of May. With irrigated walnuts, a greater daily shrinkage of the branches is visible, especially in July, which is caused by greater transpiration (Figure 3 and Figure 4). During the study period, the diameter of the branches of irrigated trees increased by an average of 3.66 mm, while it was only 1.24 mm for non-irrigated trees.

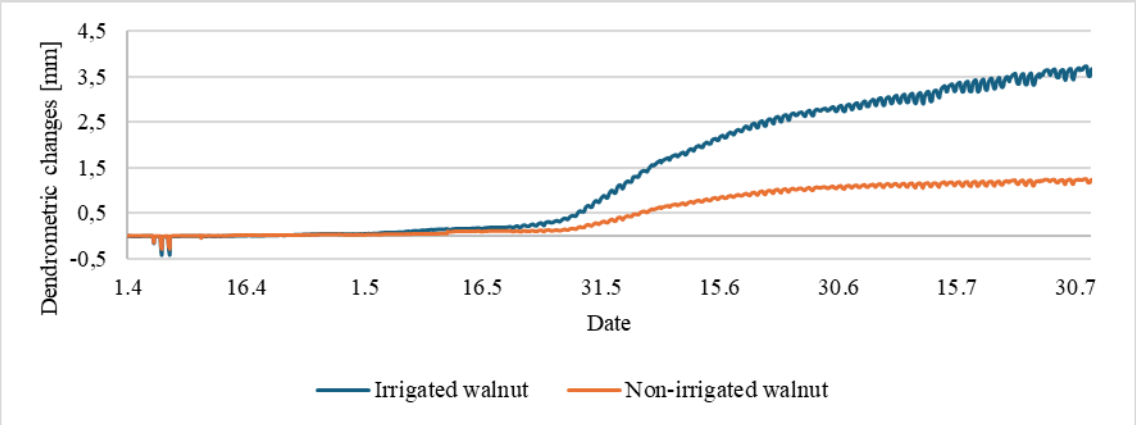


Figure 2 Development of dendrometric changes

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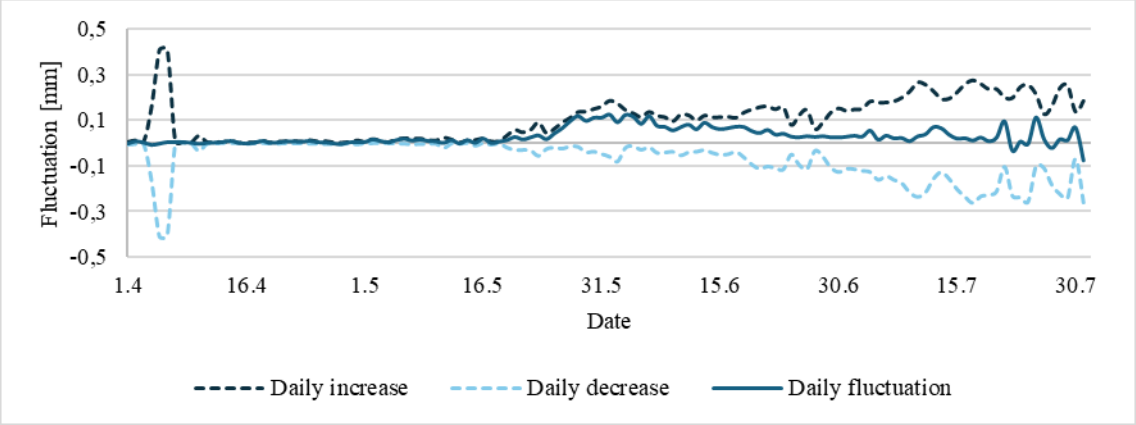


Figure 3 Daily diameter fluctuation (irrigated walnuts)

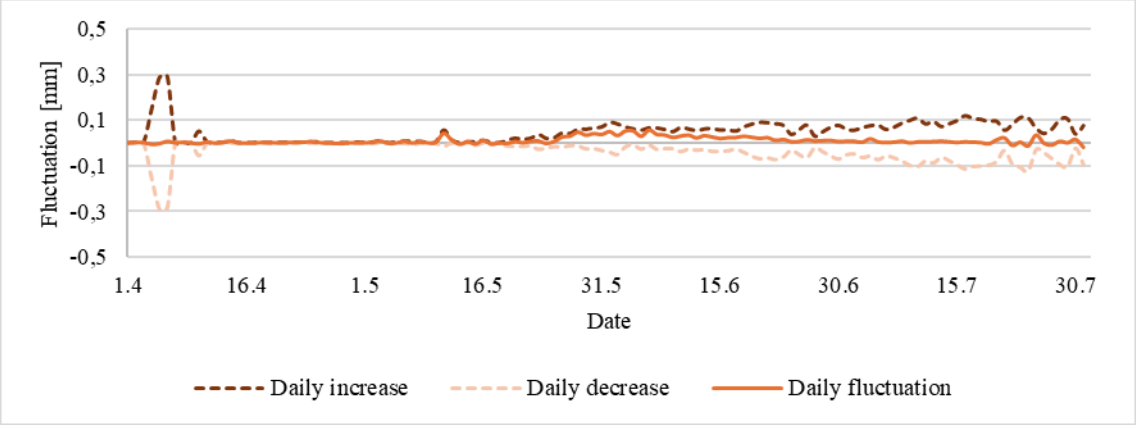


Figure 4 Daily diameter fluctuation (non-irrigated walnuts)

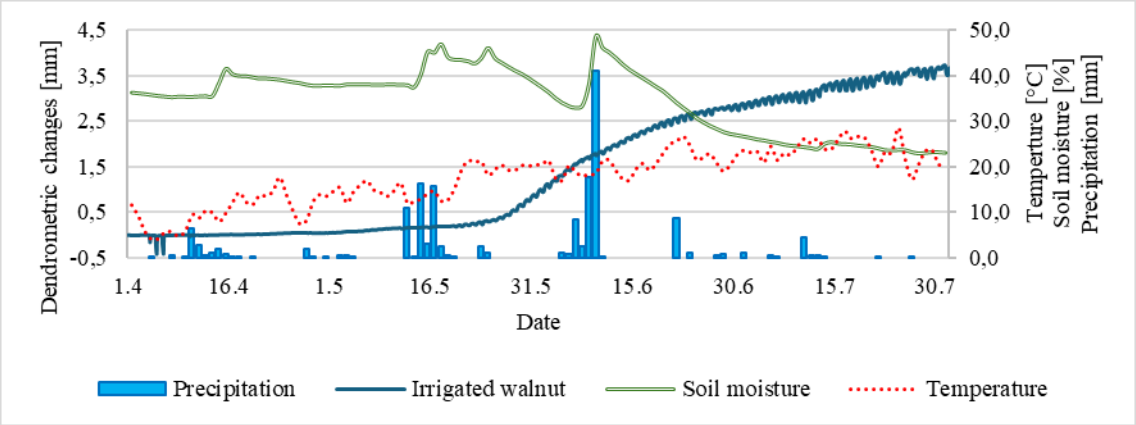


Figure 5 Irrigated walnuts

From a climatic point of view, the temperature at the research site in April reached 10.0 °C (compared to the climatic norm - cold), in May 16.4 °C (normal), in June 20.6 °C (normal) and in July 23.5 °C (warm). When evaluating precipitation, April was dry (17.4 mm), May was normal (53.6 mm). The highest rainfall totals were recorded in June (82.7 mm – wet) and the lowest in July (7.4 mm – extremely dry), while the

highest daily total was reached on 9.6.2023 (41.1 mm). Soil moisture fluctuated depending on precipitation, on average for irrigated trees 35.8-40.8% (April-June) and 24.4% in July, and for non-irrigated trees, on average 32.0-34.1% (April-June) and 24.6% in July.

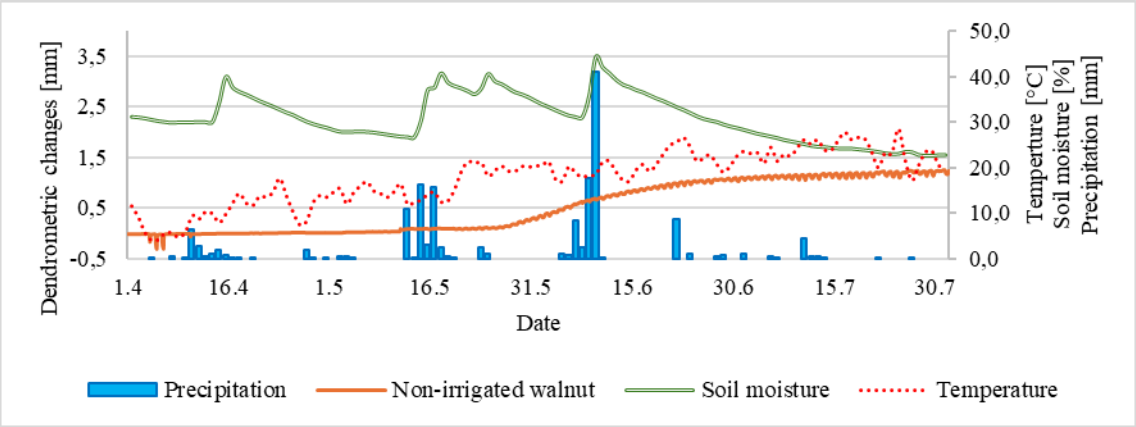


Figure 6 Non-irrigated wanuts

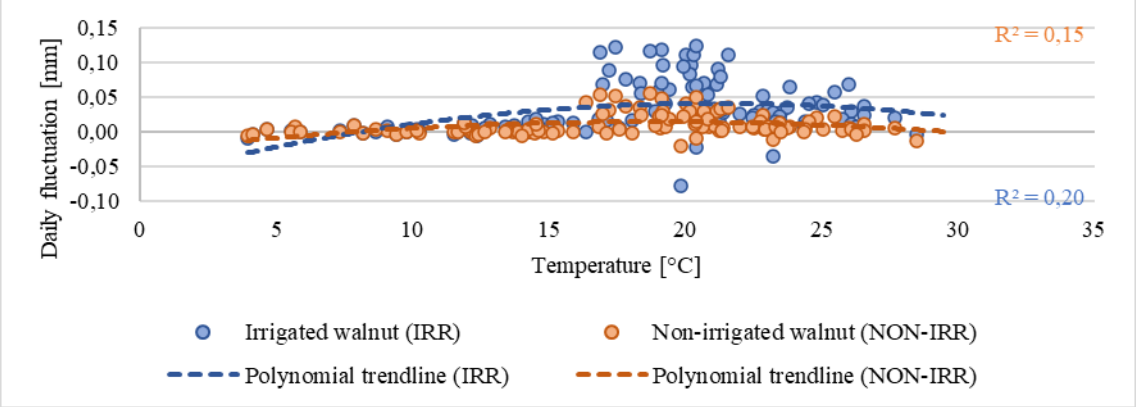


Figure 7 Dependence of daily fluctuation of branches on temperature

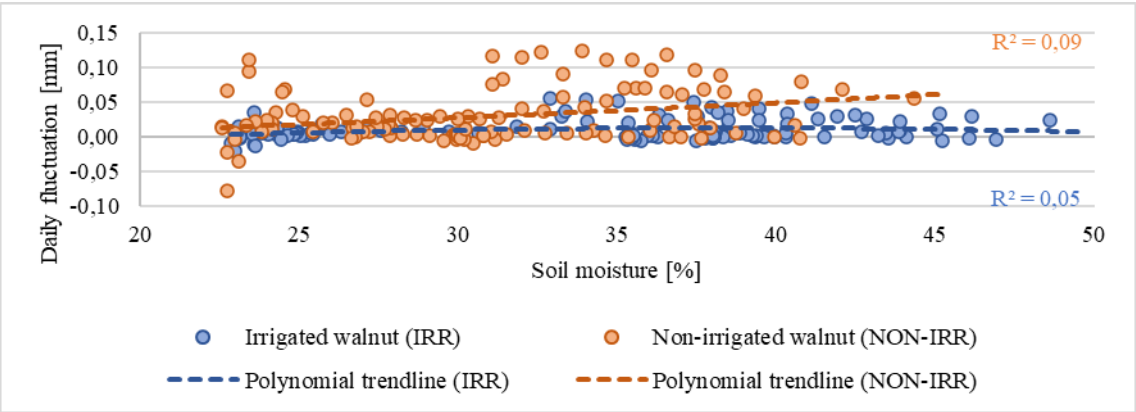


Figure 8 Dependence of daily fluctuation of branches on soil moisture

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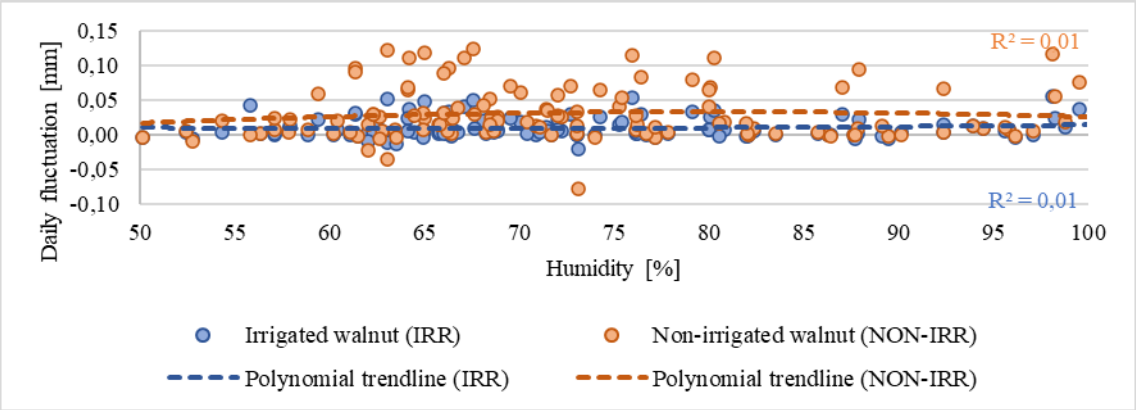


Figure 9 Dependence of daily fluctuation of branches on humidity

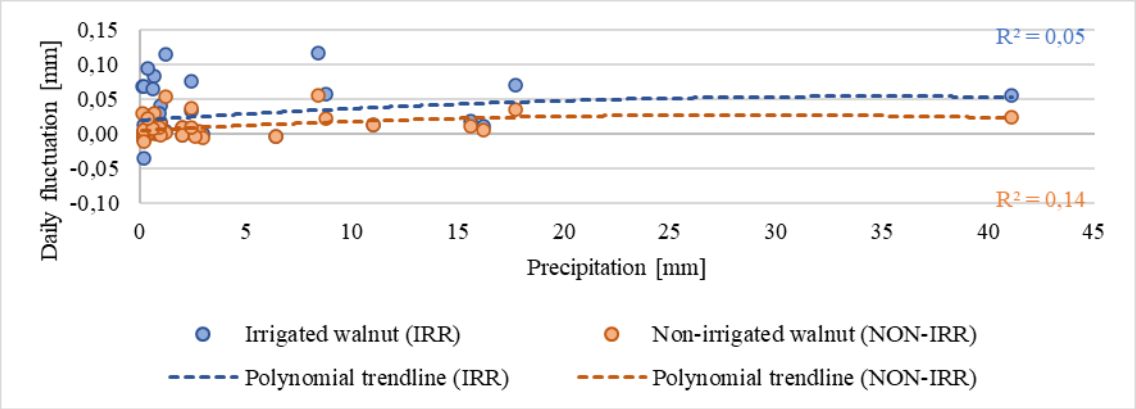


Figure 10 Dependence of daily fluctuation of branches on precipitation

From a statistical point of view, we compared the dependence between daily changes to different climate parameters. A polynomial trend was used for correlation, as this trend achieved the highest dependence among other available trends. The highest dependence was found when comparing the daily fluctuation with the air temperature. For the irrigated variant, the correlation coefficient R^2=0.20 and for the non-irrigated variant R^2=0.15. From the graph (Figure 7) it can be seen that the increase was mainly when the temperature reached 15-25 °C. When comparing soil moisture with daily changes in branch diameter (Figure 8) and when comparing air humidity with daily changes in branch diameter (Figure 9), the values of the correlation coefficient are low. Even when comparing daily changes in the diameter of branches with precipitation (Figure 10), we observe R^2=0.05 in the irrigated variant and R^2=0.14 in the non-irrigated variant (only days with precipitation were considered in this final analysis).

DISCUSSION

Several authors are engaged in research with dendrometric changes. However, many focus on research into forest trees and biomass growth. Keleş [9] focused on the comparison of dendrometric changes in managed forest and unmanaged forest of Scots pine and Sessile oak. Horst et al. [10] focused mainly on edaphic and topographic factors and their relationship with dendrometric variation of *Pinus taeda* in a high-

altitude subtropical climate. The influence of stationary factors (slope, exposure, geology) on the dendrometric characteristics of Pistacia atlantica was also investigated by Benaradj et al. [11]. The effect of irrigation on dendrometric attributes of eucalyptus was also described by Belchior et al. [12], where an increase can be seen in irrigated variants. Appropriate irrigation settings are also described by Camilo-Alves et al. [13] in the Cork Oaks trials.

Our research showed differences in the increase in diameter of irrigated nuts compared to non-irrigated ones. Although the correlation coefficient when comparing daily changes compared to climatic parameters was low and no significant dependence was demonstrated. Based on the obtained data, it will be necessary to more accurately analyse the influence of indicators, especially precipitation, temperature and additional irrigation, not only on dendrometric changes on the day of action, but also several days later.

CONCLUSION

Climate change affects all areas of agriculture, in this case fruit growing. In some areas, irrigation will become more and more necessary, which is also related to proper irrigation management. In our paper, we compared irrigated and non-irrigated nuts, and the difference in branch growth was evident. However, the correlation coefficient did not show the direct influence of individual climate indicators, which does not mean that they are not there. In the future, it will be necessary to analyse these parameters even at several-day intervals and compare the dependence.

ACKNOWLEDGEMENTS

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THE INFLUENCE OF SELECTED NEUROLOGICAL DISEASES ON THE ABILITY OF ENVIRONMENTAL EDUCATION – REVIEW

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ABSTRACT

Humanity is currently facing a number of global problems, such as global warming, air pollution, water pollution, deforestation, desertification or land degradation, which are apparently connected to the consequences of negative human activity. One of the possible and effective institutional tools for environmental protection is the environmental education of the general population. It is a relatively well-known and used environmental protection policy tool that governments of all developed countries have in their instrument mix. This qualitative analysis assigned itself the task of investigating whether the ability of environmental education can be affected by certain neuropsychological diseases in addition to thinking about the psychology of environmental education at large. In order to fulfill this main task, the authors asked themselves the following research questions: 1st - Is pedagogical psychology identical and also applicable in the case of environmental education? And 2nd - What effect do some neuropsychological disorders have on the ability of environmental education? Based on the study, analysis, selection and comparison of current professional scientific works obtained from the research activities of current researches on this topic, it is possible to accept the premise that the psychology of environmental education is basically the same as the general psychology of education and that neuropsychological diseases do indeed affect the ability of environmental education similarly to scholarly education.

Keywords: Psychology, neuropsychology, neuropsychological diseases, environmental education

INTRODUCTION

Humanity is currently facing a wide range of global problems, which are clearly the result of negative human activity [1]. In terms of severity and other related problems, global warming appears to be the most serious and it is additionally associated with other global problems such as rising sea levels, melting glaciers, and the loss of organisms in ecosystems, among others [2]. Individual states and some state groupings (EU) have different types of instruments in their environmental policy which they use in so-called instrument mixes for environmental protection, according to the specific environmental policy of the given state [3]. The group of environmental institutional tools also includes environmental education of the population [4]. Several authors refer to this tool as contemporary and modern. In particular, the Nordic countries of the

European Union have adapted this tool for a relatively long time and achieve very good results regarding environmental education of the population, which logically and subsequently manifests itself in the good state of the environment [5]. This work set itself the task of investigating, based on current published works, the influence of educational psychology and neuropsychology on the environmental education of residents. To fulfill this main task, the authors asked themselves the following research questions: 1st - Is pedagogical psychology identical and applicable in the case of environmental education? And 2nd - What effect do some neuropsychological disorders have on the ability of environmental education? For these purposes, the authors carried out an extensive research activity of scientific research published on this topic. Specifically, a qualitative selection of representative professional monographs on this topic was also carried out and to a greater extent also electronic resources indexed in scientific databases Open Access, Web of Science and Scopus were used. Selected publications were studied, compared by way of result comparison, and selected works were then included in the study. A qualitative analysis was then carried out from the material selected in this way, with the aim of satisfactorily answering the research objectives. The basis for this publication was not logically own applied research, but rather a scientific research activity, by form of the qualitative analysis. Due to the limited possibility of the scope of this publication - a review, it is not possible to include all professional literature in the research. As such, this review contains a thematically qualitative selected selection that forms a logically integrated whole. It should be noted that the relevant scientific databases basically do not contain research on the topic of the influence of neurological diseases on the environmental education ability of individuals. The originality of this review can be seen in this. The authors therefore had to support the thesis about the similarity of environmental education of the population with municipal education through a qualitative analysis. Then, in the next step, explore the psychology and politics of these types of education and their similarity. Only subsequently, in the next part of the performed qualitative analysis, the priority goal, which is the qualification of the influence of certain neurological diseases on the ability of environmental education, to be explored in the published scientific publications. It should also be noted that the authors were able to cover all neurological diseases in this form of publication, but only the most frequent ones that can affect this problem to the greatest extent.

MATERIALS AND METHODS

This chapter is divided into two sub-chapters, the first of which describes the research methods, and the second sub-chapter provides a general overview of the background of the research. Basic concepts important to research activities are explained in more detail here.

Methodology

The basic scientific method was the qualitative research activity of professional scientific publications of research carried out on the investigated issue. These publications were studied, selected, and a mutual comparison and selection was made so that in the end it was possible to fulfill the assigned task and answer the research questions [6]. Since there are basically no relevant works on the topic of the influence of

neurological diseases on the ability of environmental education in the representative databases, the method of logical deduction [7] had to be used as well.

Basic concepts

Environmental education of the general population is one of the basic institutional tools of environmental protection. It is carried out and organized by state administration bodies and local governments, and its goal is to educate residents on environmental issues to improve and maintain the environment [8]. The leaders of environmental education in Europe are the Nordic countries, which already have a relatively long tradition in this area [5]. Among European Union countries, environmental education can already be found in the institutional education of pre-school-aged children via education about the sorting of household waste, for example. In elementary schools, this education is already part of the curriculum [9, 10].

Educational psychology, also called the psychology of education, is a borderline scientific discipline that draws knowledge from psychology and pedagogy. In pedagogical psychology, the regularities of educational processes are investigated in particular [11].

Neuropsychology is a scientific discipline that stems from the close interdisciplinary relationship between neuroscience and psychology. It deals with the connections between the central nervous system and the human psyche, thus dealing with both behavior and experience. This field is traditionally studied from a primarily clinical point of view by analyzing the impact of brain lesions of various etiologies on especially cognitive psychological processes [12]. Neuropsychology studies diseases such as dementia, Alzheimer's disease, aphasia, amnesia, ADHD and others that have been proven to affect cognitive functions and negatively affect the ability to learn material related to environmental education [13, 14].

RESULTS

At the beginning of the research, it is necessary to think about education in general, its institutional organization and then about Pedagogical Psychology, i.e., about the regularities of the educational process. Subsequently, the specifics of environmental education can be sought and compared based on Pedagogical Psychology, and the theoretical influence of selected neuropsychological dysfunctions on the ability of environmental education can be explored.

In his publication, which was published in the Czech translation of Oldřich Selucký in 1998, Yves Bertrand proposes to narrow down the large number of classifications of educational theories to these seven – spiritualistic, personalistic, cognitive-psychological, technological, socio-cognitive, social and academic [15]. Due to the focus of this work, it will be appropriate for this publication to deal more significantly with cognitive psychological theory. Bertrand further states that cognitive psychological theories study the student's development of such cognitive processes as reasoning, analysis, problem solving, creation of representations, preconceptions, mental images, etc. The foundations of these educational theories must very often be sought in cognitive psychology research by which they each covered different aspects of learning. According to this theory, the teacher must consider the learning processes, the previous knowledge of the individual learning. They must additionally find out what their models, representations and ways of processing information are. It is also necessary to

assume that this knowledge may conflict with the scientific knowledge that is learned at school [16].

The following two ideas are also based on this theory, which will be discussed in more detail in this work. The first of them are the educational processes of pedagogical psychology, which can be used to influence a successful cognitive process, and the second is the effect of certain neuropsychological diseases on an individual's ability to learn.

Pedagogical psychology deals with the laws of educational processes [17]. Harry Daniels et al. examine the influence and possibilities of different types of upbringings and education on undesirable deviations of people [18]. In the psychology of education, the personality of the pedagogue and their characteristics, knowledge, erudition and pedagogical abilities and disposition are also of fundamental importance. Research on this issue was published by N.V. Akhmetzyanova in the journal Social and Behavioral Sciences in 2015. This research focuses on the specifics of higher education and demonstrates the importance of the pedagogue in the process of university education [19]. Gabriela Cristea's research also brings interesting insights into the methodology of general didactics. Here, the author deals directly with the methodology of classroom management and its influence on the educational process [20].

The following works, in accordance with the general theory, quite significantly point to the fact that environmental education is only a subcategory of general education and is governed by the same principles and rules. Among the research published on this topic, we can mention the work of Moloevi Adamovi, in which he reflects on the necessity of cooperation between parents and preschool-type facilities in the field of environmental education [21]. T. Ronnen and D. Kerret published a study in the International Journal of Environmental Research and Public Health that examines the possibility of integrating positive psychology into environmental education [22]. In their research, E. Carrus et al. also address the issue of integrating positive psychology into environmental education with the aim of ensuring the continuity of sustainable development with this tool of environmental protection [23]. A very interesting monograph, which could fulfill the aspiration of one of the best works in Asia on the topic of environmental education with an overlap of the psychology of environmental education, was published by Fang et al. in which they examine the aspects and conditions of environmental education relevant in Asia [24]. The subsequent works are all devoted to psychology and other issues of environmental education. Research by P. Konakchieva, which deals with the methodology of children's environmental education. In this case, it is a case study [25]. The publication by Fang et al. examines the psychological aspects affecting pro-environmental behavior. The authors examine different models of access to undergraduate environmental education [26]. Another work published research on the issue of the development of environmental culture among future teachers during professional training [27]. A survey of teachers' opinions on the integration of environmental education and sustainable development in primary schools was published by G. Pehoiu [28]. The topic of environmental education and its interpretation is also addressed in an article by J. Howard [29]. The correlation between teaching psychology and environmental education and sustainable development is addressed by Koger and Scott [30]. A study on motivating and guiding school-aged children to relate to nature as part of the culture of life and environmental protection was published by Audley and Stein [31]. Research based on the questionnaire method in

the field of environmental design education was published by M.D. Roske [32] and research on moderating and influencing attitudes, attitudes and behavior towards environmental protection and recycling by Schultz and Oscamp [33]. From the context of all the above-cited publications in this block, it is already stated in the previous part of the thesis. Environmental education is a subcategory of general education, in which social-environmental sciences, educational psychology and didactics are intertwined. Because of the aforementioned details, it can be stated that the didactics and psychology of environmental education are essentially identical to those of general education.

The discipline in which other social sciences such as didactics, psychology, deontology, history, logic, semantics and environmental sciences are intertwined, is environmental ethics [34]. "In contrast to ethical education perceived from the perspective of a practical philosophical discipline that works with virtues, positive behavior occurs through the development of social skills - the means of psychology." [35]. Psychology, as an applied social discipline, also extends to philosophical ethics, especially as a tool for knowing the motivation and behavior of an individual in the decision-making process when accepting an ethical judgment. Its use is also quite evident in the way of thinking brought about by the descriptive method of ethics [36]. Based on the previously mentioned ideas, it is possible to document the overlap of educational psychology into environmental education and the associated use of psychology in ethics itself and its subcategory – environmental ethics, or ethics of life sciences.

The following part of the research is devoted to some neuropsychological diseases and their influence on the individual's abilities in the educational process, and also conversely, the possibility of the benefit of education in a positive effect on some types of neuropsychological diseases. For example, the following studies were published on the topic of the possible contribution of the educational process to neuropsychological diseases: [37], which examines the influence of the educational effect in patients with advanced sclerosis, and [38], which deals with the effect and possibilities of education in patients with Parkinson's disease of the non-demented type with the aim of reducing depression and increasing their quality of life. Pavlik et al. published research on the effect of premorbid IQ and education on the progression of Alzheimer's disease [39], and this group also includes published research [40] examining the effect of education on long-term outcomes in first episode psychosis within a ten-year period. The above-mentioned studies point to the positive influence of education on the state and course of some neuropsychological diseases. In this case specifically on sclerosis, Parkinson's disease, Alzheimer's disease and incipient psychoses. The following part of the research examines the problem from the reverse point of view and will focus on publications that deal with the limiting effects of some neuropsychological diseases on the educational abilities of an individual.

Research that dealt with aspects of education for late-life dementia and Alzheimer's patients was published by Kovacich et al. [41]. McDowell et al. then deal with sessions and educational opportunities for patients affected by dementia [42]. The publication published by Sobral and Paúl directly examines the extent of the possibility of educating patients with Alzheimer's disease [43]. The relationships between education, cognitive functions of the brain and Alzheimer's disease are also investigated by Honjo et al., using an inventory neuropsychological questionnaire. They also take age and level of education into account [44]. Similar topics are addressed by Groot et al., and in their research, they deal with the relationships of education and intracranial volume with

cognitive trajectories and mortality rates in the continuum of Alzheimer's disease [45]. Gillenhammar et al. investigate the relationship between temporal atrophy and episodic memory and the effect of education on this phenomenon [46]. Wang et al. then published a study in which they deal with the possibilities of reading in cognitive deficits caused by Alzheimer's disease. Research examining the relationship between cognitive function and mortality in a population-based sample of older citizens, stratified by gender and education, was published by Wang et al. [47]. Jennifer Sotsky [48] deals with the effects of Lyme disease in psychiatry, its symptoms, the state of cognitive functions and educational opportunities. Foucard et al. then examine short-term memory and self-learning ability in patients affected by Alzheimer's disease [49]. In their work, Happawana and Diamond also reflect on the relationship between learning and Alzheimer's disease [50], and we can also mention an interesting study by Pamela Woltersthat deals with the effect of HIV in children on cognitive functions and the educational process [51].

DISCUSSION

The conducted systematic review focused on the relationship between the psychology of environmental education and general education and subsequently on the possible influence of some neuropsychological diseases on the possibility of environmental education. In all representative databases, enough relevant sources were found that deal with research on the topic of educational psychology and the influence of selected neuropsychological diseases on educational ability. It can be stated that, on the contrary, no relevant research was found on the subject of the psychology of environmental education and the influence of neurological diseases on the ability of environmental education. However, the method of logical deduction can be used, and if we accept the premise that environmental education is only a subcategory of general education, we can, based on published research, apply general knowledge to a specific category of education, in this case to environmental education of residents. We also have to state that no other published review of the professional literature was found in the conducted research, which would examine the issue of the influence of neuropsychological diseases on the ability of environmental education. Among the published reviews on the topic of neuropsychological diseases and education, one can find systematic expert reviews on cognitive function training in neurological diseases, such as the systematic review by Fava-Felix et al. [52] or a review by J.C. Rodrigues [53]. Contrarily, the possibility of educating patients with neuropsychological diseases is dealt with in systematic reviews by authors Dias Bernardo [54] or Tarver et al. [55]. As part of the comparison with the above-mentioned reviews, it can be stated that in all cases, these are systematic reviews that deal with the relationship of cognitive function training to the course and state of neuropsychological diseases, or conversely, the possibility of education in neuropsychological diseases.

CONCLUSION

This review has set itself the task of reflecting on the psychology of environmental education based on research activity and among published research - professional articles and to a lesser extent also professional monographs to explore the relationship between neuropsychological diseases and environmental education. To fulfill this research task, we asked ourselves the following research questions: 1st - Is pedagogical

psychology identical and applicable also in the case of environmental education? And 2nd - What effects do some neuropsychological disorders have on the ability of environmental education?

On the basis of the review, it can be concluded that, accepting the fact that environmental education is a subcategory of general education, pedagogical psychology can also be applied in the process of environmental education and that neurological diseases affect the possibility of educating people, which also applies to the possibility of environmental education.

As already stated in the previous section, the main benefit of this qualitative review is the originality of the survey. There are no relevant and creditable publications on the chosen topic, i.e. on the influence of selected neuropsychological diseases on the ability of environmental education of the population, to be found in the representative databases. We can accept the premise that as time progresses, more works on this topic will become available and mutual comparison of the achieved results will be possible. Due to the importance of environmental education of the population, as one of the basic tools of environmental protection, the knowledge gained can gradually be incorporated into the politics, psychology and didactics of education, with the aim of improving the technique of environmental education. Of course, it can be argued that neuropsychological diseases affect only a small fraction of the population, however, some diseases are already observed in children of pre-school age, and with the progress of medicine, the life expectancy and the need for education for older citizens are also increasing.

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THE POTENTIAL ROLE OF GEOPARKS IN NATURE POSITIVE AGENDA

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ABSTRACT

The current dramatic pace of biodiversity loss requires immediate and decisive action. The Nature Positive Agenda implies recovery of lost natural ecosystems and gain of new ones that would overcompensate for biodiversity loss. Achievement of such an ambitious agenda is not trivial. It requires mobilization of resources and stakeholders across public and private sectors. Obviously, efforts of protected area establishment are not sufficient as it only implies protection of existing habitats, not gain of new ones. Given the resource limitations, however, it is important to protect and retore ecosystems capable of maintaining high levels of biodiversity. Moreover, these biodiversity levels have to be maintained long-term in the context of global environmental change. Ecosystems with high geodiversity possess such characteristics, as recognized in the UNESCO Global Geopark programme. However, application of geopark guidelines in the context of Nature Positive Agenda has not been considered. Our aim is to critically evaluate opportunities to integrate geopark establishment into the agenda. We provide justification of the approach and policy recommendations.

Keywords: biodiversity conservation, geodiversity, ecosystems, environmental governance

INTRODUCTION

Currently the world faces a drastic decline in biodiversity. Recent World Wildlife Foundation Living Planet Report [1] has found an average 70% decline in relative species abundance across the globe. Species are often lost as a result of development projects, which are expected to accelerate at an unprecedented rate in the near future and put biodiversity at an existential risk. In this context the idea of the Biodiversity Net Gain strategy has emerged, which implies that the development projects should leave biodiversity in a better state than before construction [2]. This is an ambitious, nevertheless, achievable goal [3]. Implementation of the strategy is often embedded in development budgets. Funding of these projects often takes form of offsets. Biodiversity offsets are defined as “measurable conservation outcomes that result from actions designed to compensate for significant, residual biodiversity loss from development projects” [4]. The Biodiversity Net Gain strategy may involve a range of conservation strategies, which can also are implemented away from the construction site and may involve, for example, ecosystem restoration and protection or ecological engineering projects.

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Geodiversity is often associated with biodiversity [5]. Furthermore, geo-diverse areas can play an important role in species adaptation to climate change [6]. Areas with high geodiversity are in many cases protected in the form of geoparks, e.g. UNESCO Global Geoparks [7]. These parks sometimes coincide with protected areas. Nevertheless, biodiversity and geo-diversity conservation tend to be considered separately. There are no straightforward mechanisms to compensate for lost geo-diversity as a result of development projects. Still the fact that such areas tend to have high biodiversity provides an avenue to integrate them into Biodiversity Net Gain strategies. So far, however, it is unclear what role can geoparks play in the strategies. There is also no obvious route for geo-diversity loss compensation. Thus, the objective of this paper is to critically evaluate opportunities for geopark integration into Biodiversity Net Gain strategies in order to foster preservation of existing biodiversity and utilize geodiversity to optimize the Biodiversity Net Gain strategies in selected areas.

METHODS

Conceptual research methodology was used in present study. This methodology is based on application of interdisciplinary research to complex problems. The methodology allows finding solutions to problems not discussed in the scientific literature., The objective of our research and choice of methodology are motivated by the fact that geoparks or the related guidelines have not been a functional part of Biodiversity Net Gain strategies, neither in the literature nor in policy documentation, to our best knowledge. Application of the evidence and theoretical knowledge from across different disciplines forms the basis of the present study. Conceptual research is applied at the interface of geology, biodiversity science, landscape ecology, sustainability science, ecology and social sciences.

CURRENT SITUATION

Geopark networks are expanding globally, currently with 213 UNESCO Global Geoparks in 48 countries [7]. Nevertheless, this and other national geopark networks are far from covering all important geological sites in each country. Geopark network tend to be particularly well developed in the Global North and underdeveloped in the Global South. There is a lot to be done in future in order to protect global geodiversity. Geoparks have a great potential as the tools for protecting important geological sites and biodiversity that these sites harbour. The parks can be an attractive option for local authorities and other relevant stakeholders as geoparks tend to attract tourists, thereby contributing to economic development. They also act as important scientific and educational centres. Geoparks also often play important cultural roles as they can be associated with indigenous cultures and/or local community traditions. However, for the parks to provide a significant contribution to biodiversity conservation and Biodiversity Net Gain strategies, they have to be sited, designed and managed with his goal in mind.

To our best knowledge, there is currently no mechanism to compensate for lost sites of high geological value resulting from development activities. Nevertheless, road infrastructure, urban area expansion, mining activities and other development projects are likely to lead to destruction of the sites with high geo-diversity. Despite the fact that establishment of a geopark in these areas could potentially deliver economic value, this may not always be sufficient to avert the site destruction. For instance, if the geological

heritage site is located in the way of a new transnational highway, avoiding bisecting the site may be very problematic. This situation makes global geo-diversity extremely unprotected in the face of globally accelerating development. A crucial question is which tools could potentially be harnessed to protect the geodiversity. Several options could be considered. One approach could be to lobby for a new legislation that would include geodiversity along with biodiversity into offsetting schemes. This option, however, could take long time to implement and the outcomes are uncertain. Alternatively, existing strategies that are aiming at biodiversity conservation, such as Biodiversity Net Gain, might be utilised and improved by integrating geodiversity into them. The second option seems to be more realistic, however, it also has caveats. Successful integration would require understanding of the potential synergies between biodiversity and geodiversity conservation, as well as practical problems associated with the integration.

SYNERGIES & PROBLEMS

The fact that landscapes with high geodiversity often harbour high biodiversity is well supported by empirical evidence [5]. Another important synergy is that sites with high topographic diversity can potentially be valuable areas for biodiversity conservation in the context of the global climate change [8]. This phenomenon can be explained by the fact that geo-diverse sites tend to have a variety of micro-climatic conditions that can help species adapt to changing climate. Both these factors make it potentially possible to establish new geoparks as a part of offsetting schemes. There are, however, several questions on how exactly this could happen.

One problem is that if biodiversity is central to making decisions on compensating for lost sites, will loss of the geologically important areas be compensated with the sites with equally high geodiversity or will only biodiversity parameters be considered? This is a critical question, because if geodiversity is not explicitly considered, loss of areas with high biodiversity in connection with the geodiversity may be compensated for with protection or restoration of areas with equally high biodiversity but in areas of low geodiversity where resilience will not be provided for the same environmental stresses, such as alternative habitats with climate change. Despite this problem, economic attractiveness of geo-park development may influence site section for lost habitat offsetting. Geo-park establishment as a strategy to compensate for lost habitats with both high biodiversity and geo-diversity seems to be a viable strategy and if all associated benefits are presented to decision makers, the potential as a means to achieving Biodiversity Net Gain goals can be utilised in many areas within the established geopark networks. Landscapes with high geodiversity are often not designated as geoparks. Nevertheless, the application of geopark guidelines [7] can achieve the beneficial synergies with biodiversity.

Another problem is that important geo-diverse sites not always harbour high biodiversity. So, if such areas are lost in the context of development projects it may be particularly difficult to integrate geopark establishment into strategies associated with biodiversity conservation. At the same time, it may as be possible to pursue protection of both highly biodiverse and geo-diverse areas as a compensation for lost habitats that not necessarily have high value in terms of geo-diversity. These considerations become especially relevant when considering biodiversity conservation under changing climate conditions, as high geodiversity can help buffering species from the negative effects of

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change, thereby ensuring their long-term persistence. This approach can be particularly attractive in terms of investment in biodiversity conservation as it reduces uncertainty of the project outcomes in the long term.

OPPORTUNITIES

As was discussed above, it should be possible to integrate geodiversity conservation into Biodiversity Net Gain strategies. This may be particularly relevant in many different situations when geo-diversity is under threat. However, it seems particularly likely that these types of situations are particularly relevant in certain types of development projects. Road infrastructure construction projects seem to be one of the most relevant cases for integration of geodiversity concerns into the strategies. Currently, large transnational and transcontinental road and railway projects are underway, with numerous upcoming projects in the near future globally. Transnational road infrastructure is particularly hard to plan in such a way that it avoids bisecting biodiverse and geo-diverse areas. Roads are often built in mountainous landscapes where geo-diversity is usually found. At the same time, species assemblages in such areas tend to be adapted to habitats with high geodiversity. Such situations provide clear opportunities for joint biodiversity and geo-diversity protection projects, an offsetting strategy in cases when loss of important geological sites is inevitable.

Another straightforward opportunity for useful integration is when mining and other resource extracting projects take place in areas with diverse topography, which is often the case as natura resources tend to be extracted from mountainous areas. Here, similar to the construction of transport infrastructure, biodiversity is likely to be locally associated with high geodiversity. Again, offsetting strategies could benefit from an integrated approach to bio- and geo-diversity conservation.

Construction of urban infrastructure associated with emergence of new cities and growth of urban areas may also present opportunities for geopark development. Urbanization is an exponentially growing trend globally [9]. At the same time, geopark establishment in the cities or in vicinity of urban areas could be a particularly attractive option, as this ensures their greater accessibility for local residents and tourists.It would be logical if compensation for biodiversity lost in the process of urbanization, perhaps with innovative adaptation of the geopark concepts and guidelines. In some cases, the built environment may itself provide landscape diversity, which in combination with remaining natural areas could increase available habitats and biodiversity. Furthermore, due to the fact that urbanization happens globally, loss of geo-diverse areas in certain cities may be compensated through establishment of geoparks in other cities and perhaps even in other geographical regions. Indeed, offsetting strategies can take form of transnational conservation activities.

Energy projects are also expanding globally, with particular emphasis on green energy facilities. Construction of the facilities is often very area demanding. For instance, windmills and solar energy sites may occupy large territories. Another interesting example, hydropower facilities not only occupy large territories but also are often associated with flooding of large territories. In addition to that, the energy plants tend to be developed away from human settlements, as local communities often oppose disturbances associated with energy facilities. Remote areas often tend to be characterised with high biodiversity and may also be highly geo-diverse. This creates

yet another opportunity for integrated approach to biodiversity and geo-diversity conservation.

Obviously, opportunities for integration of geodiversity conservation into Biodiversity Net Gain strategies are not limited to above discussed cases. More research and case-by-case analysis in the field needs to take place to inform policymakers and make the proposed approach more widespread.

LANDSCAPE PERSPECTIVE

For the proposed approach to be most effective it is essential to take a holistic view of the landscape. The role of geo-diversity in biodiversity conservation in a specific context may be better understood. For instance, certain sites with high geo-diversity may play an important role in biodiversity adaptation to changing climatic conditions. This, however, depends on characteristics of the landscape surrounding the site. Geo-diverse sites may also harbour certain rare species or be an important part of their habitats. The sites may also play an important role in meta-population dynamics, such as, balancing predator-prey interactions or facilitating species co-existence. To better understand the role of geological sites that may be designated for conservation in the context of Biodiversity Net Gain strategy, a holistic view on ecosystems and ecological processes within the landscape is essential. t is also important to be able to predict landscape dynamics. This can help understanding whether the designated geo-diverse site will possess the capacity to maintain biodiversity long term. For instance, if natural habitats surrounding the geo-park are expected to disappear and be replaced with anthropogenic land-uses, the site may lose its role in biodiversity conservation as it will become isolated from other ecosystems. Thus, landscape prospective should be an integral part of the decision-making process in the context of projects considering application of geoparks as a part of Biodiversity Net gain strategy.

THE MEANS

Implementation of the landscape approach is not a trivial task. In the context of large development projects biodiversity and geodiversity assessment may be problematic. It may be even more challenging to predict future landscape changes and their impacts on biodiversity within geoparks. Reliance on the field work alone in such circumstances may be unrealistic. Luckily, currently a wide range of technological tools are available to facilitate the work. The tools include geographic information system (GIS) tools, big data and machine learning technologies. There are numerous examples of applications of modern technology tools in biodiversity conservation and geological projects. For instance, it is possible to use satellite imagery processed with machine learning algorithms to automatically extract biodiversity data [10]. It is also possible to detect sites with high geodiversity using satellite imagery and DEM-equipped unmanned aerial vehicles [11]. Another iterating case of modern technology application is scenario development using deep reinforcement learning [12]. It is also possible to make predictions of climate change impacts on biodiversity within the ecosystems using a range of machine learning techniques [13]. Furthermore, numerous techniques exist, allowing simulation of social-ecological system dynamics [14], which may be particularly helpful gaining understanding of how social factors can influence ecosystems within geoparks and how this may affect long-term persistence of biodiversity within the sites. Overall, modern technology is rapidly developing, and new

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useful tools constantly emerge. Thus, it is important to constantly monitor emerging opportunities and harness them for integrated biodiversity and geo-diversity conservation.

CONCLUSION

The aim of this paper was to critically evaluate opportunities for geo-park integration into Biodiversity Net Gain strategies. It was found that despite the current lack of mechanisms, multiple opportunities exist for such integration. Geoparks are an attractive option for implementation of Biodiversity Net Gain strategies as they can harbor highly diverse species assemblages, can potentially buffer species from negative effects of climate-change and at the same time can deliver social and economic benefits. Nevertheless, integration of geo-diversity protection with biodiversity conservation is not without challenges. Still, most challenges can be addressed, and the integrated approach remains highly promising. Development projects often involve destruction of geo-diverse sites, which creates opportunities for implementation of offsetting strategies through geo-park development. It is, however, important to ensure that the geoparks in this context possess and retain capability to maintain biodiversity long term. To ensure desirable biodiversity outcomes, landscape approach and thorough analysis of social-ecological system dynamics. Despite the fact that this is a challenging task, especially in the context of large development projects, modern technology can greatly facilitate the process. Further research is essential to explore opportunities for integrated biodiversity and geodiversity conservation.

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THE USE OF SAP FLOW SENSORS IN IRRIGATION MANAGEMENT OF ROYAL WALNUT (*JUGLANS REGIA* L.)

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ABSTRACT

Pervasive environmental stressors, particularly water deficits, have a major impact on plant production, diverting necessary energy away from growth and development to mitigate stress effects. This study addresses the impact of several water regimes (irrigated and non-irrigated) on royal walnut individuals (*Juglans regia* L.) in an orchard in western Slovakia. Our analysis focused on sap flow measurements using the stem heat balancing method from July 13 to September 21, 2021. In the midday hours, the sap flow rate measurements reached their highest daily levels. The irrigated variety had the maximum flow rate of 287.99 $g.h^{-1}$. The Highest sap flow rate in the non-irrigated variant was 148.33 $g.h^{-1}$. In the irrigated variant, the soil water content reached 41.61 %. Non-irrigated variant reached only 20.47 % of soil water content. The obtained data showed us the differences between irrigated and non-irrigated variants. The imperative for continued re-search emerges as additional data are needed for the optimization of irrigation strategies.

Keywords: sap flow, irrigation, climate change, water stress

INTRODUCTION

As water scarcity becomes an increasingly pressing concern globally, the need for efficient agricultural practices is paramount. The phenomenon of drought, a complex interplay of meteorological factors leading to reduced precipitation and soil moisture, presents a significant threat to agricultural productivity [1]. These stresses reduce plant productivity and growth due to osmotic stress, nutrient imbalances and oxidative stress. It is therefore essential to understand the physiological, biochemical, molecular and ecological mechanisms associated with this type of stress, in order to minimize production losses [2]. In walnut cultivation, where water demand is high, these challenges are particularly acute. This research explores the intricate physiological responses of walnut trees to water stress, and how these can be effectively managed through advanced irrigation techniques. Our study presents a comprehensive evaluation of sap flow sensor technology in monitoring the water usage of walnut trees. By providing real-time data on sap flow, these sensors allow for more precise and efficient

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water application, aligning with the principles of sustainable agriculture. The implications of this technology extend far beyond walnut cultivation, promising to advance irrigation practices across various agricultural sectors. By integrating sap flow sensors, farmers can significantly reduce water wastage, improve crop health, and ensure higher productivity even under challenging environmental conditions [3].

MATERIALS AND METHODS

To achieve the aim of our research it is necessary to observe the influence of the environment on the studied walnut trees in fruit orchard. In our research, we focus on measuring daily rainfall, air temperature, and soil water content at a depth of 20 cm. Measurement of biophysical changes in the selected trees is carried out using the sap flow rate measurement method.

Field measurements were established at the experimental site of private walnut or-chard in the cadastral area of the town of Nové Zámky (47°59′49″ N; 18°11′26″ E) with an altitude of 115 m above sea level (Figure 1). The territorial district of the town lies in the southern part of the Nitra region in the west of the Slovak Republic. According to the re-gional geomorphological subdivision of Slovakia, this territory belongs to the Danubian lowland part of Novozámocká plain. The walnut orchard is located in the countryside of the town. The territory has a flat relief of river floodplains with outcrops along the streams of the rivers Nitra, Žitava and Hron [4].

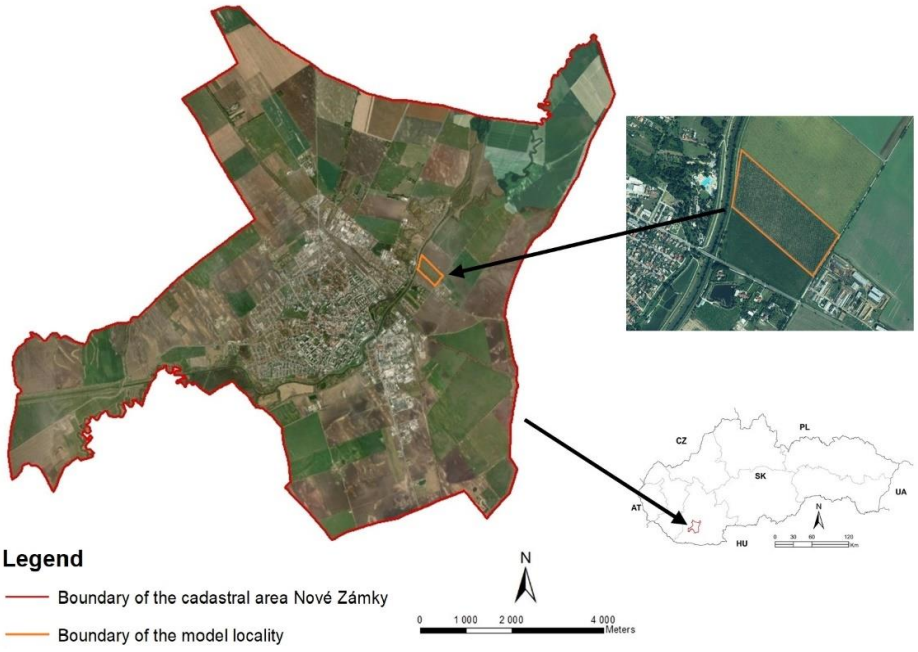


Figure 1. Experimental site coordinates [4].

Based on whole-profile soil morphology, which was analyzed by the Slovak University of Agriculture in Nitra in 2017, there are Cultivated chernozems, mostly calcific, with loam texture. The substrate contains 1.61 % of organic content. The range of pH of the humus layer is 5.6 – 6.5 in depth less than 0.09 m.

The experimental site belongs to a warm and very dry climatic region with mild winters. Climatically, the site is one of the driest and warmest areas of Slovakia, with an average annual air temperature of 9 – 10 °C, an average air temperature of -2 °C in January and

20 °C in July. The average annual rainfall in this part of Slovakia is 500 – 550 mm (30 – 40 mm in January and less than 60 mm in July), but the average annual evapotranspiration ranges from 700 – 750 mm. In winter, the snow layer on the soil surface lasts less than 40 days and its height is less than 200 mm [5,6].

The experimental orchard is located near the riverside. Walnut trees are planted on an area of 12.31 ha in 102 rows. Six sample trees are planted in the 35th row (Figure 2) in 2014. The average height of the studied trees was 3.95 meters in 2021. To study the effect of additional irrigation on sap flow in trees, examinate trees were divided into 2 groups. Group A is irrigated variant with additional irrigation and group B is a non-irrigated variant, where natural precipitation is the only source of water. In group A, an irrigation rate of 30 mm was delivered via microspray when the soil water potential rose to 80 kPa.

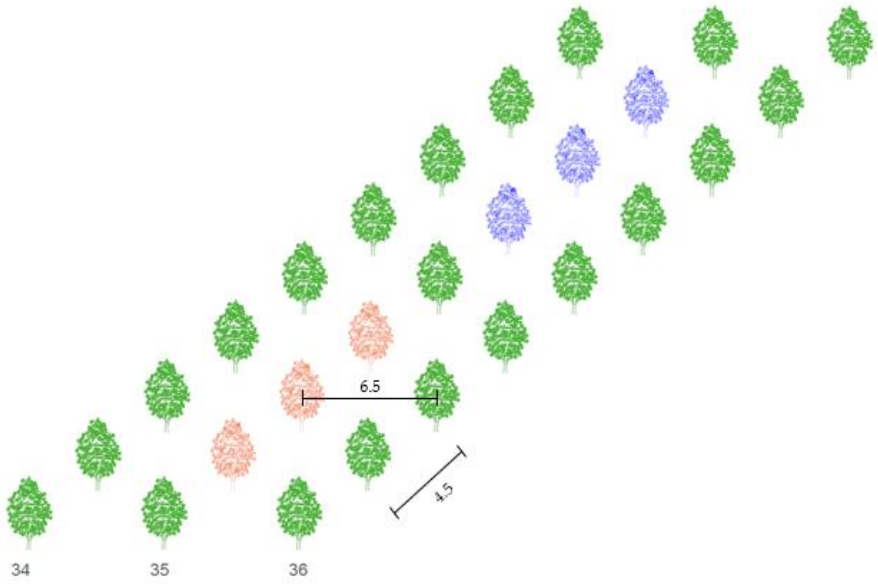


Figure 2. Scheme of spacing (m) between trees in the orchard and sample trees in row. Red colour represents non-irrigated trees (treatment A), blue colour represents irrigated trees (treatment B) [4].

Juglans regia L., commonly known as the Persian or English walnut, holds the title of being the most economically significant species within the Juglandaceae family. This species is widespread throughout Slovakia up to an altitude of 900 m. Its deep, branching root system makes it possible for it to efficiently absorb water and nutrients from the soil, which is crucial for its growth and development, particularly in environments with little moisture. Trees that receive excessive irrigation are vulnerable to Phytophthora spp. root rots [7]. The stem of the royal walnut is robust, with large complex leaves. Male and female flowers make up the floral structure of royal walnuts, and they are found individually on the same plant. The female flowers are borne singly or in clusters at the tips of young branches, while the male flowers are clustered in pendulous catkins. Wind aids in pollination (anemophilous). Nuts, or the fruits of the royal walnut tree, are well-liked for their many applications and high nutritional content [8]. Although the royal walnut may grow in a range of soil types and climates, it does best in deep, fertile, well-drained soils. The royal walnut is a significant species in

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agroforestry and agriculture because of its adaptability to a variety of growing conditions and the high market value of its fruit [9].

RESULTS

The sap flow measurements were collected from July 13th to 21st September 2021. After comparing the measured sap flow data in the irrigated and non-irrigated variants with air temperature, the sap flow rate values reached the maximum daily values in the midday hours. Thus, at the time of the highest daily air temperature. The highest value of flow rate 287.99 $g.h^{-1}$ was measured on 17th September at 13:00 and this was three hours after the irrigation dose (**Error! Reference source not found.**a). In the non-irrigated variant, the maximum sap flow rate of 148.33 $g.h^{-1}$ was measured on 18th August at 12:00, at a maximum daily temperature of 23.3 °C (**Error! Reference source not found.**b).



Figure 3. Diurnal course of sap flow rate in both treatments (a) irrigated variant and (b) non-irrigated variant in comparison with air temperature, during experiment period in 2021.

A total of 92.3 mm of rainfall fell during the experimental period. The irrigation dose was delivered automatically in the irrigated variant when the soil water potential reached 80 cbar. The course of the soil water content curve followed a similar pattern, but the measured values differed between the variants. In irrigated variant (Figure 4a)

the soil water content reached its maximum on 5th August at 16:00 with value 41.61 %. Non-irrigated variant reached only 20.47 % at the same time (Figure 4b).

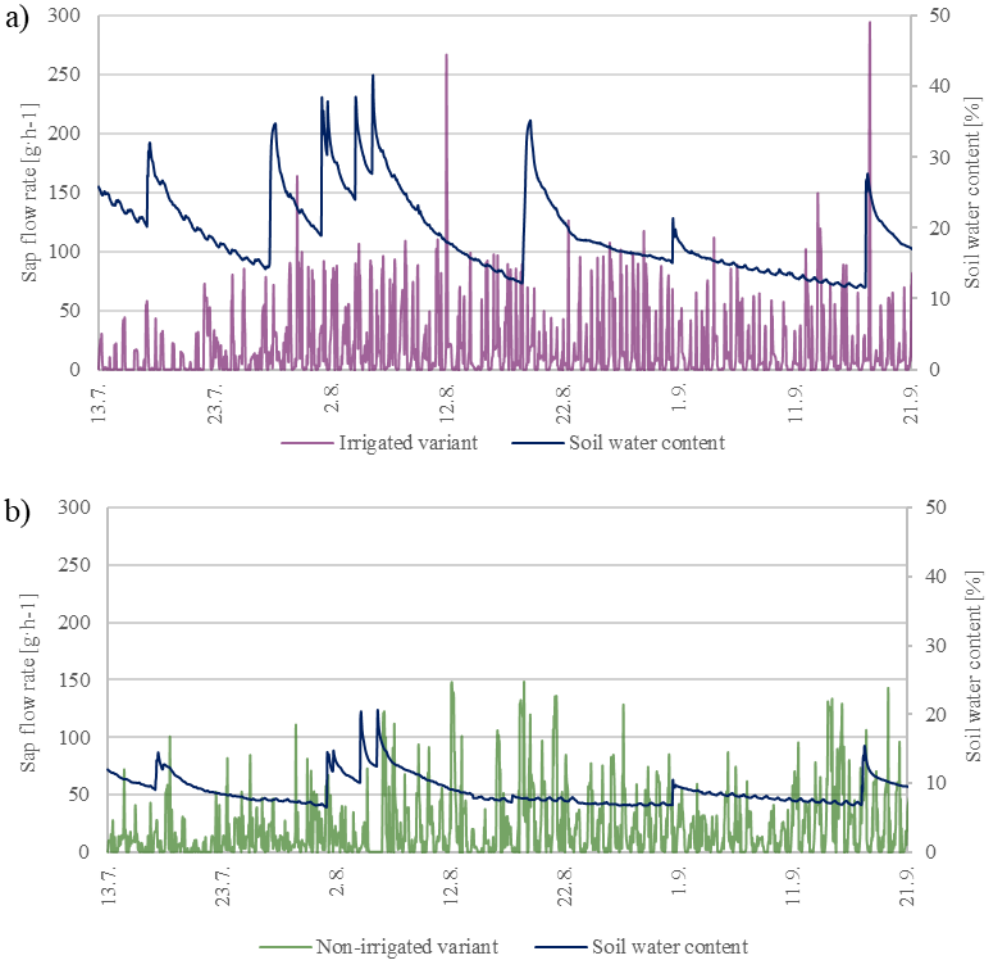


Figure 4. Diurnal course of sap flow rate in both treatments (a) irrigated and (b) non-irrigated variant, in comparison with soil water content during experiment period in 2021.

Daily rainfall totals were the same for both treatments because the irrigated trees were also exposed to natural rainfall. A total of 92.3 mm of rainfall fell during the experimental period. The highest rainfall was recorded on 16th September with a volume of 27.3 mm (**Error! Reference source not found.**a, 5b).

Assessing the relationship between the observed parameters in 2021 (soil moisture and sap flow) using Pearson's correlation coefficient. A statistically significant relationship (**P< 0.001) was identified between soil moisture and sap flow for irrigated trees (**Error! Reference source not found.**).

Table 1. Pearson correlations between selected parameters (irrigated and non-irrigated variant)

2021	Irrigated variant	Non-irrigated variant
Soil moisture vs. Sap flow	0.061 **	0.032

**P < 0.01

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Figure 5. Diurnal course of sap flow rate in both treatments (a) irrigated and (b) non-irrigated variant, in comparison with soil water content during experiment period in 2021.

DISCUSSION

The technology of measurement and sap flow data analyses are mostly focused to trunk segment heat balance (THB) and heat field deformation methods (HFD). Dynamax Inc. (USA) is one of the major companies that produce the Granier-Style sap flow sensors. Sensors work on the heater and temperature changes principle [10]. In commercial agriculture planning irrigation management and its automatization based only on sap flow measurements is time-consuming. The difficulties of this concept are in the installation of the sensors, data collection and analysis, especially if multiple crops are involved [11]. The EXO-Skin sensors used in our study are flexible design with new heater. That provides less heat losses, due to better contact between the stem and the temperature sensor [12].

The results of our study showed that different irrigation treatments have a different impact on the sap flow velocity in the plants. Sap flow in the water-stressed variant did not reach the maximal values of irrigated variant. In comparison with irrigated variant the curve of sap flow velocity changes has a similar course. In Shao et al. [13] study was water supply examine in 4 different irrigation treatments. According to the comparison of diurnal sap flow curves in all irrigation variants was flattening of the

curve was observed in variant T4 (50 % of irrigation dose T1) compared to controlled variant T1. During the dry season, a decrease in sap flow velocity in the outermost stem xylem, which is due to the availability of water to the superficial roots.

Using a sap flow sensor in irrigation management can give an accurate indication of the plant's water requirements. Esteves et al. [14] reported in their study, that changes in sap flow curve shape corresponded to water stress due to a lack of water supply in the root zone. A similar change in the sap flow profile curve was measured in our study, where the profile curve in underwater-stress trees was slightly flattened and the flow peaks did not reach the maxima of the irrigated variant.

CONCLUSION

The research presents comparison of sap flow in Royal Walnut trees under different irrigation conditions. The irrigated trees exhibited a peak sap flow rate of approximately 287.99 $g.h^{-1}$, contrasting with about 148.33 $g.h^{-1}$ in non-irrigated trees. This data highlights the impact of irrigation on enhancing water uptake and distribution within the trees. The soil moisture content also varied markedly between the two groups, with irrigated trees showing around 41.61% compared to around 20.47% in non-irrigated trees. These findings are critical for understanding the role of irrigation in managing water resources in walnut cultivation, especially in water-scarce environments. The study suggests that precise irrigation, informed by sap flow measurements, could significantly improve water use efficiency in walnut farming. Future research should explore the scalability of this approach across different agricultural settings and its potential in optimizing water use in other crop types, contributing to more sustainable and efficient farming practices.

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TOURISM ACTIVITIES AND VULNERABILITY TO NATURAL HAZARDS IN THE PIATRA-NEAMT CITY (NORTH-EAST ROMANIA)

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ABSTRACT

In the area of the city of Piatra-Neamt (North-East of Romania), the activities related to the tourism sector may register malfunctions due to the manifestation of some natural risk phenomena. The touristic potential of the city (recreational, sports, balneary, cultural-historical) represents a central component of the national tourist structure with many exploitation possibilities. Risk situations of tourist activities can be induced by the natural hazards attributes (probability and intensity) and vulnerability conditions (physical, economic and social dimensions). The approach in the present study is mainly based on documentary investigation and statistical data collection on risk events covering the period between 1887 and the present, quantitative/qualitative data processing using GIS techniques for making a relevant mapping, and the critical interpretation of the results. The study highlights the fact that some tourist actors, tourist objectives as well as elements of the tourist infrastructure fall under the incidence of geomorphological risks (landslides), climatic risks (lightning) and biophysical risks (the COVID-19 pandemic). The main effects of these risk phenomena are the economic difficulties resulting from the interruption of activities and the decrease in the number of tourists. Identifying the characteristics causing the susceptibility to adverse effects of natural hazards and assessing the vulnerability of the tourism sector in Piatra-Neamt City constitutes an essential element in the risk management strategy and sustainable development of the community.

Keywords: tourism, risk factors, natural hazards, vulnerability, Piatra-Neamt

INTRODUCTION

The recrudescence of natural risk events on a global, regional, or local scale is currently increasing and impacting both natural systems and human society.

The disruption of socio-economic activities also involves the tourism sector, which, due to its closer dependence on the natural environment, is more vulnerable to the manifestation of various climatic, hydrological and geomorphological risk factors. As tourism is influenced by a large variety of factors and forces, including exogenous ones not directly related to the tourism sector, natural hazards and unexpected events are excellent examples of such variables, as they have profound effects on individuals and society and, as a result, can significantly change the facets of a tourism destination [1].

The Piatra-Neamt city is the residence of Neamt county and is located in the north-eastern part of Romania in the Cracau-Bistrita depression, at the contact of the Subcarpathian hills with the Eastern Carpathians, at an average altitude of 301 m (Fig. 1).

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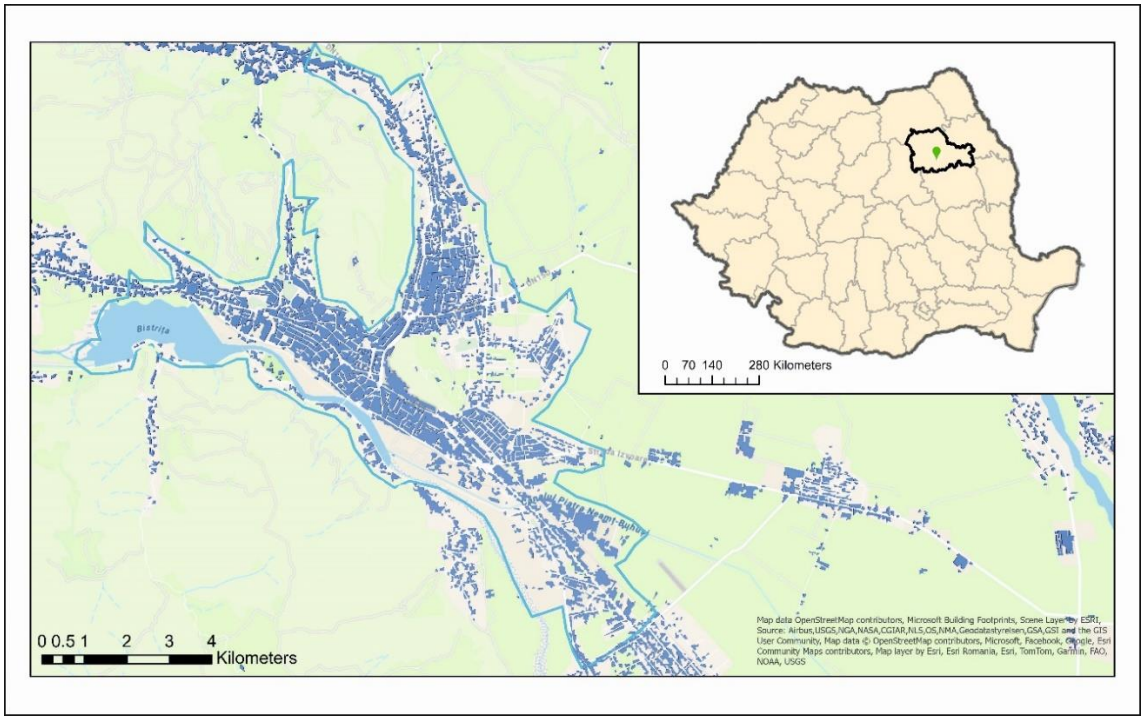


Figure 1. Location and boundary of the Piatra-Neamt city

The city is surrounded by mountains - Pietricica (528 m), Cozla (650 m), Cernegura (850 m) and Cârloman (617 m), and crossed by the rivers Cuejdiu and Bistrița, being developed in a natural environment favourable for settlement and economy, benefiting from a unique landscape setting.

The tourist potential of the Piatra-Neamt city (recreational, sports, balneary, cultural-historical) represents a central component of the national tourist structure with many exploitation possibilities.

Exploiting the city's tourist potential has been the permanent attention of the local community through the development of a specific and complex infrastructure. In recent years, many investments have been made: the renovation of the swimming place and its transformation into an agreement base; projects for transport and sports activities; the cable car that has become the most important tourist attraction of the city since its inauguration (in 2008); two ski slopes with different degrees of difficulty (first one inaugurated in 2009), night ski facility and ski lift. Moreover, the cultural-historical potential of the city is highlighted by the presence of archaeological remains with historical and cultural objectives, such as the Princely Court, Princely Cathedral (built between 1497-1498), the Bell Tower (built in 1499 and known as the Tower of Stephen) a monument-symbol and the most visited historical objective from the city and also many museums.

However, in the Piatra-Neamt city area, tourism-related activities may experience malfunctions due to climatic, hydrological, and geomorphological risk factors.

The present study proposes analysing risk situations affecting tourist activities in the city by evaluating natural hazards (probability and intensity) and vulnerability conditions (physical, economic, and social dimensions).

MATERIALS AND METHODS

For the analysis of risk situations related to tourism activities in the city of Piatra-Neamt, we propose a combination of methods and data aimed at a quantitative and qualitative analysis based on documentary investigation (various local, regional, and national sources, scientific publications, and statistical data) of risk events covering the period 1887 to the present.
It was developed based on an outline of the integrated risk assessment process in tourism (Fig. 2).

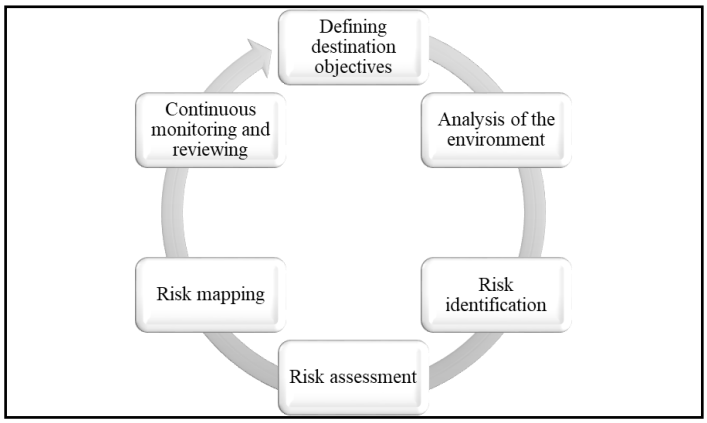


Figure 2. Integrated risk assessment process in tourism (adapted after Mikulic et al. [2])

Risk assessment includes, on the one hand, reviewing the hazard characteristics, such as their location, intensity, frequency, and probability and, on the other hand, the analysis of vulnerability with its physical, social, and economic dimensions. The specific risk is calculated using [Equation (1)] adapted from EC [3].

$$R = H \times V \quad (1)$$

where R means risk coefficient, H means natural hazards, and V means the degree of vulnerability conditions according to the Risk Assessment Matrix by Numerical Score with modifications adapted after Booth [4] (Table 1), which was built according to the frequency and intensity of the analysed hazard.

Table 1. Risk Assessment Matrix by Numerical Score

Risk Assessment Matrix								
Probability hazards			Intensity hazards		Vulnerability	Indices	Risk evaluation	Risk score
Descriptor	Likely frequency	Score	Descriptor	Score				
Frequently	Occurs frequently	5	Catastrophic consequences	5	Very high	5	Extreme risk	15-25
Often	It has occurred many times in a year	4	Major consequences	4	High	4	High risk	10-14
Likely	Has occurred more than once	3	Moderate consequences	3	Medium	3	Moderate risk	5-9
Possible	Has occurred	2	Minor consequences	2	Low	2	Low risk	1-4
Rare	Never occurred	1	Insignificant consequences	1	Very low	1		

The statistical data used to analyse the evolution of arrivals in accommodation units in the city of Piatra-Neamt during the COVID-19 pandemic were obtained from the website

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Insse.ro/tempo-online, and the statistical data regarding visitors to the Tower of Stephen were obtained from the Neamt National Museum Complex.
Data were processed in Microsoft Excel, and the spatial information analysis was carried out by processing quantitative/qualitative data using ArcGIS Pro;
Aerial photos were taken with a drone, model DJI Mavic Mini 2, and 3-axis Gimbal.

RESULTS

Based on the frequency and intensity of historical natural hazards, vulnerability conditions and risk situations were identified for tourist elements in Piatra-Neamt (infrastructure, objectives or disturbances of the tourist flow). The risk matrix shows that the tourist elements in the town of Piatra-Neamt present, in general, a medium degree of risk of floods and epidemics and a high degree of risk of landslides and extreme weather phenomena (Table 2).

Table 2. Risk Assessment Matrix of Piatra-Neamt

Risk Assessment Matrix				
Type of risk	**Probability**	**Intensity**	**Vulnerability**	**Risk evaluation**
Landslides	**Likely**	**Major consequences**	**High**	**High risk**
Floods	**Likely**	**Moderate consequences**	**Medium**	**Moderate risk**
Extreme weather phenomena (thunderstorms with heavy rain, hail and lightning)	**Often**	**Moderate consequences**	**High**	**High risk**
COVID-19 pandemic	**Possible**	**Major consequences**	**Medium**	**Moderate risk**

It highlighted the fact that some elements of the tourist infrastructure, as well as tourist objectives, fall under the incidence of risk phenomena:

- landslides (e.g., the secondary ski slope on the eastern slope of Cozla Mountain, affected by landslides and was never opened – Fig. 3);
- lightning in the summer of 2022 (e.g., the Tower of Stefan was damaged after being struck by lightning during a storm, causing severe damage to the electrical infrastructure, as a result of which the tower is still closed, with direct implications on the tourist numbers: from 3397 visitors in 2021 to zero in 2023- Fig. 4, 5, 6);
- the COVID-19 pandemic (e.g., economic difficulties as a result of activities disruption and the tourist's number decreased and number of tourist accommodation: in 2020, the number of tourists arriving in accommodation units decreased by 60% and the number of accommodation places decreased by 25%, compared to 2019 – Fig. 7, 8, 9).

The map of vulnerability to geomorphological and hydrological hazards (Fig. 10) indicates that the tourism sector in Piatra-Neamt city may be affected, especially in the areas under the threat of the respective risk phenomena.



Figure 3. Aerial view of the landslide affecting the secondary ski slope from the eastern side of Cozla Mountain

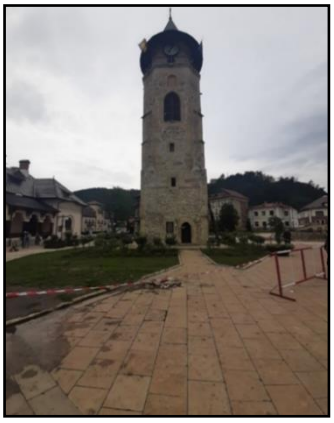


Figure 4. The Tower of Stefan damaged by lightning during the 2022 summer storm

Cozla Mountain

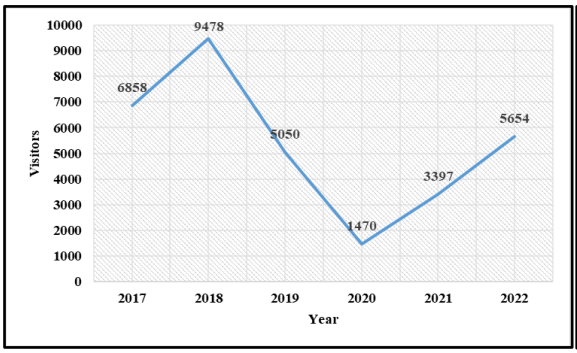


Figure 5. Statistics number of visitors Tower of Stephen (2017-2022)

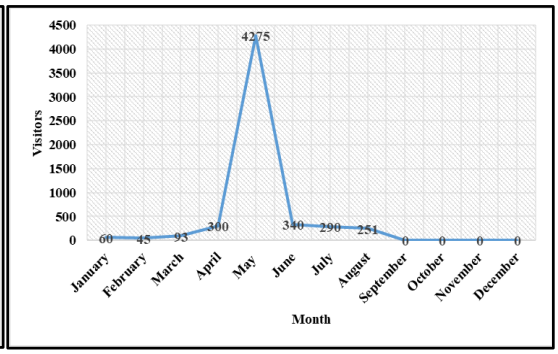


Figure 6. Monthly visitor statistics Tower of Stephen in 2022

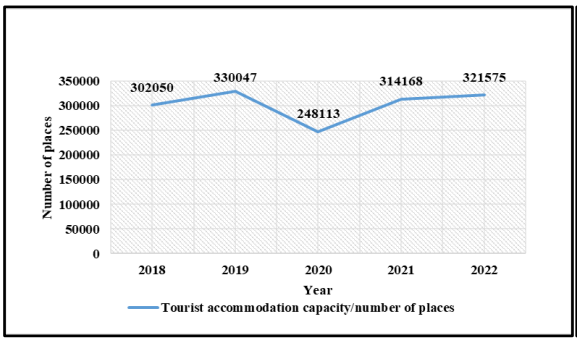


Figure 7. Tourist accommodation capacity in the city of Piatra-Neamt (2018-2022)

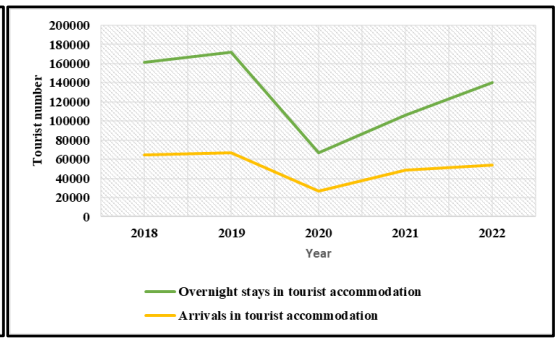


Figure 8. The number of tourists in accommodation structures in the city of Piatra-Neamt (2018-2022)

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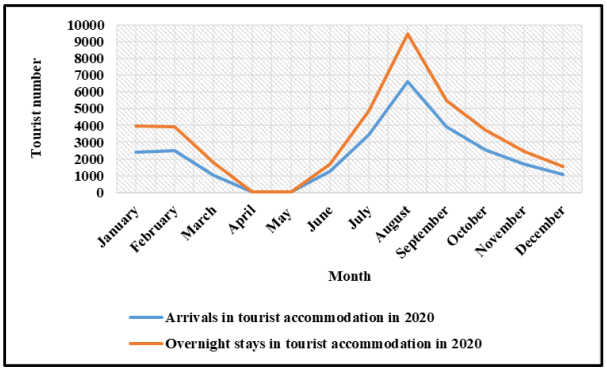


Figure. 9 Monthly number of tourists in accommodation structures in Piatra-Neamt in 2020

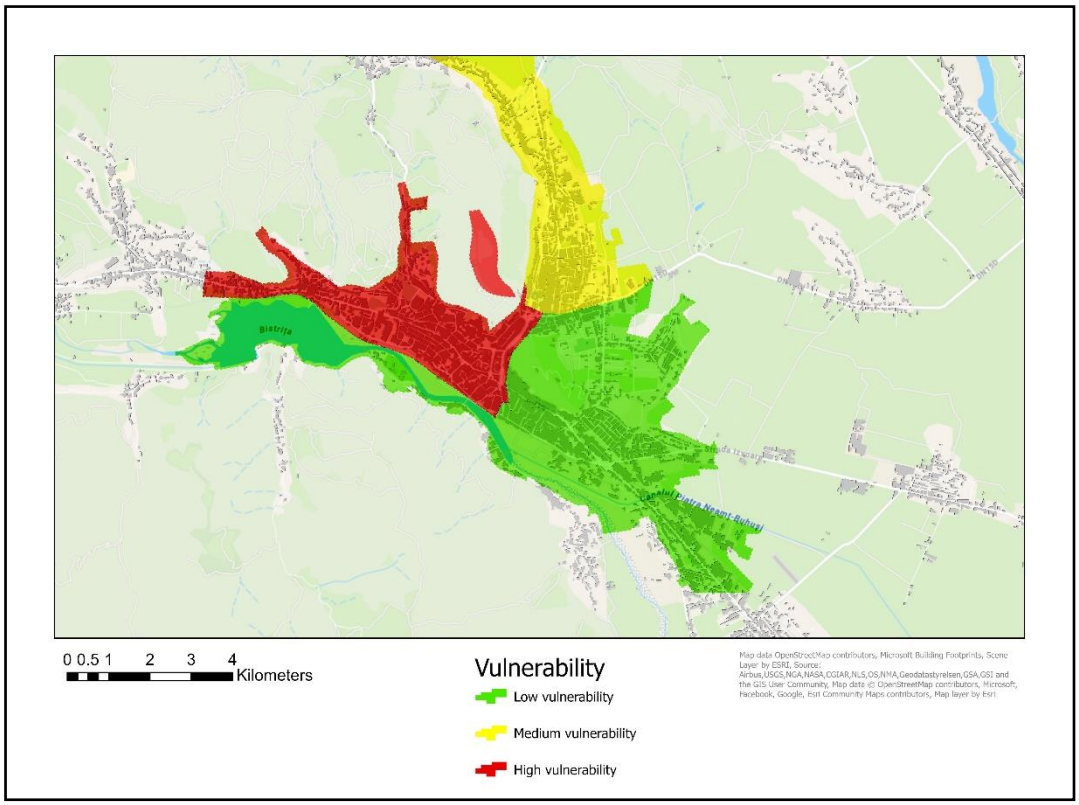


Figure 10. Map of vulnerability to geomorphological and hydrological hazards

DISCUSSION

Natural hazards are a severe problem in today's society, with threats to different economic areas, which can vary significantly in frequency, magnitude, and intensity, mainly due to the environment in which they occur, with direct impact on livelihoods, infrastructure, improvements and socio-economic development [5]. Consequently, the damage caused by natural hazards to tourism is often represented by the destruction of tourist destinations, fluctuations in tourist traffic and changes in personal tourist intentions, resulting in massive shocks to tourism business management [6,7].

Geological, geomorphological, hydrological, climatic, and biophysical characteristics determine the risk situations of the natural environment in Piatra-Neamt.

Geological and geomorphological features favour mass movement processes on slopes where landslides can occur. The Cozla Mountain, near Piatra-Neamt, has been permanently modified by natural phenomena such as landslides, which are the most frequent and risky processes. Historically, on Mount Cozla, in 1887 and 1903, respectively, after heavy rainfall, two large landslides were a natural disaster for the local community. Later, through an extensive afforestation project, the phenomenon was partially controlled [8].

The ski slope on Mount Cozla, inaugurated in 2009, is an ambitious tourist project. However, due to the mountain's low altitude, low rainfall, and high temperatures in the winter season, it was opened intermittently, operating only between 2009-2015 and 2018-2019. Currently, a landslide (Fig. 3) affects the secondary ski slope on the eastern slope of Mount Cozla, and several crumbling areas make the slope unusable.

The Bistrita River and the main tributary, Cuejdiu, form the Piatra-Neamt hydrographic structure. Under normal conditions, the Cuejdiu river has a low flow, but sometimes, following heavy rainfall, it presents a risk of flooding. This risk is now much reduced because the riverbed in the city is engineered to avoid most cases of flooding [9].

From a climatic point of view, the city of Piatra-Neamt is located in an area of double contact between mountain and hill climate and between excessive continental climate and weak oceanic climate, offering generally good living conditions, but there is the possibility of short periods of climatic excesses [9]. Climate risks are linked to extreme weather events (thunderstorms, heavy rain, strong wind, hail and lightning). Istrate et al. [10] present that, among the storm-related risks, hail causes the most significant economic damage, and the city of Piatra-Neamt is included in the high-risk category because of the higher frequency of hail.

The COVID-19 pandemic posed an immediate risk to tourism and instantly changed travel decision-making, negatively affecting economic activity, unemployment, loss of income and business closures [11].

In the Sustainable Development Strategy of the Municipality of Piatra-Neamt for the programming period 2021-2027, an important objective is to recover from the new COVID-19 crisis and its devastating impact and to increase the number of tourists visiting Piatra-Neamt:

- Rehabilitation / Modernization of the Cozla Mountain tourist area;
- Development of the Cozla Adventure Park (currently, there are two mountain bike trails);
- Children's mountain village arrangement;
- Establishment of a riding, leisure and therapy centre;
- Development of tourist trails and promenade areas;

Investments in tourism development through the actions proposed in the Municipality of Piatra-Neamt's Sustainable Development Strategy are intended to achieve the objective of sustainable tourism development.

CONCLUSION

In the area of the city of Piatra-Neamt, activities related to the tourism sector may register malfunctions due to the manifestation of geomorphological, climatic, and biophysical risk factors.

The main effects of these risk phenomena are economic difficulties resulting from activity disruption and a decrease in the number of tourists and tourist accommodations. Some elements of the tourist infrastructure of the Piatra-Neamt city, as well as tourist objectives,

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fall under the incidence of geomorphological risks (e.g., the secondary ski slope on the eastern slope of Cozla Mountain, affected by landslides), climatic risks (e.g., the Tower of Stefan, damaged after being struck by lightning), biophysical risks (e.g., the COVID-19 pandemic), or social risks (e.g., economic difficulties as a result of activities disruption and the tourists number decrease).

Identifying the characteristics causing susceptibility to adverse effects following the manifestation of the risk phenomenon and assessing the tourism sector's vulnerability in Piatra-Neamt city constitute an essential element in the risk management strategy and sustainable development of the community.

The study confirms that serious studies assessing the investment's vulnerability to the impact of hazard or risk phenomena must support any development project. In this case, risk factors delay the sustainable management of the local tourism potential and the sustainable contribution to the community's economic development.

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UNIQUE ASPECTS OF ENVIRONMENTAL EDUCATION IN GENERAL EDUCATION SCHOOLS OF ADJARA

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ABSTRACT

Education is an ongoing process that enables individuals and society as a whole to reach their full potential by developing their abilities. It serves as a crucial prerequisite for sustainable development and the formation of public awareness. Environmental education, which begins in early childhood and continues throughout life, plays a vital role in fostering environmental literacy. Thus, assessing the state of environmental education among school-age students is of great importance.

Our research aimed to evaluate the ecological knowledge of students in public schools operating in various municipalities of the Adjara region, including Khulo, Keda, Khelvachauri, and the city of Batumi. A total of 72 students from primary, secondary, and high school levels, with 24 students from each level, participated in the study, representing eight public schools in the mentioned regions. The findings revealed that the level of ecological knowledge among schoolchildren in rural areas was higher compared to students in urban areas, while the ecological awareness of elementary school students in rural schools is higher than that of students of the corresponding level in city schools. This difference can be attributed to the fact that children living in rural areas have more exposure to nature, animals, and plants, and thus have more information about them, resulting in higher ecological awareness.

Furthermore, there was no significant difference in the levels of ecological knowledge between primary and secondary school students. It was determined that students at all levels were well-versed in environmental aspects such as water pollution, waste management, climate change, biodiversity, forest and soil conditions, and natural disasters. However, there was relatively less awareness about the ecological condition of the air, energy efficiency, and green economy.

Keywords: environmental education, pollution, eco-awareness, environmental protection, student.

INTRODUCTION

Environmental education is globally recognized as a priority focus area. It plays a crucial role in shaping the modern worldview, fostering ecological awareness, promoting cultural and religious values, nurturing aesthetic views, and instilling a sense of responsibility towards the Earth's natural resources, thereby strengthening the importance of respect towards them [1]. That is why it is crucial to complement formal

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education in schools with extracurricular learning through informal education, such as learning by doing. This approach allows students to put theoretical knowledge into practice, better understand their own interests and aspirations, take meaningful steps towards realizing them, feel like valued members of society, and become responsible citizens. In alignment with the national strategy and action plan of Georgia, environmental education in schools aims to establish and operate eco-clubs, providing opportunities for both formal and informal environmental education [2].

Nature provides a unique opportunity for children to develop their abilities to understand and learn about the physical environment, observe, investigate, and experiment with processes that yield visible results. Through acquiring knowledge about the environment, children learn about living nature and develop an understanding of the importance of caring for and protecting it [3]. Environmental education is a multidisciplinary approach that fosters environmental awareness, values, and skills, enabling individuals and society to actively participate in the preservation and improvement of the environment. It is a crucial social strategy with the ultimate goal of developing individuals who possess appropriate knowledge about their living environment, are capable of evaluating it, possess practical skills for interacting with the environment, and exhibit developed environmental attitudes. The development of environmental awareness relies on improving the formal education sector, strengthening non-formal education methods, and implementing targeted information policies. However, environmental education is not isolated from other social strategies; rather, it is intricately interconnected and planned in conjunction with communication, economy, politics, legislation, ecological monitoring, planning, etc. In the process of environmental education, it is crucial to consider all aspects of the natural and human-made environment, including ecological, political, economic, technical, social, legislative, cultural, religious, and aesthetic aspects.

The special importance of environmental education in the protection and sustainable management of our environment is widely recognized. Its critical role has been firmly established in key global documents, such as the World Conservation Strategy announced by the International Union for Conservation of Nature (IUCN) and the World Wildlife Fund (WWF) in 1980, and further emphasized in the 1992 Rio de Janeiro Declaration at the United Nations Conference on Environment and Development ("Agenda-21"), which serves as a global framework for environmental protection actions [4]. In recent years, the pivotal role of environmental education has been further emphasized, as highlighted in the 1997 UNESCO document "Education for a Sustainable Future". This document advocates for a holistic approach that combines high-quality teaching and learning with awareness-raising processes. The goal is to foster the development of knowledge, skills, attitudes, and values essential for sustainable development, through an interdisciplinary approach and the establishment of a cohesive school culture and institutional framework [4]. By incorporating real-life examples, students can better understand the significance of their learning and its practical application. It also provides opportunities to reflect on values and attitudes within the learning environment, and empowers students to utilize their acquired knowledge and skills [5]. Education for sustainable development empowers individuals to recognize their capacity to turn their ideas into reality, fosters values such as responsibility towards the natural and social environment, and promotes a way of life that ensures a sustainable future.

In the national curriculum of Georgia, the development of ecological competence among students holds a crucial position, as its outcomes will have long-term impacts on economic and ecological equity. It is imperative to align our lifestyles with the needs and rights of future generations, and to acknowledge that our present actions shape the quality of life for the future. Understanding the significance of the cultural, social, economic, and biological diversity of our world is paramount. Regardless of the economic disparities among countries, every individual has an equal entitlement to live in a sustainable world. It is vital to comprehend that unsustainable growth leads to environmental degradation [6, 7]. Education for sustainable development must be integrated into all curricula and plans, spanning across preschool, primary, secondary, vocational, and higher education levels. It should not be viewed as an add-on to existing curricula, but rather an essential element of teaching and learning. This entails incorporating topics related to sustainable development into curricula and establishing learning outcomes that promote sustainable development.

A comprehensive school curriculum should not only focus on basic skills, but also emphasize critical thinking, research, problem-solving, advocacy, and conflict resolution skills, equipping children, adolescents, and young adults to become responsible global citizens [8]. The role, importance, and status of ecological education in Georgia are defined by the Law of Georgia "On Environmental Protection". The law emphasizes the need to establish a unified system of ecological education in the country, encompassing various stages of education including early and preschool upbringing, primary, basic, secondary, professional, and higher education [9]. In schools, ecological education is initiated at the elementary level through engaging ecological games. The educational program of the institution ensures that students acquire the minimum mandatory knowledge about environmental protection and sustainable use of resources. In secondary, professional, and higher education institutions, specialized courses on environmental management, ecology, and other environmental subjects are taught to further deepen students' understanding [10].

Complete general education in Georgia spans three levels and lasts for twelve years. The levels of complete general education are: a) primary - I-VI grades; b) basic - VII-IX grades; c) secondary - X-XII grades. The national curriculum of Georgia identifies priority topics based on the national goals of general education, which include: a) protection of cultural heritage; b) environmental protection; c) healthy living [11, 12]. Starting from preschool age, it is crucial for educators to dedicate time to environmental issues, to foster children's interest in the natural environment and living organisms, and to encourage the development of practical skills that help them learn about the environment, adapt to it, maintain a healthy lifestyle, take care of living organisms, and use natural resources wisely [13]. Creating an appropriate attitude towards the child and promoting education at an early age are essential for shaping their personality and fostering their intellectual, physical, ecological, social, and emotional well-being in the future [14]. Youth represents the most active segment of society, with extensive connections and influence, and proficient use of social media compared to other age groups. Higher educational institutions, being the bastions of knowledge, technological innovations, and progressive values, attract a large concentration of youth. Therefore, it is crucial to engage universities in environmental issues. Many Georgian universities, including Batumi Shota Rustaveli State University, play a significant role in providing eco-education for the next generation. Active involvement of students is crucial in leading eco-education in the right direction [15].

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MATERIALS AND METHODS

The research utilized a quantitative research method, employing a survey of targeted groups using a specialized questionnaire. The environmental education research centered on various topics, including air pollution, water pollution, biodiversity, waste management, energy efficiency, forests, soil pollution and erosion, climate change, and natural disasters.

The participants in the research were students from I, II, XIV, XV, and XXVIII public schools in Batumi, as well as Aslan Shainidze Tsablana public school in Khulo municipality of Adjara region, Gegelidzeebi public school in Keda municipality, and Tkhilnari public school in Khelvachauri municipality. The research included 24 students from each level: I-IV grades of primary level, VII-IX grades of basic level, X-XI grades of secondary level (72 students in total).

RESULTS AND DISCUSSION

The findings from the study were assessed based on relevant knowledge and skills, yielding the following evaluation criteria:

Level 1: Lack of environmental education and awareness. The student lacks general knowledge about ecology, possessing only fragmented understanding of biology. They show little interest in natural phenomena and living organisms, and fail to recognize the interdependence among different factors. Their attitude towards the socio-natural world is neutral or indifferent.

Level 2: Fragmented knowledge of general ecology. The student possesses fragmented knowledge about ecology and shows some interest in natural phenomena and living organisms. Their attitude towards the world is passive, characterized by an unconscious emotional perception of socio-natural objects. They have the ability to focus their attention on natural objects, but their contemplation lacks emotional response and does not contribute to effective moral attitudes towards them.

Level 3: Intermediate level of environmental education. The student possesses knowledge of general ecology and natural science concepts, supported by examples from textbooks. They demonstrate a keen interest in learning about natural phenomena and ensuring the habitat of living organisms. The student develops an emotional and empathic attitude towards the environment.

Level 4: Advanced level of environmental education. The student possesses comprehensive knowledge of ecology and natural science, which is practically applied in environmental protection activities. They exhibit an emotional and value-based attitude towards the environment. They actively express sensitivity and responsiveness to the social and natural environment through emotional responses, reactions, feelings, associations, and evaluations.

Level 5: Exceptional environmental education. The student exhibits a high level of ecological awareness, including a comprehensive understanding of global ecological interdependencies and proficient knowledge of ecological behaviour in both social and natural contexts. They are capable of recognizing the social significance of environmental problems.

The findings from the conducted studies are documented in Tables 1, 2, and 3.

Table №1. Statistical data on the level of ecological education in Batumi public schools

Research object	***Level***	***Batumi № 1 Public School***	***Batumi №2 Public School***	***Batumi №14 Public School***	***Batumi №15 Public School***	***Batumi №28 Public School***
Elementary level I-VI grades	1	5* / 20,8%**	5 / 20,8%	5 / 20,8%	5 / 20,8%	4 / 16,7%
	2	4 / 16.7%	4 / 16.7%	4 / 16.7%	4 / 16.7%	4 / 16,7%
	3	4 / 16,7%	4 / 16,7%	4 / 16,7%	4 / 16,7%	4 / 16,7%
	4	4 / 16,7%	4 / 16,7%	4 / 16,7%	3 / 12,5%	4 / 16,7%
	5	3 / 12,5%	3 / 12,5%	3 / 12,5%	4 / 16,7%	8 / 33.33%
Basic level VII-IX grades	1	1 / 4,17%	1 / 4,17%	1 / 4,17%	1 / 4,17%	1 / 4,17%
	2	2 / 8,3%	2 / 8,3%	2 / 8,3%	2 / 8,3%	2 / 8,3%
	3	5 / 20,8%	5 / 20,8%	5 / 20,8%	5 / 20,8%	5 / 20,8%
	4	5 / 20,8%	5 / 20,8%	5 / 20,8%	5 / 20,8%	5 / 20,8%
	5	11 / 45,83%	11 / 45,83%	11 / 45,83%	11 / 45,83%	11 / 45,83%
Secondary level X-XI grades	1	- ***	-	-	-	-
	2	-	-	-	-	-
	3	6 /25%	6 /25%	6 / 25%	6 / 25%	5 / 20,8%
	4	9 / 37,5%	9 / 37,5%	9 / 37,5%	9 / 37,5%	9 / 37,5%
	5	9 /37,5%	9 /37,5%	9 /37,5%	9 / 37,5%	10 / 41,7%

* Number of students (24 students from each level)

** The percentage of the level of ecological knowledge corresponding to the number of students

*** Corresponding ecological ignorance is not recorded at the given levels

Table №2. Statistical data on the level of ecological education in public schools of the Adjara region

Research object	***Level***	***Tkhilnari Public School of Khelvachauri Municipality***	***Keda Municipality Gegelidzeebi Public School***	***Aslan Shainidze Public school of Tsablana village, Khulo municipality***
Elementary level I-VI grades	1	2* / 8,33%**	2 / 8,33%	2 / 8,33%
	2	3 / 12,5%	2 / 8,33%	2 / 8,33%
	3	5 / 20,8%	5 / 20,8%	5 / 20,8%
	4	6 / 25%	6 / 25%	6 / 25%
	5	8 / 33.33%	9 / 37,5%	9 / 37,5%
Basic level VII-IX grades	1	1 / 4,17%	1 / 4,17%	1 / 4,17%
	2	2 / 8,3%	2 / 8,3%	2 / 8,3%
	3	4 / 16,7%	3 / 12,5%	3 / 12,5%
	4	6 / 25%	7 / 29,16%	7 / 29,16%
	5	11 / 45,83%	11 / 45,83%	11 / 45,83%
Secondary level X-XI grades	1	- ***	-	-
	2	-	-	-
	3	4 / 16,7%	4 / 16,7%	4 / 16,7%
	4	10 / 41,7%	10 / 41,7%	10 / 41,7%
	5	10 / 41,7%	10 / 41,7%	10 / 41,7%

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* Number of students (24 students from each level)
** The percentage of the level of ecological knowledge corresponding to the number of students
*** Corresponding ecological ignorance is not recorded at the given levels

The findings reveal that students living in rural municipalities of Adjara demonstrate a higher level of ecological education compared to their urban counterparts. This is attributed to their closer connection with nature, animals, and plants, which results in a better understanding of environmental concepts. Research indicates that students at the primary level have limited knowledge about nature protection and the ecological situation, while those at higher education levels exhibit a relatively better understanding of environmental protection, ecological improvement, and preservation. They are knowledgeable about topics such as water pollution, waste management, climate change, biodiversity, soil and forest conditions, and environmental aspects of natural disasters. However, they have relatively less information about air pollution, energy efficiency, and green economy (as shown in Diagram 1). Table 3 presents the issues discussed with the students during the statistical research, arranged in order of their level of awareness.

Table №3. Ranking of the issues to be discussed according to the level of students' awareness

Rank	***%***	***Issues***
1	96,8	Climate change
2	92,9	Water pollution
3	88,0	Air pollution
4	87,7	Waste management
5	87,7	Forests
6	80,8	Biodiversity
7	80,8	Soil pollution and erosion
8	79,8	Natural disasters
9	75,2	Energy efficiency
10	75,1	Green economy

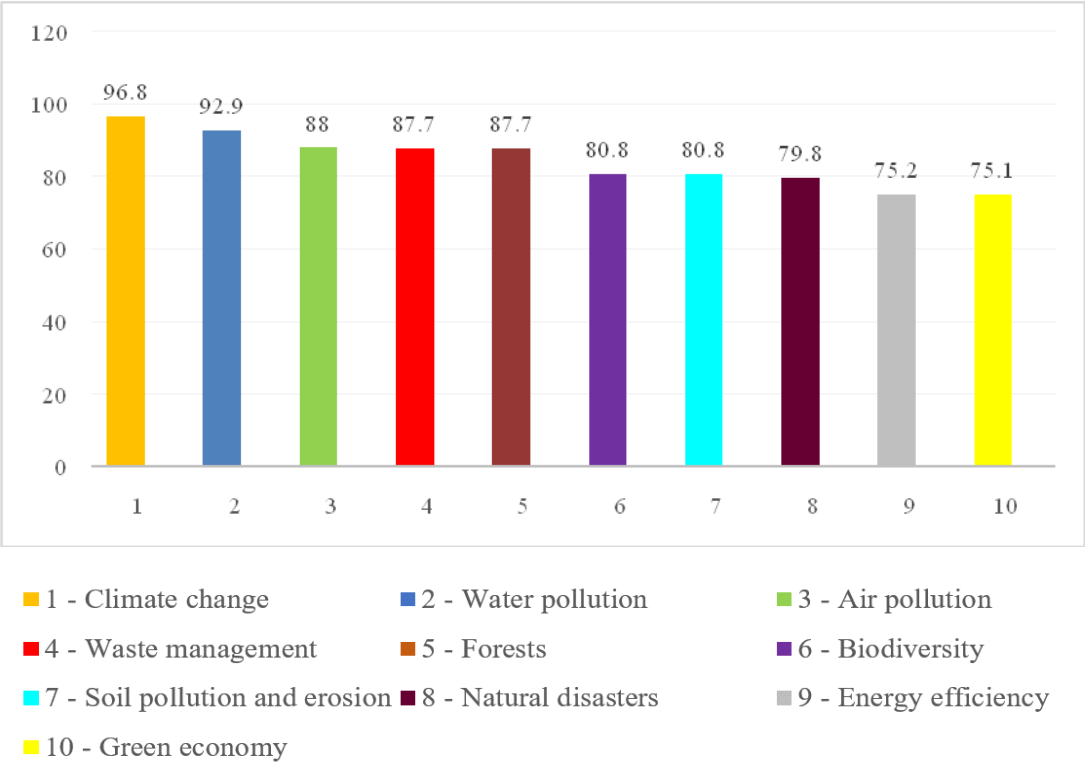


Diagram №1. ***Issues Discussed and Students' Awareness Level***

CONCLUSIONS

The educational character of the learning process in primary grades and the promotion of national-regional orientation in education are crucial aspects of environmental education. The study on the formation of students' level of environmental education reveals that a majority of students at the primary level have a low level of environmental education, while those at higher levels exhibit a higher level of environmental education. To enhance the development of a caring attitude towards nature among elementary school students, deliberate and systematic efforts using diverse forms and methods to cultivate their ecological culture are necessary. This includes organizing family education and creating an ecologically oriented pedagogical environment both at home and in school. For the primary level, methods that analyse the ecological value orientation, interests, and needs of students are most suitable to promote effective environmental education.

RECOMMENDATIONS

1. To instil skills of protection, care, and responsible use of nature in students from an early age, teachers should utilize various approaches, including curriculum-based projects, regular lesson hours, as well as voluntary and mandatory workload, optional courses, extracurricular activities, field trips, summer and winter ecological camps, trainings, preparation of young ecologists for ecological tournaments, and organizing

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public lectures and conferences. These efforts will greatly contribute to the environmental education of students. It is important to also emphasize the ethical and moral aspects of environmental education, aiming to raise students' awareness of their responsibilities towards the environment.

2. It is crucial to utilize effective propaganda tools to raise environmental awareness. This includes providing comprehensive information on the impacts of human activities on the environment and vice versa. Television can be a powerful medium for mass communication, and programs should be tailored to target audiences of different ages. Additionally, video clips with well-known personalities, printed materials such as brochures and newsletters, and organizing eco-competitions in schools can also play a significant role in promoting environmental education and awareness within society.

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USING WASTE INSINERATION AS A MEANS TO INCREASE OIL RECOVERY

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ABSTRACT

The difficult environmental situation in the world is largely a consequence of the huge volume of production and consumption waste and its constant growth. In this regard, the problem of waste placement, neutralization and utilization comes to the fore. One of the most controversial methods that contribute to a significant reduction in the amount of garbage and the production of energy is waste incineration plants. The main argument of opponents of this method of disposal is the assertion about the pollution of the atmosphere by exhaust gases, which are waste from waste incineration plants. Meanwhile, the incineration technology in many cases is currently the only possible (or best) way to solve many technosphere problems. For example, to increase oil recovery from formations, gas and water-gas methods of influencing the formation, as well as pumping heat carriers into it, are widely used. These methods require, in particular, the combustion of hydrocarbon fuel. This paper considers the option of using waste from waste incineration plants (flue gases and heat) as tools in the oil producing industry. To solve this problem, it is necessary to analyze the morphological composition of waste, which in turn contributes to the development of effective strategies for their use. The use of waste incineration to increase oil recovery allows the use of waste from one industry as secondary raw materials for another, while ensuring the saving of primary natural resources (fuel).

Keywords: technosphere, pollution, waste, carbon dioxide, waste incineration plants, oil extraction.

SUBJECT AND METHODS OF THE STUDY

The complex environmental situation in the world is largely a consequence of the growth of the population and the increase in the production of industrial and agricultural products. Accordingly, there is a constant increase in the volume of waste generation from production and consumption. In many countries, the problem of placement, neutralization and disposal of this waste, which causes irreparable harm to the environment, comes to the forefront. For this purpose, a special branch of material production has been created, various methods of disposal have been developed. Their purpose is to obtain secondary energy and material resources.

One of the methods of waste disposal in order to reduce their amount and burial problems is waste incineration using waste incineration plants. However, the use of this method of waste disposal is debatable.

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The subject of this study is a tenoretic study of the possibility of using waste during their incineration as secondary energy sources and means for increasing oil recovery from productive formations of oil fields. In this case, the disposal process itself becomes virtually waste-free and at the same time the cost of oil is significantly reduced.

DISCUSSION

Waste (garbage) incineration technology has both its staunch supporters and ardent opponents.

The former, for example, Professor B.B. Bobovich, believe that the construction of waste incineration plants occurs not only because the cost of land and the construction of landfills are extremely high, but also because modern technologies for burning waste and cleaning emissions from toxic substances make it possible to reduce the risks of environmental pollution to the required minimum level permitted by the laws of a number of countries, which, by the way, are constantly being tightened [1].

Others, for example, Professor L.I. Sokolov, do not consider incineration to be an economically justified and resource-saving method, since many secondary resources that could be used are burned with additional energy costs. In addition, waste incineration plants have a number of disadvantages, the main one of which is that their operation produces secondary, extremely toxic waste that is released into the environment along with heavy metals, flue gases, wastewater and slag [2].

At the same time, as a method of handling hazardous waste, incineration may be acceptable in the part that cannot be recycled, or when waste incineration is built into a more general technological process as its necessary component [3]. In this regard, let us consider the problem of increasing oil recovery, which is very relevant for deposits with high-viscosity oils. The share of such deposits in the world is constantly increasing and the extraction of hydrocarbon raw materials from them using the traditional method of flooding is becoming increasingly difficult. Obviously, it is necessary to look for "new approaches" to solving this problem. Such approaches include, for example, the use of gas and water-gas methods of influencing oil reservoirs [4]. One of the effective gas methods is the injection of carbon dioxide into the reservoir. This gas is non-flammable, non-explosive, and not dangerous to breathe. It dissolves in oil 4-10 times better than in water. In 1 m^3 of oil at a pressure of 10 MPa and a temperature of 27 ^{0}C, 250–300 m^3 of CO_2 dissolves.

When in contact with oil, CO_2 partially dissolves in the formation and, at the same time, extracts light hydrocarbons and is enriched with them. This leads to an increase in the miscibility of CO_2, and the displacement becomes miscible. As a result, the pressure required for miscible displacement of oil by carbon dioxide is significantly less than by pure hydrocarbon gas.

When CO_2 dissolves in oil, the viscosity of the latter decreases (fig. 1), and the volume increases significantly, which leads to an increase in oil recovery.

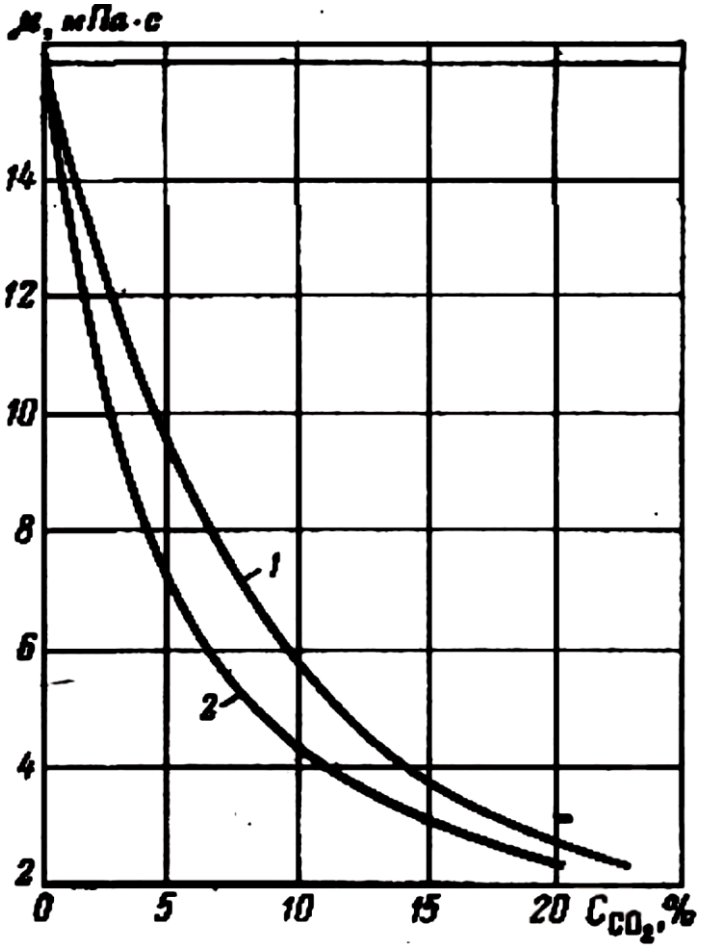


Fig. 1. Dependence of oil viscosity μ on the concentration of CO_2 in it for oils from the Arlanskoye (1) and Tuymazinskoye (2) fields [5]

Thus, in the United States of America, the share of oil additionally produced in 2004 using gas methods, in particular injection of carbon dioxide into the formation, amounted to 206 thousand barrels per day, or about 4% of oil production. Field tests of liquefied carbon dioxide injection conducted at fields in the Samara Region of Russia also showed high efficiency. Flue and associated petroleum gases are also used as a source of carbon dioxide in the oil industry.

Another effective method for developing high-viscosity oil fields is the use of thermal stimulation of the formation. In this case, the temperature in the oil-formation environment increases, the viscosity of the formation fluids decreases, and, ultimately, oil recovery increases. Thus, in Tatarstan (Russian Federation), the Ashalchinskoye field of super-viscous oils is being successfully developed using the steam-gravity drainage method [5].

It should be noted that the widespread use of carbon dioxide is constrained by the lack of available sources and their remoteness from the fields of use.

Hence, the source of heat and flue gases must be in the immediate vicinity of the injection site. A waste incineration plant may be such a source.

Let us consider in more detail the problems of using gaseous waste from a waste incineration plant. These wastes include: carbon dioxide, water vapor, nitrogen oxides

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and various impurities. In the case of using a modernized method of waste incineration associated with the replacement of air supplied to the combustion site with oxygen, the emission of nitrogen oxides is reduced. However, it should be taken into account that such technology requires additional costs for oxygen production.

Injection of hot combustion gases combines thermal action with mechanical and chemical effects, namely:

a) the resulting combustion gases under pressure (up to 100 MPa) displace liquid from the wellbore into the formation, which expands natural cracks and creates new ones;

b) heated (180–250 ^{0}C) gases, penetrating into the formation, melt paraffin, resins and asphaltenes;

c) gaseous combustion products consist mainly of carbon dioxide, which, when dissolved in oil, reduces its viscosity, surface tension and increases well productivity.

The placement of a waste sorting plant in an oil-producing region allows for industrial injection without the element of main gas transportation. At the same time, on the one hand, oil recovery increases, and on the other, problems with waste disposal are solved.

A new approach here is to integrate the incineration process into the technosphere cycle, when waste from one production is used as secondary resources for another. At the same time, primary natural resources (fuel) are saved.

A waste incineration plant requires a stable supply of a sufficient amount of non-traditional fuel, i.e. waste. Waste from oil and gas production, such as oil sludge, can be used as such fuel. As is known, the utilization and neutralization of this waste is one of the most important environmental problems of the oil producing, oil refining and petrochemical industries.

The paper [6] presents the results of a technical analysis of petroleum fuels (table).

Table

Results of technical analysis of petroleum fuels

Petroleum fuel	**Crude oil**	**Tank oil sludge**	**Ground oil sludge**
Analytical moisture content W_a, %	0,84	8,40	2,44
Volatile matter content relative to analytical fuel sample V_A, %	42,19	58,55	27,56
Volatile matter content relative to combustible mass of fuel V_G, %	42,90	70,38	29,90
Non-volatile ash-free residue content K, %	56,98	33,04	67,04
Ash content A_a , %	0,83	8,41	5,40
Coefficient α	76	50	93
Higher calorific value Q_B, MJ/kg	33,19	26,06	23,27

This analysis shows that oil sludge contains more water and ash residue than crude oil. Considering that the presence of water in oil sludge and crude oil reduces the formation of soot during their combustion, the studied oil fuels can be used to produce briquetted boiler fuel. Peat is advisable to use as a filler for briquettes, since it adsorbs organic matter well and has a high calorific value.

Thus, the combined use of peat and oil fuels in the form of briquettes is a promising and cost-effective way to utilize various types of oil sludge. In this case, the sludge moisture contained in the briquettes replaces water vapor, which must be added to the combustion zone during smokeless combustion of fuel.

Municipal solid waste can also be an important source of fuel for a waste incineration plant.

Municipal solid waste is a mixture of various types of waste, which can be divided into two main categories: organic and inorganic, including non-combustible materials. Organic waste includes food waste, plant residues, paper, cardboard, etc. They are the main source of energy when burned at an incineration plant, as they contain a high concentration of carbon.

When determining the volume of waste for burning at an incineration plant, the morphological composition plays an important role. It is important to note that the morphological composition of municipal solid waste may vary depending on the region and source of waste collection.

The inorganic fraction includes various types of materials, such as glass, metals, plastic, paper, etc. These materials are not subject to biological decomposition and require special treatment for their recycling or disposal. The inorganic fraction can be sorted, recycled, and recovered for reuse.

In particular, metals present in waste, such as iron, aluminum, copper, and others, have a high degree of recycling and can be used in the production of new metal products.

Plastic is one of the most common components in waste. It can be made from various raw materials and has different degrees of recycling. Plastic can be recycled and used to produce new products.

Paper is also a significant component of waste, especially in the office environment. Its recycling and reuse help save natural resources and reduce the impact on the environment.

Thus, studying the content of various components in waste is an important task in terms of its recycling and disposal. This allows for the efficient use of resources and the minimization of the negative impact on the environment.

Analysis of the morphological composition of municipal solid waste is an important stage in the waste management process and provides information on the content of various components. This analysis helps to understand the composition of the waste, which in turn contributes to the development of effective strategies and methods for its management.

Municipal solid waste intended for incineration at an incineration plant has certain logistics requirements. Waste must be collected, transported and delivered to the plant in accordance with the deadlines and safety requirements. It is important to ensure the

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efficient organization of the waste collection and transportation process in order to minimize the risks of environmental pollution and ensure the safety of workers and the population.

It is worth noting that waste incineration is only one method of waste management, and its use should be balanced with other methods, such as recycling, disposal and waste reduction. Full optimization of the waste management system is achieved by combining various methods and logistics solutions, which helps to minimize the negative impact on the environment and ensures sustainable development (fig. 2).



Fig. 2. Scheme for optimizing the waste management system is achieved by combining various methods and logistics solutions

CONCLUSIONS

The disposal of solid municipal waste currently remains one of the most pressing problems of our time. We do not so much offer solutions to this problem as we raise the question of the feasibility of building waste incineration plants in oil regions. The waste products (flue gases) here can become a source of energy for the economic needs of production and at the same time contribute to increasing oil recovery from high-viscosity oil formations.

The idea of using waste from a waste incineration plant to increase oil recovery from formations, according to many scientists, is very interesting, but it requires engineering support and serious economic justification, since a waste incineration plant is an expensive facility. Currently, programs are being developed for the construction of such facilities in large cities, so planning their location requires special attention and a well-founded solution [7, 8].

This idea can be implemented during the construction of a waste incineration plant in the Almetyevsk region of the Republic of Tatarstan (for example, at the Ashalchinskoye field of super-viscous oils). It should be noted that the South-East of Tatarstan is a large industrial region. Within a radius of 100 km from Almetyevsk there is a large city of Naberezhnye Chelny, and much closer are other cities: Bugulma, Leninogorsk, Jalil, Aznakayevo, etc. Obviously, a similar plant can be built in Udmurtia at one of the large deposits near the city of Izhevsk. Thus, in the future, the construction of modernized plants should perform several functions simultaneously: involving in the secondary circulation of waste that is not suitable for classical processing, which in turn will lead to a decrease in the volume of waste disposal and a decrease in the damage caused to the environment by landfills and dumps; finding ways to use recycling products for industrial and production needs.

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INNOVATIVE METHOD OF ZEOLITE MODIFICATION FOR INCREASE MERCURY SORPTION FROM SIMULATED GAS STREAM

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ABSTRACT

Packaging waste from the industry containing significant amounts of silicon and aluminum were used in synthesis of zeolites. Derived structures ware mostly A (LTA) and X from (FAU) frameworks, respectively. Zeolite were modified in order to increase ability for elemental mercury (Hg^0) removal from simulated gas stream. Mercury constitutes a hazardous threat, due to its high chemical and biological activity, durability, volatility and susceptibility to migrations over long distances from the source of pollution. According to the Agency for Toxic Substances and Disease Registry, mercury is placed third on the list of substances most hazardous to human health. The effect of zeolites modification on Hg^0 removal from simulated gas stream was studied empirically using prototype installation designed to test the effectiveness of sorption by solid state sorbents. Part of derived and modified zeolites revealed significant mercury uptake during sorption experiment. The proposed hybrid synthesis method possesses the potential to be implemented for both waste utilization as well as the time and energy saving production of aluminosilicate, porous materials with high Hg^0 removal efficiency.

Keywords: physicochemical modification, elemental mercury, sorption, zeolite.

INTRODUCTION

In the face of the current geopolitical situation and disrupted supply chains of raw materials, a number of countries are deciding to maintain the operation of coal-fired power plants. Moreover, there are plans to build new units fuelled by coal. The global installed capacity for coal-based power generation has surged, nearly doubling from 2005 to 2022, reaching approximately 2.271 terawatts. Forecasts indicate that this level will be maintained until 2050, reaching approximately 2.275 terawatts [1]. As a consequence, the energy sector will constantly facing the issue of emission of pollutants such as mercury [2]. The reduction of mercury species in industrial processes such as energy production and removing it from waste streams holds significant importance within the framework of the environmental protection and sustainable development [3]. Currently used technologies dedicated to removal mercury from exhaust gases in coal combustion processes within the energy production industry can be divided into [4]:

• Primary methods - involve the selection of parameters of the fuel combustion process and the treatment of the fuel itself before combustion.

• Secondary methods – involve removing mercury from exhaust gases resulting from fuel combustion.

But no one of above mentioned method enable to reach level of reduction imposed by IED Directive, therefore, there is still a justified need to increase the efficiency of

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mercury removal and develop new technologies. One of the researched promising paths is an attempt to use solid sorbents with appropriate mercury-binding capabilities [5]. In this study a material consisting of X and A zeolite structures was subjected to physicochemical modification, followed by Hg^0 removal tests to check whether derived materials have the properties to bind mercury stably within the crystal structure. An attempt was made to select modification methods requiring minimal expenditure of time, energy, machines and chemical reagents.

MATERIALS AND METHODS

Materials: Waste packaging glass and aluminium catering foil was utilized as a source of silica and alumina for synthesis of zeolite material. The glass was mechanically disintegrated into smaller particles and then ground using a planetary mill PULVERISETTE 6. The result was a fraction with a particle size of <200 μm.

Sodium hydroxide (NaOH, >98.8%) from STANLAB was used as the agent alkalizing the environment for waste substrates conversion into zeolite material.

Commercial molecular sieve 13X was purchased from ABC-Z System EKO s.c.

Silver nitrate ($AgNO_3$), silver chloride (AgCl), iron (III) nitrate ($Fe(NO_3)_3 \cdot 9H_2O$), iron (III) chloride ($FeCl_3$) purchased from CHEMPUR were used as precursors for synthetic zeolites surface modification.

Zeolite synthesis procedure: 12.5 g of the waste glass powder (<200 μm) was placed in polypropylene container and then poured with 65 ml of 3 mol sodium hydroxide solution. The suspension was shaken for 18 hours and then heated at 65°C for 3 hours to dissolve the glass. Then 0.6 g of aluminium foil was added. The solution was left for another 18 hours at room temperature. In the next step, 2 g of a commercial 13X molecular sieve ground to a fraction of <100 μm was added to the solution. This was intended to increase the efficiency of nucleation. Then, a six-hour aging-nucleation step was performed at a temperature of 65°C. The final hydrothermal synthesis was carried out at a temperature of 80°C and lasted 18 hours. The obtained material was rinsed several times with distilled water and dried for 24 hours at 105°C.

Zeolites surface modification procedure and sample nomenclature: For each modification, 1g of raw zeolite was dried in moisture analyser (105°C) using RADWAG MA-50R device. Subsequently, dried zeolites were evenly distributed on Petri dishes and sprayed with 0,2 ml of 1 molar solutions of silver nitrate and iron nitrate as well as silver and iron chloride. The samples modified with silver nitrate, silver chloride, iron nitrate, iron chloride were named: ZEO-1; ZEO-2; ZEO-3: ZEO-4, respectively.

Methods:

The phase composition was determined via the powder X-ray diffraction method (PXRD) using a Smartlab SE (Rigaku). The analysis was performed within the angle range of 5–65° 2θ, using reflection geometry mode with CuKβ filter. Step width was set at 0.01°, scan speed was equal to 10°/min. SmartLab Studio II software was used to process the diffraction data. The identification of mineral phases was based on the PDF-2 release of the 2024 database, formalized by the ICDD, and on the IZA-SC Database of Zeolites Structure.

The morphological forms and the chemical composition of studied materials were determined by scanning electron microscopy (SEM) equipped with the system of chemical composition analysis, based on the energy dispersive X-ray spectroscopy (EDS), using Axia CHEMISEM LV (ThermoFisher Scientific). Safematic CCU-010 LV was used for coating samples with a 15 nm layer of carbon. A SE (secondary electrons) detector was used to image the sample surface in a micro-area. A BSE (backscattered electrons) detector and a EDS attachment were used for chemical components distribution maps. The main emphasis was placed on the distribution of elements introduced into the produced sorbents using modifying precursors.

Hg^0 sorption/desorption experiments were performed using prototype device SBPR-1. 0.3 g of given surface modified zeolite was subjected to Hg^0 removal tests. The carrier gas was Argon. The gas flow during the experiments was set to 0.2 dm^3/min. The initial Hg^0 concentration was set at approximately 100 µg/m^3. After the sorption period, samples were tested for the undesirable phenomenon of mercury release indicating possible unstable mercury binding. A detailed description of the installation and methodology was presented in previous work [6].

RESULTS

The phase composition analysis – PXRD results.

The XRD results indicate that raw synthesized material consisting of zeolite A (LTA framework) and zeolite X (FAU framework). Zeolite X is represented by set of characteristic diffraction peaks with d_{hkl} values: 14.66; 8.98; 7.65; 5.82; 3.87; 3.55; 2.93. Zeolite A is represented by set of characteristic diffraction peaks with d_{hkl} values: 12.57; 8.88; 7.25; 5.62; 4.19; 3.79; 3.04; 2.67. Noticeable increase of the diffraction background in the 5–40 °2Θ angular range suggested a substantial amount of the unreacted amorphous phase (Figure 1).

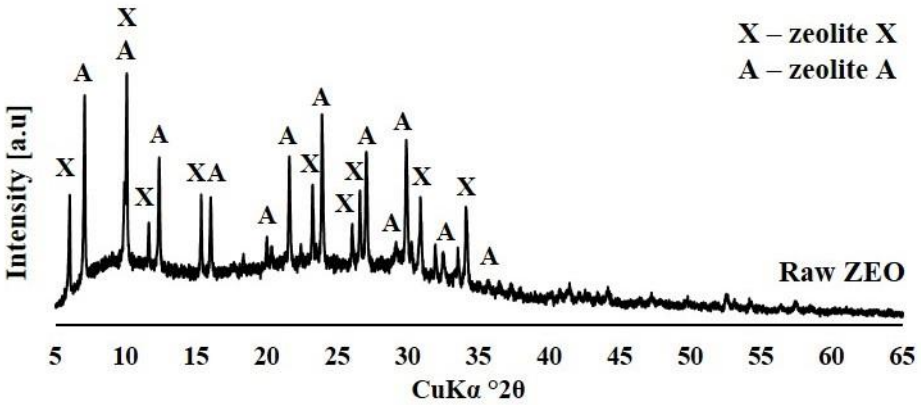


Figure 1. PXRD pattern of derived raw zeolite material.

The morphology and chemical composition analysis – SEM-EDS results.

Analyses of SEM microphotographs of modified zeolite samples (ZEO-1, ZEO-2, ZEO-3, ZEO-4) presented in Figure 2 reveal presence of well-formed, cubic LTA type zeolite (zeolite A) crystallites with side lengths up to approx. 1-2 µm. Second observed morphological form were poorly developed, rosette-shaped crystallites, with a diameter, ranging from approximately 1 to 4 µm diameter and corresponding to the FAU type zeolite (zeolite X).

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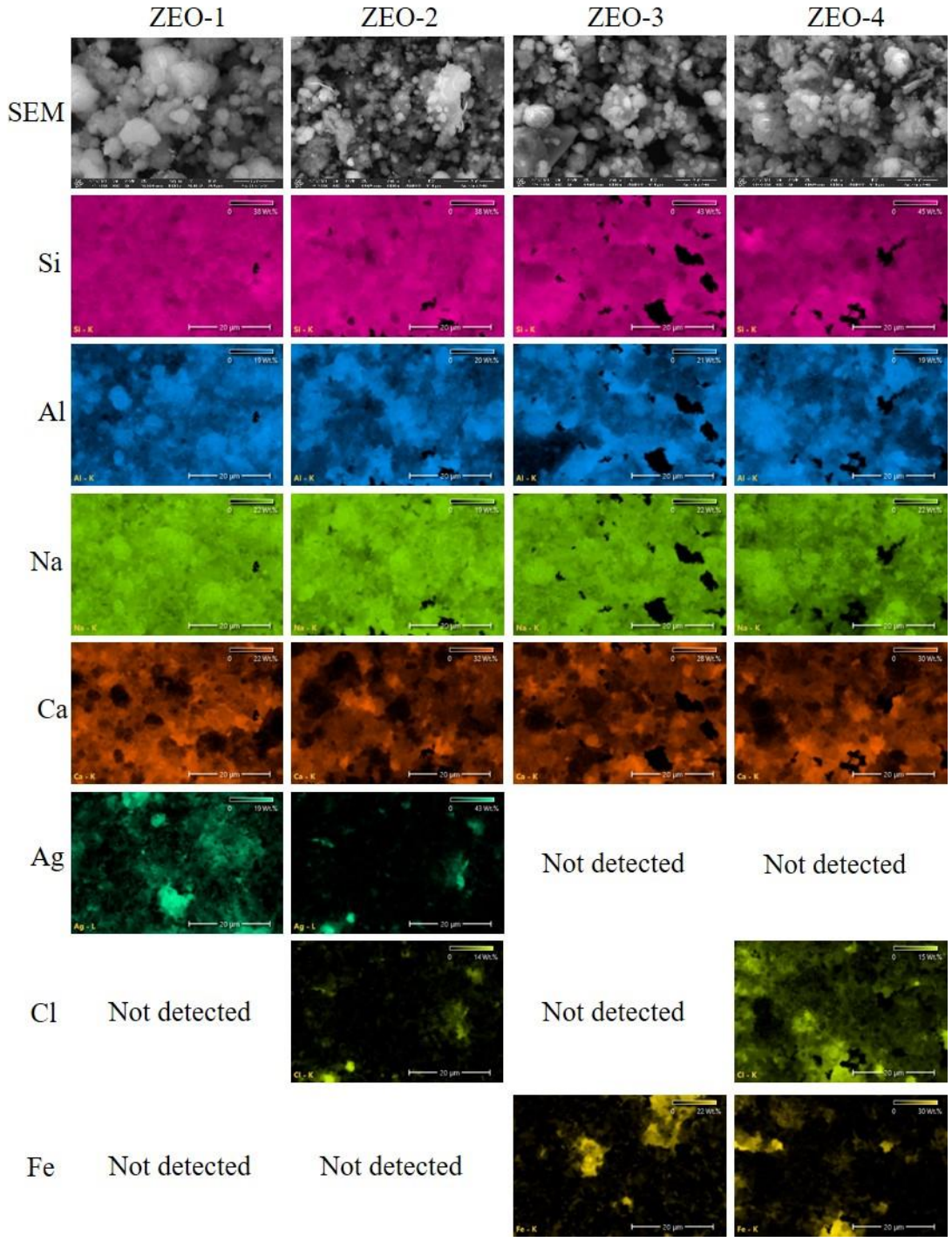


Figure 2. SEM (SE detector) images and elements distribution maps of ZEO-1; ZEO-2; ZEO-3; ZEO-4 modified samples.

Colored element maps (Figure 2) indicate an even distribution of the components that make up the zeolite structure: Si, Al, Na and Ca. Average content of Si, Al, Na and Ca in whole set of studied samples ranged from: 18.3 to 21.5 wt.%; 7.9 to 8.7 wt.%; 9.8 to 11.1 wt.% and 6.2 to 7.4 wt.%, respectively. The distribution of modification precursor residues (Ag, Cl, Fe) within zeolite structures is notably less uniform and homogeneous. Average Ag content in sample ZEO-1 ($AgNO_3$ modified) and ZEO-2 (AgCl modified)

was equal to 3.6 and 1.3 wt.% while in samples ZEO-3 ($Fe(NO_3)_3$ $9H_2O$ modified) and ZEO-4 ($FeCl_3$ modified) the average Fe content has reached 0.8 and 1.3 wt.%

Elemental mercury removal from a simulated gas stream – SBRR-1 results.

Samples subjected to the Hg^0 removal experiment showed similar abilities to bind this hazardous element. In all four tests (ZEO-1; ZEO-2; ZEO-3; ZEO-4), the mercury removal efficiency at the beginning of the experiment was around 45-50%. As the experiment continued, the sorption capacity of the samples gradually decreased, and the Hg^0 removal efficiency finally dropped to approximately 11-12% (Figure 3). During the conducted research, similar initial Hg^0 concentration conditions were obtained for the analyzed sorbents, which is particularly important from the point of view of assessing the ability of individual modified zeolites to remove Hg^0. Taking into account the entire sorption experiment (approximately 140 minutes, including six-seven 10-minute sorption stages and the same number of device calibration episodes during which the Hg^0 concentration was stabilized), it was found that the average Hg^0 removal efficiency was for ZEO-1; ZEO-2; ZEO-3; ZEO-4 was equal to: 19.96%; 19.81%; 21.25% and 18.09%, respectively. At the end of the experiment, each sample was subjected to desorption, during which pure argon flowed through the sorbent bed. During the 30-minute desorption test, the Hg^0 concentration in the test system decreased to approximately 10µg/m^3. With the carrier gas flow used (0.2 dm^3/minute), this translates into a mercury release result of 0.002 µg/minute (Figure 4).

DISCUSSION

Compared to zeolite samples obtained in previous work [6], modified by adding $AgNO_3$ to the synthesis environment, it must be stated that the samples analysed in this article showed lower mercury removal efficiency. However, in this case the samples were subjected to much higher Hg^0 concentrations and smaller sorbent bed weights were used. The obtained results are partially consistent with the work of other scientists who used $FeCl_3$ [7] as a modification precursor, but this was done using the zeolite impregnation method, while simpler and more economically effective spraying method was applied this study.

CONCLUSION

The presented synthesis method confirms the possibility of obtaining highly crystalline forms of zeolites using waste glass and aluminium as main substrates. The modification technique facilitated the resultant zeolite material's ability to adsorb elemental mercury. The average efficiency of Hg^0 removal from the simulated gas stream had similar values (18.09 to 21.25%) for all four samples tested samples. Nevertheless, it appears that the straightforward spraying technique is markedly less efficient compared to immersion in solutions containing modification precursors. The applied modification method allowed only partial and diversified coverage of the zeolite surface with activation precursors. This factor could exert a notable influence on the ultimate efficacy of Hg^0 removal, particularly when considering the potential for sorbent bed channeling [8]. All tested samples revealed significant stability of mercury binding – confirmed in the desorption test stage by the observation of a negligible concentration of Hg^0. Subsequent refinement of the synthesis procedure for zeolites derived from waste glass and aluminium, adjustments to the activation methodology, and study of sorption mechanisms will constitute the focus of future investigation.

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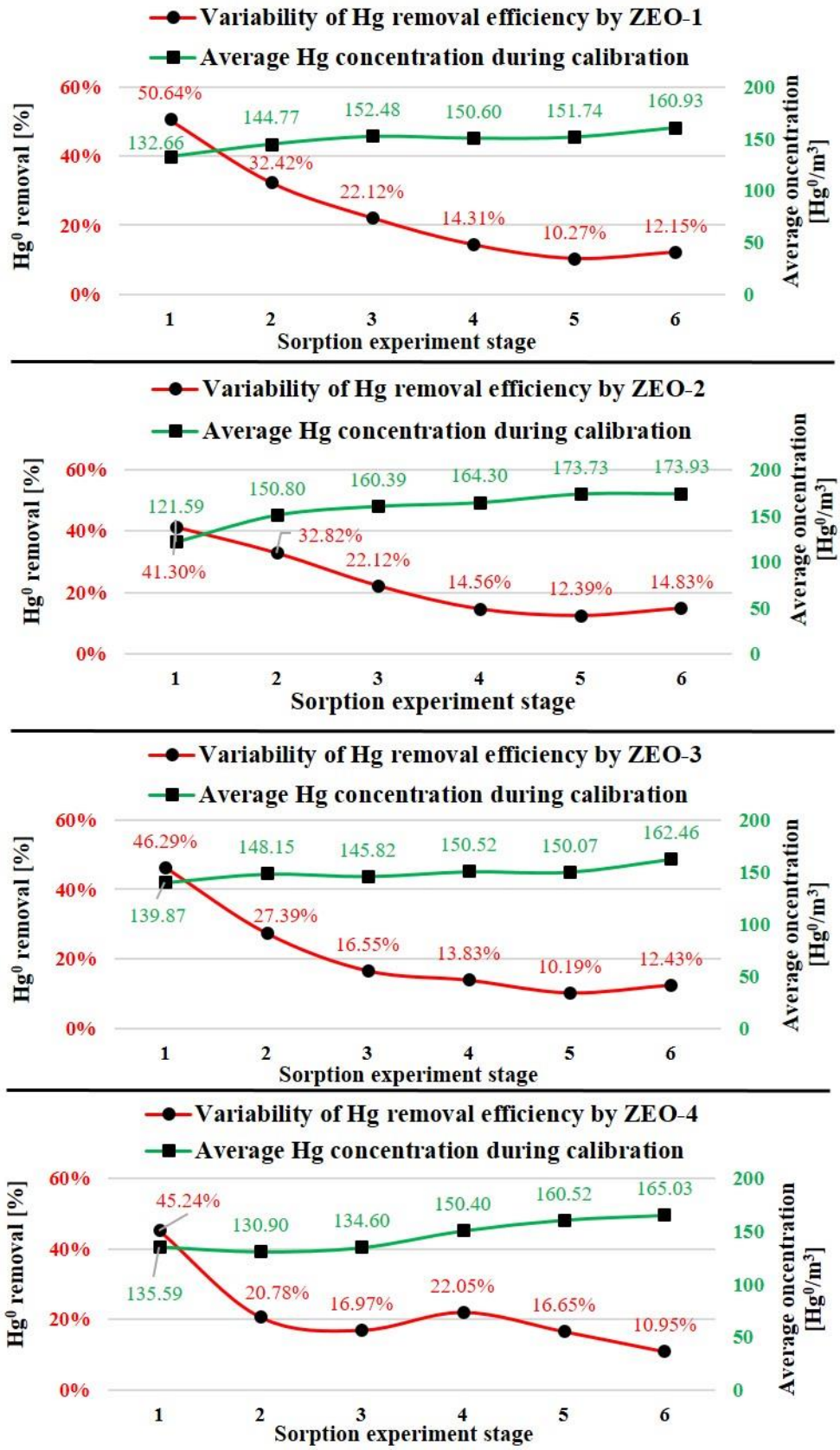


Figure 3. Hg^0 removal experiment results: ZEO-1; ZEO-2; ZEO-3: ZEO-4 (1).

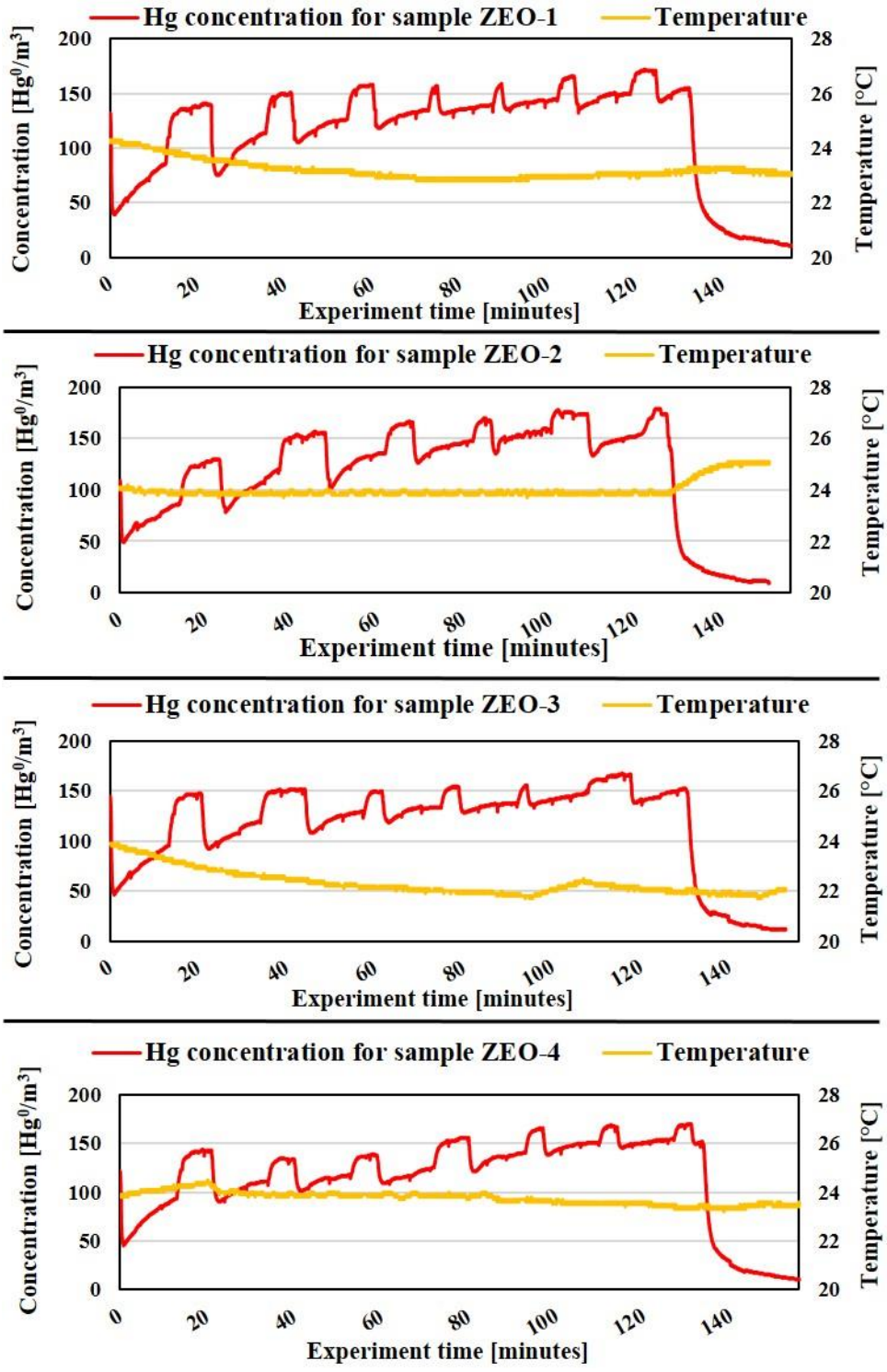


Figure 4. Hg^0 removal experiment results: ZEO-1; ZEO-2; ZEO-3: ZEO-4 (2).

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VARIATION OF VOLATILE ORGANIC COMPOUND CONCENTRATIONS EMISSION IN THE ATMOSPHERE CORRELATED WITH TECHNOLOGICAL OPERATIONS AT THE PAINTING OPERATION

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ABSTRACT

Following the vehicle painting process, residual gases containing volatile organic compounds (VOCs) are released into the atmosphere through exhaust pipes. Entrepreneurs are legally obliged to report to the Environmental Protection Agency, which, in turn, reports to the European Union to reduce greenhouse gas emissions and achieve climate neutrality by 2050.
The current paper investigates the temporal variation of VOC concentrations correlated with technological processes carried out in vehicle painting shops. Three sets of one-hour measurements were taken for each technological operation (sample preparation, painting, sample drying).
Currently, atmospheric emission monitoring from paint shops is conducted only under maximum operating conditions of the painting installation, with a measurement period of at least half an hour. In this case, the reported results indicate higher emission values for a day or a calendar year. The objective of the paper is to measure VOC concentrations from a vehicle paint shop and correlate which painting processes release the highest amounts of VOCs into the atmosphere, aiming to identify possible measures to reduce environmental pollution.
Research results indicate that the highest recorded concentrations occur during the painting operation, followed by the drying of parts and then the cleaning of parts through degreasing.

Keywords: volatile organic compounds, emission

INTRODUCTION

The organic compound is any compound that contains at least the element carbon and one or more of the elements: hydrogen, halogens, oxygen, sulfur, phosphorus, silicon, or nitrogen, except carbon oxides, inorganic carbonates, and bicarbonates) and volatile organic compound (VOC) - any organic compound, as well as the creosote fraction, which at a temperature of 293.15 K has a vapor pressure of at least 0.01 kPa or which has an appropriate volatility under particular conditions of use.
In the case of emissions of volatile organic compounds in the environment, the long-term effects on the human body are much more harmful than with other pollutants,

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among which the most known are: diseases associated with the respiratory system (asthma, bronchitis), diseases affecting the liver and kidneys, neurological conditions, various types of cancer (lung and skin).
The objective of the work is to measure the concentrations of VOCs coming from a car paint shop and to identify which of the technological processes of the car painting phase result in higher concentrations of volatile organic compounds and how they can be reduced.
The main stages in the painting activity are:
- preparing the vehicle for painting; removing the accessories; washing the surface to be painted with a liquid that does not contain silicone; drying; covering surfaces that do not need to be painted; blowing compressed air; cleaning the surface that will be painted
Manual cleaning of ferrous and non-ferrous metal surfaces is carried out with the help of tools, devices, and portable equipment: scrapers; wire brushes; abrasive paper; hand grinders.
Only dust is generated from this technological operation and no volatile organic compounds result [4].
The painting materials are composed of the following basic components: Binder - liquid component; Pigments - solid component; Filler - solid component.
Paint materials are made up of the following raw materials: binders, pigments, fillers, solvents, and plasticizers.
Pigments are colored and insoluble substances that have the role of giving color to the painting material. The degree of grinding determines the fineness of the pigment. Pigments can be inorganic or organic, natural or synthetic, as well as metal powders [4].
The main painting products are lacquers, paints, thinners, sanding materials, enamels, primers, and putties.
The largest source of VOC emission results from this process.
The pieces are dried naturally by evaporating the film of water on their surface, in conditions of average ambient temperature between 15 and 20 degrees Celsius. For this process to be successful, the atmosphere in which the drying takes place must be clean, and free of dust, gases, or smoke. During drying, it is important that the pieces do not touch each other [5].
Alternatively, drying can be done artificially by using hot air, centrifugation, or infrared rays. Hot air drying is carried out at a temperature between 60 and 120 degrees Celsius [6].

MATERIALS AND METHODS

Following the painting of car bodies and other components, VOC emissions result in the atmosphere. To reduce emissions, the paint booth is equipped with polluted air filtering installations, respectively with:
- Ceiling filter type F5;
- PAINT STOP absorbent wall filter [2].
Also, for the evacuation of gases from the painting booth, there is a noxe exhaust chimney (coming from the application of paint by spraying on metal surfaces), made of galvanized sheet, with the dimensions: H = 3.1 m, S = 700 x 700 m. [1].
On 10.07.2023, a series of measurements were carried out at this exhaust chimney during various technological operations. The series of measurements were carried out during the painting operations, namely: preparing the vehicle for painting, cleaning the surface to be painted, degreasing the surfaces, painting, aeration (evacuation of solvent vapors), and drying.

One-hour sets of measurements were made for each technological operation. VOC emission measurements were carried out in compliance with the following standards:
- SR EN 15259:2009 – Air quality. Measurement of emissions of fixed sources. Requirements regarding measurement sections and locations, as well as the measurement objective, plan, and report;
- SR EN 12619:2013 - Emissions from fixed sources. Determination of the mass concentration of total gaseous organic carbon. Continuous flame ionization detector method.

RESULTS

a) Measurements made at the VOC exhaust stack during the operation of **preparing the vehicle for painting**

The manual cleaning of ferrous and non-ferrous metal surfaces consists of the mechanical removal (where applicable) of the existing paints, as well as the preparation of the layer to be painted for better adhesion of the paint to be deposited. This is done with the help of tools, devices, and portable machinery:

- wire brushes;
- abrasive stones;
- abrasive paper
- hand grinders.





The results of VOC measurements recorded during the preparation period of the vehicle for painting are presented in table no. 1.

Table no. 1. - The VOC concentration recorded on 10.07.2023, during the **preparation operation for painting.**

Time of measurement	VOC Concentration [mgC/mcN]	Time of measurement	VOC Concentration [mgC/mcN]	Time of measurement	VOC Concentration [mgC/mcN]
10:31:24	2,96	11:01:24	2,74	11:31:24	3,45
10:32:24	2,69	11:02:24	3,45	11:32:24	2,75
10:33:24	3,78	11:03:24	2,75	11:33:24	3,81
10:34:24	2,93	11:04:24	3,81	11:34:24	2,5
10:35:24	3,1	11:05:24	2,5	11:35:24	2,8
10:36:24	3,31	11:06:24	2,8	11:36:24	3,43
10:37:24	3,74	11:07:24	3,43	11:37:24	3,85
10:38:24	3,56	11:08:24	3,85	11:38:24	4,14
10:39:24	4,17	11:09:24	4,14	11:39:24	3,6
10:40:24	3,86	11:10:24	3,6	11:40:24	3,58
10:41:24	4,03	11:11:24	3,58	11:41:24	2,8
10:42:24	2,53	11:12:24	2,8	11:42:24	3,41
10:43:24	2,68	11:13:24	3,41	11:43:24	2,65
10:44:24	3,77	11:14:24	2,65	11:44:24	3,48
10:45:24	4,14	11:15:24	3,48	11:45:24	2,89
10:46:24	3,91	11:16:24	2,89	11:46:24	3,53
10:47:24	2,79	11:17:24	3,53	11:47:24	3,63
10:48:24	3,32	11:18:24	3,63	11:48:24	2,96
10:49:24	3,82	11:19:24	2,96	11:49:24	3,63
10:50:24	2,92	11:20:24	3,63	11:50:24	2,77
10:51:24	4,05	11:21:24	2,77	11:51:24	3,07
10:52:24	3,84	11:22:24	3,07	11:52:24	4,12
10:53:24	2,59	11:23:24	4,12	11:53:24	3,4
10:54:24	4,16	11:24:24	3,4	11:54:24	3,2
10:55:24	2,56	11:25:24	3,2	11:55:24	3,19
10:56:24	4,17	11:26:24	3,19	11:56:24	3,38
10:57:24	3,87	11:27:24	3,38	11:57:24	2,95
10:58:24	3,74	11:28:24	2,95	11:58:24	3,7
10:59:24	2,84	11:29:24	3,7	11:59:24	4,01
11:00:24	2,83	11:30:24	4,01		

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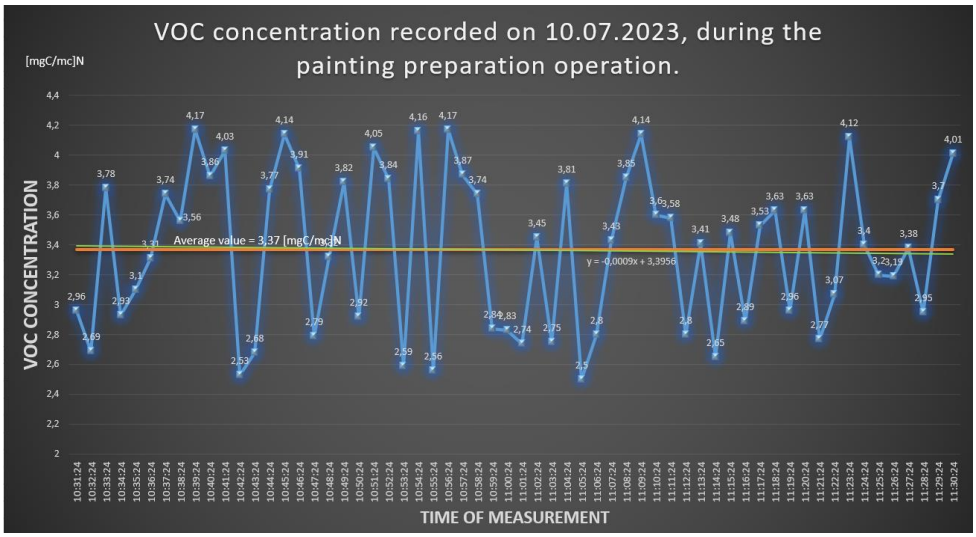


Fig. no. 1 – VOC concentration recorded on 10.07.2023, during the preparation operation for painting.

This technological operation results in low concentrations of volatile organic compounds, being much lower than the emission limit values (100 mg C/Nm3) [3]. The average value recorded for the paint preparation operation is 3.37 mg C/Nm^3.

b) Measurements taken at the VOC exhaust stack during the **painting operation of road vehicles**

The painting materials represent all the materials that are applied to the surfaces of the materials, for anti-corrosive protection (destructive action due to light, moisture, corrosive agents). By applying these painting materials, an adherent film is formed, which has two functions, namely anti-corrosion protection of the surfaces and aesthetic, commercial appearance.

The results of VOC measurements are high compared to those obtained for the preparation of samples for dyeing. The average value recorded on the painting operation is 41.89 mgC/ Nm^3, lower than the limit value allowed by Law 278/2013, namely 100 mgC/ Nm^3.

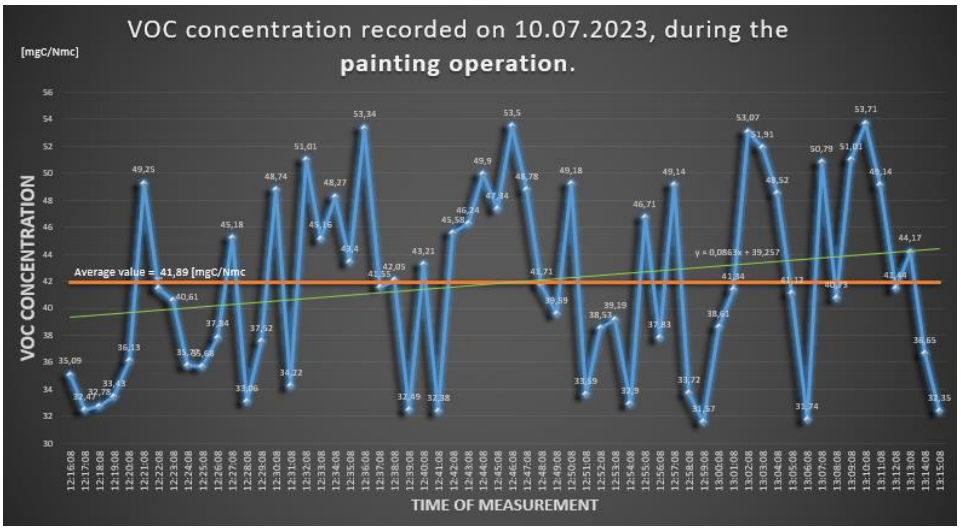


Fig. No. 2 – VOC concentration recorded on 10.07.2023, during the painting operation.

d) Measurements made at the VOC exhaust stack during the sample **drying operation.**

The drying time depends on the nature of the painting material, the thickness of the applied layer, and the temperature.

Drying can be done in several stages:

• dust drying (lasts until dust does not stick to the painted surface);

• complete drying (takes place after 7-15 days).

• air drying is generally incomplete.

• hot drying is the optimal solution (drying time is reduced to a maximum of 30 min., at a temperature of 60-180^{0}C.

In the present case, drying was carried out at the normal operating temperature, namely at an average temperature of 25.1 ^{0}C.

The determined concentrations are much lower compared to those obtained for dyeing but are higher than during the sample preparation operation. The average value recorded during the drying operation is 9.91 mgC/m^{3}N, much lower than the limit value allowed by Law 278/2013, namely 100 mgC/m^{3}N.

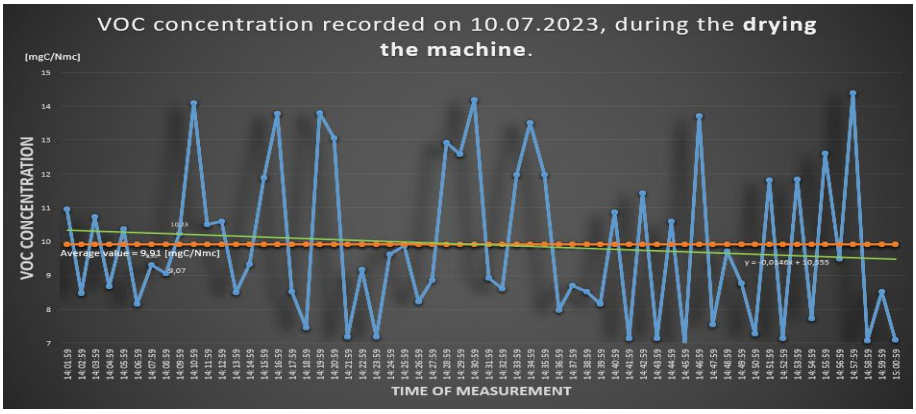


Fig. no. 3 – VOC concentration recorded on 10.07.2023, during the drying operation.

The graphic representation of all concentrations recorded for all technological operations can be seen in Figure No. 4.

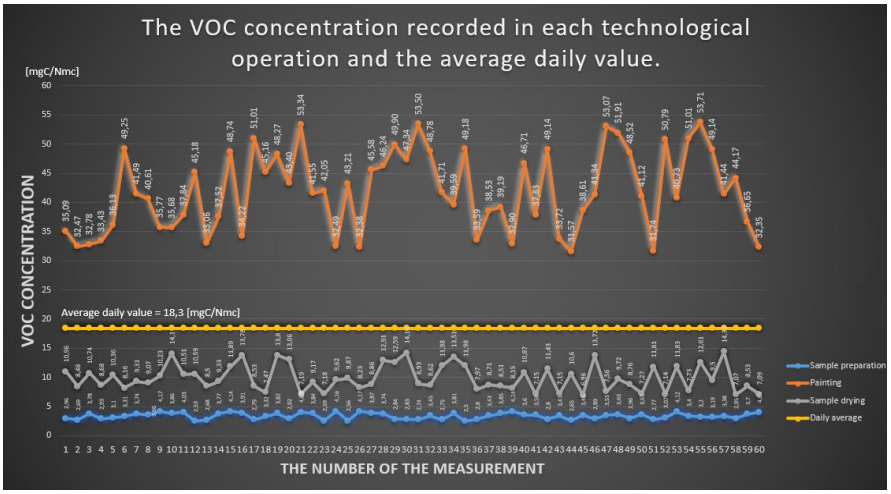


Fig. no. 4 – VOC concentration recorded on 10.07.2023, during the all three operations.

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From this figure it follows that the highest concentrations of VOC emissions were measured during the painting operation, followed by the drying operation and then the preparation for painting. At the same time, it can be observed that the average daily value for all these technological operations is 18.3 mg C/Nm^3.

DISCUSSION

Under normal measurement conditions, the emission samples of volatile organic compounds had to be taken during the most unfavorable period, namely during the technological dyeing operation, and the average concentration recorded in this case was 41.89 mg C/Nm^3. Averaging the measurements for all the captured technological operations can see a decrease in the daily concentration by 23.59 mg C/Nm^3 compared to the average that had to be reported to the Environment Agency, which represents a decrease in the concentration by almost 43%.

Calculating the mass flow rate of VOCs emitted into the atmosphere in one year for the painting operation, results in 0.312 tons/year while the average mass flow rate is 0.176 tons/year. These results indicate a higher mass flow of 0.136 tons/year if the results for the dyeing operation were taken into account, which is about 56% more than if the daily average is used.

Both the national legislation and the specific standards for the measurement of volatile organic compounds recommend making measurements both during the production process and outside it, but it is not specified exactly if there are major fluctuations in the technological process.

The measurements made throughout the process of painting road vehicles indicate significant fluctuations in the emissions generated by each technological operation, which requires the measurements to be made over a longer period, to capture all the technological operations, thus the final result being as close as possible to the actual value of the emissions. [7]

CONCLUSION

Volatile organic compounds in the environment have long-term effects on the human body and are much more harmful than other pollutants, among which the most well-known are: diseases associated with the respiratory system (asthma, bronchitis), diseases affecting the liver and kidneys, neurological conditions, various types of cancer (lung and skin).

The objective of the work is to measure the concentrations of VOCs coming from a car paint shop, and to identify which of the technological processes of the car painting phase result in higher concentrations of volatile organic compounds and how they can be reduced.

Following the painting of car bodies and other components, VOC emissions result in the atmosphere.

On 10.07.2023, a series of measurements were carried out at this exhaust chimney during various technological operations. The series of measurements were carried out during the painting operations, namely: preparing the vehicle for painting, cleaning the surface to be painted, degreasing the surfaces, painting, aeration (evacuation of solvent vapors), and drying. One-hour sets of measurements were made for each technological operation.

Measurements were taken at the VOC exhaust stack during the operation of preparing the vehicle for painting. This technological operation results in low concentrations of volatile

organic compounds, being much lower than the emission limit values (100 mg C/Nm^3). The average value recorded for the paint preparation operation is 3.37 mg C/Nm^3.

Measurements are taken at the VOC exhaust stack during the painting operation of road vehicles. The determined concentrations are high compared to those obtained for the preparation of samples for dyeing. The average value recorded during the painting operation is 41.89 mgC/ Nm^3, lower than the limit value allowed by Law 278/2013 (namely 100 mgC/ N m^3).

The measurements made at the VOC exhaust stack during the sample drying operation, the determined concentrations are much lower compared to those obtained for painting but are higher than during the sample preparation operation. The average value recorded during the drying operation is 9.91 mgC/ Nm^3, much lower than the limit value allowed by Law 278/2013, namely 100 mgC/m^{3}N.

The highest concentrations of VOC emissions were measured at the dyeing operation, followed by the drying operation and then the preparation for painting. It also shows that the average daily value for all these technological operations is 18.3 mg C/Nm^3.

Under normal measurement conditions, the emission samples of volatile organic compounds had to be taken during the most unfavorable period, namely during the technological dyeing operation, and the average concentration recorded in this case was 41.89 mg C/Nm^3. Averaging the measurements for all captured technological operations, a decrease in daily concentration of 23.59 mg C/Nm^3 can be observed compared to the average that should have been reported to the Environment Agency, which represents a decrease in concentration of almost 43 %.

Calculating the mass flow rate of VOCs emitted into the atmosphere in one year for the painting operation, results in 0.312 tons/year while the average mass flow rate is 0.176 tons/year. These results indicate a higher mass flow of 0.136 tons/year if the results for the dyeing operation were taken into account, which is about 56% more than if the daily average is used.

The measurements made throughout the process of painting road vehicles indicate significant fluctuations in the emissions generated by each technological operation, which requires the measurements to be made over a longer period, in order to capture all the technological operations, thus the final result being as close as possible to the actual value of the emissions.

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SECTION

ENVIRONMENTAL ECONOMICS

A VIEW OF THE EMERGENCE AND DEVELOPMENT OF DIGITALIZATION - AN INSIGHT FROM SCIENTIFIC DATABASES

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ABSTRACT

Since early times the civilization used to record and store their information about accumulated knowledge, everyday life necessities and other important things. Starting with clay tablets, stones and paper as a more advanced technology followed. Since that moment this trend made its way through centuries until nowadays, with new technological capabilities resulting in the form of digitalization. The paper discusses nuances of the terms, such as digitization, digitalization and digital transformation in scientific literature. The study is backed by discussion about digitalization's popularity, its impact and importance in our society as an irreversible process. The report provides a general insight into the motivation of researchers to conduct research on digitalization in various scientific fields. A historical overview of digitalization phenomena continues in two most popular databases (SCOPUS, Web of Science) insight, which is accompanied by statistical data about the evolving popularity of digitalization terms. Statistical methods were used to analyse data from different angles, including years, countries, languages and science sections, where digitalization terms are the central motive of research. Since first being mentioned in 1922 and a century later, in 2023, digitization terms have grown dramatically in popularity in scientific databases. In the Scopus database, the number of digitalization terms was less than 1000 by 2003, with the next doubling in volume occurring 9 years later in 2012. The next doubling took less than 5 years and it happened in 2017, and again the next one only two years later - in 2019. And already in 2023, it exceeded 21,000, which is a 1929% increase compared with 2003, which shows a genuine interest in the importance of the research into the given topic in modern scientific thought.

Keywords: digitization, digitalization, digital transformation, databases, analysis

INTRODUCTION

Despite the fact that nowadays most people associate digitalization processes only with information and communication technologies and the use of the Internet, the roots of their origins can be traced much earlier, for example, Houston [5] mentions that the first writing systems come from Egypt and Mesopotamia around 5,000 a year ago. People had an objective need to communicate with each other, thus also creating a consequent need for gathering and processing the generated information. Various materials served as the most important data carriers for a long time: clay tablets, papyrus rolls and later also books. Since the introduction of written systems in the daily activities of mankind, there have been various improvements in accounting systems, but they were mainly based on paper. The debate on balancing paper and digital format is active, especially in the context of ecology and sustainable development. Many prefer the paper format

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because reading texts on paper results in better retention of information than reading from a monitor.

By going digital, organizations reduce their reliance on paper documents and provide greater opportunities for employees to access information by reducing costs associated with printing or managing physical paper flows. Also, by moving from a paper-based to a digital-oriented approach to information storage, distribution and processing, organizations can improve overall resource management processes by reducing administration costs [2].

The digitalization process is very broad and comprehensive and has been rapidly dynamic in recent years. The author believes that digitalization is a logical and natural continuation of the development of human information accounting, processing and use, and it would not be possible if a fundamental base - the writing system and later - the binary number system, had not been created before. Today, digitalization is beginning to become an integral part of the economy, institutions and society, affecting even interpersonal relationships, for example, almost half of Internet users aged 18-29 believe that the Internet has had a serious impact on their personal relationships [9].

If in 2005 the first billion Internet users were reached in the world, the second in 2010, then in 2024 there were already 5.35 billion Internet users in the world, which is about 66.2% of the world's population [12]. On the other hand, current data show that as of 2019, almost every second (47.1%) household in the world has a computer [1].

Digital transformation determines the development vectors of the entire world, including in the economy, creating huge growth potential, as well as even greater risks for those who will not participate in digitization processes, in which the use of artificial intelligence opportunities will play the most important role [10].

Digitalization in its broadest sense begins with digitization, during which products and services are converted into a digital format. From the beginning, digitization has had the biggest impact on industries that are already based on information, such as music, finance and publishing. In these industries, information was transformed from physical data carriers to digital ones – vinyl records to CDs or accounting data from paper to computer programs. Then follows the stage of digitalization in its narrow sense - the advantages of these new digitized products and services are used, improving existing ones or creating new business models. Digitalization usually disrupts the positions of existing players in the market, because it makes their business models and processes obsolete, and if nothing is changed, they are pushed out of the market.

The third stage of digitalization, called digital transformation, usually involves systemic economic and societal restructuring processes based on the incorporation of new business models and technologies into people's lives and habits.

MATERIALS AND METHODS

According to Holmstrom [4], Larsson and Teigland [8], Mergel [11], Chanias & Hess [3], Rachinger [13] terminology definitions were structured.
Digitization - conversion of analog material (image, video, text) into digital format (1:1)

Digitalization - refers to changes in processes. Uses digitization advances. Digital technology, which is introduced with the aim of creating a communication infrastructure that connects the user's various processes.

Digital transformation - more comprehensive concept that covers strategic development and implementation of far-reaching / future-oriented process changes. Usually not a single project, but a whole set of interrelated projects (systemic approach).

The concept of digital maturity is often associated with digital transformation, which is understood as the status of digital transformation and which characterizes what the company has already achieved by implementing transformation measures [3].

The paper research basis focuses on database search results, which includes the terms of digitization, digitalization and digital transformation (hereinafter referred to as the *defined terms*), in the article title, abstract, and keywords, which we believe indicates a deliberate research focus on this topic.

Some papers are cooperation between scientists from different countries and relate to multiple categories, so total amount may differ from the search base data. For example, the total number of defined terms search results by year may be 127,695, but by country 157,021, because some works were written by several researchers from different countries. The same applies to the type and subject of the document.

RESULTS

The starting point of every research begins with motivation of scientist about it. Different aspects can be distinguished what is central motivation of research, but main are so called concepts of “gold” (financial rewards), “ribbon” (reputational/career rewards) and “puzzle” (intrinsic satisfaction) and it is found that financial rewards play a relatively small part [7]. The conventional hypothesis postulates that “puzzle” and “ribbon” are the best motivations for scientists, where “puzzle” is highlighted as the original motive from the inner of academics, whereas “ribbon” can be achieved from the external world and “gold” in turn can be as an effective motivator to encourage research activities but not necessarily produce quality research [15].

In general, research is conducted to identify problems or find answers to questions where there is uncertainty about a phenomenon that has or has not occurred. The research result should be finalized in a publication, the main purpose of which is to disseminate the research results and share new knowledge with other researchers, while ensuring that the research results benefit society [14].

Total (in all fields) defined term search results in publications by period from beginning (Scopus – 1922, Web of Science 1987) to 2023 show a large quantity (576,631 entries in Scopus and 83,829 entries in Web of Science database). But as we mentioned above, our main interest scope includes deliberate research focus (abstract, article title and keyword fields), so here results are less than that – 127,695 entries in Scopus and 65,857 entries in Web of Science respectively.

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Table 1. Defined term search results in databases from 1922 – 2023.

Database / decade (years)	1922-1980 [1]	1981-1990	1991-2000	2001-2010	2011-2020	2021-*2023*	**Total**
Scopus	2,205	4,957	6,615	13,202	45,338	55,378	**127,695**
Web of Science	-	23	2,587	6,588	27,013	29,646	**65,857**

[1] no data in Web of Science until 1987

Defined term search results show that in Scopus there are almost twice more entries than in Web of Science database. Data coverage in Scopus starts since 1922 and until 1987 there is no data in Web of Science regarding to defined terms. Since the 1980s, the data precise reflect defined term increase in popularity by decade. For example, in its first full decade (1990s), Web of Science had 2,587 entries, while Scopus had 6,615 entries, but in next decade (2000s) it was already 6,588 (+154.7%) and 13,202 (+99.6%) entries respectively. Following decade (2010s) shows 27,013 entries and whopping +310.0% increase in Web of Science, and 45,338 entries (+243.4%) in Scopus database. As current decade (2020s) is ongoing and we limited research period till 2023, we cannot compare to previous decade, but we can mention that this trend in massive interest for defined term entries in publications continues even in more scale and already in 3 years Web of Science accounted 29,646, while Scopus – 55,378 entries.

Table 2. Defined term search results in databases by language until 2023.

Language / database (entries, %)	Web of Science	
	number of entries	%
English	60,695	92.16
German	1,649	2.50
Russian	1,182	1.79
Spanish	1,104	1.68
Other	1,227	1.86
Total	**65,857**	**100.00**

As we can see in Table 2, only Web of Science database offers statistics about language used in publications. Absolute majority is in English (92.16%) and next most popular language German is with only 2.50% of total amount, but Russian composes 1.79%.

Table 3. Defined term search results in databases by country until 2023.

Country/database (entries, %)	Web of Science		Scopus	
	number of entries	%	number of entries	%
USA	8,559	10.01%	16,602	10.57%
China	8,305	9.71%	15,539	9.90%
Germany	7,828	9.15%	13,619	8.67%
Russia	4,641	5.43%	9,795	6.24%
United Kingdom [2]	4,948	5.72%	7,392	4.71%
Other	52,176	61.00%	94,074	59.91%
Total	**85,538**	**100.00%**	**157,021**	**100.00%**

[2] Web of Science lists England, Wales, Scotland & North Ireland separately

Table 3 shows the Top 5 by countries of both databases match, with the difference that Scopus uses the United Kingdom as a whole, while Web of Science lists each country separately. Leader in both databases is USA with 10.01% in Web of Science and 10.57% in Scopus, followed by China with 9.71% and 9.90% respectively, and in third position is Germany – 9.15% (Web of Science) and 8.67% (Scopus). Fourth and fifth positions differs by database – in Web of Science United Kingdom has 5.72% share and 4th position as Russia has 5.43% (5th), but in Scopus it is the opposite - Russia with 6.24% is in 4th position, while United Kingdom with 4.71% closes Top 5. These top 5 countries together account for about 40% of the total in both databases.

Table 4. Defined term search results in Scopus by subject area until 2023.

Subject area / database (entries, %)	Scopus	
	number of entries	%
Computer Science	49,323	19.98%
Engineering	46,609	18.88%
Social Sciences	26,818	10.87%
Business, Management and Accounting	16,510	6.69%
Mathematics	13,427	5.44%
Other	94,118	38.13%
Total	**246,805**	**100.00%**

Since both databases have differences in their way of structuring of publications, Table 4 and Table 5 shows these nuances. As we mentioned above a single publication can fall into several categories of subject or research area, so number of entries may differ from Table 1 results. In Scopus two most popular subject areas are computer science (19.98%) and engineering (18.88%), then follows social sciences (10.87%), business, management and accounting (6.69%) and mathematics (5.44%). These top 5 subject areas together account for about 62% of the total (28 subject areas) in Scopus database defined term volume.

Table 5. Defined term search results in Web of Science by research area until 2023.

Research area / database (entries, %)	Web of Science	
	number of entries	%
Engineering	15,663	14.73%
Computer Science	14,836	13.95%
Business Economics	9,699	9.12%
Science Technology Other Topics	3,915	3.68%
Education Educational Research	3,688	3.47%
Other	58,529	55.04%
Total	**106,330**	**100.00%**

Web of Science two most popular research areas also are computer science (13.95%) and engineering (14.73%), but on the contrary - engineering is more popular. Then follows business economics (9.12%), science technology other topics (3.68%) and education educational research (3.47%). These top 5 subject areas together account for about 45% of the total (152 research areas) in Web of Science database defined term volume.

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Other aspects in research also were analysed as document type in databases. Around half of all document types in both databases were marked as article (49.79% in Scopus and 52.80% in Web of Science), then followed proceeding paper (24.62% Scopus) and conference paper (35.00% Web of Science). The other less popular document types, such as book chapter, early access or review article, make up about 15-20% of the total number in both databases.

DISCUSSION

We found out that digitalization can be considered as a continuation of the development of information processing and use, and the role of preliminary work as a fundamental basis for the implementation and integration of digital transformation in society and the economy was of decisive importance.

Search results from databases help us understand origins, timescale and main motivations to research about this topic.

Defined term popularity surge in databases coincided and overlapped with active objective social network and digitalization development in 2010s, as databases also are part of these processes. Especially rapid growth can be traced from 2016, when in 2019 defined term entries in databases tripled, but in 2023 were more than sixfold compared to 2016.

Regarding the use of the languages in the publications, we can mention that China is 2nd in results by country, but there is a low Chinese language use in publications (only 165 entries which is 2.0% comparing to total number of publications associated to China), contrary – Germans and Russians write much bigger amount for internal audience in their native language and proportion of amount of defined term search results in German composes 21.1%, but in Russian even more – 25.5%, comparing to their total publications, which includes defined terms. Partly it can be explained with government supported and demanded research in these topics.

It should be noted that Scopus is more concentrated in defining of subject area – it accounts just total number of 28 types versus Web of Science - 152 research area types.

Subject and research areas in which defined terms are most popular refers to computer science and engineering, which suggests us about digitalization development growth in these sectors of economics. It is reinforced by fact, that most popular countries by defined terms entries include the biggest world economies as USA, China and Germany. However further research is needed to find out is there a link between economic development and publications about digitalization in specific countries.

CONCLUSION

The analysis of defined term search results in Scopus and Web of Science databases reveals a significant quantity of entries, with Scopus showing almost twice as many entries as Web of Science. For better understanding it is important to consider digitalization as a single process that began historically early and developed over the centuries using the latest approaches and technologies. The last decade has seen a particular surge in development, as evidenced by the rapid growth of records of defined terms in databases.

The primary motivations for research, as identified in the literature, are financial rewards ("gold"), reputational or career rewards ("ribbon"), and intrinsic satisfaction ("puzzle"). While financial rewards play a relatively small role, intrinsic satisfaction and career recognition are highlighted as key drivers for scientists. Ultimately, the main goal of research is to address uncertainties, disseminate new knowledge through publications, and ensure that the research contributes to societal benefit. And since experts predict that global GDP will increase due to digitalization, this explains why there are so many publications and overall interest for research on this topic with the United States and China leading the rankings.

Despite the rapid development of digitalization, the exact impact on organizations is difficult to predict, however, the basic direction is clear - we live in an era of human-machine collaboration, which, in turn, will determine the direction of development of all industries, especially, as we see from analysis of publications in databases – in computer science and engineering, as well as social sciences. On the other hand, organizations that are unwilling or unable to fully integrate into digitalization processes will lose time and will not be able to catch up on missed opportunities. Long-term growth is linked to innovation and the implementation of digitalization advantages [6].

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ANALYSIS OF OPPORTUNITIES AND WAYS TO IMPLEMENT THE LEAN GREEN CONCEPT AS BUILDING SUSTAINABILITY IN THE MINING INDUSTRY

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ABSTRACT

In today's European business reality, and within it in production processes, sustainability issues are becoming as crucial as economic aspects. An attempt to respond to these challenges is the Lean Green concept, which integrates financial and environmental aspects as equally important for building company value. The Agenda 2030 Sustainable Development Goals, particularly the goal of responsible consumption and production and climate action, are becoming key targets for corporate action.
The aim of this article is to examine and verify the possibility of implementing the Lean Green concept in the mining industry as building sustainable development, especially in the part related to the environment. The reference point is the environmental criteria and targets set by European legislation. The article discusses the basic principles of Lean Manufacturing, the concept underlying these considerations, and presents the Lean Green concept in the light of sustainable development and key environmental objectives. The possibility of achieving environmental performance improvements in mining companies using Lean Green tools, methods and techniques is also presented. The key parameters by which the positive impact of the Lean Green concept on improving the environmental aspects of mining companies' operations can be determined are also collated. This work confirms the validity of the implementation work of the Lean Green concept in the mining industry, which by its very nature has a significant impact on the environment.

Keywords: Lean Green, sustainabillity, mining, environmental efficiency

INTRODUCTION

Assessing the efficiency of manufacturing (production) processes can be done in several key aspects. The economic aspect, oriented towards profit and the reduction of unit production costs, remains extremely important. At the same time, environmental, social and corporate governance aspects, referred to as ESG, are becoming more important in light of the challenges of sustainable development. The Lean Manufacturing methodology is one of the most widespread concepts for organizing production processes in various industries. Its main premise is the elimination of all types of waste (classic - economic), i.e. activities that do not add value to the processes from the point of view of the end user - the customer. A Lean Manufacturing concept oriented towards improving environmental performance is Lean Green. Lean Green uses the methodological basis of Lean Manufacturing, considering its own assumptions about environmental impact, by adapting Lean Manufacturing tools and techniques

accordingly. When applied to manufacturing processes, Lean Green is a concept that contributes to improving environmental performance indicators and thus building sustainability. The methodologies mentioned are applicable to many industries, including the mining industry. Here, appropriate adaptation and targeting of Lean Green is required in order to achieve measurable results in terms of environmental impact.

MATERIALS AND METHODS

The basis for the analysis carried out is to define the essence of the Lean Manufacturing concept and then to identify opportunities for integrating classic Lean with the Green concept, a challenge arising from sustainable development. Lean is a management methodology, that creates a work culture in an organisation that makes all participants in the organisation interested in continuously reducing costs, increasing quality levels and shortening the delivery cycle. All this is done in order to maximie customer expectations and to adapt seamlessly to the environment [9]. The main objective of Lean is to eliminate those activities that do not contribute to the value creation of the company, as seen from the perspective of the customer/end user. These activities are referred to as process 'muda'. These include overproduction, inventory, unnecessary transport, overprocessing, waiting (downtime), quality deficiencies, unnecessary employee movement (lack of ergonomics). I also often point to unused or lost human potential as one of the main losses in terms of value creation. Lean methodology uses many tools, methods and techniques, the most important of which are: Jidoka, Just in Time, Total Productive Maintenance, Visual Management, 5S, Kaizen, Standardizations, SMED, Kanban and Heijunka [8]. Methodologically correct application of these tools makes it possible to achieve the objectives that constitute the 'roof' of the Lean Manufacturing House (Toyota Production System) shown in Fig.1.

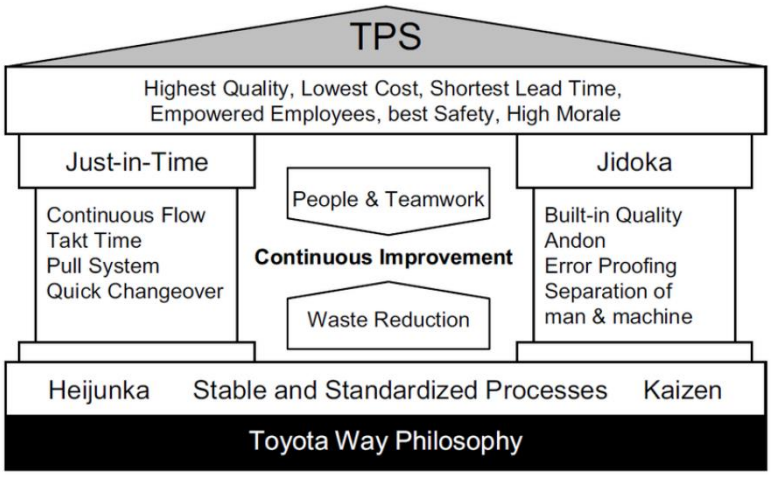


Figure 1: Toyota Production System House
Source: [6]

With changing perceptions of the added value of EU companies, there is a perceived need to adapt and apply the Lean Manufacturing concept to the requirements posed by new goals and ways of realizing added value, defined within the concept of Sustainability. Thus, the concept of Lean Green, which aims to maximize environmental performance, has emerged worldwide in recent years. Lean Green is a manufacturing method that minimizes wastes and maximize environmental protection (first of all

minimizing emissions to air, water and soil) through proper process and product design, with sustainability as its main objective [7]. Between Lean, in the classical sense, and Lean Green there are various relationships that can be identified and grouped into 4 categories that define these approaches [13]:

- The conflict approach, that the Lean approach means less Green. For example, the situation, when frequent deliveries increase emissions and emission reduction reduce productivity.
- A benign (mild) approach occurs when Lean and Green coexist but do not complement each other. The Lean team pursues economic goals, the Green team independently pursues environmental goals.
- A synergistic approach occurs when a company uses lean manafacturing tools and techniques to eliminate waste economically, but inadvertently benefits the environment. Reducing product waste simultaneously reduces environmental impact. Conversely, improving economic efficiency in energy consumption in this approach will translate into environmental benefits.
- The symbiotic approach, when Lean and Green are implemented as part of the same strategy as part of a continuous improving of the organisation. A strategy to reduce environmental losses borne by society during the entire product cycle. This type of integration is the most beneficial, as on the one hand it improves the economic efficiency of the company, while at the same time it contributes to building environmental added value [13].

The criteria (aspects) by which the effectiveness of environmental activities can be assessed are indicated by European legislation, particularly included within the CSRD (along with the European Sustainability Reporting Standards) and the EU Taxonomy. On this basis, the most important environmental aspects can be listed, the appropriate optimization of which is a measure of the level of implementation of the Lean Green concept. These include climate change (efficient energy consumption, carbon footprint, reduction of CO2 emissions), water consumption and appropriate water management, pollutant emissions, protection of biodiversity, and efforts towards a closed economy (improvement of the environmental footprint of operations) [2] [10].

An industry that requires action in the direction outlined above is the mining sector, which is an extremely energy-intensive, carbon-intensive industry, as well as one that carries a large amount of post-production waste. An important aspect of implementing Lean Green in the mining industry is the different characteristics of this type of industry, which should be taken into account when implementing Lean Green. Lean originated in the automotive industry, the specifics of which are different from the mining industry. The most important differences in terms of work organization and manufacturing processes are shown in Table 1.

Table 1. A comparison of the automotive and mining industries from a Lean perspective
Source: own elaboration based on [4][8]

Mining industry	Automotive industry
Production at the mine is a push system - a push system.	The assembly line can be stopped, and transformation to a pull system is possible - 'pulling' those materials that are needed at a given stage of production. This is a characteristic type of production organised according to the Lean methodology.
Continuous production	Production in cycles
Unstable/changing working conditions and variable working environment	Stable working conditions, fixed working environment
Geological hazards can halt production	No production risks
High variability of material availability	Controlled availability of materials
Large dispersion of work (up to several km)	Work in a relatively small factory (compared to the size of the pit)
Customers are mainly industrial companies	Product sales mainly to individual customers

A comparison of the classical concept of Lean and Lean Green in the context of good practices in the mining industry is presented in Figure 2.

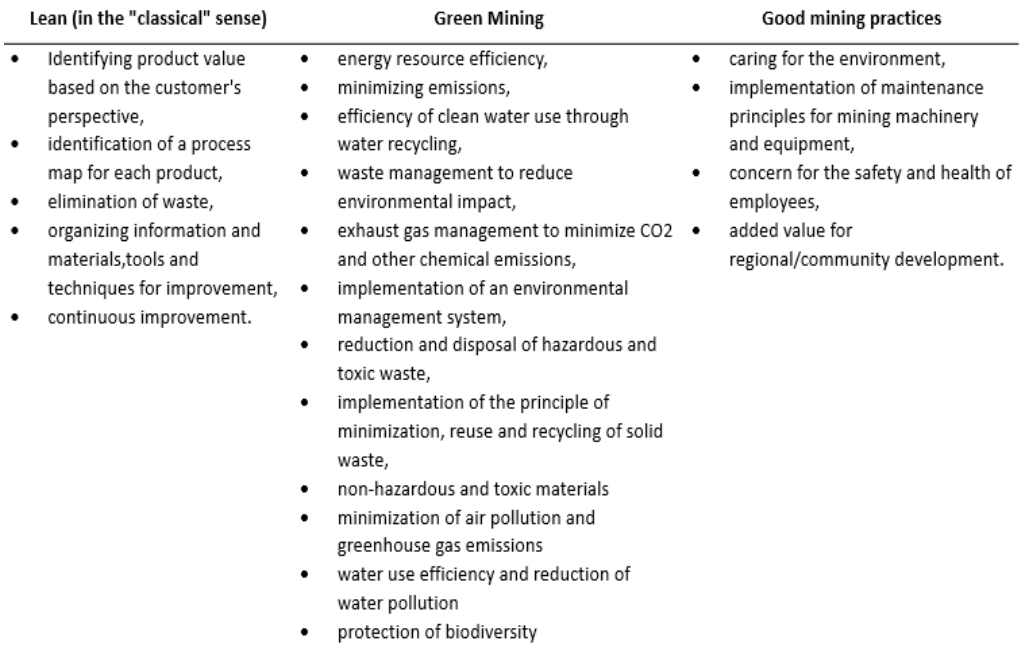


Figure 2. Comparison of Lean and Lean Green in mining
Source: [12]

RESULTS and DISCUSSION

An analysis of available sources in the form of publications and scholarly articles was used to present opportunities for Lean Green implementation in the mining industry. The examples described refer to implementations in the mining industry around the world. One of the first examples of Lean and Green implementation studies is a case

study of such implementation to reduce graphite and dust pollution in a mine in India. This study developed an implementation framework for Lean and Green, also using Six Sigma tools. Activities were conducted based on 5 key Lean principles, such as specify value, align the internal value stream, create the flow, pull-on demand, create perfection. One of the goals of implementing the Green Lean methodology was to reduce/improve the carbon footprint at the company, which is one of India's largest exporters of iron ore in the private sector. A Green Lean and Six Sigma implementation framework was identified and critical locations where dust levels in μg/m3 were measured at four strategic locations: dust emissions at the slag dryer, dust emissions at the coke screen, dust emissions at the bag filter station and dust emissions at the iron ore screen. Thanks to the Lean Green approach developed, among other things, the focus has been on improving performance in graphite and dust levels, which is a tangible environmental benefit [11]. The main benefits of implementing Lean Green include reduced emissions, reduced energy consumption, reduced business waste, reduced environmental costs, increased environmental revenues [5].

As part of the application of Lean and Green in the mining industry, particular benefits are seen in waste management. Waste generated during raw material extraction and massive waste discharges cause environmental pollution. The 5S method aims to manage the work area in a more organized manner. The processing of waste generated in coal mining should be done in a highly organized manner so that negative environmental impacts are minimized. The introduction of 5S, as a Green and Lean tool, makes it possible to standardize waste processing work. Another example of a Lean tool that can have an impact on improving environmental performance in the mining industry is VSM (value stream mapping). Creating a value stream map of, among other things, the flow of waste (generation, treatment and disposal) and identifying opportunities to reduce waste with improved waste disposal is an opportunity to improve key aspects of Green with continuous improvement of waste disposal processes [3].

In the Polish mining industry, a good example of the implementation and optimization of processes under the Lean Green concept is the action to improve energy efficiency by optimizing the transportation process in an underground mining plant. In this case, a conveyor belt system was used to transport crews. It replaced a transport model based on an overhead rail system. Mining transportation is an energy-intensive process with significant production costs. The economic benefits gained as a result of this change, seen in terms of classic Lean, are a reduction in energy consumption. Implementing and changing the way crews are transported has allowed the company to almost triple its greenhouse gas emissions, and thus has a positive impact on environmental issues. Analysis of the scope for reducing the level of energy consumption of crew transport in an underground mining plant using a conveyor belt system mining plant [1].

CONCLUSION

Based on the above analyses, the following conclusions can be drawn. The concept of Lean Manufacturing, along with the methods, techniques and tools used, is one of the most widespread strategies in the organization and management of manufacturing processes and contributes to improving their economic efficiency. At the same time, there is great potential for integrating and adapting the Lean Manufacturing concept (especially LM tools such as 5S, standardization, VSM, TPM, Kaizen) to the

requirements for sustainability, especially in its environmental part. In this light, the Lean Green concept assumes great importance as building sustainability. However, it requires an appropriate methodological adjustment, so that while achieving and improving economic efficiency, environmental efficiency is also sought to be improved. This is confirmed by the selected examples of Lean Green implementations in the mining industry presented in the paper. However, it is important to keep in mind the different characteristics of this industry, compared to the Lean source industry of the automotive industry. The use of a synergistic approach in Lean and Green is an opportunity for companies, in terms of improving the economic and environmental dimensions of their operations. It is undeniable that the Lean Green concept is still underdeveloped, especially in the mining industry. The perceived potential for Lean Green will undoubtedly be an increasingly strongly developed topic, especially in EU countries, where environmental issues of doing business are gaining great importance in legislation and becoming mandatory for selected entities. The scope is not only to report on these issues, but more importantly to conduct such activities in order to achieve measurable environmental benefits.

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BEHAVIOURAL ASPECTS OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

There is a growing social need to positively influence people's behaviour towards sustainable development. For this reason, the research community is increasingly addressing this reality. There is therefore the potential to achieve this positive influence through behavioural management tools, i.e. through the psychological and sociological aspects of society. The paper therefore explores the basic principles of a modern view of linking psychological and sociological influences to the field of sustainable development.

The main goal of the paper is to provide a basic justification for linking behavioural aspects to sustainable development, i.e. to show the importance of this connection and to provide a basic description of it. In other words, the paper shows the enormous potential that the connection of behavioural, i.e. psychological and sociological, management tools with the field of sustainable development represents.

The issue is based on two key areas, which are the effects of behavioural aspects on motivation for sustainable management and the effects of behavioural aspects on the nodes of sustainable development flows.

The authors explore the important context of the problem. Taking these contexts into account, they provide a comprehensive justification of how behavioural tools can be used to positively influence sustainable development. The main methods used in the paper are recherche, comparisons and description.

Keywords: Behavioural economics, behavioural management, sustainable development, waste management

INTRODUCTION

Sustainable development is an increasingly topical issue that is resonating in the thinking and approaches of both the non-professional and professional community. Given this urgency, the social relevance and desirability of sustainable development is growing. This forces government and scientific research institutions to address the issue of sustainability.

Many scientific research articles and projects have been presented on this topic. One of the main objectives of these scientific research outputs is to find an effective way to influence economic actors and market elements towards sustainable behaviour. This objective is a very important step. Therefore, alternative and unorthodox ways must also

be sought to fulfil it, i.e. how to influence corporate actors towards sustainable behaviour.

For this reason, it is proposed to use a modern and breakthrough topic, which is behavioural management methods. Due to the novelty character mentioned above, the connection between sustainable behaviour and behavioural management tools is explicitly offered. Such interdisciplinarity is very modern, flexible, desirable and profitable.

MATERIALS AND METHODS

The paper deals with the link between behavioural aspects and sustainable development in the sense of potential use of behavioural management methods to influence economic actors (decision makers) towards sustainable behaviour. For this reason, it is necessary to define two concepts in particular, which are environmental policy and behavioural aspects (behavioural economics and behavioural management).

Environmental policy is a policy that deals with the environment, and it does so in the following two levels of care:

- preventive care (protection);
- aftercare (for problems that have already occurred).

In simple terms, it is a set of tools, methods and approaches that consciously influence the behaviour of decision makers so that they:

- do not harm the environment;
- contribute to its protection or restoration.

This set of methods and approaches affects the following subjects:

- the consumer (individual);
- enterprise;
- the state apparatus (central government, regional government);
- the supranational entity (supranational regions, international groupings).

In this context, it is important to define the concept of environmental damage. It is a term that refers to the degradation of natural ecosystems through the extraction of non-renewable raw materials and, in turn, the introduction of harmful substances into these ecosystems, such as non-biodegradable substances, poisons, etc.

Another important area that needs to be theoretically defined for the purpose of this paper is behavioural aspects, i.e. behavioural economics and the resulting behavioural management.

The discipline of behavioural economics challenges much conventional economic thought – which works on the basis that, overall, humans make rational decisions – by

focusing instead on the ‘irrational’ cognitive biases that affect our decision making. By Egan [4] these seemingly inbuilt biases mean that certain kinds of economic decision-making are predictably irrational. Behavioural economics incorporates ideas from psychology, sociology, and neuroscience to better predict how individuals make long-term decisions. Often the ideas adopted include present or inattention bias, both potentially leading to suboptimal outcomes, French and Oreopoulos [5]. Principles of behavioural economics are implemented in researches in praxis, e.g. home dinner vegetable, Leak et al [7].

We learn of all-too-common issues of self-control and overconfidence vis-a-vis money, and how these irrationalities influence financial markets where rational choices are supposed to reign. Thaler [12] builds on Nobel-prizewinning psychologist Daniel Kahneman´s prospect theory, the idea that people make decisions on the basis of quick judgments rather than a thorough assessment of the probable outcome, Contestabile [3].

Oliver [8] attempt to bring a degree of intellectual clarity to the potentially important contribution that behavioural economics can make to public policy.

Knowledge of behavioural economics is widely used in marketing, authors Parsons, Maclaran, and Chatzidakis [9] successfully link marketing theory with practice, locating marketing ideas and applications within wider global, social and economic contexts. Tversky and Kahneman did experiments and found out that people do not act only by logic thinking. Their behaviour and decisions are influenced intuitive reaction and mental state, Tversky and Kahneman [13]. These authors together with Thaler contributed to an establishment of two new fields of study, experimental economics, and behavioural economics. Both of them are on the border of psychology and economics. Ameir [1] think that there are many new hypotheses in the science of behavioural economics and at the same time, the behavioural economics evaluates, how the results of the decision are influenced by decision process and external influences. The current research in this field of study is focused on two areas. In the first one, the research identifies and segments deviations from the rational choice theory. We can call them systematic failures in individual behaviour based on various mistakes in the decision-making process. The second area then deals with this distortion in practice and in the market environment, Wright and Ginsburg [14].

It should be noted that behavioural management is very closely linked to behavioural economics. Behavioural management differs from classical management in that:

- it places great emphasis on the psychological and sociological aspects of management;
- it is based on the assumption of irrational behaviour of the subjects of the decision-making process;
- the methods it uses are based primarily on behavioural economics.

The last condition clearly demonstrates the close relationship between behavioural management and behavioural economics.

RESULTS

The problem of influencing the subjects of the decision-making process runs into many problems. The core of these problems are unrealistic ideas about the psychological-sociological processes of individuals, especially in relation to the economic level. For example, there is the idea that when the subject of the decision process avoids waste, the problems related to waste disappear. But the reality of the economy of a developed society is such that the production of waste is inextricably linked to the existence of individuals living on this planet. If existing economic contexts are taken into account, it is true that reducing waste will lead to a reduction in living standards, both for individuals and for society as a whole.

The above connection can be taken as an example of difficulties in understanding the influence of behavioral aspects in influencing towards sustainability related to economic laws. However, it is also possible to consider contexts that are not related to economic laws. For example, the rebound effect (purchasing a more environmentally friendly boiler causes the individual to end up damaging the environment even more), or the effect of paper shopping bags, which causes an overall increase in the ecological burden, because in addition to paper bags, consumers also start to purchase plastic garbage bags.

In the methodological part of this paper, the basic entities (subjects of the decision-making process) that are influenced towards sustainable behaviour were listed, i.e. the individual (consumer), the enterprise, the state apparatus and the transnational entity.

So what are the prerequisites for influencing each of them towards sustainability using behavioural management methods?

Considering the nature and character of the individual subjects of the decision-making process, it is possible to turn to two publications, the intersection and comparison of which provides the basic premise (method, approach) for influencing the subjects of the decision-making process towards sustainability. By comparing two publications, Ameir [1] and Pawliczek and Vladík [10], it is possible to establish that the basic approach based on psychological-sociological aspects, which is applicable for influencing practically all subjects of the decision-making process towards sustainability, is the anchoring effect.

Ameir and Pavlíčková [2] think that the anchoring is called also focalism and means a form of cognitive bias for an individual to rely too heavily on an initial piece of information offered when making decisions.

The reason why the author, Ameir [1] dealt with this issue, it means whether the subject of the decision-making process must not know that he is anchored, is based on the basic conditions of behaviour economics. In general, two conditions of anchoring effect are listed in specialized publications. They are the demand of comparison the judgment with the anchor and the nescience of the solved problem.

DISCUSSION

Respect for the environment plays a key role in the creation of national and regional policies aimed at improving the quality of the environment. There is a huge range and diversity of public programs and instruments focused on environmental issues at

different levels of government when creating environmental policy. Programs and policies vary widely in their effectiveness and efficiency. The system of these policies should take into account the behavioural aspects of sustainable development, especially the anchoring effect. [1,4,9,10] In this way, space is created for further, even deeper investigation of this solved issue.

CONCLUSION

The goal of the paper was to provide a basic justification for linking behavioural aspects to sustainable development, i.e. to show the importance of this connection and to provide a basic description of it.

The introduction of this contribution was mainly devoted to justifying the importance and topicality of this topic. It was stated that, due to social interest, it is necessary to look for new challenges in the form of new unorthodox approaches. The authors of this paper proposed behavioral aspects as a new unorthodox approach, namely the use of behavioral management tools to influence decision-making process subjects towards sustainability.

In the next chapter, key terms such as sustainable development, behavioral economics and behavioral management were theoretically defined.

In the chapter dedicated to the results, the authors addressed psychological-sociological and economic myths regarding the connection of behavioral aspects with sustainable development, on the basis of which, and taking into account the nature of the problem addressed, they decided on the selection of key publications that were the source for defining a behavioral tool suitable for influencing subjects decision-making process towards sustainability.

Based on these results, it is therefore possible to determine that the contribution's objective has been met.

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CHALLENGES OF THE CIRCULAR ECONOMY IN LATVIA IN THE CONTEXT OF THE EU LONG-TERM STRATEGY

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ABSTRACT

The circular economy is targeted to increase the efficiency of resource use through prevention of waste and pollution; preservation of products and materials in circulation as long as possible and maintenance of natural capital. Therefore, the research authors aim to study the management of household waste and resources in Latvia in the context of other EU Member States in order to achieve circular economy targets. The study employs the monographic method, statistical data analysis and the correlation analysis to calculate the relation between the economic development and the amount of household waste in Latvia. The authors conclude that the amount of household waste in Latvia is increasing along with the economic development. The disposal of waste in landfills and the insufficient level of household waste recycling generate the largest problems. Better results are achieved in the recycling of paper, cardboard and glass packaging, while the recycling of plastic is not sufficient and there is a risk of not reaching the goals set by the EU. The proportion of reused materials is significantly lower than the EU average and, hence, the efficiency of resource use is twice as low. A significant improvement of the situation in Latvia requires a set of several measures. Along with economic instruments, an increasing attention should be paid to public education, which also includes raising the awareness of producers and packers about more environmentally friendly materials and new opportunities for reducing packaging.

Keywords: circular economy, household waste, recycling of household waste.

INTRODUCTION

In recent years, the circular economy has received increasing attention around the world, since it becomes a way to overcome the production and consumption model based on the ever-increasing use of resources and the increase in the amount of waste. Economic growth drives the economy of every country; however, it also leaves a negative impact on the environment. In most countries, the amount of household waste increases with the increase of the economic growth [1]. Therefore, it is necessary to transfer from an economy of aggressive expansion to an economy of sustainable development to enhance the formation of a stable identity and social sustainability, which requires a fundamentally new development paradigm. The circular economy is targeted to increase the efficiency of resource use through three basic principles: prevention of waste and pollution; preservation of products and materials in circulation as long as possible and maintenance of natural capital. Therefore, the research authors

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aim to study the management of household waste and resources in Latvia in the context of other EU Member States in order to achieve circular economy targets.

MATERIALS AND METHODS

The research employs the monographic method and statistical data analysis as well as the calculation of correlation between the economic development and the amount of household waste in Latvia. The research applies the data from Eurostat and Official Statistics of Latvia covering the period from 2000 to 2022; however, the period is often shorter depending on the availability of statistical data.

RESULTS

The data analysis confirms that in Latvia similar to the most countries, the amount of generated household waste increases along with the economic growth. The applied correlation analysis (r^2=0.86) demonstrates a direct, close linear relationship between GDP per capita and the amount of household waste per capita between 2002 and 2021 (Fig. 1).

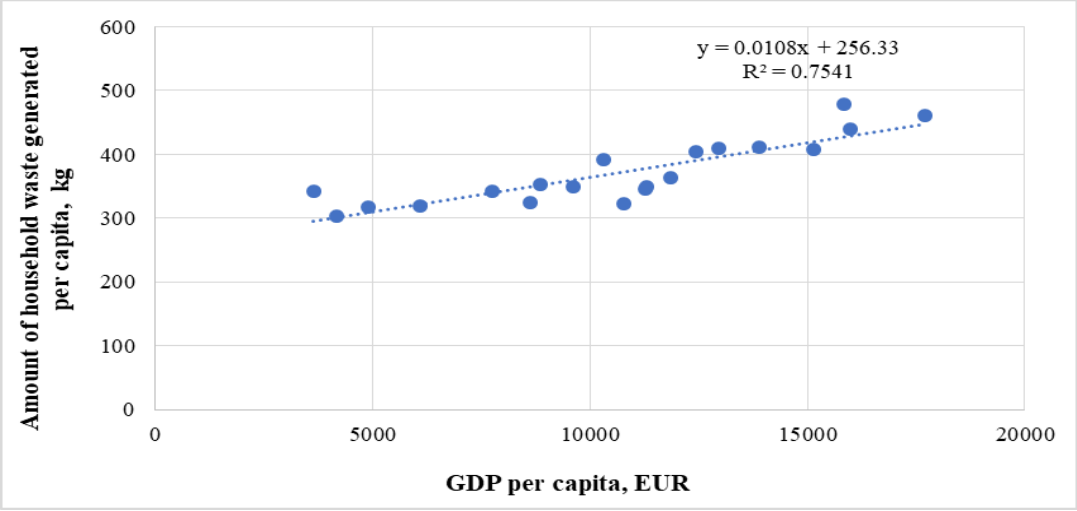
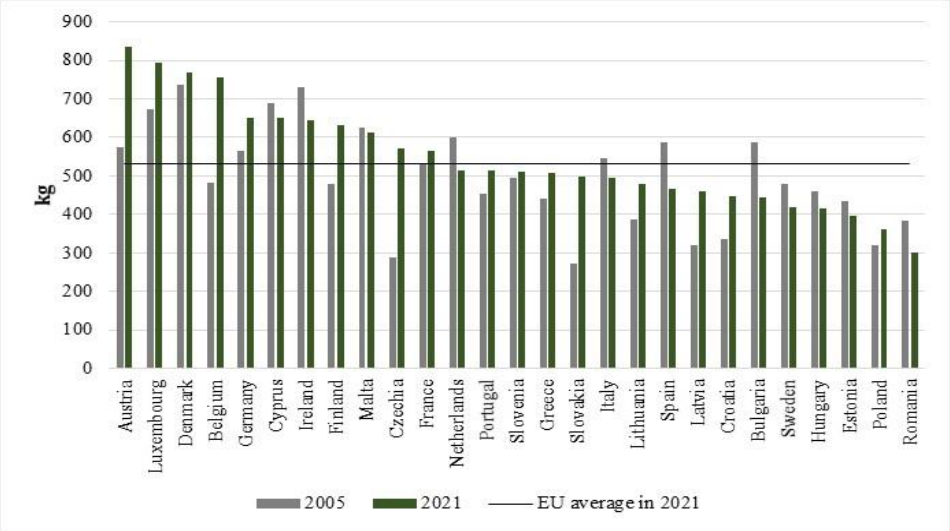


Fig. 1. GDP per capita and the amount of generated waste per capita in Latvia between 2002 and 2021 [2; 3]

The linear regression equation y=256.33+0.0108x allows to conclude that the amount of household waste generated per capita increases by 10 grams if the GDP per capita increases by EUR 1 and other factors remain unchanged. The coefficient of determination (R^2=0.7541) means that the regression model explains 75.41% of the variability related between the GDP per capita and the amount of household waste generated per capita.

The amount of household waste generated per capita significantly differs among the EU Member States (Fig. 2) due to different consumption patterns and the level of economic well-being. The amount of household waste has increased in most EU Member States, only 10 countries have achieved a reduction. The comparison of the EU average indicator demonstrates an increase in the amount of household waste by 26 kg or 5.1% in 16 years; thus, reaching 532 kg per capita in 2021. In Latvia, the increase is very significant – from 320 kg to 461 kg or by 44.1%; though, it is still lower than the EU indicator on average, which can be evaluated positively. However, the mitigation of this

alarming growth trend requires an essential action, namely, reduction of excessive and unnecessary packaging and promotion of the use of reusable and refillable packaging.



*the latest published data on Ireland refer to 2020

Fig. 2. The amount of household waste per capita in the EU Member States, kg [2]

The EU Landfill Directive has been adopted to support the EU's long-term goal of the transfer to a circular economy avoiding waste generation and use of waste as a resource. The Directive requires the Member States to reduce the amount of landfilled household waste to 10% by 2035 or less than the total amount of household waste [4]. In Latvia, an increased rate of natural resource tax is one of the tools to achieve this goal. The natural resource tax rate has been significantly increased for the disposal of household waste, i.e. from 1.06 EUR/t in 2006 to 110 EUR/t in 2024 or more than 10 times. An annual rate increase of 10 EUR/t is envisaged until 2026. In 2023, the natural resource tax rate for waste disposal in Latvia was the highest among the Member States as well as more than twice as high as the average rate in the EU Member States (46.00 EUR/t). In order to achieve the objectives of the environmental protection policy, the natural resource tax in Latvia operates in two directions: the polluter pays the tax and a responsible producer receives a tax relief for judicious use of resources and reduction of environmental pollution.

The amount of household waste disposal in landfills varies significantly among the EU Member States (Fig. 3); however, it is decreasing in all Member States, except for Germany, which disposes very small amounts of household waste. Lithuania reports the most significant decrease among the Baltic States. In Latvia, in turn, despite a significant reduction, the amount of landfilled household waste in 2021 still equalled to 52% of the total amount of waste, which more than twice exceeded the EU average level (23%). In Estonia and Lithuania, the figure is below 20%, while eight Member States already demonstrate the indicator below the required 10%. The European Environment Agency assessed and identified those Member States which might face a risk of not reaching the set goals in relation to the processing of household waste, the recycling of used packaging and the reduction of the amount of landfilled waste, Latvia being one of the identified countries. This means that raising the natural resource tax

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rate alone does not ensure a sufficient result and more attention should be paid to educating the population, especially the new generation, about the possibilities of reducing packaging, types of packaging, recycling, sorting and reusing packaging.

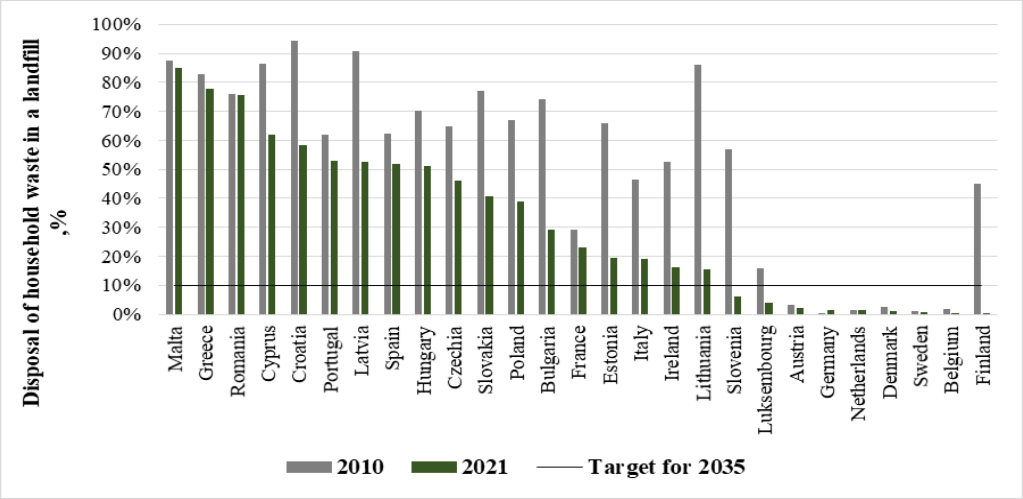


Fig. 3. The disposal of household waste in landfills by the EU Member States, % [2]

Recycling is a key waste management activity that prevents landfilling and the destruction of valuable resources in waste. Therefore, the improvement of waste sorting by introducing uniform and understandable sorting conditions as well as promoting consumer awareness on materials used in each specific package is vital to enhance processing. Household waste recycling has increased in almost all EU Member States between 2010 and 2021 (Fig. 4) with the exception of Sweden and Romania; the most significant increase of recycling was observed in Slovenia, Slovakia, Lithuania and Latvia. However, there are still essential differences. Only a few countries achieved the 55% household waste recycling target in 2021. In contrast, 18 Member States, including Latvia (44.1%) have a risk that the specified level of waste recycling will not be achieved by 2025 [5]. Nevertheless Latvia has significantly increased the total amount of investment and current expenses for waste collection and processing from 2018, these financial resources are still not sufficient [6].

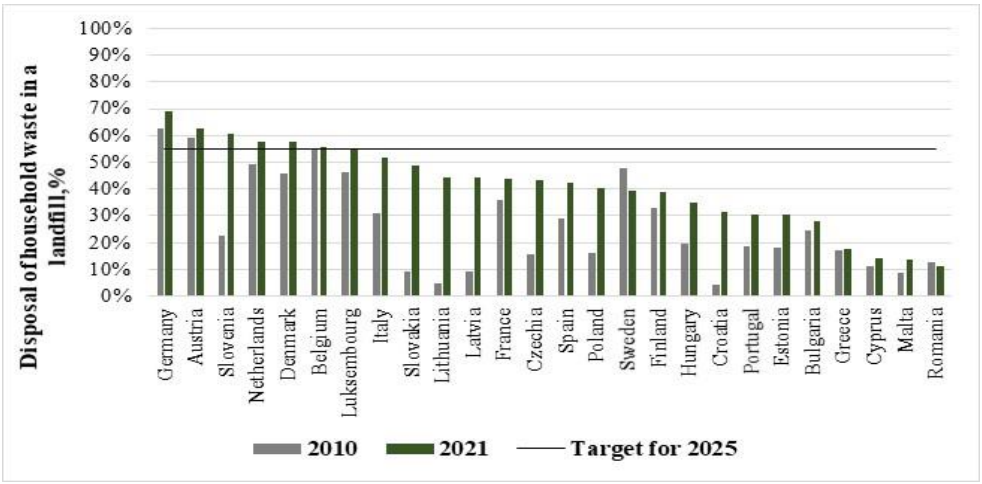


Fig. 4. The level of household waste recycling in the EU Member States, % [2]

The operation of preparing waste for processing and regeneration results in a large amount of materials unsuitable for processing; yet, they have a high energy capacity, which can be used for the production of energy resources. The use of regeneration includes several benefits: smaller amount of landfilled waste, less import of energy resources and the reduction of CO_2 that would occur if these waste residues were landfilled. Waste recycling is not developed in Latvia; it is used as fuel by only one company and there are three more projects in various stages of development for the creation of waste recycling stations. The construction of waste recovery stations is not a fast process but a very valuable one, which has been proven in the case of Lithuania. A waste recovery station has been established in Klaipeda, which uses waste to produce the cheapest heat in the city, which is delivered to the city's centralised heat supply system. Hence, the need for imported fossil natural gas is reduced, saving money and improving the export-import balance. The most important benefit is the reduction of the amount of waste to be landfilled and the amount of CO_2 emissions.

The extended producer responsibility system introduced in Latvia and the corresponding natural resource tax reliefs have contributed to the management of more than 90% of the generated packaging or environmentally harmful product waste. Therefore, the goals of recycling and regeneration of used packaging set by the EU Directive stipulating recycling of at least 55% of used packaging have been achieved. Another requirement is that at least 65% of the weight of all used packaging have to be recycled by the end of 2025. Latvia is not at risk of not reaching the set indicator in this aspect [7].

Plastic is one of the materials the use of which has grown the fastest. Although this material has many advantages, it causes very negative consequences when it becomes waste or pollution as microplastics.

Table 1 Recycling of used packaging by product groups in the EU-27 and the Baltic States, % [2]

Product	**EU-27**		**Latvia**		**Lithuania**		**Estonia**	
	2016	2021	2016	2021	2016	2020*	2016	2021
Plastic	42.4	39.7	37.2	41.6	74.4	56.1	24.6	42.5
Wood	40.7	32.2	39.9	48.3	48.3	30.1	32.5	31.2
Black metals	80.2	74.8	59.8	66.6	77.3	72.4	66.1	100.3
Glass	75.3	74.9	65.5	70.3	71.0	63.4	63.4	80.1
Paper, cardboard	85.4	82.5	81.1	77.0	85.0	80.1	79.0	89.7

*the latest published data on Lithuania refer to 2020

In Latvia, 35.9 thousand tons of plastic packaging are created annually on average, of which only 41.6% were recycled in 2021 (Table 1), being the lowest indicator among the Baltic States. Yet, the recycling has increased, which is valued positive. The European Commission has set an increasingly strict minimum recycling targets for plastic packaging waste, namely, 50% by 2025 and 55% by 2030. There is a risk for Latvia that this target will not be achieved in 2025. Recycling requires investment in the use of new innovative technologies and developed smart design solutions. The data in Table 1 clearly show that the amount of generated waste (Fig. 2) is growing faster than the amount of recycling, so the level of recycling is decreasing on average in all product groups in the EU. There is also a significant decrease in Lithuania, while in Latvia, the decrease is only for recycling of paper and cardboard. The best situation is in Estonia,

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which is one of the 10 Member States that managed to reduce the amount of household waste per capita. The EU Member States have to pay a fee of EUR 0.80 for each kilogram of non-recycled plastic in waste from 2021. In February 2022, the deposit system was introduced in Latvia, so this was a promoting year to the circular economy in Latvia. Since the introduction of this system, approximately 80% of all deposit products have been returned for recycling, while the return rate for refillable glass bottles and beer PET packaging was 90%. In order to further promote the involvement of deposit packers-producers, distributors and importers in the deposit system, it has been established that if the natural resource tax payer does not participate in this system, it shall pay natural resource tax for deposit packaging in a double amount from 2020 and in a quadruple amount from 2024.

The usage of recycled materials for the production of new products prevents the impact on the environment associated with the extraction and processing of natural resources as well as promotes the achievement of other benefits of the circular economy. On average, the proportion of reused materials in EU Member States is slightly increasing, from 10.7% in 2010 to 11.5% of the total amount of used materials in 2022.

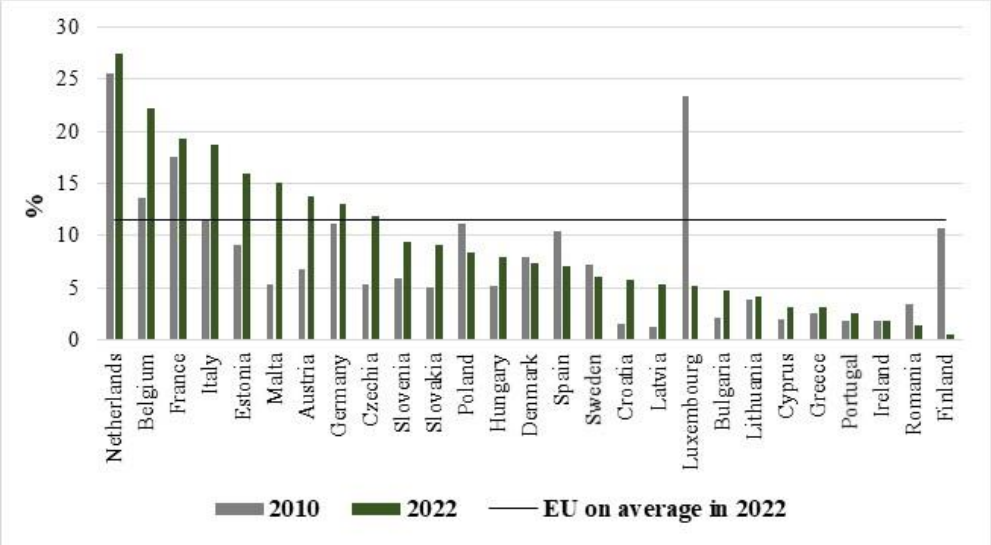


Fig. 5. The proportion of reused materials in the EU Member, % [2]

Differences among the EU Member States are significant (Fig. 5); however, most countries have increased the proportion of reusable materials. Estonia has the best results among the Baltic States, exceeding the EU average indicator. Latvia has also improved the indicator, reaching 5.4% in 2022. The market for secondary raw materials puts forward a challenge, since there are manufacturers who choose materials of the highest quality that are difficult to recycle. Moreover, processing costs are increasing due to the economic conditions. Manufacturers, in turn, want cheaper raw materials, so they choose primary raw materials for the production of new products. This has led to a situation that companies continue to invest in waste recycling but the demand for these materials is decreasing; thus, affecting the opportunities for the development of recycling.

The progress of implementing the circular economy can be assessed using the value of resource productivity, which describes the relationship between economic activity (GDP) and the consumption of material resources. The productivity of resources is a key indicator of the UN Sustainable Development Goal.

Unfortunately, the resource productivity indicator does not increase in Latvia (Fig. 6), while the consumption of domestic materials increases with the GDP growth. This means that the growth in Latvia depends on the consumption of resources.

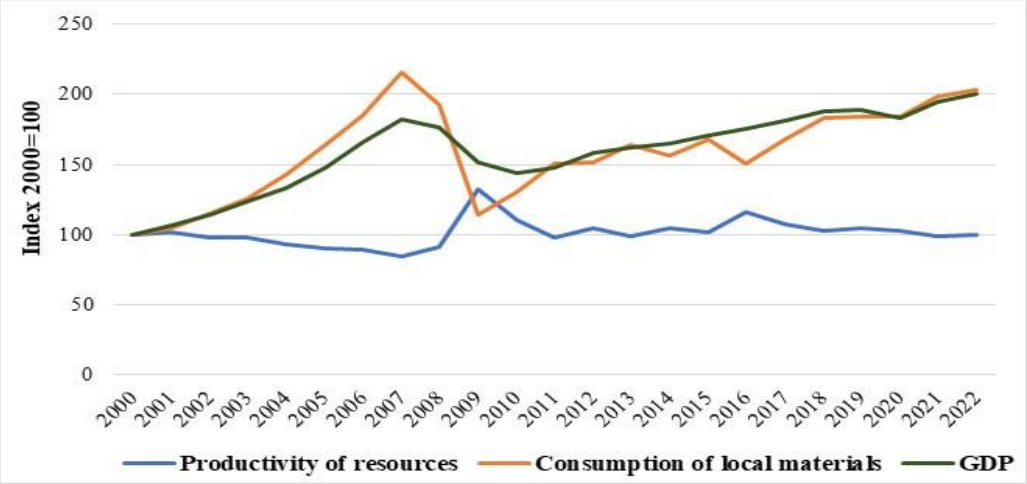


Fig. 6. The use of resources and economic growth in Latvia in 2000-2022 per year, index, (2000=100) [3]

The developed Action Plan for the Transition to a Circular Economy sets the achievement of an increase in resource productivity from 0.90 EUR/kg to 1.55 EUR/kg by 2027 as one of the goals. According to the data of the Central Statistical Bureau of Latvia, the resource productivity was 1.25 EUR/kg in 2021, which was almost twice lower than the EU average – 2.45 EUR/kg. The increase in the level of consumption of material resources reaching more than 16 tons of natural resources per capita in 2022 should be valued negative. Moreover, it exceeds the EU average indicator of 14.4 tons per capita. A set of measures is required to improve the productivity of resources: investment in the development of infrastructure, maximum increase in the use of raw materials, reduction of the waste flow through recycling and energy recovery, and motivation of companies to adopt resource-efficient business models with less impact on the environment.

DISCUSSION

Waste management is becoming a major concern of our society. Therefore, targeted policies requiring changes in legislation and development of special measures to solve the problems at local and national level are very important [8]. Latvia has annually contributed more than EUR 15 mln to the EU budget for non-recycled plastic. This amount was paid from the state budget due to the fact that no system was established to make producers or importers pay for non-recyclable packaging. Only starting from 1 July, 2024, this amount will be collected from the operator who has concluded an agreement on the application of the extended producer responsibility system. As a result, producers and traders will be motivated to use more easily recyclable materials.

Unfortunately, manufacturers and retailers in Latvia have a poor understanding on the new opportunities offered by the use of smart packaging technologies. In order to improve the situation, researchers recommend narrowing the variety of packaging materials to facilitate their recycling, reducing the volume of packaging and abandoning the use of non-recyclable materials [9]. The creativity of individuals, which would serve

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as an incentive for private individuals to start their own business, should be promoted to motivate entrepreneurs to produce new ecologically friendly products [10].

CONCLUSION

The amount of household waste in Latvia like in most EU Member States is also increasing with the economic development. The biggest problems are caused by the disposal of waste in landfills. The amounts disposed in landfills have decreased but they are still far from the goals set by the EU despite significant and regular increases in the natural resource tax rate for these activities. The level of household waste recycling has also significantly increased; however, there is a risk of not reaching the goals set by the EU. Latvia could achieve the EU goals in packaging recycling and regeneration, the best results are demonstrated in the recycling of paper, cardboard and glass, while plastic recycling is not sufficient and there is a risk of not reaching the goals set by the EU. Although the proportion of reused material in Latvia is increasing, it is significantly lower than the EU average; thus, the efficiency of resource use in 2021 is twice as low as the EU average. Latvia needs a set of several measures along with the economic instruments (environmental taxes, their reliefs and subsidies) to significantly improve the situation and promote the achievement of the long-term goals of the EU's circular economy. In addition, more and more attention should be paid to public education, which also includes raising the awareness of producers and packers about the environment friendlier materials, new possibilities in reducing packaging and using new technologies. The researchers, in turn, are responsible for creation and popularisation of such materials and technologies.

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CLIMATE CHANGE AND INVESTMENTS FOR URBAN RENOVATION: ASSESSING THE FINANCIAL SUSTAINABILITY WITH THE APPLICATION OF FUZZY LOGIC PRINCIPLES TO REAL ESTATE APPRAISAL

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ABSTRACT

Climate change requires significant measures to adapt existing cities to new requirements; extensive urban renewal actions are therefore necessary. In order to be financially sustainable, such investments are mainly based on real estate and market operations, also at long term. The current valuation practice would require to resort to appraisal methods based on actual, historical market data, also known as Revealed Preference Methods (RPMs), which allow to derive the preferences expressed by the actions of market. Because of the instability, complexity and uncertainty of real estate markets as they are today, the results obtained with the application of standard RPMs are often not fully reliable.

The most advanced and current solutions to the above problems mainly focus on possibilistic models, based on fuzzy logic. Such models can account for the uncertainty in the input data and single out some estimated values that are associated with a certain likelihood of occurring or, alternatively, detecting a range of possible values. Such models represent a support to operate always within the range of the RPMs. They are instrumental to improving the quality of the input data and to describe the level of uncertainty.

The paper proposes the application of fuzzy logic in valuation methods, considering another type of uncertainty from the one considered through the probability theory. After the framework of the issue and a brief description of the principles of the fuzzy logic theory, some proposals, at international level, concerning the application of fuzzy logic to real estate appraisal techniques (Sales Comparison Approach, Discounted Cash Flow Analysis and Multiple Linear Regressions) are described, analysed and critically discussed.

Keywords: Climate change, Fuzzy logic, Uncertainty, Possibilistic models, Real estate appraisal, Revealed Preference Methods.

INTRODUCTION

The consequences of global warming and climate change [1] in the urban contexts need to program measures in order to adapt services, infrastructure, urban spaces and housing to new requirements and make citizens' lives more sustainable socially, economically and environmentally. To adapt existing cities to new requirements, extensive urban renewal actions are therefore necessary and, in order to be financially sustainable, such investments are mainly in real estate and market operations, also at long term. In the light of this, it is necessary to assess the financial feasibility of such operations.

The common valuation practice requires to resort to methods accounting for actual, historical market data, also known as Revealed Preference Methods (RPMs), which

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allow, through actual real estate transactions, to derive the preferences expressed by the actions of market subjects. Such methods, in order to provide reliable estimates, assume the availability of a large number of data, whose quality and correctness is proven. Moreover, in order to be applicable, the RPMs must rest on the existence of an active market for the subject of valuation [2]. But in the current economic context, the global economic scenario is uncertain; the credit crunch led to market stagnation, and the real estate market is no exception, thus the market operators have taken a "wait and see" attitude. In such a market, the real estate appraisal process is exposed to several sources of uncertainty; there are few market operations to be used as comparable data, and reading through the market sentiment is difficult. The investment market, strongly expanding towards the end of last century, had protected valuation from the need of fully considering the impact of uncertainty.

Uncertainty is a real phenomenon in the real estate appraisal process. In academic literature the terms risk and uncertainty are often used as synonyms. Risk is regarded, then as a synonym with uncertainty. According to Byrne and Cadman [3] uncertainty is what one does not know about a future event in the moment a decision is made, while risk is the measure of a loss identified as the possible outcome of the decision. With the term risk we refer to such situations where, given an alternative, there is a probability for a negative outcome, but such probabilities are known or believed to be known. The term uncertainty, in turn, refers to the situations where apparently no elements are there to allow an estimate of the likelihood of the event. Usually, uncertainty is due to the lack of knowledge or poor or imperfect information on the inputs that may be used in an analysis. Within real estate appraisal, it depends mainly on the information inherent to the comparable properties. In the impossibility of confirming the truthfulness of data, the estimation will also appear uncertain. Nevertheless, if it is possible to assign a probability of the input variables, this will allow to determine a set of possible results [4].

Basically, two meanings of the term risk may be given; namely, the subjective/perceptive and the rational one. The distinction is based on the fact that on the one side individuals have their own ways of perceiving and processing the information regarding the degree of risk. On the other, though, there is a rational approach to the issue of risk, which is based rigorously on the concept of probability and, most importantly, on a rigorous way of combining the data regarding the probabilities in the process that will lead to the final decision. Some scholars highlighted that the first meaning has a purely descriptive meaning, while the second has a regulatory meaning. In other words, the two meanings would not seem incompatible and both could be equally well substantiated, be it in different contexts. After all, some also objected to the fact that a strictly regulatory vision in the real world would eventually have limited practical use [5].

The outcome of an appraisal is certain only if one can foresee the future with a certain degree of accuracy. Since this is practically not possible, there will always be a risk that the actual value would differ from the estimated value. All valuations are price projections to see how a given asset should be traded at the time of the valuation. A valuation is a pricing model that, depending on the implicit or explicit nature of the model at hand, detects the market sentiment towards the prices from a number of reference parameters [6].

As in all projections and opinions, the degree of subjectivity varies significantly, as well as the degree of certainty (that is, the likelihood for the valuer's opinion may coincide with the value actually registered for the sale transaction). Such differences may arise because of the characteristics of the asset, the market or the available information. The uncertainty of the appraisal may derive from different sources [7]:

- Characteristics of the property or the context: special properties in terms of intrinsic or extrinsic characteristics, which are not commonly traded in the market, make it rather difficult to source historical data; counting on very few or no comparable sales, the appraisal will be rather uncertain;
- Limit in the provided information: when the information available to the valuer are limited or subject to constraints, both from the client or by the appraisal context, the appraisal itself will tend towards uncertainty;
- Choice of the valuation method: some appraisal procedures require the formulation of several assumptions and projections in terms of future values; the level of uncertainty in such processes is usually higher that that correlated to other methods, in that the latter imply the appraisal of different parameters, which are sensitive to basic assumptions and slight changes to their values;
- Market instability: unexpected macroeconomic and political crises may produce an immediate effect on markets; instability may produce a decrease in the number of transactions, due to concern or simple reluctance; in the long term, the decrease in transaction reflects in market prices; if the valuation is performed in unstable markets, then the reference data may be misleading, incomplete or inconsistent, with the inevitable effect on the level of correctness of the appraisal.

With the aim of improving the quality of appraisal and describing the level of uncertainty of an estimation when applying RPMs in real estate valuation, the paper proposes the application of fuzzy logic in appraisal methods, considering another type of uncertainty from the one considered through the probability theory. After a brief description of the principles of the fuzzy logic theory, some proposals, at international level, concerning the application of fuzzy logic to real estate appraisal techniques (Sales Comparison Approach, Discounted Cash Flow Analysis and Multiple Linear Regressions) are described, analysed and critically discussed.

MATERIALS AND METHODS

In the early sixties, L. A. Zadeh [8] started considering that traditional system analysis techniques were excessively and pointlessly accurate for many of the typical issues in the real world. The "degree of membership" principle was introduced in 1965. Fuzzy logic is such that each position may be attributed a degree of truthfulness comprised between 0 and 1. The term "fuzzy logic" has two different meanings: wide and narrow. In a narrow sense it is a logical system which aims a formalisation of approximate reasoning. In this sense it is an expansion of multi-valued logic. In its wide sense, fuzzy logic is fuzzily synonymous with the fuzzy set theory of classes of unsharp boundaries [9].

In the fuzzy set theory, the Aristotelian principles of non-contradiction (each element belonging to A cannot belong to non-A) and excluded middle (the combination of A and its complement non-A constitutes the universe of discourse) do not exist. Such

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principles give a bivalent character to classic logic (it admits only two values of truth: true or false, white or black, all or nothing), which often bring to paradoxes it cannot shed light on.

With a degree of truthfulness or degree of membership, we mean how true a property is: it may be, beside true (value =1) or false (value = 0), as in classic logic, also equal to intermediate values. A statement may be proven if and only if it may be demonstrated also in its formal negation, hence it is possible to cross the mirror of classic logic and be in a world where truth, demonstrability, consistency and absolute certainty do not exist. A world where the degree of truthfulness/of falseness is important together with the degree of demonstrability and non-demonstrability and the degree of certainty [10].

An element may be within or without a set in a way that is neither absolute nor certain; not all the elements that belong in a set are identical, though they possess a given characteristics at different degrees. The boundaries of fuzzy sets are not certain, they are blurred and vague. In classic logic the characteristic function assigns values 1 or 0 in order to determine the membership of an element in a set; in fuzzy logic, the function of membership is a set completely and univocally defined by a vector that matches each of the N units considered with a number expressing the degree of membership of the unit to the set. In the function of membership, the values, which vary between one and zero, may be construed as degrees of membership and may be recombined in order to derive the functions of membership of composite entities. The boundaries of fuzzy sets do not depend on a single function of membership but by as many functions as the elements in the set [11].

There are many forms that the function of membership may take: triangular, trapezoid, sigmoid, bell-shaped, etc. with the indication that the form to be assumes is, for the most cases, completely subjective. Determining this function is one of the critical points in fuzzy logic. In reality there are other determination methods that use statistical methods or more sophisticated tools such as neural networks. The use of the above methods allows to increase the degree of objectivity in determining the function, though they require some data to interpolate.

The fuzzy set theory includes and contains that of probability as a particular case; the reality, then, would be deterministic but blurred: the theory of chaos highlighted these deterministic components; the fuzzy theory shoed the importance of the principle of *homo mensura*. In such models, indeed, the subject is the focus of the entire system. The subject, based on its categorisation, detects the key points of interest and builds the functions of membership in order to analyse the situation it is faced with. The subject is put back in its place as knower, discoverer and creator of portions of reality and social relations. It is not possible to research all and making choices becomes necessary. Such choices will depend on the personality, beliefs, cultural level, in a word, the philosophy that determines the mental categories and the judgement criteria of the subject.

RESULTS AND DISCUSSION

The early applications of fuzzy logic involved the industrial sector. Over the past decades, fuzzy logic found its application also in the financial sector, mostly in Asia, while recently the first experiments have been promoted also in the field of investment valuation. Traditional investment valuation models use deterministic measures called crisps: these do not consider uncertainty if not to a limited extent. The application of

fuzzy logic in valuation methods allows to run different analyses from those made with other tools, considering another type of uncertainty from the one considered through the probability theory. We may say that the main purpose of using this tool is that we intend to preserve uncertainty as long as possible in order to leave it last, since it is always possible to reduce uncertainty through an information loss process. Distribution of probability allows uncertainty to be resolved as soon as we determine the average value, while we will see that by using this logic, uncertainty shall remain until the end and may be eliminated through a process called "defuzzification".

Following is a description of some experiments underway at international level, concerning the application of fuzzy logic to real estate appraisal techniques for the purpose of governing the uncertainty of information sources.

a. Application of Fuzzy Logic to the Sales Comparison Approach

The aims of this method [12] are: a) reproduce the reasoning pattern of the potential purchaser based on a set of characteristics that in turn determine the value of the asset, which is a reasoning subject to inaccuracy; b) keep account of the conditions of uncertainty of the information sources.

The method implies the application of fuzzy logic to Ratcliff's "Statistical Inference" model [13], a multi-criteria version of the Sales Comparison Approach. The offered procedure breaks down into the following phases:

- define of the characteristics of the subject and comparable properties;
- indicate the weight for each characteristic;
- define the scores for each characteristic relative to the comparable and the subject properties: scores and weights are expressed as triangular fuzzy numbers; for the scores the measurement scale is homogeneous for all characteristics (cardinal scale from 1 to 10); the ratio between the measure of the characteristic in the suitable scale and the score is defined, in turn, through fuzzy numbers;
- assess of the overall desirability level of the comparable and the subject properties through the weighted sum of the scores of each characterises for the weights they are associated with; the level of desirability is expressed, in turn, in the form of a fuzzy number;
- graphic comparison between the fuzzy number regarding the level of desirability of the subject and that of every comparable property: based on the comparison, it is possible to associate the known price of the comparable to the degree of membership/level of truthfulness regarding the price of the subject;
- estimate of the most likely market value of the subject in the form of a fuzzy number.

This process allows to obtain a finite number of results with a different degree of membership to the hypothetical set "Probable market value". The fuzzy set may be expressed in any case in terms of unique value by applying a mathematical approximation process, such as linear regression. The result, described in the form of a fuzzy set, better approximates the decision-making process of a potential buyer rather than the confidence interval produced by linear regression.

b. Application to the Discounted Cash Flow Analysis

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The model [14] sets out to use fuzzy logic as a tool to consider the uncertainty in valuing the feasibility of an investment in the Discounted Cash Flow analysis, as well as to keep account of all pieces of information at hand without claiming to set a punctual value.

Assuming to have a single yearly net cash flow value, though there is uncertainty on its value and, more specifically, the return for the first period is assumed to be represented by a fuzzy set or, more simply, by a fuzzy number. For each period there is a triplet of values representing the flow that may be derived for a given investment. Moreover, it is assumed that the function of membership is triangular and that the interest rate is provided as a triplet of numbers. Once the measures have been expressed in terms of fuzzy numbers, then the discounted cash flows may be determined as expressed by a fuzzy number. Having detected the $\alpha - cut$ (representation of the triangular numbers according to the variable), a table is produced to indicate the behaviour of the yearly cash flow and the discount rate at the variation of α (degree of membership) between 0 and 1, by replacing the values comprised between 0 and 1 in the α.

In order to determine the current value, each cash flow shall be multiplied by its own discount factor for each level of α. Thus, not a single current value, but a triangular fuzzy number, is obtained. Once the result has been obtained in terms of fuzzy number, it is necessary to analyse the same in order to verify the financial feasibility of the investment and, if need be, proceed to selecting the best investment in case several choices should be available.

The selection outside of the cases in which the choice seems obvious from a simple visual analysis, implies the use of one or more comparison indexes whose determination rests on the use of a process known with the name “defuzzification”. There are many defuzzification methods: they range from some very simple methodologies, which do not always lead to a solution in terms of choice between one investment or another, to quite complex methods. The defuzzification process must also be intelligible in economic terms, that is, the process adopted to narrow down to a single value must follow an explainable and acceptable line from an economic standpoint.

c. Application to multiple linear regressions

The goals of this application [15] may be summed up in the following points: a) exceed the constraints of probabilistic regression models, given the different sources of uncertainty both in measuring the phenomena and in the relations among the variables; b) detect a theoretical-methodology framework where the different fuzzy regression models are justified; c) detect a new fuzzy regression model (fuzzy adaptive regression), to study the relation between a dependent fuzzy variable and a set of independent deterministic variables (crisp).

The traditional regression analysis is reformulated in the Informational Paradigm. Such paradigm may be generalised in order to allow the processing of fuzzy information, both empirical (data) and theoretical (models). In general, the fuzzy regression analysis models used are two: possibilistic models or models based on least squares. The presented model features a new approach, called “fuzzy adaptive regression”. It consists of a deterministic model (crisp model) suitable to analyse the relation between a dependent fuzzy variable and one or more independent crisp variables. The model refers to the principle of least squares applied to a new distance, between observed and theoretical fuzzy values. Thus it is possible to define a linear valuation function that

bears in mind of different information data uncertainty factors, which is easily applied to real cases and allows to have better results as compared with traditional fuzzy regression models.

The joint use of theoretical and empirical fuzzy information allows to manage the different multiple regression uncertainty factors with more efficiency; moreover, through the adaptive model the main uncertainty factors are incorporated in the dependent fuzzy variable.

CONCLUSION

The consequences of climate change on cities require interventions to adapt to new needs, including intensive and radical ones; such investments are often based on market operations supported by real estate valuations; due to the instability, complexity, and uncertainty of real estate markets as they are today, the results obtained in estimation by applying standard RPMs are often not fully reliable.

Applying the principles of fuzzy logic to RPMs, as seen in the examples given in this paper, makes it possible to take into account the uncertainty of the input data and identify estimated values that are associated with a certain probability of occurrence or, alternatively, detect a range of possible values. They represent a support to operate, in each case, always within the range of RPMs by improving the quality of input data and to describe the level of uncertainty.

The results obtained from the application of these methodologies, described in the form of fuzzy sets, better approximate the decision-making process of a potential buyer; they allow preserving uncertainty as long as possible to leave it for last, since it is always possible to reduce uncertainty through a process of information loss.

Finally, the use of fuzzy information allows multiple uncertainty factors to be handled more efficiently, and through the adaptive model, the main uncertainty factors are incorporated into the dependent fuzzy variable.

In order to enable a more widespread application and further development of such models to real estate valuation, however, in-depth phases of experimentation, verification of results and discussion in scientific and professional spheres are necessary, including by taking as reference and comparing with applications being made in other areas of economics and finance.

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COAL DEVELOPMENT IN THE ARCTIC REGIONS OF YAKUTIA: SOCIAL AND ENVIRONMENTAL SECURITY

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ABSTRACT

The article analyzes the main problems associated with the import of fuel and energy resources to the Arctic regions of Yakutia. The article considers existing multi-link schemes of fuel delivery to the final consumer, the main disadvantages of which are significant transportation time and a large share of logistics costs as well as environmental impact on northern rivers (Lena, Kolyma, Indigirka). High transport costs are shown to increase cost per ton of fuel and energy resources by 3-5 times. The paper shows that the development of local coal resources located in close proximity to consumers is one of the directions to increase the energy security, improve environmental conditions for coal delivery of the Arctic regions of the Yakutia and reduce the regional budget expenditures. Deposits of fuel and energy resources in remote transport isolated Arctic regions of the Republic of Sakha (Yakutia) have a social orientation, not a commercial one. However, profit earning should not necessarily be the main goal for companies already performing mining or planning to mine in the Arctic zone. Feasibility and needs for companies oriented rather to welfare, than commercial interests is predetermined by increased energy requirements for safety, creation of new jobs etc. Such deposits should be approached from a social perspective rather than from an investment perspective. The article introduces the concept of ultra-small coal company for the Arctic regions, which takes into account the specifics of inaccessibility, transport remoteness with severe climatic and physical and geographical conditions, increasing the energy and ecology security of the population.

Keywords: North-East Arctic, coal, development, efficiency, energy security, social orientation, deposits

INTRODUCTION

The Arctic Zone of Yakutia comprises 13 municipal districts over the area of 1.7 Mkm^2 with 70.000 inhabitants, including 42.000 people (56 %) living in neighborhood centers and small towns. The rest population (around 30.000) is scattered over the area of these regions. Percentage of human settlements with less than 500 inhabitants is more than 56 %, which creates an additional load on the distributed and disjunct power system. The artic regions feature long haulage distances to end consumers (up to 2–3 thousand kilometers), an underdeveloped territory, low density of population (0.03–0.06 man/km^2), an intricate and lengthy logistics (to 3–4 transshipments and shipping time to 2.0–2.5 years), a limited and nonsynchronous period of operation of water and road transport, and a low-quantity consumption of fuel-and-energy resources in individual districts (5–50 Kt). The consequences of such situation are the gigantic specific and general expenses connected with fuel supply (the final cost is 3–8 times higher as

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compared with the place of shipment), and the high quantitative and qualitative losses of fuel, which aggravates the environmental pressure.

Production facilities of the municipal housing economy in different towns in the Republic of Sakha (Yakutia) (RS (Ya)) were created and are functioning not using a unified scheme, and are characterized with a high wear. The Anabarskiy, Bulunskiy, Allaikhovskiy, Olenekskiy, Nizhnekolymskiy and Eveno-Bytantayskiy districts (Fig. 1) use liquid fuel burnt in boiler-houses (gas condensate, oil). In six districts (Abyyskiy, Momskiy, Ust-Yanskiy, Zhiganskiy, Srednekolymskiy and Verkhnekolymskiy), bituminous coal is mostly used. In Eveno-Bytantayskiy district some individual residential settlements are yet heated with firewood. Regarding fuel deliverability, the most inaccessible regions are Ust-Yanskiy, Verkhoyanskiy, Momskiy and Abyyskiy.

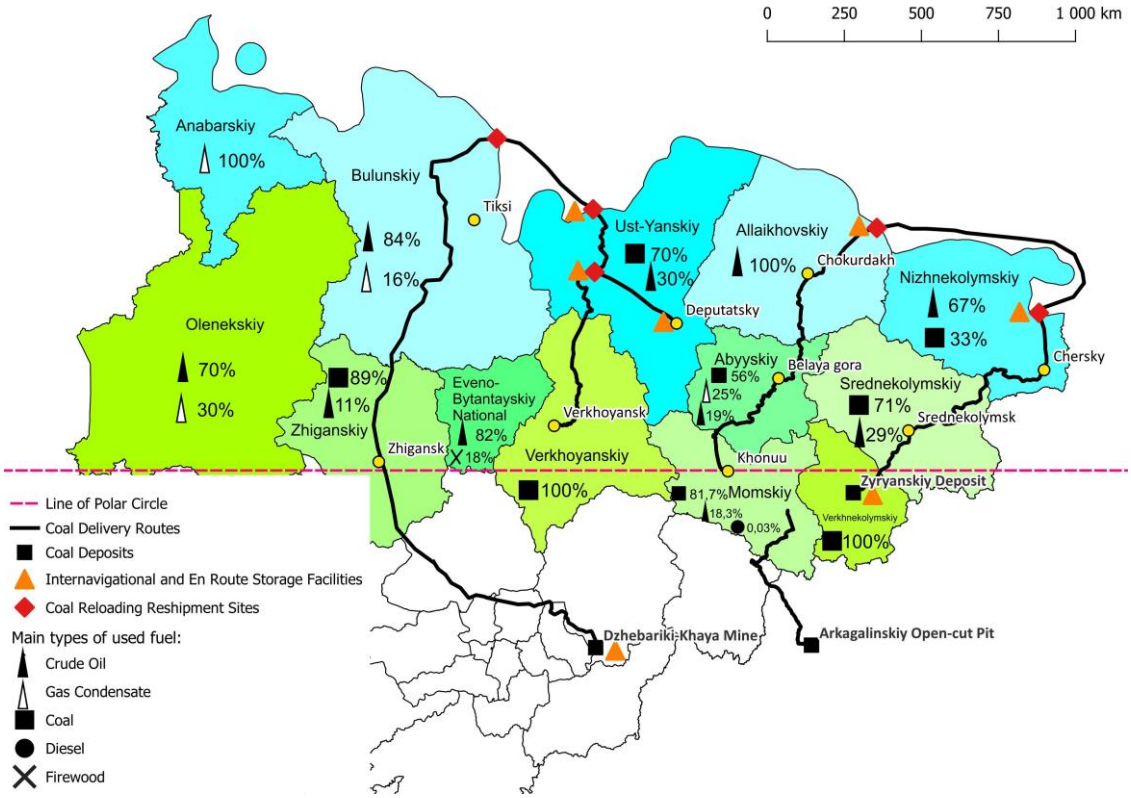


Fig. 1. Polar regions of RS (Ya) and common types of fuel in municipal housing economy

In 2023, the municipal housing economy in the Arctic Zone of RS (Ya) was supplied with 78 Kt of coal from Dzhebariki-Khaya Mine, 99 Kt from Zyryankskiy Deposit, 5 Kt from Sangar Coal Mining Company and 4.1 Kt of Arkagalinskiy coal from the Magadan Region. Moreover, the supplies included 57 Kt of oil, 12.2 Kt of gas condensate and 2.56 Kt of diesel fuel.

The total expenses connected with fuel-and-energy resources used in generation of electric and heat power continuously tend to increase. The overall shipment cost of fuel-and-energy resources in the Arctic Zone in RS (Ya) in 2023 totaled RUB 6816 million, including RUB 3707 million for coal, RUB 2473 million for oil and RUB 630 million for gas condensate. The volumes of fuel-and-energy resources shipped annually to every consumption point are very small, sometimes only a few dozens of tons.

Table 1. Coal shipment to polar regions of RS (Ya) for needs of municipal housing economy, Kt (as per the Committee on Pricing Policy for RS (Ya))

Consumer area/supplier	2017	2018	2019	2020	2021	2022	2023
Zhiganskiy	23.6	25.7	20.4	20.0	21.2	20.3	21.3
Verkhoyanskiy	64.4	66.8	60.6	61.2	60.9	61.2	61.4
Ust-Yanskiy	34.8	33.1	30.4	32.5	33.1	32.4	32.8
Abyyskiy	13.5	15.7	14.7	15.0	16.1	15.9	16.7
Momskiy	4.4	4.6	6.3	7.4	7.5	7.9	7.2
Verkhnekolymskiy	26.1	26.5	25.7	25.1	25.3	25.9	25.1
Srednekolymskiy	29.0	29.8	32.1	32.6	33.1	32.7	32.9
Nizhnekolymskiy	5.1	5.3	19.3	19.4	19.8	19.4	19.3
Total	200.9	207.5	209.5	213.2	217.0	215.7	216.7
Dzhebariki-Khaya open-cut coal pit	122.8	125.6	81.1	63.5	62.0	61.9	60.3
Zyryanskiy open-cut coal pit	76.2	79.8	94.1	95.8	94.7	93.2	95.2
Arkagalinskiy open-cut coal pit	1.9	2.1	3.9	3.8	3.8	3.8	3.8
Sangar open-cut coal pit	–	–	30.4	50.2	56.5	56.8	57.4

According to the Committee on Pricing Policy for RS (Ya) in 2023, the cost of coal, including shipping and transport to the above-listed regions, totaled 7.000 RUB/t (Nizhnekolymskiy) and to 25.000 RUB/t (Ust-Yanskiy).

Percentage of coal in the structure of its cost at a consumption point in the most hard-to-reach areas is only 15–20 % (Abyyskiy, Momskiy, Ust-Yanskiy and Verkhoyanskiy districts), and is 37–50 % in the other regions (Zhiganskiy, Srednekolymskiy and Nizhnekolymskiy). Only in the Verkhnekolymskiy district, the fuel cost is around 100 % as coal mining is carried out directly in this region.

Under the circumstances, there is a growing interest in coal production by local small and very small mines instead of its delivery in the Arctic. This can, for the first term, improve the energy security of the local population, maintain the social and economic development, and reduce the environmental pressure. For the efficient coal mining from local sources by small and very small mines in hard-to-supply and hard-to-reach arctic regions, it is required to work out and validate a technical approach adaptable to the regional peculiarities.

MATERIALS AND METHODS

The technical approach to validating expediency of development of local micro-scale coal deposits in the Artic is described below.

At the first stage, it is required to formulate requirements for such small-scale coal deposits and micro coal mine. At the present time in Russia, the notions of a small-scale deposit (mini, small, low-efficient) and of a micro mine, as well as their clear criteria and standards are yet an open question due to a wide variety of geological, physical and geographical and social and economic conditions of their location and functioning. The main problem is delineation and appraisal of small-scale deposits, and determination of production outputs for micro coal mines [1]. Without deciding these issues, it is

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impossible to formulate the process requirements, the licensing and taxation policies, and the social safety nets.

At the second stage, on the basis of the developed criteria, the notions of a small-scale deposit and a micro coal mine are defined with regard to social and environmental requirements.

After that, it is determined whether it is expedient to set upon development of a certain site in the hard-to-supply and hard-to-reach arctic regions.

From the final technical-and-economic calculation and after the comparison of coal costs with regard to its delivery to an end user by variants, the conclusion is drawn about the expedience of utilization of coal from the studied deposits in the arctic regions in Yakutia.

RESULTS

Russia's Strategy of Development for the Arctic Zone proposes to improve the "northern shipping" mechanism among other things "by using local energy sources and energy-saving technologies, and by modernizing power plants" [2].

Considering the extremely limited current and future volumes of consumption, and in view of the great distances between human settlements in the arctic regions in Yakutia, spotlight can only be on local generation systems and on small and extremely small capacity facilities using various types of fuel-and-energy resources.

Evaluation of the efficiency of local coal mines participating in the "northern shipping" uses two approaches. The first approach is connected directly with the fact that a mine to function even in remote and inaccessible areas of the North should be estimated by the commercial efficiency criteria [3, 4]. A set fuel cost should cover both the operating expenses and the capital expenses, including mineral exploration. In the meanwhile, the government rejects the mechanisms of the direct and indirect effect, which leads to treating small and very small open pit coal mines in the North similarly to the common mines in the central belt of Russia [3, 4]. It is typical of the second approach that estimation of small open pit coal mines which supply decentralized regions should take into account social, economic and environmental effects. For this reason, making a profit is not a primary purpose for such business units [5–7].

When addressing issues of fuel supply of the arctic regions, lavish attention is paid to small nuclear power plants, and to renewable (wind, solar) and nonconventional sources of energy. However, it is untimely to speak about waiving hydrocarbon fuel in the conditions of extreme nature and harsh logistics, at least in the medium term. This is connected with the fact that in the presence of cheap, less risky and lower capital-intensive sources of power supply in the Far North, for example, coal deposits suitable for open pit mining, the latter should be preferred [8, 9].

First, it is required to formulate special standards for small-capacity coal mines. To this effect, it is attempted to include the category of a micro coal mine in the existing classification of coal mines.

It is necessary to represent peculiarities of a mine and to include such criteria as production output (annual), mineral resources (reserves) and useful mineral quality (ash content, grain size composition, etc.). This is a challenging problem, especially at the

point of determining standards and criteria of a small-scale deposit. Typization of such deposits should take into account the types of raw materials, as well as the relevance and conditions of the subsoil use in the Arctic.

Table 2 describes the criteria proposed by the authors for defining small-scale deposits and small-size mines for the Republic of Sakha (Yakutia) by types of minerals.

Table 2. Definition criteria of small-scale deposits and micro mines (Arctic Zone of the Republic of Sakha, Yakutia)

<table>
<tr><td rowspan="2">Mineral</td><td>Small-scale deposit</td><td>Micro mine (coal)</td></tr>
<tr><td>Resources (reserves)</td><td>Annual production output</td></tr>
<tr><td rowspan="3">Coal (bituminous, lignite), peat, bituminous shale</td><td>To 300–500 Kt</td><td>20–50 Kt</td></tr>
<tr><td rowspan="2">Best coal quality sites (ash content not higher than 15 %, moisture lower than 20 %, etc.)
Maximal heat value, MJ/kg
Simple geological conditions</td><td>Manpower
15–50 men</td></tr>
<tr><td>Coal supply – exclusively on a municipal scale</td></tr>
</table>

In the context of mineral mining in the Arctic, a micro coal mine is a mine with a coal output capacity to 50 Kt/year, which functions in hard-to-reach, hard-to-supply and no-transport areas with harsh climatic and physical and geographical conditions, with the prime purpose not to make a commercial benefit but to enhance the energy security of population and to maintain the social and economic development and the environmental safety of the territory. Such business units have a higher social value.

Meanwhile, the cost of coal produced by small open pit mines can be high because of low production outputs and high initial expenditures.

The cost should be set such that mines operate smoothly, in the conditions of minimized economic risks, with covering both operating and capital expenses connected with exploration, and with making a profit sufficient for the development of production. Despite the possibility to reduce expenses, simplify shipping and to enhance the energy security of population, the risks of potential unprofitability of such mines in the remote arctic areas remain high.

In the world practice, small mining companies, including artisanal, are widely attracted in mineral mining, including coal [10, 11]. Experience of such companies in the USA, China, India, Pakistan, Mongolia and in other countries shows that such business units can only be established with a view to satisfying local needs by developing limited areas of mineral deposits in inaccessible regions which are uninspiring for large companies because of a low scale of production. In underdeveloped countries, coal mining is carried out using primitive technologies and tools, sometimes using manual work of women and teenagers. For instance, in the remote mountainous regions in Pakistan at the Afghanistan border, coal mining is exclusively implemented by such small companies (Reshit or Pamir) [12].

For small and very small open pit mines operating in the arctic zone, making a profit may not be a primary goal. It is quite possible that mines operate at the verge of commercial viability or even unprofitability in the competitive environment given limited resources. Essentiality and expediency of such mines is governed by the requirement to enhance the energy security and efficiency of a region, create new jobs,

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to ease social strain, etc. Such small mines and small deposits have a social value in a greater degree rather than a commercial importance.

It should be constantly remembered that the main point in creation of mines of a limited capacity is not the increase in taxes, which even may be partly uncharged, and not the reduction in social strain through the creation of 15–20 new jobs, which is not a prime importance in the regions with the population of 3–5 thousand in size. The main thing is that local coal is available for the local consumers, and that the energy security of the territory and population enhances due to essentially simplified flow charts of fuel delivery from other regions. Creation of small mines allows rapid response to any alteration in local fuel-and-energy chains.

DISCUSSION

In the conditions of harsh market and information onslaught from supporters of other types of energy, scanty attention is paid to the issues of creation and efficient performance of mines, including coal, of small and very small capacity, aimed at development of available sources of fuel in the arctic regions. This situation exists despite considerable coal reserves available in the North and in the Far East of Russia, in registered coal deposits that feature reliable geological exploration, not very difficult geological conditions, suitability for mining using the open pit method, and proximity to the main areas of consumption. Although the cost of the local fuel is lower than the imported fuel has, which is critical for the inaccessible areas, the use of local coal becomes increasingly more problematic in the era of oil dictate and overassessment of other types of energy.

A new micro coal mine to be created in the arctic zone of Yakutia within not less than 2.5–3.5 years assumes attraction of the initial capital in amount of RUB 150–200 million and more in case of additional geological exploration required. Even these financial resources, which are comparatively small by standards of average-size open pit mines, can be unbearable in view of the current risks of very high dependence on state contracts. Similar to large mining companies, small mines have to arrange 18 to 40 obligatory readings and approvals of exploratory design paperwork mostly on the local and regional scale, and many documents need to be extended or renewed annually. On this basis, it is critical to simplify handling procedure for permits, licenses and approvals for mineral mining when creating small mines to produce local coal in remote and isolated areas in the Arctic.

The accomplished calculations show that in case of development of the Tikhonskoe field site on the bank of the Indigirka River in the Momskiy district, the coal price for the close-in settlements can be reduced 2.5 – 3.0 times as compared with the current prices of the imported Zyryanskiy deposit coal. In case of the substitution of the imported coal at the planned production output and consumption of local coal, expenses of the municipal budget can lower by 20–50 and more per cent. In money terms, the saving can reach RUB 150–200 million.

The delivery route being shortened, coal dusting and spillage are also reduced, and no damage is inflicted on the environment and inhabited localities along the route of coal delivery. Dust-free shipping of coal (in big bags) should become a mandatory standard even in short-route deliveries in the arctic zones.

Even if the price of coal from new deposits in the close neighborhood of the main consumption points is equal to the price of the imported fuel (e.g. 14.000 RUB/t versus 140 USD/t for the Momskiy district in 2024), implementation of the proposed project is wise nevertheless as in this case the top priorities are the energy security, social and economic efficiency and reduced ecological load. Regarding the discussed arctic areas in Yakutia, these benefits are even higher owing to the decrease in quantitative and qualitative loss of fuel along delivery chains, and thanks to the improved availability of coal for its consumers. This approach conforms with the philosophy of market economy and has the right to exist in the arctic husbandry zone.

CONCLUSION

The study has demonstrated the necessity of coal mining in the Arctic Zone of the Republic of Sakha (Yakutia) in the currently prevailing conditions as the expenses of mines which supply human settlements in the Arctic grow annually, and the high cost of transportation of coal increases the price per ton. Local coal mining is one of the trends of enhancing the energy security of the arctic regions in RS (Ya) and of social and economic maintenance.

The criteria and standards of small-scale coal deposits and micro coal mines are defined. The article introduces the notion of a micro coal mine for the arctic regions, which is limited to a coal output up to 50 thousand tons, and which has a greater social value than commercial importance, and the creation of a micro coal mine is connected with the energy security of population, and with the social, economic and environmental maintenance of the territory.

The proposed approach can promote creation and functioning of new coal mines in the Arctic Zone of RS (Ya). This, in its turn, can and will enable reduction in time between coal extraction and consumption, decrease in the quantitative and qualitative losses of the fuel, simplification of coal transportation and storage flowsheets and improvement of operation of local fuel-and-energy facilities.

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COST-BENEFIT ANALYSIS OF DIGITALIZATION OF PROCESSES IN CONTROL INSTITUTIONS

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ABSTRACT

The control institutions of each country are the leading organizations that deal directly with citizens and businesses. These institutions are strongly affected by the digitization of processes and the introduction of new technologies. All these innovations are aimed at improving the quality of implementation of control activities on the one hand, and on the other hand at supporting the interaction of control institutions and citizens, respectively legal entities. The article examines the problems regarding the application of the "costs - benefits" method in the control institutions in the digitalization of processes. Here, accordingly, the innovative thing in this article is that the digital projects in the control institutions are tested from the point of view of the static project evaluation methods and the dynamic project evaluation methods aimed at the digitalization of processes. A significant problem will be presented in the report, but due to the limitations of the development, it will not be possible to develop and explore it fully. The most important points of the cost-benefit model will be highlighted here.

Keywords: control, digitalization, control institutions, digitalization of processes

JEL classification: M41, M42, M38

INTRODUCTION

The methods of analysis, including financial analysis, have not yet been practically established to establish facts and results for control institutions. The introduction of new technologies and the implementation of the digital transformation of the processes in the control institutions pose another challenge to the control institutions in modern conditions. It can be assumed that there is an overlap of problems in the control institutions, as in recent years the institutions have turned their attention to achieving better sustainability through digitalization of processes. In Bulgaria, digital processes in control institutions began to be gradually implemented from the end of the 19th century and continue even now. Unfortunately, the control institutions in Bulgaria have not yet reported the benefits of the digitization and digital transformation carried out so far, while at the same time, they set long-term goals in their long-term strategic plans for new technological changes to processes, without sufficient clarity as to whether it is about improving existing processes or implementing new ones. The control institutions are the main instrument through which all state goals are achieved aimed at the protection of the environment, namely: establishing and controlling the effects of globalization of natural resources; proper waste management; stimulating and supporting enterprises that apply recycling technologies; full implementation of environmental monitoring; strong enforcement and control of compliance, and enforcement of measures against environmental pollution. Since the objects of control are becoming more and more comprehensive, specific, and present in a meaningful

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aspect of the novelties of the time, in this regard it is essential that the control institutions also meet the modern conditions and requirements, which means that they are technologically very well secured. This poses many questions, the answers of which cannot be sought in only one study, but from the point of view of this article, the main purpose of the study is aimed at investigating the problem of the costs and benefits of the digitization of the processes in the control institutions, through the application of the financial analysis. To achieve the stated goal, the following tasks are set to be solved:

1. Determining the applicability of static evaluation methods when evaluating digital projects in control institutions.

2. Characterization and determination of the applicability of methods for dynamic assessment of digital projects in control institutions.

The reasons for the topicality of the article are that:

1. Enterprises cannot independently achieve the expected environmental results if there are no well-functioning control institutions to guide them on how exactly they should achieve the state's environmental goals and objectives.

2. The control institutions also have their importance in the eco-equilibrium of the state administration, which is aimed at improving the ecological environment of the state.

EXPOSITION

Every country strives to have and achieve a very good Environmental Economics. Many of the studies emphasized the possibilities, quality, and activity of the development of enterprises and their role in achieving a good state economy of the environment. Here we put another focus of the research, namely on the role of the control institutions, as the main bodies with the help of which it is regulated and influenced to achieve the established state requirements for a good environmental economy. It should be taken into account that with the new economic-ecological factors that influence the development of state units, new control objects appear and arise. To properly control these control objects, it is necessary to change the entire methodological toolkit of the control institutions according to the specifics and characteristics of the new control objects.

Until now, Bulgaria has invested quite a bit of money from the state budget to support the control institutions in the digitization process, but despite this, according to a study by the Institute of Public Administration, using data from the European Commission's annual study - DESI (Digital economy and society) for 2018, Bulgaria is placed in one of the last places in all 5 main indicators, through which the development of the EU member states in terms of digitalization is monitored: connectivity, human capital, the use of the Internet, integration of digital technologies and digital public services. In the Index, our country is in one of the last places in terms of development of basic and advanced skills, as the indicators are related to the use of the Internet and the availability of digital competencies.

In the newly approved program of the EU - "Digital Europe", for the period 2021 - 2027, 9.2 billion euros have been provided, and additional funds for 28 billion euros have also been allocated, directed as costs for digitization, to return Europe as a leader "on the world digital stage and for citizens and businesses to feel the real benefits of

digital transformation". infrastructure involves not only citizens, and companies, but also control institutions.

In the control literature, the methods are studied and tested from the point of view of their application, as methods of carrying out control. Control methods are aimed at determining how to influence the corresponding control object, and thus are aimed at the implementation of control technology. ([1], [2], [3], [4] and [5]). Due to the specificity of the objects, the presence and application of different methods of control can be explained. In this study, we focus our attention not on the control objects and how they change over time, but we will examine some processes that have started in the development of the control institutions in Bulgaria, but the effect of their impact has not yet been established. The scope of the study includes the digital processes that are introduced in the control institutions considered as long-term investment plans. The problem we put in the foreground is to examine the costs and benefits of these digital processes and transformations in the control institutions themselves.

METHODS

The first method we present in this study is the static method, through which the static assessment of the effect of digital projects in control institutions is derived. A weakness of the static method is that it does not consider the value of money over time and gives an undiscounted assessment of the completed projects.

The digitization of control institutions, as a process, was carried out with the help of various projects aimed at the public (state) sector. ([6]; [7]; [8] and [9]). These projects are aimed, on the one hand, at the digitalization of all activities carried out by the control institutions, and their effectiveness is associated with increasing the economic sustainability of the control institution in front of citizens and society, as well as with the rational use of budgetary resources. Regarding the ecological effect that these digital projects have, they significantly reduce the use of paper and optimize the time for the implementation of control activities. These effects are most pronounced over time, by reducing the negative effects on nature as a result of paper production or by reducing the additional manual processing of information.

Cost-benefit analysis is a method of comparing different alternatives by systematically evaluating their advantages and disadvantages. It can be used to compare completed or future courses of action or to evaluate their advantages and disadvantages. Cost-benefit analysis has two main uses:

1. To determine whether an investment is good, establishing whether and by how much its benefits exceed the costs.

2. To serve as a basis for comparison between several investments (or other decisions), comparing the total expected costs with the total expected benefits of each of them.

Since 1990, cost-benefit analysis has been used in the Cohesion Policy, and since 2000, it has been required to be applied in the implementation of every single project. The method is applied to absolutely all investment projects, both from the private sector and from the public sector.

The first method gives the most general presentation of the project, as even its goal-setting reveals. This method includes the following methods, namely the "review" method, the "payout" method, the method of receipts per BGN 1 expenses, etc. The

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static method, as much as it has its shortcomings, is applied in practice, because it presents the tasks of the project, gives a technical and economic analysis of the project, and also presents the sensitivity of the project and the impact of the project on various risks.

The second method, calculates the value of money over time. In the second method, the so-called present value. In this second method, the most serious problem is the determination and analysis of costs and benefits "the participation of many components representing "benefits" and, respectively, "costs" with the real impossibility of accounting for all of them, or at least to a sufficient extent" [10]. Therefore, when using this approach, it is necessary to follow one basic principle - the introduction of a single unit of measurement. [11], [12] , [13] and [14].

When calculating the present value (NPV) of the project, the following formula is applied:

$$NPV = (Bt – Ct)/(1+R)t$$

Where:

Bt – benefits of the project for period t

Ct – project costs in period t

R – public discount rate (SDR)

t – number of periods/years useful life of the project

Each project is oriented towards needs that cannot be met by undertaking any other project from the relevant set. For these projects, the decision rule is: "Any project for which NPV > 0 is approved". This is because virtually any project with a positive NPV makes a positive contribution to public welfare.

RESULTS

When testing the digital projects that have been approved and operating in the control institutions, it should be taken into account that: 1. When in the entire set of alternative projects there is only one project for which NPV > 0, the choice rule for independent projects is applicable. 2. when, however, in the set of mutually exclusive project alternatives, there is more than one project with NPV > 0, it is chosen according to the rule: "The project with the highest positive NPV is approved". We are testing 2 control institutions, which for the period 2000-2023 have implemented 2 digital projects. During this period, the projects were implemented in separate sub-periods, namely from 2000 to 2008 and from 2009 to 2023. The benefits of these projects are measurable, through the monetary value, and not measurable. The benefits of the first type are easier to measure, in contrast to the benefits of the second type, since they cannot be represented directly in terms of value, but only through specific qualitative positive changes. Such qualitative positive changes are improved reputation, morale, improved quality, increased readiness, and security.

For the first control institution, the present value of the project NPV is 2.53 units for the period from 2000 to 2008, for the same control institutions for the period from 2009 to 2023, the present value of the project is 1.64 units, i.e. there is a change in the present value because the benefits of the project are not so significant and the costs of implementing the project are significant.

For the second control institution, the results are as follows, for the period from 2000 to 2008, the present value of the project is 3.56 units, and for the period from 2009 to 2023, the present value of the project is 4.98 units. The increase is a result of the benefits that the respective project has, especially the environmental benefits. Environmental benefit assessment is a systematic integrated assessment of the positive and negative impacts of the project on the natural environment. Environmental impact assessment ensures that the project is aimed at helping society and achieving ecological balance.

CONCLUSION

Based on everything stated up to this point, it should be assumed that the cost-benefit method is applicable in the control institutions, and with its help, the impact and influence that the relevant project has on the environment can be determined. From the point of view of the control institutions, the digitization of the processes affects the environment, as the way of carrying out the control activity is significantly changed, the use of technologies changes the work process and changes the way of applying the available resources. The cost-benefit model is good for long-term rather than short-term goals. With the help of this model, the effect of the actions taken can be reported. Digitization should not be considered only in one direction, namely only towards improving the technological environment. We accept that digitalization gives the opportunity to improve the ecological environment and ecological working conditions. Of course, every activity has its own risks, but when digitalization is aimed at good intentions, then the effects that will be reported through it will be positive. Digitization always takes more resources, but the benefits it gives are not only material, but also intangible. Intangible benefits are the most difficult to account for, this will be the subject of further research and studies.

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CROP PROTECTION COSTS AND FARMING INTENSITY IN LATVIA

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ABSTRACT

Nowadays, sustainability has become the core concept affecting the public perception of economic development and natural resource management all over the world. Although intensification of agricultural practices is typically viewed as a way to achieving and retaining food independence at national and supra-national levels, there are concerns about its potential negative impact on biological diversity, natural habitats, healthy ecosystem and resilience to climate change. As a result, intensive farming might be regarded as unsustainable, damaging and environmentally unfriendly mode of agricultural production. This study aims to conduct a comparative analysis of the trends in intensification of agricultural practices adopted by crop farms of various economic sizes and specialization in Latvia since its accession to the EU in 2004. Our calculations are based on information obtained from SUDAT – a national system of data collection in Latvia that constitutes an integral part of the EU Farm Accountancy Data Network (FADN). Statistical data are adjusted for inflation and input price fluctuations using the price indices of the means of agricultural production. In our analysis, crop protection costs are used as an environmental indicator of natural resource and biodiversity conservation. Results provide evidence of high heterogeneity in farming intensity in Latvia where sustainable crop farming coexists with conventional farming based on intensive production technology.

Keywords: crop farms, farming intensity, FADN, Latvia

INTRODUCTION

While a rise in world population creates a strong demand for various agricultural commodities, the provision of additional agricultural land is limited and further spread would be possible only at the expense of wildlife habitats. As about 35 % of crop yield is lost to pre-harvest pests, it is unsurprising that not only higher usage of pesticides becomes a precondition for higher productivity of agricultural production and further reduction in yield losses, but also pesticides remain a powerful tool for bringing socio-economic benefits such as raising living standards and alleviating food poverty across countries. Rapidly increasing costs of hired and self-employed labour (both in real terms and in relation to pesticide prices) become an insurmountable obstacle to applying labour-intensive pest-control methods. As a result, over the years, the amount of pesticides used in the world has surged 15-20 times [1]. However, misuse of energy inputs – both direct (e.g., fuels and oils) and indirect (e.g., pesticides and fertilisers) are considered as environmentally harmful practices [2]. Consequently, a steady increase in the amount of consumed pesticides collides with the prime target of achieving sustainability and following environmentally friendly agricultural practices. This study attempts to fill the gap in the literature and conduct a comparative analysis of the trends

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in intensification of agricultural practices adopted by crop farms of various economic sizes and specialization in Latvia since its accession to the EU in 2004.

SUSTAINABILITY AND PLANT PROTECTION

Over the last century the risk of crop loss has been mitigated by using various plant protection products, including pesticides whose usage in agriculture has considerably increased since the early 1960s. Simultaneously, the average yield of wheat, rise and maize has more than doubled [1]. Although plant protection products can improve farm's profitability by reducing labour and machinery costs [3], in the long term the consumption of pesticides increases because of herbicide-resistant weeds, resurgence and secondary pest outbreaks. The "pesticide treadmill" offers two responses: a continuous rise both in the frequency of treatment and the amount of less effective pesticides as well as the development of new more effective pesticides. However, it does not provide a solution to declining biodiversity, environmental contamination and issues with public health [1].

The Farm to Fork Strategy is the core of the European Green Deal that responds to formidable challenges of agricultural sustainability, promotes environmentally-friendly food systems and rewards farmers' transition to sustainable practices. This new comprehensive approach suggests that by the year 2030 the usage of chemical pesticides in the EU agriculture should be reduced by 50 % whereas at least 25 % of the EU's agricultural land should be used for organic farming. However, this sharp curtailment might be problematic. Although on average agriculture in Latvia is considerably less intensive compared with the majority of developed Western countries, some farms focus on producing high yields. Thus, plant protection practices have major impact not only on environment, food security and safety but also on economic efficiency of farming as they are of much greater magnitude in those areas of agricultural production that generate substantial profit [4].

The proportion of plant protection costs differs across countries and on farms of different size. Although pesticides constitute approximately 7-8 % of total farm production costs in the EU and 5-6 % of total farm inputs in the USA, their proportion fluctuates between 11 % in France and 4 % in Slovenia [1], [5]. In Poland, on crop farms with the lowest production intensity and the smallest amount of direct costs per 1 ha the costs of plant protection products vary from 13.6 to 53.8 % of direct costs incurred by crop farms with the highest production intensity [6]. As nowadays excessive usage of pesticides is widespread [7], [8], Jacquet et al. (2011) argue that their possible reduction by 30 % would not have a negative impact on farmers' income [9].

METHODS

As the analysis of micro-level sustainability indicators for agriculture frequently is based on data available in the EU Farm Accountancy Data Network (FADN) [10], we use statistical data for 2005-2022 (the period after Latvia's accession to the EU in 2004) obtained from *SUDAT* (*Saimniecību uzskaites datu tīkls*), i.e. FADN's integral national part in Latvia. FADN is the primary source of comprehensive micro-level data on the financial and economic performance of farms classified according to their specialization, size and geographical region. The FADN sample size widely differs

between countries and in Latvia it consists of 1000 farms. The economic size of a farm is measured as the total Standard Output of the farm expressed in euro[1].

Skarżyńska et al. (2016) suggest that the intensity of agriculture is measured using the amount of expenditure per area unit [6]. Although the environmental sustainability and performance of farms typically is assessed using numerous multidimensional sustainability tools, in this paper we use a single indicator "crop protection costs[2] per ha of the total utilised agricultural area (UAA)" that other scholars have employed either as a standalone indicator or as a part of a complex set of weighted indicators [2], [11], [12], [13]. At present, farm-level costs of crop protection are the only FADN indicator for the usage of pesticides. However, the correlation between pesticide costs and pesticide usage, intensity or toxicity is particularly weak for those farms where the actual treated area may be smaller than the total farm area (e.g., livestock keeping farms) and, as a result, actual crop protection (incl. pesticides) costs per ha are much higher than the above indicator shows. For other types of farms (e.g., arable farming such as field crops) this difference is less significant and crop protection costs can approximate to an ecological indicator [13].

To adjust numbers for inflation and input price fluctuations, crop protection costs were recalculated using Eurostat price indices of the means of agricultural production (input), specifically, for plant protection products and pesticides, in Latvia. Thus, costs are constant in 2005 prices. Adjustment for inflation identifies the major trend but does not differentiate between prices in the same category of inputs (for example, between a pesticide X and a pesticide Z). Thus, the exact amount of inputs (e.g., pesticides) used in a particular year cannot be calculated. In contrast to field crops farms, no (or limited) data are available for horticulture, permanent crops and mixed cropping farms of different economic sizes in Latvia. Therefore, only average values were used in calculations for these types of farming.

RESULTS AND DISCUSSION

Although the proportion of crop protection costs in specific crop costs increased with the economic size of farms, on smaller farms this proportion varied more widely compared with larger farms (Table 1; Figure 2 [A] in Appendix). On farms with the total standard output over EUR 100 000 the above proportion was higher than on average. Though in the second half of the analysed period the proportion of crop protection costs started consistently increasing on most farms, in 2022 it plunged to the level preceding this rise.

Crop protection costs per ha of UAA also went up with the economic size of farms and on average a difference between costs on the largest and smallest farms exceeded 14 times. While cost fluctuations decreased with the economic size of farms whose total

[1] For detailed information on the concept of the Standard Output and its calculation methodology, see https://fadn.pl/wp-content/uploads/2021/11/RICC-1750-Standard-Results-v-Sep-2020.pdf. Economic size groups are as follows: (1) 4 000 - < 15 000 EUR; (2) 15 000 - < 25 000 EUR; (3) 25 000 - < 50 000 EUR; (4) 50 000 - < 100 000 EUR; (5) 100 000 - < 500 000 EUR; (6) >= 500 000 EUR.

[2] In addition to pesticides, these costs also include different kinds of plant protection products (e.g., traps, baits, bird scarers, anti-hail shells, frost protection).

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standard output was below EUR 500 000, variation surged on those farms whose economic size was above this threshold (Table 2; Figure 2 [B] in Appendix).

Table 1. Descriptive statistics of the proportion of crop protection costs in specific crop costs on farms of different economic sizes in Latvia (2005 - 2022)

Descriptors	Average	4 -< 15	15 -< 25	25 -< 50	50 -< 100	100 -< 500	>= 500
Average 2005-2022	0.20	0.10	0.12	0.14	0.18	0.22	0.25
Max	0.25	0.14	0.18	0.18	0.21	0.27	0.30
Min	0.16	0.07	0.07	0.10	0.15	0.19	0.19
Coef. of variation	0.13	0.22	0.21	0.14	0.10	0.09	0.11
Coef. of oscillation	0.43	0.74	0.86	0.54	0.34	0.36	0.43

Table 2. Descriptive statistics of crop protection costs (EUR) per ha of UAA in constant input prices of 2005 on farms of different economic sizes in Latvia (2005 - 2022)

Descriptors	Average	4 -< 15	15 -< 25	25 -< 50	50 -< 100	100 -< 500	>= 500
Average 2005-2022	33	5	10	14	25	53	72
Max	54	9	14	21	34	68	102
Min	15	3	7	11	16	36	46
Coef. of variation	0.30	0.31	0.23	0.19	0.19	0.17	0.20
Coef. of oscillation	1.18	1.03	0.78	0.75	0.76	0.62	0.78

Although the major trends identified on field crops farms were similar to the ones described above, there were a number of peculiarities. On average, the proportion of crop protection costs in specific crop costs on the largest field crops farms was twice as large as the one on the smallest farms. The variation of this proportion increased with the economic size of farms in the group whose total standard output was over EUR 100 000 and decreased in the farms with smaller total standard outputs (Table 3; Figure 2 [C] in Appendix).

Table 3. Descriptive statistics of the proportion of crop protection costs in specific crop costs on field crops farms of different economic sizes in Latvia (2005 - 2022)

Descriptors	Average	Average (field crops)	4 -< 15	15 -< 25	25 -< 50	50 -< 100	100 -< 500	>= 500
Average 2005-2022	0.20	0.24	0.14	0.18	0.18	0.21	0.24	0.28
Max	0.25	0.28	0.22	0.26	0.21	0.26	0.29	0.34
Min	0.16	0.17	0.09	0.12	0.13	0.19	0.17	0.22
Coef. of variation	0.13	0.12	0.24	0.20	0.13	0.10	0.12	0.14
Coef. of oscillation	0.43	0.49	0.89	0.81	0.45	0.35	0.51	0.45

Not only did the variation of crop protection costs per ha of UAA decreased with the economic size of fields crops farms, but also a difference between costs on the smallest and largest field crops farms (Table 4; Figure 2 [D] in Appendix) was not so fundamental as between the Latvian farms in general (Table 2; Figure 2 [B] in Appendix) and made up approximately six times. In a similar manner, on average crop protection costs per ha of UAA on the largest field crops farms were approximately 1.6

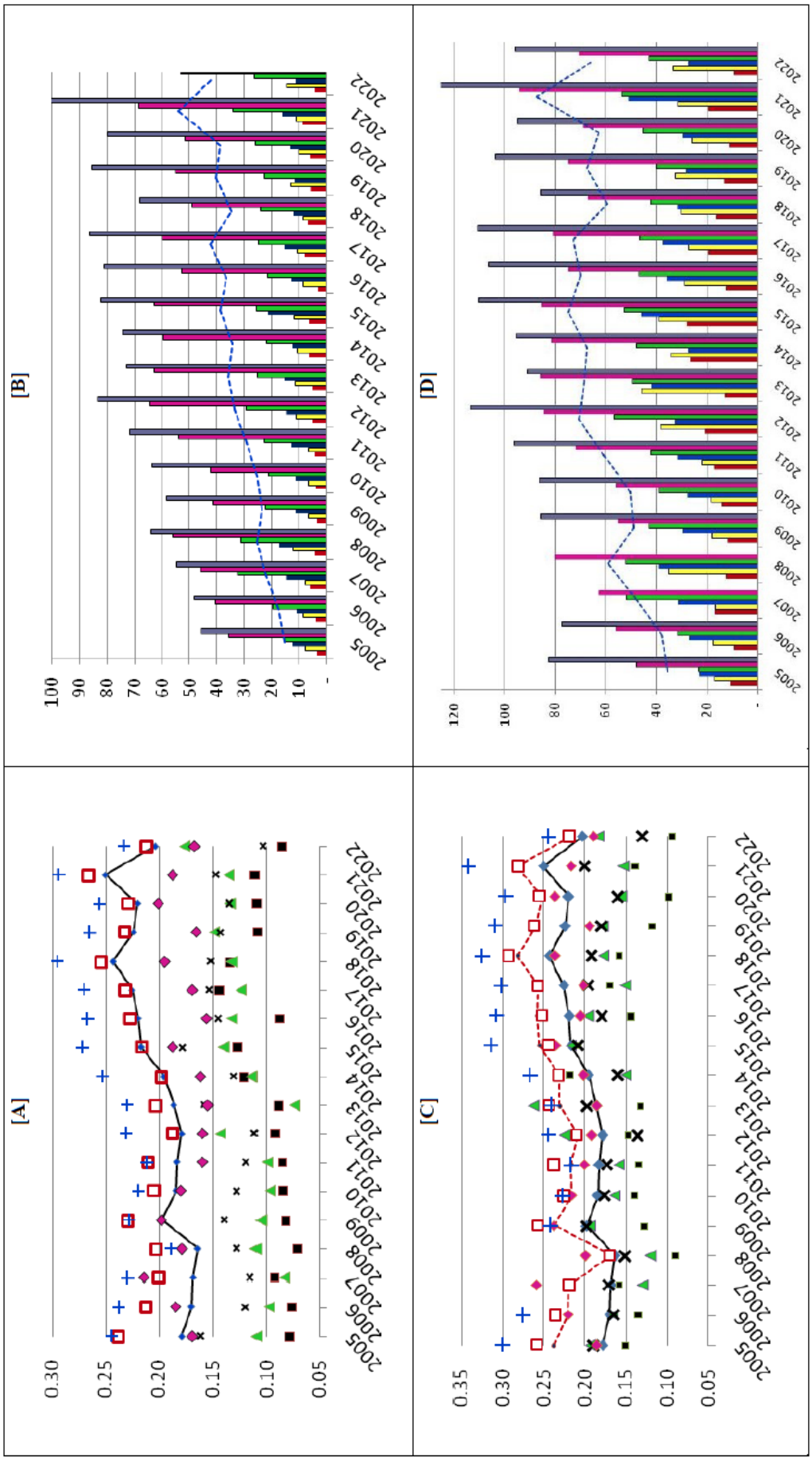


Figure 2. The proportion of crop protection costs in specific crop costs [A and C] and crop protection costs per ha of UAA in constant input prices of 2005 [B and D] on farms of different economic sizes [A and B] and field crops farms [C and D] in Latvia (2005 - 2022)

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times higher that on the average field crops farm whereas on the Latvian farms this difference constituted 2.2 times. Overall, our results are consistent with the trend identified in Poland [14], [15] where pesticide protection costs per ha of UAA increase with farm size and on large winter wheat farms (over 300 ha) they are more than 3.2 times higher compared with small farms (up to 10 ha). In contrast, in China this correlation between costs and farm size is negative [16].

Table 4. Descriptive statistics of crop protection costs (EUR) per ha of UAA in constant input prices of 2005 on field crops farms of different economic sizes in Latvia (2005 - 2022)

Descriptors	Average	4 -< 15	15 -< 25	25 -< 50	50 -< 100	100 -< 500	>= 500
Average 2005-2022	62	16	28	33	45	72	98
Max	88	28	46	51	57	94	127
Min	35	9	17	23	23	48	77
Coef. of variation	0.22	0.35	0.31	0.22	0.18	0.18	0.14
Coef. of oscillation	0.85	1.19	1.04	0.84	0.75	0.64	0.51

Horticulture farms stood out for both an extremely low proportion of crop protection costs in specific crop costs and exceptionally large crop protection costs per ha of UAA (Table 5; Figure 1). A discrepancy between these costs in horticulture and on average in the Latvian farms was particularly substantial in the years 2019 (13.7 times), 2017 (12.7 times), 2014 (10.6 times), 2016 (9.01 times) and 2020 (7.2 times). While on mixed cropping farms crop protection costs per ha of UAA were consistently below average in the Latvian farms, on permanent crops farms they exceeded average starting with the year 2014 and this difference achieved maximum in 2019-2020 (2.9 and 3.6 times). Therefore, there is no evidence of high pesticide intensity (costs per ha) on permanent crops farms in Latvia in contrast to Germany, France and Poland [13].

Table 5. Descriptive statistics of the proportion of crop protection costs in specific crop costs and crop protection costs (EUR) per ha of UAA in constant input prices of 2005 on farms of different type of farming in Latvia (2005 - 2022)

Descriptors	Proportion			Costs per ha of UAA		
	Horticulture	Permanent crops	Mixed cropping	Horticulture	Permanent crops	Mixed cropping
Average 2005-2022	0.03	0.26	0.14	187	48	18
Max	0.05	0.50	0.22	553	141	33
Min	0.01	0.09	0.07	28	5	8
Coef. of variation	0.36	0.44	0.30	0.89	0.82	0.48
Coef. of oscillation	1.36	1.56	1.11	2.81	2.81	1.41

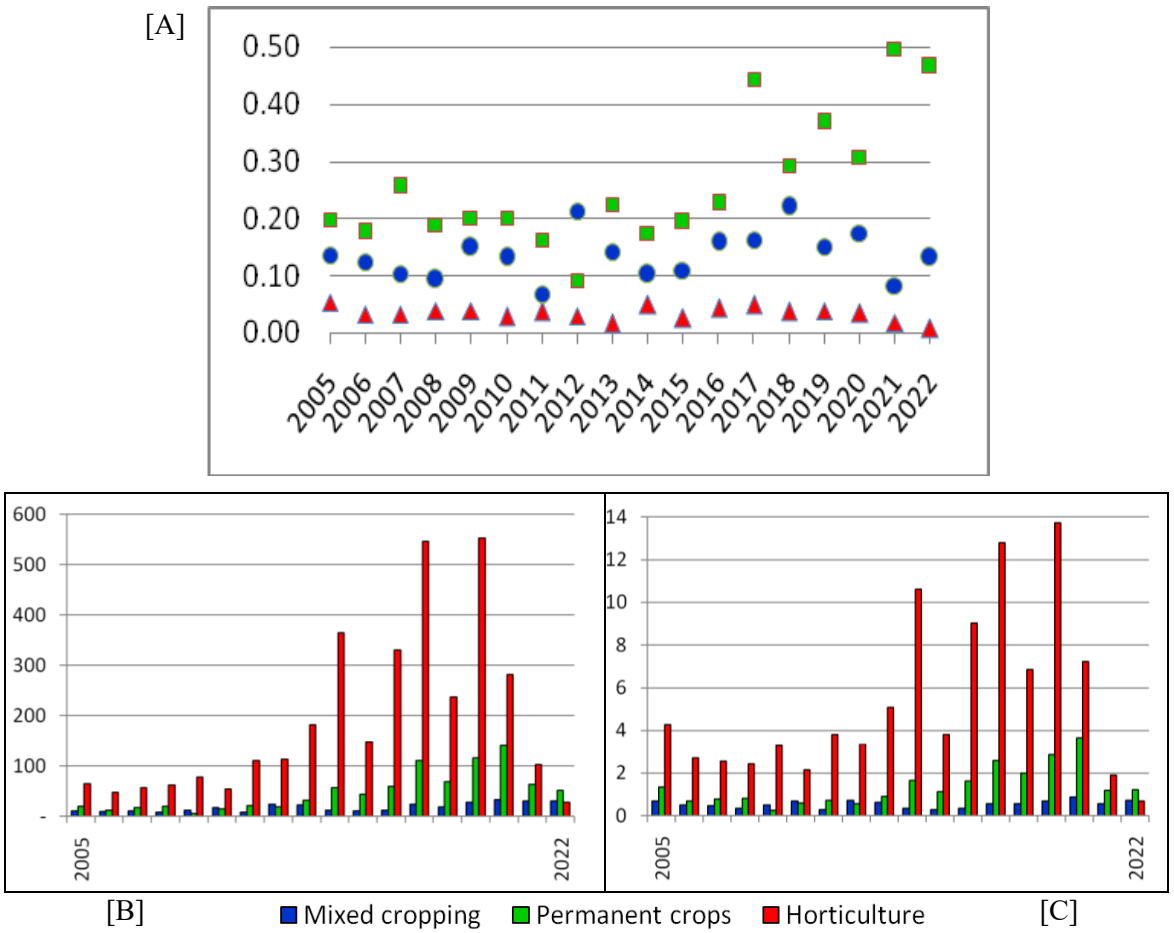


Figure 1. [A] The proportion of crop protection costs in specific crop costs; [B] crop protection costs (EUR) per ha of UAA in constant input prices of 2005 and [C] their comparison with average on farms of different types of farming in Latvia (2005 - 2022)

CONCLUSION

Our findings reveal high heterogeneity in farming intensity measured by crop protection costs across various agricultural holdings in Latvia. Similar to Poland [6], in Latvia an environmentally friendly approach such as sustainable and ecological farming coexists with conventional farming based on intensive production technology. The proportion of crop protection costs in specific crop costs and crop protection costs per ha of UAA increased with the economic size of farms. As a result, a difference between the above indicators on the smallest and largest farms was considerable. It was more profound on the Latvian farms in general compared with field crops farms. On horticulture farms, the proportion of crop protection costs in specific crop costs was very low whereas crop protection costs per ha of UAA were exceptionally large and in some years costs were 12-13 times higher than on average on the Latvian farms. Unlike Germany, France and Poland, in Latvia permanent crops farms did not emerge as intensive pesticide users compared with other farms.

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CUSTOMER RELATIONSHIP MANAGEMENT IN LATVIA

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ABSTRACT

Understanding the nature and role of customer relationship management (hereinafter CRM) is an important prerequisite for business success. A customer requires the company to adhere to certain quality standards as well as affects the performance and management of the company. Customer relationships could be managed and developed to attract new customers and increase business profitability and customer loyalty. The customer is the most valuable asset of a company that helps to achieve goals set by the company. In Latvia, the need to view customer relationships as important in business management is understood only in some industries and by the segment of large companies, and problems with customer relationship management in companies have not been sufficiently researched. Digital transformation, personalized customer experiences, the use of mobile devices, the ability to integrate various management systems into a company, artificial intelligence and analytical tools shape trends in customer relationship management. The new trends and challenges increase the role of customer relationships in business process management in almost every industry and any company. **Research methods.** The research employed the monographic method, logical construction as well as analysis and synthesis. **Research period.** The data were analysed for the period from 2018 to 2022. The research analysed the division of customers into classes and average purchases for the period 2019-2021. The sources of information used: specialist economic literature, research documents and scientific conference papers, internal company data on economic activity and data from a customer database. In Latvia, there is no unified accounting for and no information about companies that have developed and implemented CRM in their operations; therefore, the research summarized the legal framework for customer relationship management in Latvia and analysed the experience of a company in managing customer relationships.

Keywords: customer relationship management, indicators, value

INTRODUCTION

Nowadays, customers mean much more to a company than just economic indicators. Currently, customers represent the main value and priority of any company. Considering a customer to be a value, it is important for companies to establish long-term relationships with their customers; however, before the company develops and introduces customer relationship management, it needs to understand the concept and purpose of such relationships, as well as the ways to properly implement it to achieve the desired results. **The research aims** to perform an analysis of customer relationship management in Latvia. **The following specific research tasks were set:** 1. To give insight into the

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theoretical principles of customer relationship management and factors therein; 2. To analyse the legal framework for customer relationship management in Latvia. 3. To analyse a company and identify prospects for the development of customer relationship management therein. **Research methods:** the following general methods were employed: monographic, statistical analysis, logical construction, analysis and synthesis.

Research results and discussion

The indicator of application of the CRM approach and tools in business directly relates to overall company growth. In their research, Kristiani (2021), Carr (2018), Linina (2018) and Payne (2005) have emphasised the role of customers in achieving the goals of the company and concluded that there are problems with the activity of entrepreneurs to develop CRM as a component of the general strategy for the company and the ability to use the CRM system as a strategy implementation tool. According to various authors, the application of the CRM approach and tools is associated with many potential problems [1], [2], [3], [4].

Khana, Ehsanb, Mirzaks and Sarvards (2012) have found that it is **problematic for companies to integrate customer data** from various sources: data warehouses that meet the basic CRM requirements for detailed customer transaction data are called customer data warehouses. A company data warehouse is a centralized, granular warehouse of data from all relevant source systems, which allows for the identification of several benefits that CRM and data warehouse integration can bring to an industry. A detailed and targeted analysis of customer transactions could also be performed. All historical transaction data are stored in one centralized data warehouse. Based on data retrieval and information access tools, business users acquire relevant facts, figures and business trends. Data warehouses and business intelligence solutions are the key to customer identification. CRM integration with a data warehouse can bring corporate benefits: reduction in customer attraction costs, reduction in sales costs, reduction in service costs and reduction in customer servicing time. Similarly, introducing CRM into a company contributes to customer satisfaction, relationship feedback, competitive advantages, the number of customers, the customer retention rate, analytical measurements of a customer value, revenue per customer and the impact of fast order processing, a return of customers and call centre performance, which are the actual sales indicators [5].

Mendoza et al. (2009), Curry and Kkolou (2004), Kale (2004), Raman et al. (2006); Starkey and Woodcock, (2002); Rahimi and Gunlu, (2016) consider personnel involvement and training as an important factor in the introduction of CRM [6], [7], [8], [9], [10], [11].

Personnel involvement and training ensure organizational **readiness** and cooperation for the successful introduction of CRM. Challenges in the introduction of CRM involve ensuring the willingness and readiness of personnel to accept, understand and support the new company strategy and support training to work with the new CRM system. The personnel might lack motivation to change their daily routines and accept new challenges and changes in working with the customer when using the CRM system [6]. However, several researchers associate the involvement of personnel and progress in training with the influence of organizational culture on the introduction of CRM. There are positive correlations between organizational culture and the introduction of the CRM strategy and

system. A high rating of organizational culture is associated with the company's high adaptability, consistency and high personnel involvement and the personnel's understanding of the shared vision and mission [6], [7], [8], [9], [10], [11].

Chang (2007) has concluded that a problem with CRM introduction is the **technical compatibility of systems and the security of customer data**. Data security integration problems or software incompatibilities can cause delays and complications in the introduction of a CRM system. In Latvia, the requirements of the Data Protection Regulation of the European Union are applied to the security of customer data, which, like everywhere else in the world, strictly governs the protection of customer data. Improper data processing or unauthorized access could result in data leakage that violates the terms of use of customer data [5], [12].

According to some researchers, the **choice of measuring and analytical tools** is essential to effectively measure and analyse company performance. Incorrectly taken measurements can lead to inaccurate results and decision-making problems. Sometimes, companies face difficulty in introducing and using analytical tools, as the tools might require highly qualified personnel and specific training [11].

Several researchers associate the introduction of CRM with the strategic management of the company and the **alignment of customer interests**. To view the customer as an asset of the company and develop long-term cooperation with the customer, it is necessary to include customer relationship management in the company's strategic development priorities as one of the general strategic priorities. This would allow the company to understand customer wishes and become customer-centric by applying a customer-focused approach; consequently, long-term customer relationships are turned into company profits [13], [14], [15], [16].

In today's economic conditions, there is a high financial cost of introducing a CRM system if additional customizations and integrations are added. This could cause financial problems for companies and require careful budgeting [5].

Some researchers have specified the following benefits of CRM for companies: identifying customers, developing performance drivers and generating value added for customers. CRM advantages are as follows: giving customers exactly what they need; knowing the habits of creating a shopping basket; excellent customer service; effective sales; faster transaction processing; reduction in customer price sensitivities; attracting and retaining new customers; efficient use of the call centre; integrity of the marketing and sales process; reduction in the costs of maintaining customer relationships [16], [4].

In introducing CRM, according to researcher Linina (2018), the customer database is the most valuable informative component of the CRM system, which provides information about the product, the customer and the promotion of the product in the market. CRM contributes to the creation and maintenance of a database to develop long-term cooperation with customers. Based on the information obtained from CRM system databases, it is possible to respond quickly to the wishes and needs of customers as well as to customer attitudes towards prices, new goods and marketing activities [4]. Next, the authors focus on an analysis of the customer database to summarize customer database analysis methods employed by various researchers.

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Researcher Linina (2018) recommends using ratings of customer satisfaction for customer relationship management analysis. Ratings and measurements of customer satisfaction could be divided into two categories:

- initial data – information collected for the first time and intended for a specific research purpose;
- processed data – information previously collected and intended for certain research purposes [4]. Performance indicators for a company, which are the source of processed data, are analysed by employing statistical analysis methods, comparing indicators such as turnover, mark-up of goods, profit, current asset turnover, turnover costs, sales area and market share, while the following indicators could be used to identify the effectiveness of customer relationship management: sales volume, average purchase, customer lifetime value, market share and profit growth [4].

However, initial data include surveys, interviews as well as databases. Customer databases provide information about customers, whether they belong to the B2C or B2B segment, as well as purchase size. Using a customer database and sales volumes, one can identify who a company's largest customers are, and apply Pareto analysis. **Pareto analysis** is a method created by Italian sociologist, economist and philosopher Vilfredo Pareto; based on the Pareto principle: 80% of the consequences arise from 20% of the causes. Using Pareto analysis, it is possible to determine which 20% of customers generate 80% of the company's total revenue. As regards the Pareto principle, a ratio of 30 to 70 could also be considered, as 30% of customers would make up 70% of the total revenue. The ABC analysis method could also be applied to identify the most important customers of a company. ABC analysis is a widely used method employed to divide numerical information into meaningful groups. In principle, ABC analysis is based on the Pareto principle, while in this case 3 classes are distinguished: A, B and C [17].

Class A contains the company's most valuable customers, meaning they have made the largest purchases, while Class C contains those who are the least valuable to the company. The contribution of each customer to the company's turnover could be identified based on the classification of customers into classes [17]. The company should focus its sales on Class A customers because they are the most valuable financially.

ABC analysis is performed using information from the customer database about the sizes of purchases made by customers, i.e. turnover. Database information is divided into 3 classes based on the following principle:

- Class A – the most significant customers who contribute to 80% of the company's total turnover;
- Class B – average customers who are in the category contributing to 80-95% of the total turnover;
- Class C – the least significant customers who are in the category contributing to 95-100% of the total turnover [17].

The most important legal documents were selected to analyse the legal framework governing customer relationship management in companies in Latvia. This field is governed by the legal acts of the EU and the Republic of Latvia. At the EU level, the Data Protection Regulation (2016/679), which governs the B2C segment, could be considered

an important legal act. This regulation states that a natural person has the right to receive information about how and why the natural person's data are processed and used [18].
As regards business, the Commercial Law (2000), the Accounting Law (2021) and the Competition Law (2001) represent important national-level legal acts. The Commercial Law is under the administration of the Ministry of Justice, and its purpose is to enhance the business environment, as well as to promote respect for the rights and legal interests of persons involved in legal business.
The Accounting Law is under the administration of the Ministry of Finance, and the purpose of this law is to ensure the availability of reliable and true information about a company's financial position. The Competition Law is administered by the Ministry of Economics, and its purpose is to protect and develop fair competition in all industries of the economy.
Customer relationships with companies are monitored by the CRPC (Consumer Rights Protection Centre) whose mission is to implement the protection of consumer rights and interests, thereby providing residents with an opportunity to live not only healthily and safely but also sustainably. Customer relationships with a company are governed by laws such as the Law on the Protection of Consumer Rights (1999), the Personal Data Processing Law (2018) and the Civil Law 1937.
The Law on the Protection of Consumer Rights applies to B2B and B2C segment customers, and the purpose of this law is to provide an opportunity for consumers not only to exercise and protect their legal rights but also to protect their collective interests.
The Personal Data Processing Law applies to the B2C segment, and the purpose of the law is to create a legal environment for establishing a data protection system for natural persons. The Civil Law applies to both customer segment groups: B2B and B2C, thereby setting the limits of personal rights.
The research analysed AUTO Parts Ltd, a company engaged in trade using a website; therefore, in addition to the mentioned legal acts, Cabinet Regulation No. 255 Regulations regarding Distance Contracts is also binding. The regulation prescribes the principles of concluding a distance contract and the information to be included in it, while compliance with the regulation is monitored by the CRPC.
In Latvia, there is no unified accounting for and no information about companies that have developed and implemented CRM in their operations and use the CRM system as a strategy implementation tool. The empirical part of the research randomly selected AUTO Parts Ltd for a case study; the company operates in Latvia and sells auto spare parts wholesale. The researchers' interest related to the fact that the company recorded customer data by using the ANKRAVS platform, but the company did not analyse its customer database, did not classify its current customers and did not calculate their economic value. The research calculated and compared the following indicators: distribution of customers (based on an ABC analysis) and customer average purchase value during a certain period.
The research analysed the company's customer database and performed a comparison of the distribution of customers and changes in the company's revenue (Fig. 1) for the period from 2018 to 2022. A growing trend could be observed in revenues; however, there was a slight decrease in revenue by 1.8% or EUR 200 thousand in the period 2020-2021. In the opinion of the authors, the decrease in revenue in 2021 could be explained by the

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COVID-19 pandemic because various trade restrictions were in force in the country. One of the trade restrictions implemented during this period was the limited number of customers allowed per square meter in a shop at one time. Since the floor area of the store was relatively small, only up to 2 customers were allowed to enter the store of AUTO Parts Ltd at one time during these restrictions.

Table 1. AUTO Parts Ltd revenue and changes therein in the period 2018-2022

Indicator/year	2018	2019	2020	2021	2022
Revenue, mln. EUR	0.84	1.09	1.10	1.08	1.12
Change in revenue from the previous year, %	0.00	29.76	0.92	-1.82	3.70
Change in revenue from the base year (2017), %	0.00	29.76	30.95	28.57	33.33

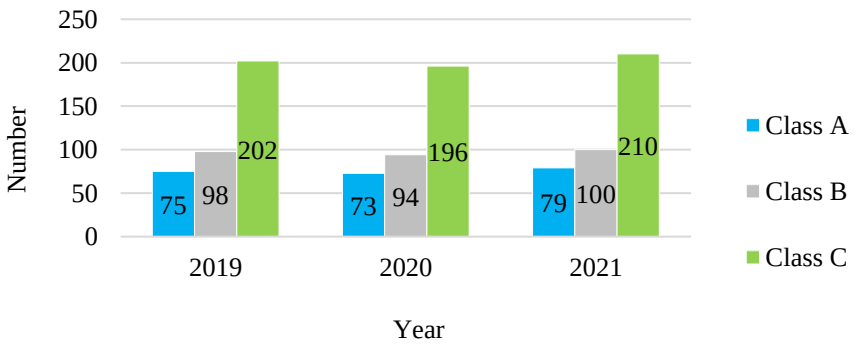
Source: author's calculations based on AUTO Parts Ltd annual financial reports

AUTO Parts Ltd uses the ANKRAVS platform to collect customer data. It is an application program for accounting and warehouse accounting that has been available for over 25 years. The solutions provided by the platform have been designed for companies representing various fields: shops, wholesale warehouses, manufacturing plants, sports clubs and even universities. ANKRAVS provides various forms of reports, which are also intended for company managers so that they can quickly organize work processes, make decisions as well as assess the company's situation.

The ANKRAVS platform performs the following functions for customers and their data accounting:

- order documents and settlement of accounts with suppliers and customers;
- various reports on goods and customers.

Using the capabilities of the ANKRAVS platform, the research analysed the company's customer database (Fig. 1), grouping B2B segment customers. The analysis used data from the customer database for the period 2019-2021. The distribution of customers by the ABC analysis method allows the company to identify the company's largest and most important customers requiring special attention. Customer lifetime value allows the company to calculate the average financial benefit per customer and also enables the company to identify the factor that affects the performance the most, thereby giving an opportunity for the company to increase this value in the future.

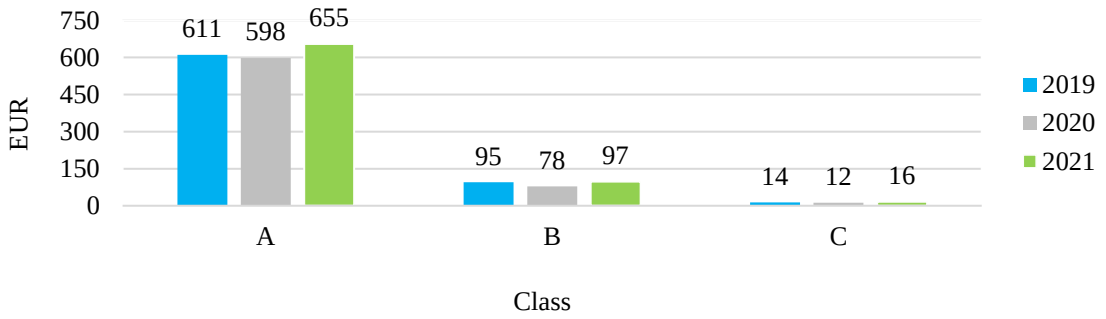


Source: authors' construction based on ANKRAVS platform data for AUTO Parts Ltd

Fig.1. Distribution of B2B customers of AUTO Part Ltd by class from 2019 to 2021

In 2021 (Fig. 1), Class A customers, which contributed to 80% of the company's total revenue, included 79 customers, the Class B category included 100 customers, which contributed to 15% of the total revenue, while the Class C category included 210 customers, contributing to 5% of the total revenue. Class A customers were the most important customers of the B2B segment, as these customers contributed to 80% of the total revenue from the B2B segment for AUTO Parts Ltd.

To perform a more detailed analysis of the shopping habits of B2B customers, the research calculated monthly average purchases made by each class group in the period from 2019 to 2021 (Fig. 2).



Source: authors' construction based on ANKRAVS platform data for AUTO Parts Ltd

Fig.2. Distribution of monthly average purchases made by AUTO Parts Ltd B2B customers by class from 2019 to 2021, EUR.

An analysis of the data revealed that in the period 2019-2021, the average purchase made by B2B segment customers representing Class A increased by 7.30% or EUR 44.56. In 2021, the largest B2B customers of Class A made an average monthly purchase worth EUR 655.14. However, an analysis of Class B customers revealed that in the period 2019-2021, their average monthly purchase increased by 2.09%, while for Class C customers the increase was 12.84%. In 2021, the average monthly purchase made by Class B customers reached EUR 97.19, while for Class C it was EUR 15.56. In the same period, the largest increase in the average monthly purchase was found for Class C, while the smallest increase was for Class B. It could be concluded that in the period from 2019 to 2021, the average purchase by B2B customers representing Classes B and C increased, while the average monthly purchase by Class A customers exceeded the average purchase by customers representing Classes B and C in the range of ~6 to 40 times, which indicates the significance of Class A customers for the company in terms of customer relationship management.

CONCLUSION

1) Customer relationship management and the factors therein relate to customers being the largest asset of a company, without which the economic goals of the company cannot be achieved.
2) Some researchers believe that there are problems with the activity of entrepreneurs in Latvia and the world to develop CRM as a component of the general strategy for the company and the ability to use the CRM system as a strategy implementation tool.

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3) Relevant legal documents have been adopted in Latvia, which, following the EU regulation, prescribe requirements for customer relationship management with the aim of protecting and developing fair competition to enable consumers not only to exercise their legal rights but also to protect their collective interests.
4) The implementation of customer relationship management in a company can bring various benefits, which are indicated by several indicators: turnover, mark-up of goods, profit, current asset turnover, turnover costs, sales area and market share, while the following indicators can be used to identify the effectiveness of customer relationship management: sales volume, average purchase, customer lifetime value, market share and profit growth.
5) In today's economic conditions, there is a high financial cost of introducing a CRM system into the company, which is associated with the need to develop a CRM strategy as a component of the general strategy. Besides, there are some problems because of the multiple ways of accounting for internal customers and the cost of data integration, the technical incompatibility of different systems used, the choice of measuring and analytical tools and the need to involve and train personnel to work with the CRM system.
6) In the period from 2019 to 2021 in the company analysed, the number of B2B customers as well as the average purchase by customers of this segment increased, which indicates that the company implemented customer relationship management successfully.
7) The company should focus its sales on Class A customers because they are the most valuable financially. More data from the customer database should be processed to identify the customer attraction rate and the customer change rate.

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DELIBERATIVE ECONOMIC VALUATION METHODS TO ASSESS THE EFFECTS OF CLIMATE CHANGE ON URBAN INFRASTRUCTURES

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ABSTRACT

Consequences of climate change have social, economic and environmental effects. Changes in weather patterns directly impact to transport infrastructures, which play a strategic role in emergency management. Calamitous events as consequence of weather and climatic processes raise the need to foresee adaptation measures to climate change, which is already in place. Although there is a large literature on the effects of climate change, individual and collective responses and behaviours are unclear to such changes.
Infrastructures are urban community goods, so adaptation actions concern values and preferences that affect the community itself. In order to measure these values, it is appropriate to consider the impacts (understood as the interpretation of the effects) perceived by communities, but most of the conventional evaluation approaches show obvious limitations.
The paper proposes to use inclusive processes, based on the theory of deliberative democracy, in the economic judgments of value and choice in the field of climate change and the adaptation measures related to urban infrastructures. Given the series of effects climate change generates on a single infrastructure and the related adaptation measures, the procedures proposed in this paper enable the members of the community involved to: a) appraise the Shared Economic Value (SEV) of the impact produced by climate change and the related adaptation measures; b) to obtain a Shared Multi-criteria Judgment of alternative adaptation measures.

Keywords: Climate change, Deliberative approaches, Inclusive approaches, Shared Economic Value, Shared Multicriteria Analysis.

INTRODUCTION

Human activities are changing the global climate system and the warming of the climate system is unequivocal; in addition, extreme heat events (e.g. heat waves) will be more frequent on most emerging lands and the average global sea level may rise to a range of 0.45 to 0.82 m due to the increased heating of the Oceans and mass loss from glaciers and ice caps. These consequences will have social, economic and environmental effects, such as risk of disasters, water stress, food security, health risk, exploitation of natural resources, social and economic conflicts and migrations. Calamitous events as consequence of weather and climatic processes raise the need to foresee adaptation measures to climate change, which is already in place. It also includes action which will ensure more resilient and climate-proof transport infrastructures. The main climate change challenges which interfere with transport infrastructures are extreme air temperatures (e.g. heat waves and harsh winter weathers), flooding, storms, and sea level rise [1].

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Since the effects of climate change, and the adaptation of the urban infrastructure system to it, have an impact on entire communities, it follows that every procedure adopted to estimate and evaluate these effects must be implemented along with a Social Impact Assessment [2]. The international principles for Social Impact Assessment [3] classify as impacts all those issues that directly and/or indirectly influence the members of any given community. With the term "impact" we intend an effect perceived (interpreted or judged with the aim of establishing a value or a choice) and, above all, stated directly by the members of the community in question. In this perspective, it is not the effect of climate change in itself or the ensuing adaptation measures that are taken into account for estimation and evaluation, but how the members of the community involved perceive, interpret and judge their impact.

The economic valuation applied to the effects of climate change on infrastructures and related adaptation measures can be utilized at different levels in order to obtain: a) the estimation of the value of the impact produced by climate change; b) the estimation of the value of the impact produced by the adaptation measures introduced to cope with climate change; c) the evaluation of alternative adaptation measures.

In well-established practices related to public decisions in the urban infrastructure sector, the approaches implemented for the appraisal and evaluation of impacts generally fall into three categories: a) approaches of a monetary nature, based on the economics of wellbeing and Cost-Benefit Analysis; b) non-monetary multi-criteria approaches, utilized in support of the adaptation measure chosen from a number of alternative options; c) mixed approaches that combine monetary and non-monetary inputs and outputs, which derive from the need to include monetary information or from the decision to exclude it.

When utilized for the measurement of the impacts on infrastructures generated by climate change and those related to the adaptation measures on the community involved, conventional economic valuation procedures highlight specific limitations regarding finding and analysis.

A first limitation regards an incomplete calculation of the socio-economic impacts. In fact, the appraisal and valuation of the economic impacts, despite being performed from a social point of view, sometimes take into account only certain components (sectors or groups) of the community involved. On the contrary, employing a sample that is fully representative of the community, defined on a scientific basis, allows an accurate knowledge of the economic impacts generated by the issue considered on the members of the community.

A second limitation of some conventional and operative approaches, for example those using a social welfare function, derives from the fact that the valuations are not stated directly by members of the community. They are formulated by subjects delegated by the competent institutions who, although placing themselves from the citizens' viewpoint, in reality only interpret their will, without guaranteeing that this interpretation matches the real intentions of the members of the community.

A third limitation regards the absence of an effective involvement of all the members of the community, in order to give explicit evidence to all the existing positions on the issue subject of assessment. This implies that the will of the entire community - the fundamental requisite for fully democratic decisions - is not stated and, therefore, the resulting economic judgement has neither general validity nor does it express general

interest; it should be noted that, in the future, the developments of telematics technology prefigure direct involvement of the real universe of a community.

Lastly, since the overall economic value of the impacts is not always calculated in a disaggregated form, it is not possible to verify how such impacts are distributed, with the consequence that the valuation risks being based only on criteria of efficiency neglecting those of fairness.

Considering the limitation of conventional economic valuation procedures, the aim of this paper is to present and discuss the use of inclusive processes, based on the theory of deliberative democracy, in the economic judgments of value and choice in the field of climate change and the adaptation measures related to urban infrastructures. Given the series of effects climate change generates on a single infrastructure and the related adaptation measures, the procedures proposed in this paper enable the members of the community involved to: a) appraise the Shared Economic Value (SEV) of the impact produced by climate change and the related adaptation measures; b) to obtain a Shared Multi-criteria Judgment of alternative adaptation measures.

MATERIALS AND METHODS

The limitations of conventional approaches emerge when they are used to measure collective values, i.e. those stated directly by a community in unitary and shared way. Since an impact expresses the interpretation of an effect directly stated by each single member of a community, the appraisal and evaluation of the impacts must necessarily consider the points of view of the entire and heterogeneous population that goes to form the community involved. If this does not occur, the resulting decisions will not take into account the general interests nor the will of the entire community.

In view of these aspects, this paper proposes to use inclusive processes, based on the theory of deliberative democracy, in the economic judgments of value and choice in the field of climate change and the adaptation measures related to urban infrastructures.

During the second half of the 20th century, the demand in support of democratic inclusive forms, i.e. forms aimed at the direct inclusion of all the members of a community in public decisions, grew in strength and consistency. These democratic forms are characterized by the involvement of extra-institutional players, recipients of interventions and citizens in public decision-making processes [4].

The valuation approaches that derive from the concept of inclusion are based on a structured involvement in the process of appraisal and valuation of the relevant subjects of the issues in question, with the aim either to contribute to the decision or to take it directly. They are approaches that provide for the exchange, interaction and reciprocity of information between citizens and public institutions or among the members of the community, and give rise to two different theoretical and operational forms: participatory approaches and deliberative approaches.

Participatory approaches rely on the interaction between citizens and the public sector decision maker in a continuous process of cooperation [5, 6]. The deliberative procedures [7] are characterized by two essential aspects: a) the valuation is expressed directly by the universe of a community (or a fully representative sample of it) [8, 9]; b) the only instrument used to reach a decision is the “rational argument regarding the common good” [10]. This criterion goes to substitute preferences stated individually in

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favour of a single shared preference taken unanimously by the community or, for operational needs, approved to quasi-unanimity or by qualified majority.

The incorporation of deliberative methods within a structured valuation process leads to the expression of shared choices or values formulated by citizens, able to overcome individual positions [11, 12, 13, 14]. Given the series of effects climate change generates on a single infrastructure and the related adaptation measures, the procedures proposed in this paper, characterized by a direct, informed and discursive approach, enable the members of the community involved to: appraise the Shared Economic Value (SEV) of the impact produced by climate change and the related adaptation measures; to obtain a Shared Multi-criteria Judgment, not monetary, of alternative adaptation measures.

The SEV is formulated examining the various economic characteristics of the good, on the basis of a preliminary and in-depth information, and results from a free and conscious sharing by all the valuation subjects involved in a deliberative process. The economic judgment formulated according to the modality of sharing is capable of conferring a general validity to the value. In order to estimate the SEV, firstly it is necessary to identify the community affected by the impact of climate change on the infrastructure (target population -TP), from which a random sample of citizens who will go to form the Valuation Group (VG) is drawn. The VG, which has to be statistically representative of the community in question, is asked to express a shared value related to its perception of the impact of climate change on the infrastructure. The valuation of the VG is the outcome of informed aware choices based on their personal opinions after discussing them and possibly changing them as the result of the ensuing debate. After an introductory step related to the valuation process, the VG will have a series of meetings with experts and stakeholders during which they will be given the information necessary to enable them to put forward valid awareness-based arguments. At the end of the meetings, the VG will have one or more group sessions during which they will discuss and try to reach a monetary measure of the shared value, expressed through the Willingness to Pay (WTP), with the aim of eventually achieving a unanimous decision.

The fundamental element of the valuation-deliberative process is debate, which is necessary to ensure that an aware-based shared choice is reached through dialogue. The economic value that emerges is therefore the outcome of a process based on reflection and debate, which as it develops makes it possible to form a group that is socially representative of the community, has a long-term vision, and is better informed and more impartial regarding the perception of the effects of climate change on the infrastructure in question. The SEV expresses a perspective of general interest as each person makes a choice that he or she deems right both for him/herself and for others.

Reasoning in monetary terms, when is explicitly required a valuation based on a monetary formulation, becomes a crucial requisite. The use of a monetary scale makes it possible to verify the existence of the economic preferences for a good and to quantify it. Furthermore, it is suitable to plan intervention/investment priorities according to the level of appreciation shown by citizens; to size the amounts of bonds or dedicated taxes, and perform comparative studies to identify the best alternative use of available funds.

The purpose of the Shared Multicriteria Judgment is the choice of the intervention preferred by the community in a perspective of general interest. From an operative viewpoint, the evaluation procedure introduces the operative practices of the

deliberative processes with multi-criteria evaluation techniques. As for the SEV, also the multi-criteria evaluation requires the identification of the TP and the formation of a VG, fully representative of the relevant community. The first operation that involves the VG is a preliminary informative phase regarding the object to be valuated during which the characteristics of the infrastructure, the effects of climate change on it, and the possible alternative adaptation measures are illustrated. This information is discussed in more detail during the meetings with the experts and stakeholders. At the end of this phase, the VG defines the key elements they will base their assessment on: a) a shared set of criteria, by means of which alternative adaptation measures are assessed, and related indicators; b) a shared priority among the criteria.

After a first debating phase, each member of the VG begins formulating an Individual Impact Matrix in which he/she expresses the valuation of the individual alternatives with respect to the identified criteria; the matrices are subsequently given to the Steering Team (ST). The ST then creates a single matrix putting in evidence the elements for which the individual members of the VG have formulated the same evaluation; the elements for which a slightly discordant evaluation was expressed and those with a completely different evaluation. This matrix represents the starting point of the next deliberative phase. The aim of the subsequent deliberative phase is to compose a single impact matrix shared by all the members of the VG. Once the Shared Impact Matrix has been composed, the ST can apply multi-criteria methods with the aim of obtaining an overall evaluation for each single alternative intervention and if deemed necessary a ranking for the interventions. During a last phase of discussion, this result is submitted to the final shared approval of the VG.

RESULTS

Before being applied in real-life cases, the deliberative method proposed has to undergo laboratory testing to verify not only the procedure's feasibility, but also the suitability of the expressed values or preferences to be assessed. A real-life environment would be unsuited to the applications of procedures addressed to experimental verification. In fact, these operations need a controlled environment where the introduction of modifications and additions, and the possibility of reiterating the experiment, allow verification and clarification of the method.

This is why the aim of the Experimental Valuation Laboratory (EVL), activated in the Sapienza University of Rome, is to reproduce in a controlled environment, with the participation of the students, the valuation procedures for the deliberative method of appraisal and valuation. Once a real topic for the experiment has been identified, during the EVL the students are asked to represent a group of citizens taking part in a valuation process by acting out these roles in a role-playing game. Firstly, the experimental designers introduce the environment of the case study and illustrate the characteristics to be interpreted by the students. This practice has been consolidated in experimental economics laboratories and several academic studies have compared the results obtained at experimental level from students with those obtained from real life situations, thus confirming their reliability [15]. To date, the EVL has performed experiments not linked to climate change but which nonetheless have demonstrated that the procedures proposed are capable of providing a shared economic value. The first application regarded the experimentation of a multi-criteria deliberative procedure the aim of which was to choose the best project from among those which had competed in the tender for

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the upgrading of the Moretta zone in Via Giulia, Rome. During the first meeting, the VG received exhaustive information about the project; then they entered the consultation phase with the experts and stakeholders they had previously identified. Once the consultations had terminated, a list of criteria in order of importance to be used for the valuation was drawn up. Following a first individual valuation of the matrix, a shared single matrix was obtained during a deliberative phase.

One of the monetary experiments dealt with one of Rome's large infrastructures – the elevated highway "Tangenziale Est" in the stretch above the San Lorenzo neighbourhood, gradually falling into disuse. The shared social appreciation acknowledged by the community regarding the idea of converting the infrastructure into a linear elevated park was assessed. From an operative viewpoint, once the target population had been identified and the VG formed (30 people who had been informed about what the scheme entailed), the latter drew up a list of experts and stakeholders to consult. Following the consultations, a long deliberative phase with the aim of obtaining a shared WTP began. The purpose of the shared WTP was to determine the social importance the VG attached to the converted infrastructure.

DISCUSSION

The Via Giulia experiment confirmed the possibility to obtain a shared ranking by applying an inclusive approach to a multi-criteria procedure. When evaluating the matrix, the VG took into account the opinions expressed by the various stakeholders, which were decisive to obtain the shared matrix. Today, following protests on the part of several local stakeholders, the municipality has decided to replace the project it had chosen following a competitive tender – a high-density scheme that would have occupied the entire area – with a project envisaging a park, one of the preferences chosen during the experiment.

One of the most important results of the elevated highway experiment was that gradually the majority of the VG changed their opinion. According to their responses to a questionnaire they were asked to fill in during the first deliberative phase, about half of the sample were not willing to contribute anything towards the conversion of the Tangenziale, and opted for its demolition; gradually, however, they were all persuaded how important it was to conserve and convert it. It is also important to point out that if the shared WTP were to be extended to Rome's entire adult population the amount would be much greater than either the cost of demolishing it or the cost of converting it into a linear green park.

CONCLUSION

Climate change impacts on the transport systems in three different sensitivity aspects: infrastructure, transport operations and transport demand. From the economic appraisal and valuation viewpoint, the illustrated method is suitable for expressing the economic value of the social importance of the impact produced by climate change and the related adaptation measures, and to arrive at a shared judgment of choice concerning the alternative measures. It produces judgements of value and choice directly expressed by the citizens involved in the infrastructure in question, who are well informed on the issue and fully aware of their preferences. Thanks to the use of a rigorously stratified sample based on the main distribution statistics of the population of reference, it is possible to achieve a full representativeness of the community. In addition, the method

is based on a procedure of absolute transparency and reproducibility, elements that characterize every single phase of the valuation. The fact that the valuation subjects are asked to state their opinion only after in-depth well-structured consultations with the experts and stakeholders, ensures that the approach of the members of the VG is based on responsibility and awareness. Moreover, the method produces results that are almost devoid of cognitive biases.

The estimation of the SEV does not require the use of statistical-mathematical tools for achieving the results as it is directly formulated and expressed during the deliberating phases. In addition, sharing, sense of citizenship, and impartiality are all characteristics of the method that make it possible to formulate valuations that best incorporate general interest.

Since the multi-criteria procedure is an approach thanks to which every key step becomes a decision-making phase that is the outcome of the VG's sharing, the limitations linked to the influence of certain calculation procedures (quantifying weights, the conversion of qualitative scales into quantitative ones, and standardization) can be overcome. The multi-criteria approach is preferable when a choice has to be made between alternatives and compiling rankings where the monetary information may be considered of secondary importance.

The experiments conducted so far have shown that it is possible to reach judgements of value and choice that synthetize and reflect the shared opinion of a VG that is representative of the community and that through its stated viewpoints it is also able to safeguard the general interests of the community itself. However, in order to perform a more contextualized verification, further experiments directly linked to infrastructures and climate change need to be conducted.

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DESIGN THINKING IN DEVELOPING PLANS FOR ADAPTATION OF URBAN AREAS TO CLIMATE CHANGES

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ABSTRACT

The challenges raised by climate changes are diverse and unpredictable to the extent that makes them hard to manage after the onset. Under such conditions the trends assessment is a valuable approach, which enables efficient preparation to the expected effects and impacts. The process of adaptation provides possibility to reduce possible losses and create background for some benefits from changing climate. A variety of solutions and strategies for adapting urban areas to climate changes is already available for analysis and consideration. Still, each city is a separate case with a set of peculiarities and developing plan for adaptation involves searching for solutions, fitting the exact case. This calls for combination of analytical work and design thinking, which can yield efficient solutions based on the available experience and creative rethinking. The paper presents consideration of three possible strategies of urban area adaptation to climate changes, formulated via solution-focused approach. The methodology of the strategies analysis and comparison is based on factorial assessment and aims to demonstrate the potential of design thinking in developing long term plans with changing initial and target parameters. The factors affecting the efficiency of solutions produced for adaptation plans of cities were considered as well as the interactions between these factors, which form a specific working environment for the design of adaptation. The variations in the role of factors for different types of solutions do exist, but the design thinking has proved to be important in any application.

Keywords: adaptation to climate changes, decision making, design thinking, solution focused thinking, factorial assessment.

INTRODUCTION

Climate changes represent a wicked problem of modern times, which call for unprecedented massive cooperation to tackle it. However, being wicked means being practically irresolvable, which is not what we can agree to. Therefore, it is important to work out new ideas and approaches on continuous basis. To be successful and able to make real effect, these ideas must be innovative and non-standard. This offers a vast field for design thinking application, which is one of the methods used to manage wicked problems [1].

As the experience of previous decades has shown, the accumulation of knowledge about climate changes mechanism has not provided many insights into how to organize adaptation in places. It has become clear that not a single specialist possesses the necessary set of knowledge and multidisciplinary is a key to at least a glimmer of

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success [2]. Organization of multidisciplinary research is a separate problem, but it is again different from working out solutions able to provide efficient adaptation. Thus, a team with different expertise and authority, involved in developing adaptations plans, is in need for basic design competences, since this problem is a continuum, rather than a discrete problem [3]. The wicked problematic continuum produces new problems when solutions are implemented, and no modeling can predict the outcomes. As a result, working on adaptation is a process, which must follow a closed loop principle [4], so that the developers constantly revise and amend their actions and plans, based on what they see in the field. Under such conditions design thinking is what can help manage the continuous flow of challenges, generated by intruding into the climate system at local, regional, national and global levels by complicated and often uncoordinated adaptation actions [5]. Initial conditions at which a planning was performed at the beginning of the process change under the effect of both further climate transitions and responding actions applied. Thus, the framework for adaptation modifies constantly and rethinking and thinking out new answers must be applied. Moreover, adaptation is cloud-type problem, which depends on the actions of many people, and this makes it even less predictable and guarantees less certain results.

Another important aspect of developing solutions for climate adaptation is that this task can be approached efficiently only from the solution perspective [6]. As it was mentioned above, adaptation deals with reaction and anticipation of climate change effects, rather than with trying to understand why they take place. Building work on adaptation in this way is indeed about creating new technical, organizational and combined answers, which are all born via design thinking, grounded in abductive reasoning.

The design thinking has recently become actively discussed as an integral element of climate changes adaptation in many applications – from local communities to regional intergovernmental plans of adaptation to sea level rise [7]. There are no ready solutions, efficiency and correctness of actions is not known until they are in place and the results of any actions are complex and multiple. So, the **question** is to what extent is solution-focused design thinking important for the successful adaptation plans development, how it interacts with the other factors and does its role depend on the type of solutions generated.

The final aim of the research is to derive factors important for the efficient development of climate change adaptation plans and outline the principles of design thinking maturation in the process, as it is hypothesized to be one of core elements.

MATERIALS AND METHODS

Although design thinking was initially attached only to developing new things and services, it is now widely used by organizations in various fields to find the best way to satisfy the whole diversity of customers' needs. In the context of climate adaptation, the needs of customers basically mean mitigation of climate related risks for target groups of people and assets. In these terms, the exact solutions are varied in scale and essence, but the sequence of work can be formulated in a common scheme.

Many models of design thinking are offered by researchers and practitioners, e.g. Stanford University design school model, 3i model of IDEO or Herbert Simon' 7Stage design process. The efficiency lies in the collection of as much information about

customers' demands and requirements as possible, using these data as a source of ideation. In case of searching for adaptation solutions the framework for design is in the end of the design pathway. Literally, one knows what a designed object or process must do but is not sure what will that be. In case of climate adaptation, one knows what is should provide in the end, but has little understanding on how it really works.

The stages of discovering and designing (as in the Diamond Model by the Design Council [8]) stands for data collection and prediction of climate change impacts specific for each site under consideration, but it is usually done using standard tools and approaches, as well as prognosis is derived from the most used global models. As such minor variations are possible at this stage and the major impact on the design process is done by the quality of data, for the purpose of the given research, we have assumed that these stages are a part of a background framework of design process.

The given research represents a combination of three different problems, studied using their specific protocols. The common ground of these studies is urban areas adaptation to climate changes.

The first question – the role of design thinking in the adaptation planning and implementation, – was studied through a survey, conducted among the researchers with previous experience of participating in such type of design work. These specialists were invited to the survey via personal contacts and the final sample included:

- 9 specialists of NGOs, dealing with nature protection with confirmed experience of working on adaptation plans in total for 4 town communities, 2 cities and 4 administrative units of various levels, but those including urban areas (each respondent participated in at least 1 adaptation design project);
- 5 scientists, representing 3 universities (2 in Ukraine and 1 from Poland), who have been previously involved in adaptation programs development;
- 2 members of local authorities, who were involved in working groups on adaptation plan development.

All participants were given survey forms, which included the following blocks of questions:

- Characteristics of previous experience: name and type of urban area, type of work performed, working group structure (multidisciplinary or branch, mode of work (group or individual), tools applied, results obtained (comprehensive plan, list of actions, policy etc.;
- Set of climate change impacts they have dealt with and their general expertise.

The core of the survey was defining relative weights of the components/factors of the adaptation action plan development. The factors, contributing to the quality of adaptation solutions were formulated based on the analysis of research works, presenting case studies of plans developed for urban areas around the world. A total of 15 papers were considered, presenting examples from Latvia, Ukraine, the Netherlands, Greece, China, Nigeria, Uganda, USA, Nepal, Bangladesh, Australia, Kiribati, Finland, Italy, and cooperation of coastal cities of the Baltic region. Even though none of these papers presents a fixed list of factors, contributing to efficient adaptation plan development, we were able to derive them based on conclusion of the studies in terms of quality factors they mention.

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Respondents were then asked to assign weighting indices to each of the component based on the extent they believe it affects the quality and efficiency of adaptation solution designed. The relative importance of factors of adaptation efficiency was defined via pair-wise comparisons.

Relative weights of planning process were assigned by the respondents individually and then we assigned final weights based on data received. The principles of weights integration included the following:

- If the weights showed no dominant value, but the range of fluctuations was not very wide, the final weight was calculated as a mean.
- If answers represented a set of data with clearly seen common value (over 2/3 of responses), then it was used as a final weighting index.
- In case of inconsistent results, the farthest outliers were excluded, and mean value was calculated.

The general idea of the pair-wise comparison is reverse symmetry: in each pair of components, if one was rated as 3-6-9 and then the second factor would be granted a reverse weight – 1/3-1/6-1/9 correspondingly. If both factors are equally important, they are both given rating of 1.

The components of the adaptation planning process were also studied in terms of their mutual interactions. The impacts within the stages of development and revision of the adaptation plan were rated from 0 to 4. These interactions were also presented as a figure, demonstrating interactions and mutual impacts of different strengths and potential for feedback loops.

The respondents represent a group with varied expertise, but all of them possess valuable experience in the field of adaptation planning. Therefore, they were also asked to express their opinion about the combination of components they consider the most appropriate for developing adaptation plans. For this purpose, the massive of adaptation solutions offered at special resource platforms were split into 3 groups: managerial, nature-based and technical.

Technical solutions represent the most intensive action, which include engineering projects for enterprises, transport modernization, planning changes to urban areas and other reconstruction activities. By contrast, managerial solution stand for a complex of action, which do not involve massive changes in urban infrastructure, rather they deal with modifications of existing facilities, adding them possibility to mitigate, for example, urban heat island, manage excessive surface run-off or provide additional cooling with outdoor cooling systems. This group also includes educational and information activities, aimed at changing citizens behaviour towards more efficient use of resources and limitation of activities able to reduce climate resilience of urban ecosystems. Finally, nature-based solutions offer escape from climate change pressures through the development and expansion of urban greenery and water bodies.

RESULTS

The analysis of research papers, containing information about successfully completed adaptation plan design projects resulted in a list of the following factors:

- clear goal – formulated goal of the project concentrates efforts of developers on the very specific problems of a community, urgently in need for solution;
- "Know your resources" - stands for the resources (financial, labor, expertise etc.) available for adaptation plan implementation and annual revision;
- understanding mechanisms of climate change impacts of urban system;
- design thinking;
- maladaptation awareness – includes knowing about the cases, when adaptation plans failed and even worsened the situation;
- stakeholders, interested in the development of efficient adaptation plan;
- multidisciplinarity of the team is the diversity of backgrounds of the project team members;
- comparison procedure – clear and consistent approach to comparing and choosing final options for the adaptation plan out of the pool of alternatives, generated by developers;
- institutional barriers are lack of coordination and communication in the governance of adaptation, which has potential to affect both the design and adaptation stages.

This list is not about the success of adaptation overall; rather it attempts to outline the preconditions of efficient progress though the design stage.

The responded were able to weight these factors and the results given on Fig. 1 demonstrate different perspectives: the overall importance of each factor relative to others and their relative importance in the development of adaptation actions of specific profile – nature based, managerial and technical.

The interactions in the system of factors, contributing to the efficient development of adaptation plan, were plotted to demonstrate their position in the system of interacting components. The resulted plot shows the scores obtained by each component of the adaptation planning process in terms of being either cause or effect, used as coordinates.

DISCUSSION

The design thinking is rated by the respondents as one of the most influential factors for the development of feasible and efficient climate adaptation plants. In the general perspective it is followed by the stakeholders and in-depth understanding of the climate change impacts on urban environment. As a result, this means that people with certain background in the science of climate changes should be involved in the process, but it is still possible for specialists with well-developed design thinking skills to be the most important players in the team, without extensive knowledge of climate system dynamics.

The variations in relative importance of the same factors in the work aimed at development of specific types of solutions is quite high, which is predictable to certain extent, since the initial targeting towards specific type of solution will affect all its components and lead to reduced variety of participant expertise and increased representation of elements important for this type of developments.

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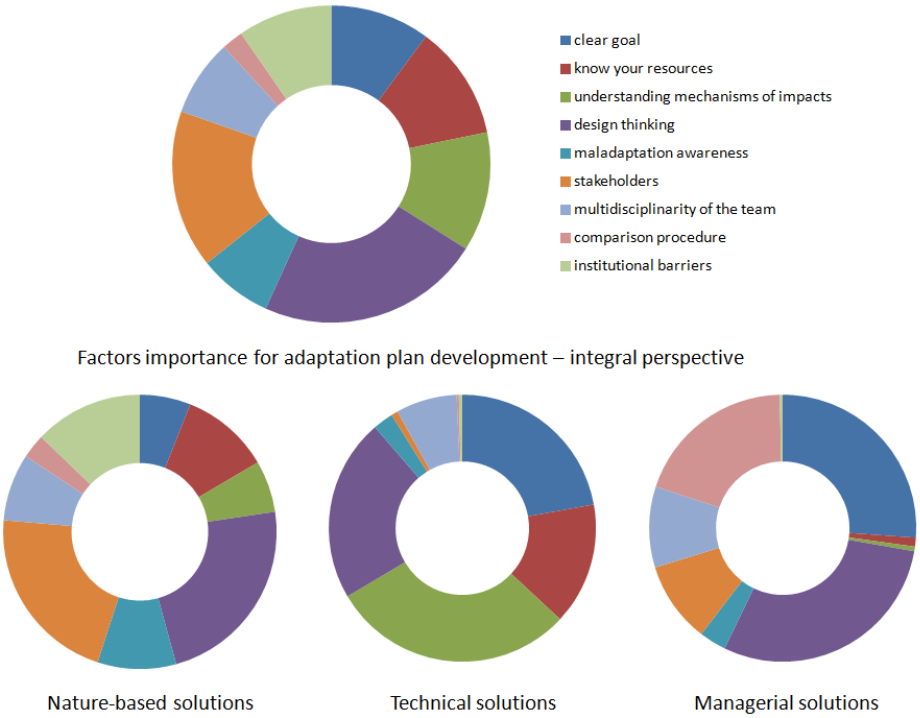


Fig. 1. The weights of components of adaptation development process

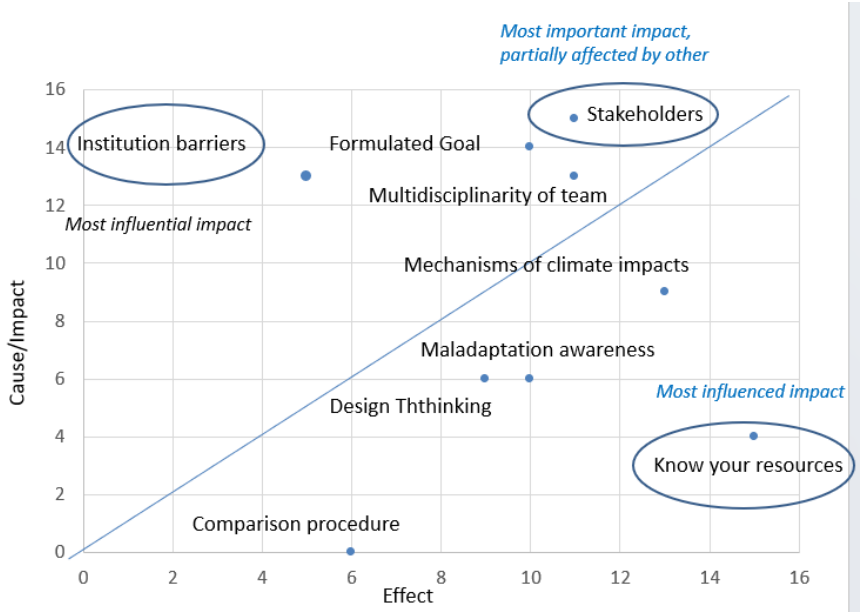


Fig. 2. Interactions and roles of factors in the adaptation design process

The role of design thinking is still high in all cases, even in technical solution, which tend to follow the existing schemes, only tailoring them to specific conditions of each site. An important insight is a great value of awareness about maladaptation for technical and organizational groups of solutions. Nature based solutions depend on this factor to a lesser extent, since they are more often successful and bare less risks of implementation complications [9]. Studying maladaptation helps in avoiding failures

and seeing the range of possible outcomes of implemented actions, which has many options between success and failure [10]. Thus, we can recommend that maladaptation overview should be a part of preparation to the work on the adaptation plans development. Moreover, as it is seen from interaction plot on Fig. 2 maladaptation awareness contributes to design thinking, which is applied to figure out the reasons of getting wrong results.

It is also worth mentioning that most factors of the process on the impact diagram tend to be located along the diagonal line, demonstrating their mutual interaction and ability to affect each other. Institutional barriers and stakeholders are obviously the most important as they form the framework of the project work, and this is consistent with the conclusions of many researchers. The resources component turned out to be the most affected by other, which is probably due to different perspectives that may participants have and project targets' demand.

CONCLUSION

Working out climate change adaptation plans is partially creative task, which needs a set of core elements for success. Moreover, since climate changes represent a wicked problem, there is no well-defined recipes for success, and the success itself is doubtful. Under such conditions being able to react to constantly changing conditions and tasks, in other words being inventive and flexible, is the core of design thinking and most important factor for positive outcomes from interventions in the climate system.

The given work represents an initial analysis, which provided certain insights into the system of adaptation project design, however, there are still many other factors, which may contribute to success. The continuous research work in the field yields new data and success stories which should be analyzed for further progress of adaptation design and implementation principles.

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DIGITAL TOOLS AND CLIMATE ACTION: A FRAMEWORK FOR GHG EMISSIONS CALCULATION IN AGRICULTURE

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ABSTRACT

The increased importance and availability of digital tool leaves an impact on shaping the digitalization of countries and their economies. Links between the digitalization and economic sector productivity and climate change risk adaptation and/or mitigation increase trough different streams have also been found. The use of digital tools can also help in decision making process in terms of climate change including the reduction of greenhouse gas (GHG) emissions. The aim of this study is to develop a base framework for a GHG emission calculation tool in the sector of agriculture. The tool framework is based on three different standards: IPCC Guidelines for National Greenhouse Gas Inventories in the sector of Agriculture, Greenhouse Gas Protocol Corporate Accounting Standard and Statistical classification of economic activities in European Union (also known as NACE code classification system). The developed framework will simplify the GHG calculation tool use for agriculture companies, as the needed input data will be required based on the company NACE code. Additionally, the tool will segregate the calculated GHG emissions in Scope 1 and Scope 2 emissions for easier reporting of GHG emissions, for example, to financial institutions or regulatory bodies.

Keywords: GHG calculation framework, agriculture, mitigation measures, Statistical classification of economic activities

INTRODUCTION

With the new developments of information technology, artificial intelligence, and sensors, as well as their application on a daily basis, all economic sectors are starting to understand the help these technologies can offer in daily operations. These tools support the data analysis, including data storage, interpretation and even decision making [1] not only in engineering and computer science, but many others as well, including environmental sciences, meteorology, agriculture, and financial sector. The 2023 study by European Investment Bank [2] presents that although European Union (EU) has increased its rate of corporate digitalization as of the beginning of COVID-19 pandemic, to further digitalization measures should be implemented across EU to close the corporate digitalization gap between the EU economy and the economy of the USA. The digitalization in economies is also a driver for the transition of more sustainable business operations, contributing to reduction of GHG emissions by increasing the productivity of companies, reducing the need for inputs or unwelcomed output streams, as well as increasing product circularity [1].

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Agriculture, contributing to Baltic country economies and greenhouse gas (GHG) emissions, also is expected to be exposed to means of digitalization. Digitalization in the sector is recognized as an opportunity for decarbonisation, either by implementing digital solutions in the direct operations, or by using tools, that help with GHG emission accounting and management [3], [4].

The digital tools for GHG accounting in agriculture are being developed and used more frequently [5], [6]. These tools very in terms of cost, geographical coverage, base of the tool, assessment scope and how the final results are presented [6]. At the moment of conducting this study the availability of easy-to-use GHG accounting tools focused on Agriculture emission accounting in Baltics is limited, as the existing company level reporting tool in Latvia [7] has a limited functionality and does not provide input data segregation based on company NACE code. Therefore, the authors find it necessary to develop a framework for GHG accounting, that could be available for agricultural companies and farms to use, at the same time meeting the growing demand for reporting purposes and providing insights on potential mitigation actions for GHG emission reduction in their businesses.

This study focuses on development of the tool operational framework or algorithm, that is based on IPCC developed methodology for GHG emission accounting [8], Greenhouse Gas Protocol (GHGP) Corporate Accounting Standard [9] and Statistical classification of economic activities [10] also known as NACE codes. The further development of the GHG accounting tool using the developed framework should result in a simplified digital GHG accounting tool for farmers, helping them to provide the farms GHG emissions to regulatory bodies, financial institutions, or other organizations, that require to provide GHG emissions divided into three Scopes of GHG emissions. The GHG emission calculation within the potential digital tool would be limited only to Scope 1 and Scope 2 GHG emission accounting.

MATERIALS AND METHODS

The approach to create the calculation framework involved a qualitative systematic analysis regarding the sector of agriculture of two most referenced methodologies for GHG accounting: IPCC Guidelines for National Greenhouse Gas Inventories in the sector of Agriculture [8] and GHGP Corporate Accounting and Reporting Standard[9]. Latest available versions of the frameworks as of the beginning of April 2024 were used. The standards were obtained from the official websites of the framework owners, meaning, IPCC and GHGP [8], [9]. Both standards were analysed in the sense of input data requirements. From IPCC methodology all required input data for agriculture emission calculation was retrieved, separating it by topics: crop farming, livestock, land use, etc. The GHGP Corporate standard provided requirements on segregating the calculated GHG emissions into scopes, more specifically, Scope 1 GHG emissions, that cover all direct emissions generated in and by the company, and Scope 2 GHG emissions, that covers emissions from purchased heat energy and electricity. Scope 3 emission accounting is excluded from the scope of this study and the developed tool framework.

Additionally, Statistical Classification of economic activities in EU revision 2 [10], more commonly referred to NACE codes was analysed in the respect of IPCC methodology and GHGP corporate standard, to identify, if any comparable relationships

exist in the required input data between the different input data topics for emission calculation when segregated between NACE codes.

Furthermore, to understand the most efficient level of detail to be incorporated into developed framework, NACE code groups (level 3 NACE codes) and classes (level 4 NACE codes) directly linked to agricultural activities were subjected to screening process, whereby the alignment with the input data requirements identified in the analysis of the two GHG accounting methodologies was evaluated. The screening process identified, if NACE code level 3 or NACE code level 4 should be entered into the tool in the first stage of its use, to accordingly present the tool user the input data fields required to fill in, at the same time avoiding the complication of the tool development process.

The analysis process of finding interlinkages between the used methodologies to develop framework for GHG emission calculation is presented in figure 1.

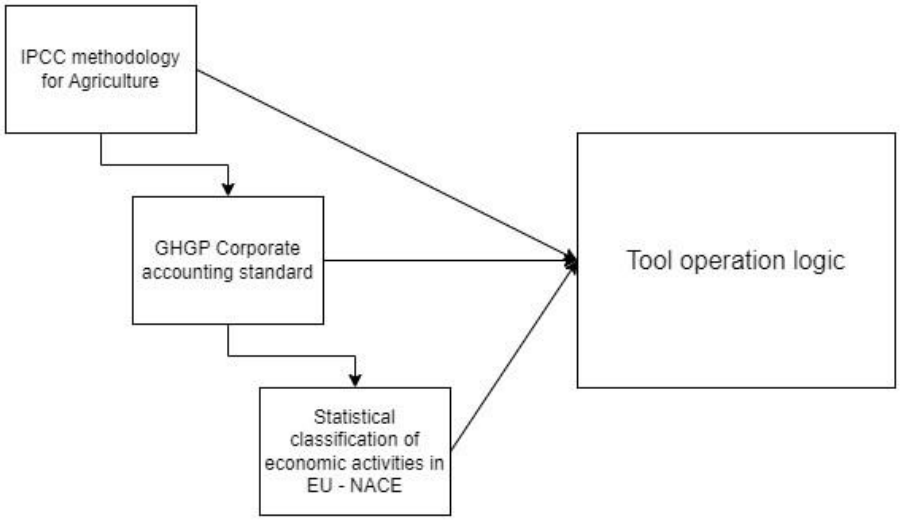


Figure 1. Methodology analysis process to find interlinkages for tool calculation framework

RESULTS

The analysis of IPCC Guidelines for National Greenhouse Gas Inventories in the sector of Agriculture [8] and GHGP Corporate Accounting and Reporting Standard [9] provided a comprehensive list of input data requirements for GHG emission calculation on a farm level. The required data can be divided into following categories based on topics: a) input data for crop farming activities, b) input data for livestock, c) input data for used transport, d) input data for used electricity, heat energy and cooling, that further is divided by energy, that is purchased and energy, that is generated on site [8], [9]. In the emission accounting all energy, that is generated on-site, will be accounted under Scope 1 emissions, while the energy purchased will be accounted under Scope 2 according to Corporate Accounting and Reporting Standard [9].

A qualitative analysis of the NACE codes revealed that the NACE code level 1 section ‘A – Agriculture, Forestry and Fishery’ encompasses activities related to agriculture. This section is further divided into NACE code level 2 which consists of three chapters

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Only the first chapter ‘A.01 – Crop and animal production, hunting and related service activities’ is directly related to agricultural activities on a farm level. Therefore chapters ‘A.02 – Forestry and logging’ and ‘A.03 – Fishery and aquaculture’ were excluded from further analysis, due to not meeting the tools’ scope criteria. The third level of NACE codes is groups, that further divide the level 2 NACE codes. For chapter ‘A.01 - Crop and animal production, hunting and related service activities’ seven groups that are further divided into level 4 NACE code classes were identified [10].

When screening the IPCC and GHGP required input data against NACE codes, it was found that the use of level 3 NACE codes is comparable with the IPCC methodology and would allow to include the simplification for the input data in the tool framework. Level 3 NACE codes in their names do make resemblance with the identified input data categories for GHG emission accounting, providing a potential for simplification in the framework. For example, if user would choose the level 3 NACE code ‘A.01.1 – Growing of non-perennial crops’ [10] the required input data corresponds with the input data required for crop farming [8]. Therefore, in framework as the first step the NACE code of the farm or the agriculture company chosen, filtering the required input data, as depicted in figure 2.

The analysis of IPCC Guidelines for National Greenhouse Gas Inventories in the sector of Agriculture [8] and GHGP Corporate Accounting and Reporting Standard [9] showed that not only company specific data is needed, but also data from national inventories depicting the emission factors for the country. This finding is also supported in Berzina et al. [7] article. For this reason, additional stream of input data needs to be included in the tool.

The developed framework for GHG emission calculation tool for the agricultural farms and or companies, are provided in the figure 2.

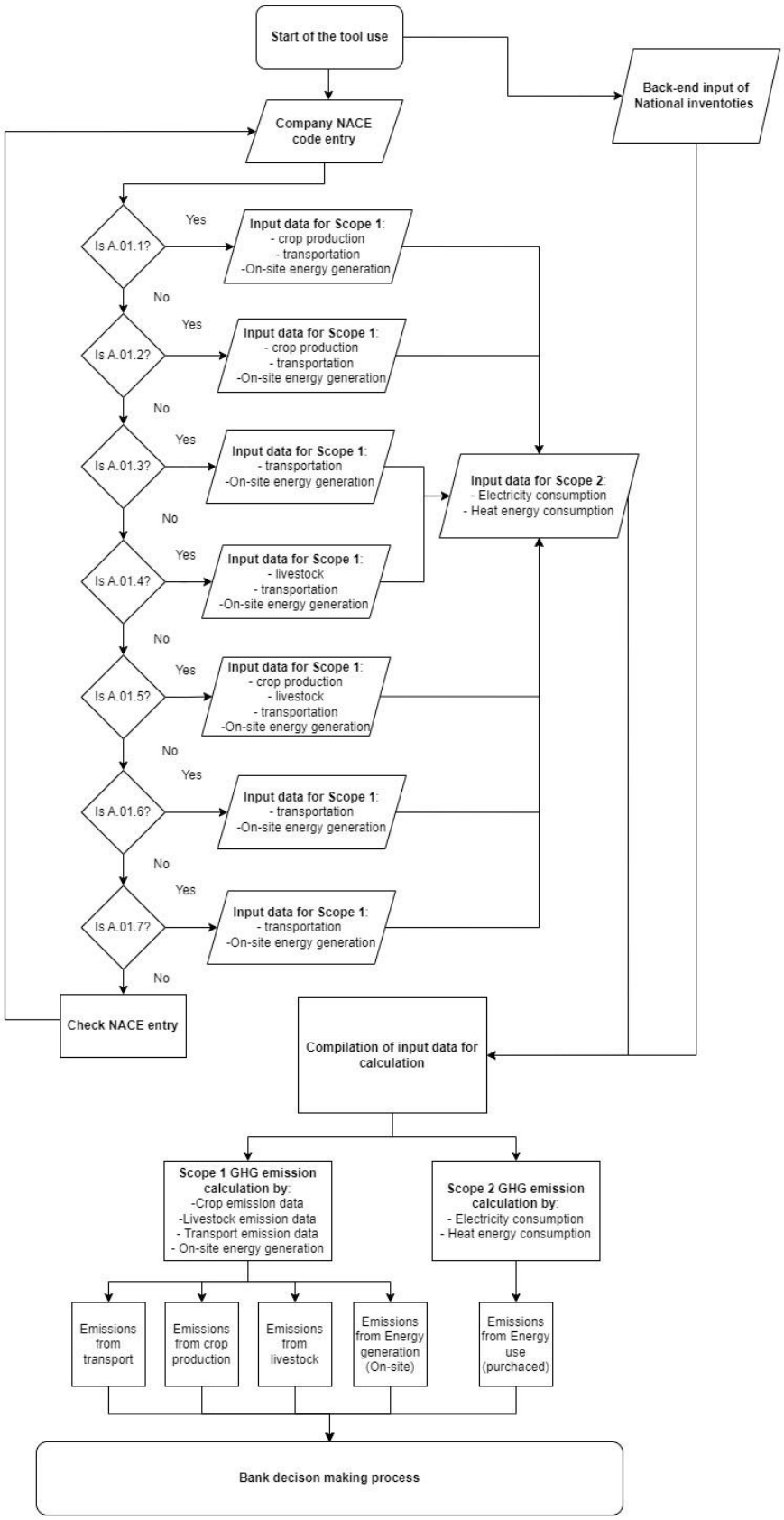


Figure 2. GHG emission accounting tool framework

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DISCUSSION

The developed framework, that includes the input of NACE code of the farm or the company, would ease tool users' decision making process of required input data [1]. For example, based on tools users NACE code input, the tool would show only the input data fields, that are applicable for this company and its NACE code with the linked input data requirements, allowing the user not to spend additional time on the decision-making process if the presented input data fields of other categories, e.g., livestock farming, are or are not applicable to them [11].
As one of the aims of the framework creation was also simplification for the tool users and tool development process. The calculation input data requirements, separated by categories, showed, that level 3 NACE codes already provide enough granularity for the input data segregation, while level 4 NACE codes for agriculture already focus on specific activity, e.g., 'A.01.21 – Growing of grapes'. If level 4 NACE granularity is included in framework, on one hand it reduces the work-load regarding input data of the tool user [1], [6], while on the other hand, it may not require the full information about the farm, e.g., if the farm is growing more than one crop type, and would provide more complexity in the development process, specifically in terms of filtering relevant input data fields [11]. For this reason, it was decided to include in the framework level 3 NACE codes for input data sorting purposes. Due to emission split into Scopes, this segregation will be impacted only for agriculture specific data for Scope 1 emission calculation data input [9].

As the input data stream from national inventories would be the same for all the tool users from the same country, based on the developed framework [5], this input data stream can be built in the back end of the tool without a requirement for this data stream to be entered in the user interface. Colomb et.al. [5] study highlights potential increase in uncertainty for company-level emission accounting when national inventory average values are used. Additional research can be performed to statistically determine the increase of uncertainty in the geographical use area, if average data or more granular data of national inventories is incorporated into the tool [12].
The validation of the developed framework was excluded from the scope of the study. The framework validation shall be performed and analysed in future studies upon the development of the respective tool.

CONCLUSION

The developed framework that is based on IPCC Guidelines for National Greenhouse Gas Inventories and GHGP Corporate Accounting and Reporting Standard and aligned with the NACE code classification system for economic activities enables a simplified user experience by working with only relevant tool inputs, reducing the tool users decision-making time, when choosing relevant input data for their company. The tool, which would be developed based on the framework developed in this study, will enable agricultural companies to report their emissions to a range of organizations including regulatory bodies and financial institutions.

The comprehensive analysis of GHG emissions accounting standards provided the understanding of national inventory data inclusion in the tools' algorithm. Such approach is also supported in other scientific articles. While for this framework development it was recognised as providing simplification for the tool user, potential uncertainty increase might be observed in the agricultural company-level output data.

Further research can be performed to determine the uncertainty level if national average input data is used compared to more granular data from national inventories.

The developed framework enables GHG emission accounting process for agricultural companies in a user friendly and more efficient manner with the input data segregation by level 3 NACE codes, simultaneously meeting the GHG emission reporting requirements by enabling the accounted emission segregation into Scope 1 and Scope 2 emissions.

The study was limited in terms of framework validation process. The validation of the framework shall be performed in future studies simultaneously with the development of the respective tool.

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ECOLOGICAL PROBLEMS OF NATURAL MANAGEMENT RELATED TO AGRICULTURAL DEVELOPMENT IN AUTONOMOUS REPUBLIC OF AJARA

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ABSTRACT

Solving the problem of supply the population with food products during the boom period of global demographic directly depends on agriculture and the least essentially depends on land resources and environment. Coming out of it, finding out the natural management topics of agricultural development is especially urgent in Autonomous Republic of Ajara, which is one of the regions of Georgia with land scarcity, where in line with establishment of land`s private property and market economy, due to irrational natural management – a serious ecological problems are shaped in agricultural field. By application of traditional and modern study methods, geographic originalities of quantitative and qualitative properties of the land resources are evaluated. There are determined a field structure of agriculture, indicators of manufacture, natural management topics of agricultural development and related ecological problems. As a result of a study, main trends of agricultural production are defined by taking into account the basic principles of rational natural management, requirements of internal and external markets and environment`s ecological sustainability.

Keywords: Nature, Resource, Natural management, Ecology, Sustainable development.

INTRODUCTION

Autonomous Republic of Adjara is one of the significant regions of Georgia with agricultural production, where as a result of irrational natural management relating to transition into market economy, agriculture become one of the important factors for activation geodynamical processes. As a result, region has intensely developed landslide and mudslide processes decreasing the land resources and increasing village population`s migration processes thus, falling social-economic development level of rural settlements. Coming out of this, the topic is quite urgent and finding out the main mechanism of problem and the references set in line with its solution will have scientific-research and applicable meaning as well.

Main goal of the research is to determine ecological problems of natural management related to agriculture in Autonomous Republic of Ajara. In order to achieve the aim set, the following tasks should be solved:

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- Find out quantitative and qualitative properties of changes of agricultural lands into Ajara`s land fund;
- Determine spatial originalities of cultivated lands and natural management issues of its application regarding changes of ecological conditions;
- Find out geographical originalities of sectoral structure of agriculture and its impact on environment`s ecological sustainability;
- Determine ecological problems of natural management related to agricultural development and originalities of its territorial organization;
- Work out rational natural management topics (coming out of environmental sustainability) for the sectoral specialization`s development of agriculture in Ajara and set the main directions for solution of the problem.

Object of the research is Autonomous Republic of Ajara, which covers Kobuleti Municipality, Khelvachauri Municipality, Keda Municipality, Shuakhevi Municipality and Khulo Municipality. Area of Ajara is 2900 sq. km, where 361,4 thousand population resided by 2023.

MATERIALS AND METHODS

Any type of economic activity more or less impacts on ecological condition, but agricultural influence on environment is higher comparing to other sectors. Agricultural production on some particular territory should be based on basic principles of sustainable agricultural development. Ecological problems of natural management related to agricultural development of Autonomous Republic of Ajara constitutes one of the most important challenges of the region and its complex study and application of preventive measures need sharing of research results in an international context [2], [4], [5]. In order to reach the aim set, application of traditional and contemporary (modern) research methods became necessary.

By using statistical method, there was found out quantitative properties of agricultural cultivable lands, their dynamics and originalities of spatial distribution. Via application of comparative method, there was determined the dynamics of agricultural lands according to some particular time and municipalities. By using the field research method, there was evaluated the sectoral structure of agricultural production on the territory of Ajara, originalities of territorial organization of agricultural production, agricultural impact on the environment and by studying the landslide locations, there was determined the reasons causing geodynamical processes activated due to agricultural production and originalities of their further development. In order to define the topic in details, it was necessary to conduct sociological surveys and application of method of in-depth interviews. During the research, there was also used historical, space-time analysis and other methods.

RESULTS AND DISCUSSION

None of sectors of the economy have such direct contact with environment like agriculture has. Therefore, agricultural production constitutes the special sector of artificial impact on environment, the development of which (in case of irrational natural management) often presents the significant factor for ecological condition`s worsening. Coming out of it, existing problem constitutes the trend with global nature, and the preventive measures conducted worldwide and research results [1], [3], [8], [9], [10],

[11], [12], [13], [14], [15], [16] during agricultural production ensures maintenance of natural landscapes from one side, and increases agricultural products by foreseeing the environmental sustainability from the other side. Existing problem is not less urgent in almost all regions of Georgia, especially in Ajara, which is characterized with complex nature of natural conditions (77.1% of territory constitutes mountains and foothills, with highest precipitation throughout the Europe) and scarcity of land resources. Actually, environment of most territory of Ajara is characterized with less sustainability for economic activity, where (in line with implementation of market economy and establishment of private property on the land) agricultural activity is held in the direction of irrational natural management. As a result, geodynamical processes are being activated therein [6].

In order to reach the main goal of the research, first of all there should be determined the resources necessary for agricultural development and evaluate spatial originalities of dynamics of quantitative indicators of agricultural lands being in Ajara`s land fund (see table 1).

Table 1: Distribution of agricultural cultivable lands in Autonomous Republic of Ajara by municipalities (during 1990-2012 years)

Municipalities in Autonomous Republic of Ajara	years	total area (ha)	Agricultural cultivable lands (ha)	Including	
				arable lands (ha)	Perennial plants (ha)
Kobuleti	1990	72000	21058	2236	12212
	2012	72000	16042	2229	8635
Khelvachauri	1990	43000	11263	1209	8322
	2012	43000	11123	1508	6889
Keda	1990	45200	6056	3074	741
	2012	45200	10248	2466	293
Shuakhevi	1990	58800	15463	2561	152
	2012	58800	17634	1643	37
Khulo	1990	71000	23446	3272	55
	2012	71000	21895	2463	45
Total in Ajara	1990	290000	77286	12352	21486
	2012	290000	76924	10309	15899

Source: table is made on the basis of data by Ministry of Agriculture of Autonomous Republic of Ajara. Note: No land reform and census of agriculture was held since 2012.

Table 1 shows us that agricultural lands constitute 26,5% of Ajara`s land fund and their amount in 1990-2012 years was slightly (only by 344 ha) decreased, whilst amount of lands fit for cultivation (arable lands, perennial plants) was significantly (from 33838 ha to 26208 ha or by 22,5%) decreased. The mentioned tendency covered absolutely all municipalities, especially sea coast regions, where urbanization rate is quite rapid. Besides, the mentioned region is passed by Transport Corridor Europe-Caucasus-Asia (TRACECA), some particular part of which passes through agricultural territories [7].

Because of the fact that agriculture (especially horticulture) is directly related to lands fit for cultivation, it is noteworthy to discuss quantitative properties of arable lands and their distribution per capita. If in the country up to 1200 sq. m arable land comes per villager, this indicator in Ajara is extremely low and in average it equals to 683 sq. m and almost half of it in some particular village settlements of mountainous Ajara. Actually, low indicators of cultivated lands and their maximum application without

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taking into consideration the basic principles of rational natural management constitute the condition provoking the geodynamic processes. Moreover, without foreseeing the environmental sustainability, village settlers in order to extend their land resources – plough highly inclined slopes, cut forest, build internal agricultural ways, performs overwatering, implements other types of irrational natural management during the agricultural production, etc. Besides, under market economy condition, some particular changes were implemented in renovation of sectoral specialization of agricultural economy, which lead to increased load to already loaded land resources. In particular, if in mountainous Ajara tobacco planting was the leading sector of horticulture during the recent past, it was not only highly profitable sector but somehow contradicted the activation of erosion processes on the arable lands. Now tobacco planting actually exist no more and priority is granted to gardening specialization, in case of which (during high precipitation conditions) highly inclined slopes are being washed out from fertile soil layer thus promoting the activation of erosion processes. Almost similar condition is at sea coast regions, where tea and citrus planting was remains as the leading sectors. Recently in the mentioned region annual crops are gradually planted more and more, which is not able to protect the soil resources during the high precipitation conditions. Actually, agriculture in rural settlements of Ajara constitutes the leading sector of material manufacture and not less than 92-95% of production falls upon it. Therefore, agriculture constitutes the most significant factor provoking anthropogenic impact on Ajara`s environment and most of part of development of geodynamical processes in the region falls upon it. According to data acquired from the field research conducted by us and with materials by Geological Service of Division of Environmental Protection and Natural Resources of Autonomous Republic of Ajara there is found out that there almost is no settlement throughout the region where is not developed some kind of natural disaster. Spatial originalities of geodynamical processes developed as a result of agricultural production on the research territory are more or less different. Therefore, the main method for determination of the quality of existing threats according to municipalities presents identification of quantitative indicators of landslide processes according to specific rural settlements and cultivated lands as it is clearly observed in table 2.

According to research 373 landslides were stated in Ajara only in 2023, or it is 1.2 landslide per one populated area in average. This indicator is higher in mountainous Ajara, especially in Shuakhevi Municipality, where 2.4 landslide comes per one populated area. The mentioned originality firstly relates to landscape`s complex nature and high anthropogenic load on cultivated lands [6]. Number of landslides is low in sea coast regions like one landslide per two populated area in average. If we approach to topic in a complex manner, then development of geodynamical processes according to cultivated lands is necessary (see table 2). In Ajara, one landslide falls upon 70,3 ha cultivated land in average, but these indicators differ by municipalities. In particular, number of landslides is high in mountainous Ajara (1 landslide per 18,5 ha in average). Especially high indicator regarding this is in Shuakhevi Municipality – 1 landslide per 10,3 ha). Drastically different results we have in seaside Ajara, where average indicator is 1 landslide per 394 ha land. The mentioned originalities firstly is the result of natural conditions, which as a result of agricultural production and together with rise of elevation gradually increase geodynamical processes and ecological condition even worsens.

Table 2: Quantitative indicators of landslide centers in rural settlements and cultivated lands of Autonomous Republic of Ajara in 2023

Municipalities in Autonomous Republic of Ajara	Number of rural settlements	Number of landslides	Average number of landslides per settlement	Amount of cultivated lands (ha)	Average number of landslides per cultivated lands (ha)
Kobuleti	48	23	0,5	10864	472,3
Khelvachauri	64	26	0,4	8212	316
Keda	64	67	1,1	2759	41,1
Shuakhevi	68	162	2,4	1680	10,4
Khulo	78	95	1,2	2508	26,4
Total in Ajara	322	373	1,2	26208	70,3

Source: table is made on the basis of data by field research and Geological Service of Division of Environmental Protection and Natural Resources of Autonomous Republic of Ajara.

In order to reach the research goal set and in order to find out the quantitative and qualitative properties of ecological condition of agricultural production`s natural management at the research territory, here we bring the following conditional properties:

1. In the municipalities where number of landslides per one rural settlement is less than 1, and less than 1 landslide is observed on above 100 ha territory of cultivated land – it should be evaluated like “slightly worsened”; 2. In the municipalities, where 1-2 landslide(s) are observed in rural settlement, and more than 1 landslide is observed on 40-100 ha cultivated land – should be evaluated as “significantly worsened”; 3. In the municipalities, where 2 landslides in average are in the rural settlement, and more than 2 landslides are observed on 1-40 ha cultivated lands, should be evaluated as “extremely worsened”. Therefore, spatial properties of research results are reflected in table 3.

Table 3: Qualitative properties of landslide centers in rural settlements and cultivated lands of Autonomous Republic of Ajara in 2023

Municipalities in Autonomous Republic of Ajara	Properties of ecological condition		
	Slightly worsened	Significantly worsened	Extremely worsened
Kobuleti	Slightly worsened	-	-
Khelvachauri	Slightly worsened	-	-
Keda	-	Significantly worsened	-
Shuakhevi	-	-	Extremely worsened
Khulo	-	Significantly worsened	-
Total in Ajara	-	Significantly worsened	-

Source: table is made on the basis of data by field research and Geological Service of Division of Environmental Protection and Natural Resources of Autonomous Republic of Ajara.

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The research makes clear that we have a quite complex situation in Ajara in line with activation of natural processes, which gradually increases as the elevation rises. Existing condition firstly is caused by agricultural production by violating the basic principles of rational natural management and without foreseeing the high demographic load of agricultural cultivable lands and environmental sustainability.

As of the issue that one of the reasons for worsened ecological condition on the research territory is agricultural production – it is necessary to find out the attitude of farmers (main productive force involved in development of the sector) towards the environmental protection topics. Actually, more than 95% of production in the region is being manufactured by small farms (families with 1-3 members), which are less informed with knowledge regarding rational natural management topics in these or those natural conditions. For clarification of the topic, we have conducted sociological surveys. On the question "how much do you know sustainable agriculture"? 138 respondents answered as follows: 86 of them (or 62.3%) responded negatively, 38 of them (or 26,8%) had partial idea of it and 14 of them (about 10,9%) knows it. On the question: "How well are you informed with information leaflets about environmental protection by governmental and non-governmental agencies"? 138 respondents answered as follows: 83 of them (or 60,1%) responded negatively, 55 of them (or 39,9%) answered positively. The research has proven that most of farmers traditionally implements agricultural production and is less likely aware of basic principles of rational natural management.

CONCLUSION

As a result of the research there was found out that agricultural activity in Ajara presents one of the significant factors of activation of geodynamical processes, that is related to complex nature of natural conditions, scarcity of land resources and not taking into consideration the basic principles of rational natural management during the agricultural production. Absolutely in every municipality of research territory, ecological condition is more or less changed due to agricultural production. In particular, seaside regions (Kobuleti, Khelvachauri) is "slightly worsened", in Keda Municipality and Khulo Municipality is "significantly worsened" and in Shuakhevi Municipality – "extremely worsened".

The most important direction for solution of the problem is that sectoral structure of the economy in rural settlements should be renovated in line with sustainable economic development. In order to improve the ecological condition in the region, coming out of environmental condition it is necessary to change the agricultural production`s sectoral specialization. Besides, in order to increase the protection of basic principles of rational natural management of agricultural production, it is necessary to create large farms and increase the farmers` awareness regarding the environmental security.

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ECONOMIC AND ENVIRONMENTAL GOALS OF THE MUNICIPAL COMPANY

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ABSTRACT

Economic and ecological goals of urban society. These goals are important for the fulfillment of all legislative and ecological requirements on the part of the Czech Republic, but also on the part of the European Union or the European Commission. This article is being prepared for the relevant project called CEVYKO. of this article will be a description of the economic and environmental goals that the project is to use in the future. The CEVYKO project is a purely municipal task and the goal is to build a modern technological facility for waste processing. Incorporating all of the company's goals into this is undoubtedly a great effort for the authors, respectively the company's shareholders. for public administration. The article will be divided into two parts. The first part of the publication will be the theoretical basis of the publication, and the second part, i.e. the practical part, will be evaluated and goals will be proposed. And goals both from an economic point of view and from an environmental point of view. The article will bring new knowledge and can be an inspiration for other similar projects. The authors of the article will further develop this idea in other publications.

Keywords: Economic, environment, waste management, CEVYKO, goals.

INTRODUCTION

Glass recycling is an essential part of CEVYKO's strategy, as it not only brings significant economic savings by reducing the need for new raw materials and energy, but also significantly reduces the company's ecological footprint. Thanks to modern technologies and innovative approaches, CEVYKO effectively minimizes the amount of glass waste that would otherwise end up in landfills, thus saving natural resources. These facilities not only offer efficient recycling of glass, but also other types of waste, which contributes to the overall reduction of the company's environmental impact. In this way, the CEVYKO project not only supports environmental sustainability, but also creates new economic opportunities and jobs. CEVYKO cooperates with local communities, businesses and public institutions to support and promote recycling activities and sustainable development. The economic benefits of these activities are obvious: reduction of production costs, increase in efficiency and strengthening of

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competitive advantage in the market. The aim of the thesis is to fulfill environmental goals through the reduction of greenhouse gas emissions and the protection of natural resources. With this approach, CEVYKO confirms its commitment to ecologically responsible business and represents an example of a company that successfully integrates economic and better ecological interests, thus contributing to a future for all.

MATERIALS AND METHODS

Conducting a literature search focused on:

- The history of glass recycling.
- Current methods of glass recycling.
- Economic aspects of glass recycling.
- Environmental benefits and challenges associated with glass recycling.

a) Data collection and analytical methods

Primary data. Interviews with experts from industry and academia. Secondary data. Analysis of existing studies, statistical data and reports from governmental and non-governmental organizations. Quantitative analysis. Using statistical tools to evaluate the economic costs and benefits associated with glass recycling. Cost-Benefit Analysis (CBA). Modeling and simulation [1,2,3].

Creating economic models to simulate different glass recycling scenarios. Predictions of impacts on the glass market at different levels of recycling. Glass is a material that can be reused in many forms. This applies especially to bottles and other glass containers, which can continue to serve as containers even after their original use. [7,8,9]. This fact has led to manufacturers and governments alike recognizing the potential for energy and resource savings through the reuse and recycling of glass packaging. In many parts of the world, container back-up laws require consumers to pay a small fee at the time of purchase, which is refunded when the container is returned at the redemption point. [4,5,6].These redemption points can take many forms, including stores selling recalled products and automated "reverse vending machines" where consumers can return containers and receive a receipt that can be exchanged for cash. [10,11,12]. Currently, the recycling of glass from electrical and electronic equipment is relatively limited. The reason is the frequent contamination of the glass with other substances. In addition, many of these products contain rare elements whose high market value reduces the incentive to recycle glass [1]. For example, the insides of fluorescent lamps are coated with a phosphor layer that is often contaminated with toxic mercury [11]. The quality of this glass is unsuitable for recycling, and therefore the emphasis is placed on recovering valuable mercury and phosphorus. Nevertheless, technologies are being developed that allow for the effective removal of the contaminated phosphor layer, which could improve glass recycling options. The closed cycle of soda lime silica glass recycling brings many environmental benefits. Above all, it enables the return of mineral resources back into circulation, which is a key element of sustainable development [4,5,]. Although raw materials for glass production are not significantly scarce (silica sand and limestone are abundant, and soda ash is produced either by the Solvay process or from trona mineral, which is available worldwide), recycling nevertheless contributes to the efficient use of resources[4,5,6,9,10,11,12].

RESULTS AND DISCUSION

The aim of this research is to analyze the economic side of the fragmented economy in the company CEVYKO, a.s. We examine input costs, annual costings, and annual cost-benefit balances for recycling 1,000 tons of glass per year.

b) Entry costs

Input costs include all expenses required to start and operate a shard farm. These costs include:

- Processing of operating regulations
- Noise study;
- Administration.

Table 1 Input costs for a volume of 1,000 t of glass per year

Item	Price
Operating rules	16 000 CZK
Noise study	20 000 CZK
Administration	10 000 CZK
TOTAL	**46 000 CZK**

The table lists prices for individual items related to a project or activity. Here is a more detailed breakdown. Operating Rules. The price for processing or securing the operating order is CZK 16,000. The operating procedure is an important document that establishes the rules and procedures for operating a certain activity or facility. Noise study. The price for preparing a noise study is CZK 20,000. A noise study is necessary to assess the noise load in a certain location and may be required, for example, during construction projects or during the operation of noisy equipment. Administration. The costs of administrative activities are CZK 10,000. Administration includes all necessary administrative tasks associated with a project or activity, such as handling documentation, communication with authorities, etc. TOTAL. The total cost for all the listed items is CZK 46,000. This table provides a clear overview of the costs associated with operating regulations, noise studies and administration.

Table 2 Annual calculation of glass for a volume of 1,000 t of glass per year

Cost			
Item	**Poison. price**	**Amount**	**In total**
Purchase of glass	500 Kč	1000	500 000 CZK
Cubicle rental	3 600 Kč	12	43 200 CZK
Mechanical work	900 Kč	90	81 000 CZK
Administration	2 500 Kč	12	30 000 CZK
TOTAL			**654 200 CZK**

Sales			
Item	**Poison. price**	**Amount**	**In total**
Sales glass	1 000 Kč	1000	1 000 000 CZK
TOTAL			**1 000 000 CZK**

Annual balance of costs and sales	
Cost	654 200 CZK
Sales	1 000 000 CZK
PROFIT	**345 800 CZK**

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The table provides an overview of the annual costs and revenues associated with the activity, which includes the purchase and sale of glass, cubicle rental, mechanical work and administration. Below is a more detailed commentary. Costs. Purchase of glass. Unit price: 500 CZK

Quantity: 1000 t. Total per year: CZK 500,000. The purchase of glass represents the largest cost item with the amount of CZK 500,000 per year.

Cubicle rental. Unit price: CZK 3,600 per year Quantity: 12 (months) Total for the year: CZK 43,200 Renting a cubicle costs CZK 43,200 per year. Mechanical work. Unit price: 900 CZK Quantity: 90 hours Total for the year: CZK 81,000 The cost of mechanical work is CZK 81,000 per year.

Administration. Unit price: CZK 2,500 per month. Quantity: 12 (months). Total per year: CZK 30,000. Administrative costs are CZK 30,000 per year. TOTAL costs: CZK 654,200

Sales. Sales of glass. Unit price: CZK 1,000. Quantity: 1000 tons. Total per year: CZK 1,000,000. The total annual revenue from the sale of glass amounts to CZK 1,000,000.

Annual balance of costs and sales. Cost: CZK 654,200. Sales: CZK 1,000,000 PROFIT: CZK 345,800.

The table shows that the annual profit after deducting costs from sales is CZK 345,800. This result is positive, which indicates that the business is profitable.

Table 3 Input costs for a volume of 1,250 t of glass per year

Item	Price
Operating rules	16 000 CZK
Noise study	20 000 CZK
Administration	10 000 CZK
TOTAL	**46 000 CZK**

The table contains an overview of individual cost items and their prices. Below is a more detailed commentary. Operating Rules. Price: CZK 16,000. The operating procedure is an important document that determines the rules and procedures for operating a certain activity or facility. The costs of its processing or acquisition are listed at CZK 16,000.
Noise study. Price: CZK 20,000
A noise study is an analysis of the noise load in a given location and is often required for construction projects or the operation of noisy equipment. The cost of this study is CZK 20,000. Administration. Price: CZK 10,000. Administrative costs include all necessary administrative tasks associated with a project or activity, such as processing documentation, communication with authorities, etc. These costs are listed at CZK 10,000. TOTAL: Price: CZK 46,000
The total costs for all the listed items amount to CZK 46,000.
The table provides a clear overview of the costs associated with the operating regulations, noise study and administration. The stated amounts can be used for budgeting or financial planning of the related project.

Table 4 Annual calculation of glass for a volume of 1,250 t of glass per year

Cost			
Item	**Poison. price**	**Amount**	**In total**
Purchase of glass	500 Kč	1250	625 000 CZK
Cubicle rental	3 600 Kč	12	43 200 CZK
Mechanical work	900 Kč	100	90 000 CZK
Administration	2 500 Kč	12	30 000 CZK
TOTAL			**788 200 CZK**

Sales			
Item	**Poison price**	**Quantity**	**Total per year**
Prodej skla	1 000 Kč	1250	1 250 000 CZK
TOTAL			**1 250 000 CZK**

Annual balance of costs and sales	
Cost	788 200 CZK
Sales	1 250 000 CZK
PROFIT	**461 800 CZK**

The table provides a detailed overview of the annual costs and revenues related to the activity including the purchase and sale of glass, cubicle rental, mechanical work and administration. Below is a more detailed commentary. Costs. Purchase of glass. Unit price: 500 CZK
Quantity: 1250 tons. Total per year: CZK 625,000. The purchase of glass represents the largest cost item with the amount of CZK 625,000 per year. Cubicle rental. Unit price: CZK 3,600 per month. Quantity: 12 (months). Total for the year: CZK 43,200
Renting a cubicle costs CZK 43,200 per year. Mechanical work. Unit price: 900 CZK. Quantity: 100 hours. Total per year: CZK 90,000. The cost of mechanical work is 90,000 CZK per year.
Administration. Unit price: CZK 2,500 per month. Quantity: 12 (months). Total per year: CZK 30,000. Administrative costs are CZK 30,000 per year. TOTAL costs: CZK 788,200. Sales. Sales of glass. Unit price: CZK 1,000. Quantity: 1250 tons. Total per year: 1,250,000 CZK. The total annual revenue from the sale of glass amounts to CZK 1,250,000.
Annual balance of costs and sales. Cost: CZK 788,200. Sales: 1,250,000 CZK. PROFIT: CZK 461,800
The table shows that the annual profit after deducting costs from sales is CZK 461,800. This result is very positive, indicating that the business is profitable and generating a significant financial surplus.

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Table 5 Input costs for a volume of 1,500 t of glass per year

Item	Price
Operating rules	16 000 CZK
Noise study	20 000 CZK
Administration	10 000 CZK
TOTAL	**46 000 CZK**

The table provides an overview of the costs associated with a specific project or activity. A more detailed commentary on individual items follows. Operating Rules. Price: CZK 16,000. The operating procedure is a key document that establishes the rules and procedures for operating a certain activity or facility. This document is necessary to ensure safe and efficient operation and its processing costs CZK 16,000. Noise study. Price: CZK 20,000. A noise study is an analysis aimed at assessing the noise load in a certain area. This study is often required when planning construction projects or when operating equipment that can generate noise. The cost of preparing a noise study is CZK 20,000. Administration. Price: CZK 10,000. Administrative costs include all activities related to project administration or activities such as handling documentation, communication with authorities, contract management and other administrative tasks. These costs amount to CZK 10,000. TOTAL: Price: CZK 46,000. The total costs for all the listed items amount to CZK 46,000. This table provides a clear overview of the financial expenses associated with the operating regulations, noise study and administrative activities. It helps in budgeting and financial planning for a given project or activity.

Table 6 Annual calculation of glass for a volume of 1,500 t of glass per year

Cost			
Item	**Poison. price**	**Amount**	**In total**
Purchase of glass	500 CZK	1500	750 000 CZK
Cubicle rental	3 600 CZK	12	43 200 CZK
Mechanical work	900 CZK	110	99 000 CZK
Administration	2 500 CZK	12	30 000 CZK
TOTAL			**922 200 CZK**

Sales			
Item	**Poison. price**	**Amount**	**In total**
Sales glass	1 000 CZK	1500	1 500 000 CZK
TOTAL			**1 500 000 CZK**

Annual balance of costs and sales	
Cost	922 200 CZK
Sales	1 500 000 CZK
PROFIT	**577 800 CZK**

The table provides a detailed overview of the annual costs and revenues associated with the activity of buying and selling glass, cubicle rental, mechanical work and administration. Below is a detailed commentary on individual items. Costs. Purchase of glass. Unit price: 500 CZK. Quantity: 1500 tons. Total per year: CZK 750,000. The cost of purchasing glass amounts to CZK 750,000 per year, which is the largest cost item. Cubicle rental. Unit price: CZK 3,600 per month. Quantity: 12 months. Total for the year: CZK 43,200. The cost of renting a cubicle is CZK 43,200 per year.

Mechanical work. Unit price: 900 CZK. Quantity: 110 hours. Total for the year: CZK 99,000. The costs of mechanical work amount to CZK 99,000 per year. Administration. Unit price: CZK 2,500 per month. Quantity: 12 months. Total per year: CZK 30,000. Administrative costs amount to CZK 30,000 per year. TOTAL costs: CZK 922,200

Sales. Sales of glass. Unit price: CZK 1,000. Quantity: 1500 tons. Total per year: 1,500,000 CZK. The total annual revenue from the sale of glass amounts to CZK 1,500,000.

Annual balance of costs and sales. Cost: 922,200 CZK. Sales: 1,500,000 CZK. PROFIT: CZK 577,800.

The table shows that after deducting costs from sales, the annual profit is CZK 577,800.

CONCLUSION

Today, more and more businesses are focusing on issues of sustainability and environmental protection. One of the key elements of this effort is recycling, which makes it possible to reuse raw materials and minimize waste. In this contribution, the authors of the article focus on the specific case of CEVYKO, which currently specializes in glass recycling. The authors investigated three different variants of glass recycling, whose impact on the profitability and sustainability of the business is analyzed in detail. As part of their current strategy, three different variants of glass recycling are being considered, which vary according to the amount of glass recycled and the profit involved. First option: 1,000 tons of glass per year. The first variant of glass recycling that CEVYKO is considering involves the processing of 1,000 tons of glass per year. The resulting profit of this variant is CZK 345,800 per year. This option would involve a lower volume of recycled glass, which could be suitable for the initial phase of expanding the company's recycling operations. Recycling this amount of glass could have a positive effect on the overall reduction of the ecological burden, although the economic profit from this option is lower compared to other options. Second option: 1,250 tons of glass per year. The second option focuses on recycling 1,250 tons of glass per year with an expected profit of CZK 461,800 per year. This variant represents an expansion of the recycling capacity by 250 tons compared to the first variant. With this step, CEVYKO could achieve higher efficiency and economic profit at the same time. Increasing the volume of recycled glass by 250 tons per year can have a significant impact on reducing waste and better use of raw materials. Third option: 1,500 tons of glass per year. The most ambitious option that CEVYKO is considering is the recycling of 1,500 tons of glass per year. This variant assumes the highest volume of recycled glass and also the highest expected profit of CZK 577,800 per year. Recycling this high volume of glass would allow the company not only to achieve a significant economic profit, but also strengthen its market position and increase its ability to compete.

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Evaluation of impacts and strategic decision. Each of the listed glass recycling options has its own specific advantages and challenges.

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ECONOMIC BALANCE OF THE SORTING LINE FOR MUNICIPAL WASTE PROCESSING

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ABSTRACT

The contribution focuses on the optimization of the economic balance of the sorting line for the processing of municipal waste with the aim of increasing the efficiency and sustainability of waste management. This abstract provides an overview of the key economic aspects that affect sorting line operations, including cost, revenue and financial return analysis. Major cost items include investment in modern sorting line technology, installation and commissioning costs, and operating costs associated with maintenance, energy and labor. On the revenue side, the income from the sale of sorted materials such as plastics, metals and paper and the savings achieved by reducing the volume of waste sent to landfills are analysed. The study also takes into account possible subsidies and financial support available for environmental projects. The economic analysis of a purely municipal project (without the involvement of foreign capital, the involvement of public funds and subsidies) CEVYKO includes an assessment of the overall financial efficiency, the identification of potential risks and obstacles, and the proposal of measures to increase profitability and sustainability. Special emphasis is placed on long-term economic and environmental benefits, including improving the local economy, creating jobs and reducing the ecological footprint. The results of this analysis provide valuable information for decision-making processes and strategic planning in the field of municipal waste management. The recommendations arising from this study support the efficient allocation of resources and contribute to the achievement of the CEVYKO project goals. in the field of economic sustainability.

Keywords: optimization, economic balance, sorting lines, costs, revenues

INTRODUCTION

Today, companies face increasing challenges in the field of municipal waste management. With increasing volumes of waste and increasingly strict environmental regulations, it is crucial to find efficient and sustainable ways to process it. Sorting your

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waste is a vital step towards minimizing the amount of waste ending up in landfills and maximizing the recycling and reuse of materials. [8]

The CEVYKO project focuses on improving the economic balance of sorting lines for municipal waste processing. The economic balance represents a comprehensive assessment of the financial costs and revenues associated with the operation of these facilities. This introduction to the issue provides a basic overview of the key aspects that must be considered when analyzing the economic efficiency of sorting lines. On the cost side, investment expenses for the acquisition of modern technology, costs for installation and start-up of the line, as well as operating costs that include labor must be taken into account power, energy, maintenance and repairs. An important aspect is also the assessment of economic returns, which may include income from the sale of sorted raw materials (plastics, metals, paper), savings from a smaller volume of waste destined for landfill and potential subsidies and support for ecological projects. The CEVYKO project seeks to identify and quantify these cost and revenue items to provide a holistic view of the economic sustainability of sorting lines. The goal is also to propose strategies to optimize costs and increase operational efficiency. In the long term, the project focuses on supporting sustainable development and reducing the environmental burden through more efficient management of municipal waste. [1,2,3,4,5,6]

MATERIALS AND METHODS

The economic analysis was prepared for 3 assumed scenarios, which are based on the available knowledge at the date of the feasibility study. This is a basic realistic scenario to simulate the more improbable expected development of the operation of the sorting line. In addition to this basic scenario, an optimistic scenario and a pessimistic scenario were also processed. This analysis was processed for the CEVYKO project. Individual scenarios were evaluated in terms of their economic return. In order to make it possible to compare individual scenarios, some common assumptions for their evaluation were established. Similarly, for all scenarios, it is assumed that the construction will be carried out between 2025 and 2026. All investments associated with the project (preparatory work, processing of project documentation, selection of a contractor and related sub-activities, construction of the hall, delivery of the sorting line itself, including installation, training and testing operation) will thus be spent until the end of 2026. The start of operation is planned in 2027 in all scenarios, while the economic evaluation of individual scenarios was carried out until 2046. All prices are given in 2024 prices without VAT. [5,6,7,8]

Net present value (NPV - Net Present Value).

Net Present Value (NPV) is an economic indicator that expresses the difference between the present value of future income and the present value of future expenses associated with a given project or investment. NPV is used to assess the profitability of investments or projects and is calculated by discounting future cash flows to their present value using a discount rate.

Mathematically:

$$NPV = \sum \left(\frac{C_t}{(1+r)^t} \right) - C_0$$

- C_t are cash flows in individual periods,

- r_r is the discount rate,
- t_t is the time period,
- C_0 is the initial investment. [5,6,7,8]

Payback Period)

Definition: The payback period is the period of time required for an investment to return in the form of net cash flows. In other words, it is the time it takes for the total cumulative income from the investment to reach the amount of the initial investment.

Mathematically:

$$\text{Doba návratnosti} = \frac{\text{Počáteční investice}}{\text{Roční čistý příjem}}$$

A shorter payback period is generally considered more favorable because the investment will return faster, reducing risk and increasing liquidity. The disadvantage of this ratio is that it does not take into account the cash flows after the payback period or the time value of money. [1,2,3]

RESULTS

A. Investment expenses

All considered scenarios for building a sorting line are based on preliminary qualified budget estimates and are identical. For investment expenses, a sensitivity analysis is prepared for all three scenarios, where the impact of a change in total investment expenses on the economic evaluation of the project is tested. In addition to expenses related to the construction of the hall, utility networks, paved areas and the subsequent delivery of sorting line technology, the project budget also includes the acquisition of the necessary handling equipment and large-volume containers.

Table 1 Investment expenses

Investment expenses	**thousand CZK**
Projecting, documentation, consulting	10 000
Construction work (halls, shelters, IS, earthworks)	240 000
Sorting line technology	340 000
In total	**600 000**

Construction work includes all anticipated investment expenses associated with construction objects (mainly construction of the main hall), then earthworks (including preparatory works), utility networks, roads, paved areas. The following table shows the most important categories of investment expenses for sorting line technology.

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Table 2 Investment expenses - separation line

Investment expenses - separation line	**thousand CZK**
Basic elements of the line	120 000
Optical separators	80 000
Production of fuels	55 000
Other elements of the sorting line	60 000
Engineering, delivery, assembly	25 000
In total	**340 000**

The basic elements of the sorting line include a hopper with waste dosing and a bag ripper, as well as a rotary sieve, a ballistic sieve, a sliding sieve, ferrous and non-ferrous metal separators and a continuous press.

1) Reconstruction

The economic evaluation also includes the implementation of a more significant reconstruction of the line. For all scenarios, reconstruction is assumed after 15 years from commissioning. Expenses associated with future reconstruction correspond to 10% of the total initial investment, adjusted to current prices of the given year. In the year of reconstruction, the volume of material to be sorted is then reduced to 75% of normal operation.

2) Material flows – input waste

The capacity of the sorting line must be set taking into account the amount of collected municipal waste components. This is therefore the following annual amount of incoming waste in a realistic scenario:

- Mixed municipal waste (so-called black bin): 83,000 tons
- Separately collected plastic (so-called yellow container): 5,000 tons
- Separately collected paper (so-called blue container): 5,000 tons

3) Number of workers

Although it will be a technologically highly advanced solution for sorting waste including many elements of machine sorting, it is necessary to assume the necessary number of workers, which is based not only on the need to manage the entire technology, ensure manipulations, continuous control and cleaning of the technology, but also on the worker jobs themselves. The future operation of the sorting line is planned as a two-shift operation, which also corresponds to the expected future number of workers.

Table 3 Number of workers and profession

	Number of workers
Line manager, control room, cabin manager	4
Executive cabin sorter	2
Locksmith, technician	4
Technician, laborer, operator, locksmith	42
In total	**52**

4) Project revenues

The project's revenue structure is primarily based on 3 main types of revenue:

- Waste collection fee
- Sale of output commodities
- Contribution from EKO-KOM, a.s.

a) Fee for accepting waste for sorting

The economics of the device itself must operate in a market environment compared to alternative end devices offering a comparable service. The setting of individual fees is based on the hierarchy of waste management, where separate collection is preferred over mixed municipal waste, and the fee for accepting waste for sorting should motivate this. In addition, it should be mentioned that the planned facility will assist municipalities in meeting the legislative goals of waste management, which many other terminal facilities cannot do. The estimated fee for waste collection is shown in the following table.

Table 4 Type of waste

Type of waste	**Charge**
Mixed municipal waste	1 600 Kč / t
Separately collected plastic	1 400 Kč / t
Separately collected paper	0 Kč / t

In the case of the pessimistic variant, it is assumed that the fee for mixed municipal waste will be increased to 1,650 CZK/t.

b) Sale of output commodities

The output sales commodities from the waste center will be handed over for further recycling. It will be about individual plastic materials (e.g. PET bottles according to the main colors, HDPE, LDPE film, PP, beverage cartons), as well as metals (ferrous and non-ferrous) and paper. The selling prices of individual commodities are based on current market prices. These prices have fluctuated a lot in recent years, so this is a risk factor. As part of the sensitivity analysis, both the decrease and the increase in sales prices within a certain range are tested.

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5) Contribution from EKO-KOM, a.s.

The calculation of the contribution is based on the EKO-KOM tariff, which is valid from 1 October 2023. The contribution is provided for waste (paper, plastic, beverage cartons, aluminum cans) entering sorting, and then it is a contribution at the output, the so-called reward for ensuring use (e.g. for paper, PET, HDPE, etc.). Given that a similar sorting line is currently operated in the Czech Republic only in Ostrava, the remuneration for commodities sorted from mixed municipal waste is not listed in the published tariff lists.

6) Project costs

The highest cost items include personnel costs, fuel transfer costs, waste disposal costs, electricity consumption, line service and maintenance and other costs. Other costs consist of operating and administrative overhead, insurance and various operating costs related to, for example, binding wires or payment for storm water.

7) Personnel costs

Personnel costs include expected wage costs according to the number of workers and their positions (including adequate tax, social and health contributions). They also include the related costs of food and equipment required for the performance of work from the point of view of health and safety at work.

8) Costs for handing over fuel and disposal of waste

The costs of handing over fuels and disposal of residues after sorting relate to materially unusable waste, which will need to be handed over to an authorized person for their removal or use. These wastes are divided into solid alternative fuels (so-called TAP) and waste intended for stabilization and further use or storage at a landfill. Waste that cannot be sent for material recycling and can be used as solid alternative fuels will be designated for direct energy use. Thanks to its flexibility, the sorting line will produce suitable TAP for heating plants with different input wastes (SKO, plastic). Because of the better future utilization, the costs associated with the transfer for TAP production are lower than the removal or utilization of the subgrid fraction.

9) Electricity consumption

Electricity consumption is a significant cost associated with mechanical sorting and crushing of waste. The total expected input is approximately 1.2 MW, while the actual consumption will vary according to the load intensity of the given level of technology, the need for lighting, etc. In the economic evaluation, we assume an electricity price of CZK 8.0 / kWh. Total annual costs for electricity are expected to be around CZK 19 million in two-shift operation.

10) Financing

The initial assumption is a combination of funding from several sources, namely from subsidies from the European Union, external and own sources. A large part of the investment expenses will be financed from CEVYKO's own resources – CZK 90 million is assumed in all scenarios. The second source of financing is an investment subsidy, only in the pessimistic scenario it is not expected to be obtained.

External financing in the form of a bank loan would be used for all investment expenses that are not covered by the investment subsidy and own resources, where for the purposes of the economic evaluation of the project we assume a repayment period of the bank loan of 10 years. The repayment of these external sources and the related payment of interest costs are included in the assessment.

11) Discount rate

The net present value is calculated based on a real discount rate of 6.08%.

12) Economic evaluation of individual scenarios

Individual scenarios were evaluated on the basis of the above assumptions. Further details and some other assumptions are given in a separate table below.

The evaluation of individual scenarios was carried out until 2046 with the assumption of the start of operation in 2027. During this period of operation, 1 major reconstruction is carried out (after 15 years of operation). The following table shows the basic evaluation of the individual scenarios, where the net present value and the real payback period were calculated based on the above discount rate.

Table 5 Economic evaluation of individual scenarios

Assumption	Optimistic scenario	Realistic scenario	Pessimistic scenario
Net present value of the project	516,4 million CZK	175,9 million CZK	8,3 million CZK
Real project payback period	**7 years**	**12 years**	**20 years**
Internal revenue percentage for CEVYKO	44,5 %	22,1 %	8,4 %

All three scenarios achieve a positive net present value and thus a realistic payback period.

13) Sensitivity analysis

As part of the sensitivity analysis, the effects of changes in the following basic variables on the value of the project, specifically on the net present value and the real payback period, were verified.

Table 6 Sensitivity analysis

Variable	**Range tested**
Received investment subsidy	0 %; 20 %; 30 %; 40 %
Investment expenses	- 20 %; - 10 %; + 10 %; + 20 %
Amount of incoming (processed) waste	- 20 %; - 10 %; + 10 %; + 20 %
Selling price of output commodities	- 20 %; - 10 %; + 10 %; + 20 %
Contribution of the company EKO-KOM, a.s.	- 20 %; - 10 %; + 10 %; + 20 %

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To test the change in the amount of the project subsidy, it was chosen to test the project for its economic feasibility in the event that the project did not receive any investment subsidy and also for variants according to the % of the investment subsidy in relation to the total investment expenses. The other main parameters were tested in the same ranges from the basic assumption, i.e. -20% / -10% / +10% / +20%. Among the assumptions that CEVYKO can influence to a relatively good extent are the total investment expenses, the volume of subsidies obtained and amount of processed waste per facility. Another category is assumptions, which CEVYKO can also influence, but with relatively more difficulty.

DISCUSSION

Several key findings emerged from the performed economic balance of the municipal waste processing sorting line. The use of net present value (NPV) and payback period methods provided a comprehensive view of the financial sustainability and effectiveness of the investment. Net Present Value (NPV) Method.The calculations showed that in a realistic scenario, the NPV is positive, indicating that the investment in the sorting line is economically beneficial and will bring a profit. In the pessimistic scenario, the NPV turns out to be negative, meaning that the investment would be loss-making. Conversely, the optimistic scenario showed a very high positive NPV, confirming the potential for significant profit under favorable conditions. Payback time. The payback period was within acceptable limits in a realistic scenario, indicating that the investment would return within a reasonable timeframe. In the pessimistic scenario, the payback period was significantly longer, which could deter investors due to the higher risk and longer time to payback. The optimistic scenario again showed a very quick payback period, increasing the attractiveness of the investment. Sensitivity analysis. The performed sensitivity analysis provided valuable insights into possible risks and opportunities. In a realistic scenario, the expected returns are sufficient to cover investment costs and generate profit. The pessimistic scenario highlighted the need for caution and the need to have strategies in place to minimize risks, such as higher operating costs or lower than expected revenues. The optimistic scenario confirmed that, under ideal conditions, investment in a sorting line can be extremely profitable.

CONCLUSION

Based on the analyzes carried out, it is clear that investing in a sorting line for the processing of municipal waste can be economically advantageous, especially in a realistic and optimistic scenario. However, it is recommended to carefully consider all the risks identified in the pessimistic scenario and have corrective measures in place. In a pessimistic scenario, risks may include, for example, higher than expected operating costs, lower sorting efficiency or lower income from the sale of sorted materials. Investors should consider creating a reserve fund to cover unexpected costs, implementing modern technologies to increase sorting efficiency, and concluding long-term contracts with buyers of sorted materials to minimize market risks. In addition to financial metrics, investors should also consider other factors such as long-term sustainability and environmental benefits. The sorting line contributes to reducing the amount of waste going to landfills and promotes recycling, which has positive effects on the environment. This can also increase corporate social responsibility and improve its

public image. It is also important to take into account the regulatory framework and legislative requirements that may affect the economic balance of the project. In some cases, subsidy programs or tax credits may be available that can significantly improve the financial value of the investment. This confirms that the use of Net Present Value (NPV) and payback period methods in combination with sensitivity analysis provides a thorough and comprehensive overview of the economic balance of an investment in a municipal waste sorting line. This approach allows investors to better understand the financial and non-financial aspects of the project, which is key to making informed decisions. Investing in a sorting line can not only be financially beneficial, but also bring significant environmental and social benefits.

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EUROPEAN UNION FARM TO FORK STRATEGY: FERTILIZER USE REDUCTION POSSIBILITIES

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ABSTRACT

In the European Union (EU), food production needs to become more sustainable and environmental-friendly. Farmers play a crucial role in sustainable agricultural practices on their farms because one of the goals of the EU Farm to Fork Strategy is to reduce nutrient losses by at least 50%, while ensuring that there is no deterioration in soil fertility, which could reduce fertilizer use by at least 20% by 2030. Therefore, the aim of the present research is to examine fertilizer consumption in EU Member States and to assess the impact of the potential fertilizer use reduction by at least 20% by 2030 on value of crop output. The research examined and analysed information on inorganic nitrogen fertilizer consumption in the EU and the Member States in 2016-2021, as such fertilizers account for 89% of the total consumption of mineral fertilizers in the EU. The research applied the monographic method, statistical data analysis and scenario development methods. In 2021 in the EU, inorganic nitrogen fertilizer consumption totalled 9.8 mln. tonnes, which was a 5% decrease compared with 2016. Inorganic nitrogen fertilizer consumption per ha utilized agricultural area, per ha arable land and per 1000 EUR value of crop output varied in EU Member States, which was affected by the composition of agricultural production, technologies applied and other factors. The research analysed a possibility to achieve the target set by the Farm to Fork Strategy – to reduce N fertilizer use by 20% by 2030 – through designing two scenarios. However, achieving this target would probably lead to a decrease in value of crop output. It would be desirable to set different rates of reduction of inorganic nitrogen fertilizers for the Member States, depending on the intensity and effectiveness of the previous use of nitrogen fertilizers.

Keywords: inorganic nitrogen fertilizers, consumption, crop output value, reduction.

INTRODUCTION

Globally, there is a need to increase crop production and maintain soil fertility, while reducing environmental impact [1]. Nutrients are essential for crop productivity and food production [2]. A fertilizer has to provide nutrients to plants, but because of the Russian invasion of Ukraine, the dependence of the EU on imported fertilizers creates uncertainty for the agricultural industry [3]. European agriculture is a major importer of inorganic fertilizers. The availability of inorganic fertilizers has changed the past

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dependence of farms on manure [4]. The use of pesticides and inorganic fertilizers in agriculture is a habit that is difficult to get rid of [5]. Fertilizers are important for high and stable yields; however, using too much fertilizers can harm the environment and promote plant diseases [6]. Therefore, in recent years, technologies have been introduced to increase the application of manure and reduce waste, thereby increasing resource use efficiency, while reducing the need for inorganic mineral fertilizers, which is very important for changes in the farm management system [7]. Farmers need to transform their production methods more quickly, and make the best use of nature-based, technological, digital, and space-based solutions to deliver better climate and environmental results, increase climate resilience and reduce and optimise the use of inputs (e.g. pesticides, fertilizers). Therefore, the Farm to Fork Strategy (F2F) adopted for the implementation of the *European Green Deal* in 2019 specifies that it is necessary to reduce nutrient losses by at least 50%, while ensuring that there is no deterioration in soil fertility. This will reduce the use of fertilizers by at least 20% by 2030 [8]. This will be achieved by implementing and enforcing the relevant environmental and climate legislation in full, by identifying with Member States (MS) the nutrient load reductions needed to achieve these goals, applying balanced fertilisation and sustainable nutrient management and by managing nitrogen and phosphorus better throughout their lifecycle. Therefore, the aim of the present research is to examine fertilizer consumption in the EU MS and to assess the impact of the potential fertilizer use reduction by at least 20% by 2030 on value of crop output.

MATERIALS AND METHODS

The research period was 2016-2021 with the aim of assessing the most current trends in consumption of inorganic nitrogen fertilizers (N fertilizers) in the EU MS and make analytical assumptions to identify the possibilities of meeting the target set by the F2F Strategy: to reduce fertilizer use in the EU by 20% by 2030, as well as contribute to more environment-friendly and sustainable food production. It should be noted that no data were available on the consumption of N fertilizers for Cyprus and Malta; therefore, the data on both countries were excluded. The research used information publicly available in the Eurostat databases [9, 10, 11] and research papers available in the Scopus database on the research problem. The research applied the monographic method, statistical data analysis and scenario development.

EVALUATION OF RESULTS AND DISCUSSION

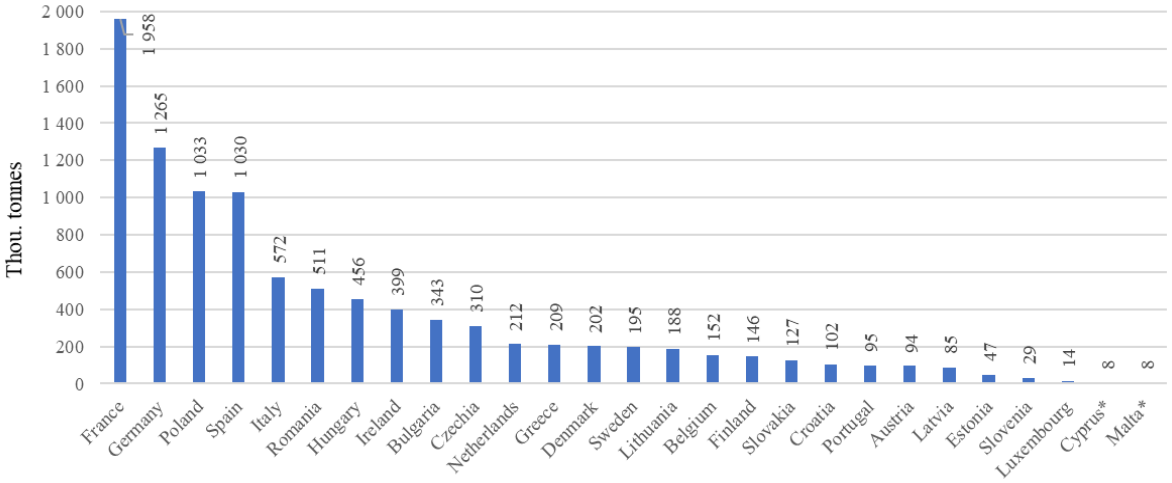
1. Consumption and use of inorganic N fertilizers in the EU Member States

In 2021 in the EU, the consumption of N fertilizers totalled 9.8 mln. tonnes or 89% of the total consumption of mineral fertilizers, yet the consumption decreased by 5% compared with 2016. In the four EU MS – France, Germany, Poland and Spain – it has exceeded one mln. tonnes and accounted for 54% of the total N fertilizer consumption in the EU in 2021. In 2021 in Latvia, the consumption of N fertilizers was 84.6 thou. tonnes and accounted for 0.86% of the total EU consumption of N fertilizers and was the sixth lowest among the EU MS (behind Malta, Cyprus, Luxembourg, Slovenia and Estonia) (Figure 1).

In the EU in 2016-2021, the highest consumption of N fertilizers was in 2017 at 10.5 mln. tonnes and in 2018 at 10.4 mln. tonnes. In the period analysed, the consumption of N fertilizers increased most significantly in Romania (by 48%), Croatia (415%), Estonia

(29%), Ireland (18%), Lithuania (17%) and Greece (13%), whereas the largest decrease was reported in Austria (by 29%), Germany (26%) and Czechia (24%) [9].

In 2021 in the EU-27, the consumption of N fertilizers was on average 362 thou. tonnes.



*expected

Fig.1. Annual consumption of N fertilizers in the EU Member States in 2021, thou. tonnes [9].

Indicators such as mineral fertilizer consumption per ha utilized agricultural area (UAA) and arable land were analysed to compare the consumption of N fertilizers with farming intensity in a respective country.

Table 1. Consumption of N fertilizers per hectare UAA in EU Member States in 2016-2021, kg [9, 10].

The EU MS	2016	2017	2018	2019	2020	2021	Base growth, %
Austria	49	42	38	39	44	36	74
Belgium	119	117	111	113	111	111	94
Bulgaria	73	70	67	70	72	68	93
Croatia	46	66	67	65	66	69	150
Czechia	117	113	100	94	81	88	75
Denmark	92	90	85	86	89	77	84
Estonia	36	38	39	42	42	47	131
Finland	61	61	61	65	61	64	106
France	76	77	78	73	70	68	90
Germany	103	99	90	81	83	76	74
Greece	35	37	34	37	39	40	114
Hungary	76	79	79	78	89	90	120
Ireland	76	82	90	81	84	92	121
Italy	45	44	45	44	44	44	98
Latvia	41	40	38	41	43	43	106
Lithuania	54	57	54	60	63	64	118
Luxembourg	105	103	99	105	99	105	100
Netherlands	128	129	117	118	120	117	91
Poland	72	79	81	68	70	71	98
Portugal	30	28	27	27	26	24	80
Romania	25	29	35	33	36	39	153
Slovakia	66	64	67	67	67	69	104
Slovenia	57	56	57	58	57	61	107
Spain	41	45	43	41	43	42	102
Sweden	62	66	61	61	72	65	105

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The situation across the EU MS was different of the consumption of N fertilizers per ha UAA, and its consumption per ha varied from 24 kg in Portugal to 129 kg in the Netherlands in the period 2016-2021(a difference almost 6 times). In Latvia, the consumption of N fertilizers was 43 kg per ha UAA, and it was one of the lowest among the EU MS in 2021. In 2021 in the EU-27, the consumption of N fertilizers per ha UAA was on average 53 kg, which decreased by 17% compared with 2016 (Table 1).

In terms of consumption of N fertilizers per ha arable land, the position of individual MS changed. In 2021, the highest figure was reported in Ireland at 918 kg per ha, which related to a relatively small share of arable land in the total UAA. However, Latvia had the second lowest N fertilizer use among the EU MS in 2021 (Table 2). Therefore, also in terms of intensity of N fertilizer use, agriculture in Latvia was competitive compared with that in other EU MS, of course, without considering the different agro-climatic conditions, the cropping pattern and the structure of farms.

In 2021 in the EU-27, the consumption of N fertilizers per ha of arable land was on average 88 kg, which decreased by 15% compared with 2016.

Table 2. Consumption of N fertilizers per hectare arable land in the EU Member States in 2016-2021, kg [9, 10].

The EU MS	2016	2017	2018	2019	2020	2021	Base growth, %
Austria	99	84	75	78	89	71	72
Belgium	188	185	175	178	175	175	93
Bulgaria	105	101	98	102	105	98	94
Croatia	82	121	124	118	111	119	146
Czechia	163	159	141	133	115	125	77
Denmark	101	100	94	94	99	86	84
Estonia	53	55	57	60	60	67	126
Finland	62	62	62	65	62	65	106
France	119	120	123	117	118	115	96
Germany	145	141	128	115	118	109	75
Greece	94	101	97	104	115	119	127
Hungary	93	98	98	97	109	110	118
Ireland	737	802	908	832	857	918	124
Italy	86	84	86	83	83	83	96
Latvia	61	60	58	61	63	62	102
Lithuania	75	80	75	81	83	82	110
Luxembourg	222	218	209	222	210	222	100
Netherlands	224	222	208	212	216	211	94
Poland	97	105	107	90	93	93	97
Portugal	111	104	106	108	106	98	89
Romania	40	45	54	51	55	59	148
Slovakia	94	91	96	95	95	96	103
Slovenia	156	155	158	161	158	166	107
Spain	79	87	85	84	89	88	111
Sweden	72	78	72	72	85	77	106

In terms of consumption of N fertilizers per value of crop output, the intensity of N fertilizer use in Latvia was average on the EU scale (although in this case the conclusions are not completely correct because, for example, grasslands are used for livestock production). In 2021, the consumption of N fertilizers per value of crop output (in constant prices) ranged from 14 kg in the Netherlands to 187 kg in Ireland (where large areas were under grasslands that were used for livestock production). In 2021, the

consumption of N fertilizers in Latvia was 82 kg per 1000 EUR value of crop output (Table 3).

Table 3. Consumption of N fertilizers per 1000 EUR value of crop output in EU Member States in 2016-2021, kg [9, 11].

EU MS	2016	2017	2018	2019	2020	2021	Base growth, %
Austria	44	36	32	33	36	23	53
Belgium	45	44	41	39	38	31	70
Bulgaria	139	127	118	122	136	83	59
Croatia	57	79	71	70	69	63	111
Czechia	138	141	119	107	86	77	56
Denmark	75	65	64	60	58	44	58
Estonia	114	101	111	82	86	82	72
Finland	100	103	96	83	89	97	96
France	56	55	50	48	47	40	71
Germany	68	64	64	48	50	43	64
Greece	25	24	23	23	24	24	97
Hungary	81	87	87	84	90	78	97
Ireland	192	195	192	195	196	187	98
Italy	20	20	18	18	17	16	83
Latvia	111	106	112	87	82	82	74
Lithuania	98	95	100	95	86	82	83
Luxembourg	82	88	78	87	86	67	82
Netherlands	17	17	15	15	16	14	79
Poland	99	101	108	84	80	74	74
Portugal	27	23	22	22	21	16	59
Romania	34	33	36	34	43	34	99
Slovakia	93	96	104	106	99	86	93
Slovenia	40	46	34	38	35	40	101
Spain	33	36	33	34	35	29	88
Sweden	71	69	71	65	75	57	81

In 2021 in the EU-27, the consumption of N fertilizers per 1000 EUR value of crop output was, on average, 34 kg, which decreased by 33% compared with 2016 and indicated that the fertilizers were used more efficiently – more was produced while using less fertilizers. In addition, in all EU MS, except Croatia and Slovenia, the consumption of N fertilizers per 1000 EUR value of crop output decreased in 2021.

2. Possibilities for reducing N fertilizer use and the potential impact on the output value in the EU Member States

Since N fertilizers consumption in total, per ha of UAA or arable land and value of crop output varied significantly across the EU MS, which was determined by the composition of agricultural production, technologies applied and other factors, it is necessary to assess the possibility of achieving the target set by the F2F Strategy for 2030 – to reduce fertilizer use by 20% by 2030. In 2016-2021, the total consumption of N fertilizers decreased by 5% in the EU. If the reduction is 5% in a 6-year period, assuming that the rate of reduction is the same, it could be concluded that in the period 2022-2030 (9 years), a potential reduction could be another 7.5%, which overall is not enough to achieve the target of the F2F Strategy. Therefore, it is necessary to assess how the potential reduction of N fertilizer consumption could affect the total value of crop output achieved in each MS. Therefore, the potential reduction of N fertilizer consumption was calculated against 2016 (reference year) as follows:

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$$FC_{2016\text{-}20\%} = 0.8 \times FC_{2016}, \quad [1]$$

where $FC_{2016\text{-}20\%}$ – consumption of N fertilizers reduced by 20% in each MS according to the F2F Strategy; FC_{2016} – N fertilizer consumption in the respective MS in 2016.

The research designed two scenarios. Under the first scenario, a linear trendline option formula was created for 2016-2021 for each MS:

$$CO_{2016\text{-}2021}\ (y) = a \times FC_{2016\text{-}2021}\ (x), \quad [2]$$

where $CO_{2016\text{-}2021}$ – real value of crop output in 2016-2021; $FC_{2016\text{-}2021}$ – N fertilizer use in 2016-2021, a - coefficient that considers a relationship between the consumption of mineral fertilizers and value of crop output.

By combining formulas 1 and 2, the potential value of crop output is calculated at the reduced consumption of N fertilizers (-20% of consumption in 2016):

$$CO_{new1}\ (y1) = a \times FC_{2016\text{-}20\%} \quad [3]$$

Under the second scenario, given the fact that in 2021 compared with 2016 EU MS either increased or decreased the consumption of N fertilizers, it is necessary to take these changes into account:

$$CO_{new2}\ (y2) = (FC_{2016\text{-}20\%} \times CO_{2021}) / FC_{2021} \quad [4]$$

The calculations were compared and analysed to identify the potential value of crop output in each MS and in the EU as a whole. The calculation results are presented in Table 4.

Table 4. Calculation results for various scenarios on the potential value of crop output at the reduced consumption of N fertilizers, based on the target of the F2F Strategy [9, 10, 11].

The EU Member State	Formula 2	R-squared value on chart, R^2	$FC_{2016\text{-}20\%}$, tonnes	$FC_{2016\text{-}20\%}$ compared to 2021, tonnes	N fertilizers reduction 2021/2016, %	CO_{new1}, mln. EUR (results for formula 3)	Potential crop output at $FC_{2016\text{-}20\%}$ against 2021, %	CO_{new2}, mln. EUR (results for formula 4)	CO_{new2}, mln. EUR against 2021, %
Austria	y = 0.0293x	0.962	105625	11306	71	3095	77	4505	112
Belgium	y = 0.0256x	0.984	128706	-23755	95	3295	67	4123	84
Bulgaria	y = 0.0085x	0.964	292730	-50160	94	2488	60	3540	85
Croatia	y = 0.0146x	0.991	57856	-44334	141	845	52	918	57
Czechia	y = 0.0090x	0.947	325747	16101	76	2932	72	4254	105
Denmark	y = 0.0165x	0.973	192581	-9597	84	3178	69	4400	95
Estonia	y = 0.0108x	0.983	29112	-17655	129	314	55	355	62
Finland	y = 0.0106x	0.995	110502	-35305	106	1171	78	1143	76
France	y = 0.0202x	0.987	1771760	-186718	88	35790	73	44307	90
Germany	y = 0.0289x	0.969	1368493	103016	74	39549	135	31641	108
Greece	y = 0.0421x	0.999	148015	-60737	113	4337	50	6135	71
Hungary	y = 0.0119x	0.997	323176	-133130	113	3846	66	4123	71
Ireland	y = 0.0052x	0.999	271283	-127881	118	1411	66	1449	68
Italy	y = 0.0553x	0.996	462750	-109355	99	25590	73	28309	81
Latvia	y = 0.0107x	0.982	62628	-22018	108	670	65	765	74

Lithuania	y = 0.0109x	0.994	128190	-59316	117	1397	61	1564	68
Luxembourg	y = 0.0124x	0.990	10985	-2947	101	136	66	163	79
Netherlands	y = 0.0645x	0.994	183860	-27988	92	11859	76	13592	87
Poland	y = 0.0111x	0.980	834403	-198643	99	9262	66	11348	81
Portugal	y = 0.0463x	0.973	86752	-8112	87	4017	66	5529	91
Romania	y = 0.0281x	0.993	275449	-235353	148	8071	54	8104	54
Slovakia	y = 0.0103x	0.995	100989	-26506	101	1040	70	1176	79
Slovenia	y = 0.0259x	0.991	21676	-7467	108	635	88	538	74
Spain	y = 0.0301x	0.996	785724	-244189	105	23571	67	26876	76
Sweden	y = 0.0148x	0.992	148800	-46200	105	2202	65	2592	76
EU -27	x	x	8227793	-1546942	95	190700	76	210779	84

The total potential reduction of N fertilizer use would be 1.5 bln. tonnes in the EU-27 in 2030, which would lead to a decrease in crop output by 24% in the case of the first scenario and 16% in the case of the second scenario, compared with the real level reached in 2021. In three countries (Austria, Czechia and Germany), it would be possible to even slightly increase the use of N fertilizers because in 2021, the MS had actually exceeded the target set by the F2F Strategy. However, in view of the historical development of the MS, different reduction targets for N fertilizers should be set. For example, in the MS where the consumption of N fertilizers was low (or below the EU average level) per ha of arable land (< 88 kg, see Table 2) in 2016-2021, the target set could be lower than a 20 % reduction of N fertilizer use, which in turn would allow them to avoid a significant decrease in crop output value, compared with 2021. It should also be taken into account that in the period analysed, the MS demonstrated the ability to use N fertilizers more efficiently because at a 5% reduction in N fertilizer use, an increase in output value by 24% was achieved in 2021 compared with 2016. This allows us to make an assumption that in 2030 when reaching the F2F fertilizer reduction target, we could probably have a similar crop output value, which in turn would not reduce food security in the EU and provide farmers with incomes.

Similar conclusions have been drawn by e.g. K.G.Cassman and A.Dobermann (2022) that on a global scale, the average N fertilizer use efficiency has increased slowly over the last 20 years [12]. Thus, in order for farmers and policy makers to make informed decisions about how to increase food output while reducing the negative impacts of farming on the environment, proper farm management practices should be evaluated and applied to achieve win-win outcomes [1]. Crop rotations and mineral fertilization intensity, especially with nitrogen are key management options in cropping systems [13]. K.Heyl et al.(2023) have stressed that digital precision fertilization and sustainable agricultural practices are expected to contribute to this nutrient objective. Support for these measures is provided through the Common Agricultural Policy [14, 15].

CONCLUSION

The Farm to Fork Strategy prescribes that it is necessary to reduce the consumption of fertilizers by at least 20% by 2030. Thus, after examining inorganic N fertilizer use in the EU and the MS in 2016-2021, it could be concluded that: 1) the consumption of N fertilizers in the EU accounted for 89% of the total consumption of mineral fertilizers, and the consumption in the EU decreased by 5% compared with 2016; 2) the consumption of N fertilizers per hectare UAA in EU MS in 2016-2021 varied from 24 to 129 kg, while per ha arable land – from 40 to 918 ha –, per 1000 EUR value of crop output – from 14 to 187 kg –, which was determined by the composition of agricultural

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production, technologies applied and other factors; 3) in the EU, N fertilizer use efficiency increased, as more was produced while using less fertilizers in 2021 in comparison with 2016. After analysing the possibilities of reducing N fertilizer use by 20% in the EU by 2030, it could be concluded that this would probably lead to a decrease in value of crop output by 16%-24% compared with 2021, depending on the scenario implemented. It would be desirable to set different rates of reduction of N fertilizers for the MS, depending on the intensity and efficiency of the previous use of N fertilizers.

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ABSTRACT

Pesticides are traditionally used in agricultural production to protect crops against pests and diseases. However, there is growing public concern about the negative impacts of pesticides on human health and the environment. Therefore, one of the policy documents of the European Green Deal, which plays an important role in long-term agricultural development and environment-friendly management, is the Farm to Fork Strategy, which requires reducing pesticide use by 50% in the European Union (EU) by 2030. Therefore, the present research aims to examine trends in pesticide use in EU Member States (MS) to identify the potential impact of the target set by the Farm to Fork Strategy, i.e. to reduce pesticide use by 50%, on crop output value. The research applied the monographic method, statistical data analysis and scenario development methods. The research found that in 2021, according to Eurostat, the sales of pesticides in the EU totalled 356.5 thou. tonnes, with Spain, France, Italy and Germany accounting for 69% of the total. In 2016-2021, the intensity of pesticide use per ha UAA varied from 0.6 kg in Ireland and Sweden to almost 6 kg in the Netherlands. Similar differences in pesticide sales per ha arable land and crop output value were observed in EU MS. The research designed scenarios for identifying the potential impact of a 50% reduction in pesticide use on crop output value, and it was found that this would probably lead to a significant decrease in crop output value by 47-55% compared with 2021, depending on the scenario implemented, and the farmers will need to replace their daily traditional practices with more environmentally and climate-friendly ones.

Keywords: pesticide sale, intensity, crop value, reduction.

INTRODUCTION

The Farm to Fork Strategy (F2F) is a new comprehensive approach to how Europeans value food sustainability. It is an opportunity to improve lifestyles, health, and the environment. The European Commission will take additional action to reduce the overall sale and risk of chemical pesticides by 50% by 2030 [1], because there is increasing public concern and evidence about the negative impacts of pesticides on human health and the environment [2, 3]. Pesticides are traditionally used in agricultural production to protect crops against pests and diseases. Therefore, in recent years farmers have tended to shift their farming practices to those being less dependent on chemicals, in many cases adopting conservation farming principles and strategies [4]. The intensity of pesticide use for various crops varies considerably from region to region. This allows countries and their farmers to adopt strategies that reduce pesticide use as well as to take the least risk or target crops for which management alternatives are available [5]. The use of pesticides is strictly regulated in the EU. However, data on

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pesticide use are rather limited and poorly available, and the monitoring of pesticide use is often insufficient to identify the real exposure to and impacts of pesticides [6]. Therefore, the present research aims to examine trends in pesticide use in EU Member States to identify the potential impact of the target set by the Farm to Fork Strategy, i.e. to reduce pesticide use by 50%, on crop output value.

MATERIALS AND METHODS

The research period was 2016-2021, which allowed us to identify the most current trends in pesticide sales in EU Member States and make analytical assumptions to identify the possibilities of achieving the target set by the F2F Strategy – to reduce chemical pesticide use in the EU by 50% by 2030 – as well as to contribute to environment-friendlier, healthier and sustainable food production. The research has assumed that the pesticides sold also represent the pesticides used. Information publicly available in the Eurostat database [7, 8, 9] and research papers available in the Scopus database were used to research the problem. It should be noted that data on pesticide sales for Bulgaria and Malta were available only for 2021; therefore, the data for these Member States were not analysed in detail. The research applied the monographic method, statistical data analysis and scenario development.

EVALUATION OF RESULTS AND DISCUSSION

1. Pesticide sales in EU Member States

According to Eurostat, in 2021 for which data are available for all EU MS, the sales of pesticides in the EU totalled 356.5 thou. tonnes. Four EU MS (Spain, France, Italy and Germany) reported the largest sales of pesticides – together 245.5 thou. tonnes or 69% of the total, including Spain with 76.2 thou. tonnes or 21% of the total quantity of pesticides sold in the EU, France – 69.4 thou. tonnes (19%), Italy – 50.2 thou. tonnes (14%) and Germany – 48.7 thou. tonnes (14%) (Figure 1). These EU MS reported the largest crop output value in 2021 in the EU (EUR 148.4 mln. or 59% of the total) and exploited 82.7 mln. ha or 51% of the total EU utilized agricultural area (UAA) and 49 % of the total EU arable land area. Six MS – Malta, Luxembourg, Estonia, Slovenia, Cyprus and Croatia – represented less than 1% of the total pesticide sale in the EU, ten MS – Latvia, Sweden, Slovakia, Lithuania, Denmark, Ireland, Finland, Czechia, Bulgaria and Greece – approximately 1% of the total pesticide sale (Figure 1), which could limit their possibility to reduce pesticide use in the future.

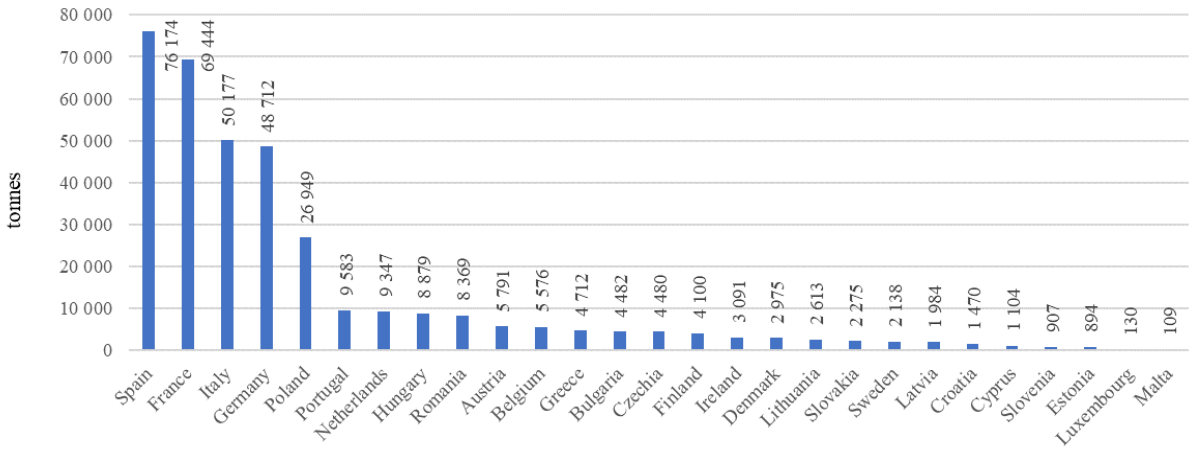


Fig.1. Annual pesticide sales in EU Member States in 2021, thou. tonnes [7].

Calculations of the intensity of pesticide use per ha UAA in the period 2016-2021 revealed that the situation in EU MS varied, as the sales of pesticides, in kilograms per hectare UAA, varied 10 times from approximately 0.6 kg in Ireland and Sweden in some years to almost 6 kg in the Netherlands in 2016. With 0.8-1.0 kg, Latvia was one of the six MS where the sales of pesticides did not exceed 1 kg per ha UAA (Table 1). In 2021 in the EU, on average, the intensity of pesticide use per ha UAA was 2.2 kg.

Table 1. Sales of pesticides per hectare UAA in EU Member States in 2016-2021, kg [7, 8].

EU MS	2016	2017	2018	2019	2020	2021	Base growth, %
Belgium	4.9	4.7	4.7	4.4	4.1	4.1	84
Czechia	1.7	1.5	1.5	1.4	1.2	1.3	75
Denmark	1.0	1.0	1.0	1.0	1.2	1.1	115
Germany	2.8	2.9	2.7	2.7	2.9	2.9	104
Estonia	0.8	0.7	0.7	0.8	0.8	0.9	109
Ireland	0.7	0.7	0.6	0.7	0.6	0.7	102
Greece	0.9	0.9	0.9	0.9	0.9	0.9	101
Spain	3.2	3.0	3.0	3.1	3.1	3.1	97
France	2.5	2.4	2.9	1.9	2.3	2.4	98
Croatia	1.2	1.1	1.1	1.0	1.1	1.0	84
Italy	4.7	4.3	4.2	3.7	4.3	3.9	83
Cyprus	…	…	8.9	9.8	9.3	9.1	101
Latvia	0.9	0.8	0.8	0.8	1.0	1.0	113
Lithuania	1.1	1.0	0.7	0.8	0.9	0.9	78
Luxembourg	1.6	1.4	1.2	1.1	1.1	1.0	63
Hungary	1.8	1.8	1.6	1.5	1.7	1.8	96
Netherlands	6.0	5.9	5.1	5.1	5.4	5.2	86
Austria	1.6	1.7	2.0	1.9	2.1	2.2	137
Poland	…	1.7	…	1.7	1.7	1.9	107
Portugal	2.7	2.2	2.1	2.5	2.4	2.4	90
Romania	0.8	0.9	0.8	0.7	0.7	0.6	80
Slovenia	2.4	2.3	2.5	2.0	2.0	1.9	78
Slovakia	1.1	…	1.3	…	…	1.2	112
Finland	2.0	1.9	2.2	1.8	2.2	1.8	90
Sweden	…	…	…	0.6	0.7	0.7	119

… no data. *2021 against the last year for which the data are available.

In 2016-2021 in the EU MS analysed, the quantity of pesticides sold per ha in 14 MS decreased from 27% (Luxembourg) to 2% (France), whereas increased (contrary to policy priorities) in 11 MS, including in Austria by 37%, Sweden by 19% and Denmark by 15%.

Calculations of the sale of pesticides in arable land (Table 2) in EU MS in 2016-2021 revealed that the positions of individual MS changed, except for the Netherlands. This was largely affected by the proportion of areas under grassland, as the intensity of pesticide use for perennial grasses was much lower than for arable land, which could be clearly identified in the case of Ireland. In terms of pesticide use per arable land, the position of Latvia among the other EU Member States did not change significantly, and Latvia was in the group of Member States with relatively low pesticide use. In 2021 in the EU, on average, the intensity of pesticide use per ha arable land was 3.7 kg, and in eleven Member States, it was higher than the EU average. In thirteen Member States, the sale of pesticides per ha arable land increased in 2016-2021. The environmental impact of pesticides is directly related to the intensity of pesticide use, measured per area; therefore, Latvian agriculture is competitive with that in other EU Member States in terms of intensity of pesticide use.

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Table 2. Sales of pesticides per hectare of arable land in EU Member States in 2016-2021, kg [7, 8].

EU MS	2016	2017	2018	2019	2020	2021	Base growth, %
Belgium	7.7	7.4	7.4	6.9	6.5	6.4	83
Czechia	2.4	2.1	2.1	2.0	1.8	1.8	76
Denmark	1.1	1.1	1.1	1.1	1.3	1.3	116
Germany	4.0	4.1	3.8	3.9	4.1	4.2	105
Estonia	1.2	1.0	0.9	1.1	1.1	1.3	105
Ireland	6.8	6.4	5.9	6.7	6.6	7.1	105
Greece	2.4	2.4	2.6	2.7	2.8	2.7	113
Spain	6.2	5.9	6.0	6.3	6.4	6.5	105
France	3.9	3.8	4.6	3.0	3.8	4.1	105
Croatia	2.1	1.9	2.1	1.9	1.9	1.7	81
Italy	9.0	8.2	8.0	7.0	8.2	7.3	81
Cyprus	…	…	11.3	12.8	12.0	11.8	104
Latvia	1.3	1.1	1.2	1.3	1.4	1.5	109
Lithuania	1.6	1.5	1.0	1.1	1.2	1.1	73
Luxembourg	3.3	3.1	2.6	2.3	2.4	2.1	63
Hungary	2.3	2.3	2.0	1.8	2.1	2.1	95
Netherlands	10.5	10.2	9.2	9.1	9.8	9.3	89
Austria	3.3	3.5	4.0	3.7	4.2	4.4	134
Poland	…	2.3	…	2.2	2.2	2.4	106
Portugal	10.0	8.2	8.4	9.9	10.0	9.9	99
Romania	1.3	1.4	1.3	1.0	1.0	1.0	77
Slovenia	6.7	6.2	6.8	5.6	5.5	5.2	78
Slovakia	1.6	…	1.8	…	…	1.7	110
Finland	2.0	1.9	2.2	1.8	2.2	1.8	89
Sweden	…	…	…	0.7	0.8	0.8	119

… no data. *2021 against the last year for which the data are available.

It should be considered that it is partly determined by the different agro-climatic conditions, the cropping pattern and the structure of farms. However, in terms of pesticide sales per value of agricultural output, Latvia was among the moderately intensive sellers in the EU in 2021. A similar opinion was also expressed by V. Triantafyllidis et al. (2023) that in the EU-27, only 7 MS – Latvia, Lithuania, Estonia, Malta, Luxembourg, Slovenia and Slovakia – were those with low pesticide sales [10].

In terms of pesticide sales per value of crop output (at constant prices), the sales of pesticides in 2021 ranged from 0.5 kg in Denmark, Greece and Sweden to 3.4 kg in Cyprus. In 2021 in the EU, on average, the intensity of pesticide use per value of crop output (at constant prices) was 3.7 kg, and in ten MS, it was higher than the EU average. It is important to note that in all the MS analysed, pesticide sales per value of crop output (at constant prices) decreased in 2016-2021 (Table 3).

In 2021 in Latvia as well as Hungary and Portugal, the pesticide sale of 1.5 kg per 1000 EUR value of crop output was the fifth highest in the EU. This was largely affected by the low proportion of fruits and vegetables in total crop output, as well as relatively low yields (Table 3). This means that it is more beneficial for the agricultural sector of Latvia to achieve the pesticide reduction targets that would focus on equalizing the intensity of pesticide use per hectare UAA in the EU. However, the technical approach providing that the intensity of pesticide use should be reduced by all EU MS, with equal or similar percentage targets being set or additional taxes on pesticide sales being imposed, without considering the real situation in pesticide sales, is relatively disadvantageous for Latvia.

Table 3. Sales of pesticides per 1000 EUR value of crop output in MS in 2016-2021, kg [7, 9].

EU MS	2016	2017	2018	2019	2020	2021	Base growth, %
Belgium	1.8	1.7	1.7	1.5	1.4	1.1	61
Czechia	2.0	1.9	1.7	1.6	1.3	1.0	48
Denmark	0.8	0.7	0.8	0.7	0.8	0.5	65
Germany	1.9	1.9	1.9	1.6	1.7	1.3	72
Estonia	2.6	1.9	1.8	1.5	1.6	1.1	42
Ireland	1.8	1.6	1.2	1.6	1.5	1.2	67
Greece	0.6	0.6	0.6	0.6	0.6	0.5	74
Spain	2.6	2.4	2.3	2.5	2.5	2.1	79
France	1.8	1.7	1.9	1.2	1.5	1.2	67
Croatia	1.5	1.3	1.2	1.1	1.2	0.7	51
Italy	2.0	1.9	1.7	1.5	1.7	1.3	62
Cyprus	…	…	4.3	4.3	4.3	3.4	79
Latvia	2.4	2.0	2.4	1.8	1.8	1.5	60
Lithuania	2.1	1.7	1.3	1.3	1.2	0.8	38
Luxembourg	1.2	1.2	1.0	0.9	1.0	0.6	49
Hungary	2.0	2.0	1.8	1.6	1.8	1.5	77
Netherlands	0.8	0.8	0.7	0.6	0.7	0.6	72
Austria	1.5	1.5	1.7	1.6	1.7	1.1	79
Poland	…	2.2	…	2.1	1.9	1.4	62
Portugal	2.4	1.8	1.8	2.0	2.0	1.5	64
Romania	1.1	1.0	0.8	0.7	0.8	0.6	53
Slovenia	1.7	1.9	1.5	1.3	1.2	1.1	64
Slovakia	1.5	…	2.0	…	…	1.3	84
Finland	3.3	3.2	3.4	2.3	3.2	1.8	54
Sweden	…	…	…	0.6	0.7	0.5	85

… no data. *2021 against the last year for which the data are available.

2. Possibilities to reduce pesticide sales and the potential impact on crop output value in EU Member States

Since the sales of pesticides in total, per ha of UAA or arable land and crop output varied significantly in EU MS, which was determined by the historical evolution of agriculture, technologies applied and other factors, it is necessary to assess the possibility of achieving the target set by the F2F Strategy for 2030: to reduce pesticide sales by 50% by 2030, as well as the potential impact on crop output value. In 2016-2021, the use of pesticides in the EU MS analysed has decreased by 4%. If the reduction is 4% in a six-year period, assuming that the rate of reduction is the same, it could be concluded that in the period 2022-2030 (9 years), a potential reduction could be another 6%, which overall is not enough to achieve the target of the F2F Strategy. Therefore, it is necessary to assess how the potential reduction in pesticide sales could impact the total value of crop output achieved in each MS. Therefore, the potential reduction of pesticide sales was calculated against 2016 (base year) as follows:

$$PS_{2016\text{-}50\%} = 0.5 \text{ x } PS_{2016}, \quad [1]$$

where $PS_{2016\text{-}50\%}$ – pesticide sales reduced by 50% in each Member State according to the F2F Strategy; PS_{2016} – pesticide sales in the respective Member State in 2016 (Poland 2017, Cyprus 2018, Sweden 2019 due to data unavailability).

The research designed two scenarios. Under the first scenario, a linear trendline option formula was created for 2016-2021 for each Member State:

$$CO_{2016\text{-}2021}\,(y) = a \text{ x } PS_{2016\text{-}2021}\,(x), \quad [2]$$

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where $CO_{2016-2021}$ – real crop output in 2016-2021; $PS_{2016-2021}$ – pesticide sales in 2016-2021, a- coefficient that considers a relationship between pesticide sales and crop output value. By combining formulas 1 and 2, the potential crop output is calculated at the reduced pesticide sales (-50% of sales in 2016):

$$CO_{new1}\ (y1) = a \times PS_{2016-50\%} \quad [3]$$

Under the second scenario, given the fact that in 2021 compared with 2016 EU Member States either increased or decreased pesticide sales, it is necessary to consider these changes:

$$CO_{new2}\ (y2) = (PS_{2016-50\%} \times CO_{2021}) / PS_{2021} \quad [4]$$

The calculations were compared and analysed to identify the potential crop output in each MS and the EU as a whole. The calculation results are presented in Table 4.

Table 4. Calculation results for various scenarios on the potential value of crop output at the reduced pesticide sales, based on the target of the F2F Strategy, in EU Member States [7, 8, 9].

EU Member State	Formula 2	R-squared value on chart, R^2	$PS_{2016-50\%}$, tonnes	$PS_{2016-50\%}$ against 2021, tonnes	Pesticide sale reduction in 2021/2016, %	CO_{new1}, mln. EUR (results for Formula 3)	Potential crop output at $PS_{2016-50\%}$ against 2021,%	CO_{new2}, mln.EUR (results for Formula 4)	COnew2 against 2021, %
Belgium	y = 0.0006x	0.972	6 570	-2291	85	1971	40	2878	59
Czechia	y = 0.0006x	0.956	5 943	-1508	75	1783	44	2682	66
Denmark	y = 0.0014x	0.994	2 587	-1681	115	1811	39	2009	43
Germany	y = 0.0006x	0.996	46 889	-25267	104	14067	48	14082	48
Estonia	y = 0.0006x	0.969	834	-477	107	250	44	266	47
Ireland	y = 0.0007x	0.990	3 113	-1535	99	1089	51	1074	50
Greece	y = 0.0017x	0.997	4 707	-2358	100	4001	46	4321	50
Spain	y = 0.0004x	0.996	76 941	-37703	99	15388	44	17792	51
France	y = 0.0006x	0.979	72 076	-33406	96	21623	44	25416	52
Croatia	y = 0.0008x	0.979	1 861	-539	79	744	46	1026	63
Italy	y = 0.0006x	0.986	59 964	-20195	84	17989	51	20913	60
Cyprus	y = 0.0002x	0.997	1 183	-513	93	118	41	156	54
Latvia	y = 0.0005x	0.987	1 725	-1122	115	431	42	449	43
Lithuania	y = 0.0007x	0.950	3 385	-920	77	1185	52	1482	65
Luxembourg	y = 0.001x	0.949	203	-28	64	102	49	162	78
Hungary	y = 0.0005x	0.983	9 764	-3997	91	2441	42	3201	55
Netherlands	y=0.0014x	0.990	10 765	-3964	87	7535	48	9019	58
Austria	y = 0.0006x	0.996	4 361	-3610	133	1308	33	1515	38
Poland	y = 0.0005x	0.999	25 074	-14412	107	6268	45	6536	47
Portugal	y = 0.0005x	0.982	9 772	-4697	98	2443	40	3083	51
Romania	y = 0.0012x	0.953	10 813	-2963	77	6488	43	9708	65
Slovenia	y = 0.0007x	0.978	1 156	-329	78	405	56	461	64
Slovakia	y = 0.0006x	0.984	2 093	-1229	109	628	42	683	46
Finland	y = 0.0003x	0.980	4 592	-1804	89	689	46	845	56
Sweden	y = 0.0015x	0.997	1 801	-1237	119	1351	40	1431	42
EU -27	x	x	368 170	-167 788	96	112 108	45	131 190	53

The total potential reduction of pesticide sales to be achieved would be 167.8 thou. tonnes in the EU-27 by 2030, which would lead to a decrease in crop output by 55% in the case of the first scenario and 47% in the case of the second scenario, compared with

the real level reached in 2021. It should be noted that the decrease in crop output value could be significant in all Member States and the EU-27 as a whole (Table 3); therefore, it is necessary to seek possibilities not leading to such a significant decrease. Therefore, the scientific literature suggests various measures, which are essential and implementable in agriculture in the near future. For example: a) action plans for implementing the strategies need to specify pesticide application rates specific to each plant protection product component and region [11]; b) implementation and application of Integrated Pest Management and Integrated Weed Management in daily agricultural practices that are consistent with sustainable farm management [12]; c) it is required to develop and introduce new innovations and more sustainable pest and weed control strategies, methods, techniques and means, including biopesticides by developing public and private sector multidisciplinary research [13]; d) a faster transition to organic farming practices is necessary [14]; e) it is still important to apply a complex approach to land management, which is based on the reduction of mechanical soil disturbances and measures to improve nutrient cycles, as well as proper crop rotation [15]; f) revision of legal documents (revision of the Sustainable Sale of Pesticides Directive, revision of the implementation rules for the sale of biologically active substances), as well as private and social incentives etc. need to be specified in the legal framework for plant protection [16]; g) it is important to continue providing targeted subsidies to support farm investments, the introduction of new and precise technologies into agricultural practice [17, 18]; h) it is particularly important to promote farmer training, seminars and information [17] etc.

CONCLUSION

An analysis of pesticide sales in the EU and the MS in 2016-2021 revealed that: 1) four MS – Spain, France, Italy and Germany – reported the largest sales of pesticides – 69% of the total; 2) the intensity of pesticide use per ha UAA, arable land or crop output value varied significantly across the MS. This could determine the possibility of reducing pesticide use in the future, which is necessary to be implemented to a greater extent in the MS with a high intensity of pesticide use. After analysing the possibilities of reducing pesticide sales in the EU by 50% by 2030, according to the Farm to Fork strategy, it could be concluded that this would probably lead to a significant decrease in crop output value by 47%-55% compared with 2021, depending on the scenario implemented. Accordingly, it will be necessary to introduce and apply in daily practice various recommendations suggested by the scientific literature to replace the traditional practices with more environment- and climate-friendly ones in agriculture.

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FEATURES OF ACCOUNTING FOR LAND IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

In today's globalized society, it is becoming more and more necessary to include sustainable development ideas in accounting methods. The main concepts of land accounting within the context of sustainable development are covered in detail in this abstract. Sustainable development requires an accounting methodology that goes beyond typical financial measurements since it is defined by the balance of economic, social, and environmental components. We examine how social responsibility, resource efficiency, carbon footprint calculations, environmental impact assessments, and resource efficiency are all taken into account when accounting for land in the framework of sustainable development. Accounting helps to foster responsibility, openness, and well-informed choices when it comes to managing and investing in real estate. In addition, it draws attention to new developments in sustainable land accounting, such as the implementation of global frameworks and standards like the Sustainability Accounting Standards Board (SASB) and the Global Reporting Initiative (GRI). The significance of incorporating sustainability principles into land accounting practices to address the issues of climate change, resource depletion, and social equity. By doing so, it will help to advance sustainable

Keywords: accounting for land, land account structure, ESG

INTRODUCTION

In today's increasingly globalized society, the need to incorporate sustainable development principles into accounting practices has become more crucial than ever [1]. Sustainable development is defined by the balance of economic, social, and environmental components, necessitating an accounting methodology that goes beyond traditional financial measurements. This paper examines the key features of land accounting within the framework of sustainable development, highlighting how social responsibility, resource efficiency, carbon footprint calculations, environmental impact assessments, and resource efficiency are all taken into account.

Accounting plays a vital role in fostering responsibility, transparency, and well-informed decision-making when it comes to managing and investing in real estate [2]. Furthermore, the paper explores the latest developments in sustainable land accounting, such as the implementation of global frameworks and standards like the Sustainability Accounting Standards Board (SASB) and the Global Reporting Initiative.

By incorporating sustainability principles into land accounting practices, this paper aims to address the pressing issues of climate change, resource depletion, and social equity,

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ultimately contributing to the advancement of sustainable development goals worldwide.

1. Features of accounting for land

Land accounting is denoted as the systemic measurement, observation, and documentation of the alterations in land resources over temporal spans. It entails the quantification of the physical dimensions and quality metrics of land, in addition to the comprehension of the diverse applications and roles of land within specified territories. Concerning sustainable development paradigms, land resource accounting holds significant importance owing to its indispensability in sustaining various ecosystemic functions, providing fauna habitats, and facilitating anthropogenic activities including agriculture and urban sprawl. Accurate land accounting aids in evaluating anthropogenic environmental impacts, discerning land use modification trends, and facilitating informed decision-making practices essential for the sustainable stewardship of land resources. Incorporating land accounting into sustainability schemas enables policymakers and vested parties to attain an enhanced grasp of the interplay between land utilization, economic progression, and environmental preservation, conducive to the formulation of effective strategies aiming at the advancement of sustainable development objectives.

The significance of land accounting within the domain of sustainable development holds a substantial level of importance. The integration of land into accounting frameworks affords policymakers and decision-makers an enhanced understanding of the intrinsic value of natural resources and ecosystems. As highlighted, land accounting provides an organized mechanism for quantification, surveillance, and documentation of land resource usage, thereby facilitating more well-informed and enduring land management approaches. This amalgamation of land within accounting structures acts as a nexus between environmental preservation and economic progression, ensuring the prevention of overexploitation of land beyond its regenerative limits. Consequently, the incorporation of land accounting into sustainable development methodologies potentially yields more proficient resource governance, augmented resilience to environmental adversities, and superior long-term socio-economic outcomes. Thus, the principal importance of this research is attributed to its capacity to guide policy formulation and encourage sustainable development practices that emphasize the preservation and judicious utilization of land resources for the benefit of succeeding generations.

2. Link between Land Accounting and Sustainable Development

The accounting of land engages the processes involving the quantification and disclosure of assets and liabilities related to land in the context of financial statements. The importance of proficient land accounting cannot be overstated, as it serves as a foundation for promoting transparency and accountability within the spectrum of resource administration, which in turn plays a pivotal role in the progression toward sustainable development aims. Proper land resource accounting facilitates stakeholders in comprehensively grasping the various economic, social, and environmental derivatives of decisions about land use. Such an exhaustive modality aids in the delineation of potential risks and opportunities tethered to land management practices, thus fostering informed decision-making which is pivotal for the attainment of sustainable development targets. Empirical evidence suggests that a well-structured land

accounting framework significantly augments the assimilation of land-related datasets into the arenas of policy creation and execution, culminating in more efficacious land governance and resource deployment [3]. Consequently, it is incumbent upon the establishment to forge a dependable connection between land accounting methodologies and sustainable developmental doctrines to ensure the enduring viability of land assets whilst advocating for equitable and inclusive developmental outcomes.

In the evaluation of the intersection concerning Sustainable Development Goals (SDGs) and the domain of land accounting, it proves crucial to attend to the extensive analysis rendered in [4]. This particular analysis scrutinizes the worldwide impacts attributed to the evolution of light industry pertinent to the attainment of SDGs, particularly accentuating the influences on climate action, responsible consumption, clean water, alongside other pivotal goals. These elucidations highlight the complex interrelation between industrial endeavors and sustainable development aims, revealing the necessity for tactical alignment in the effective resolution of confronting issues. Additionally, the scrutiny of land use efficiency assessments manifested in [5] signifies the critical nature of ameliorating land utilization methodologies within the SDGs framework. The focus on quantitative modeling and heterogeneous analytical approaches accentuates the progressive sphere of land efficiency iFnquiries, indicating the imperative of integrating advanced methodologies to enhance land use practices for sustainable advancement results. By amalgamating theoretical paradigms, such as rational expectations, with practical evaluations of land use efficiency, a sophisticated strategy can be devised to bolster the comprehensive goals of sustainable development in the scope of land accounting.

The pivotal role that land use planning assumes within the ambit of achieving sustainable development goals is underscored by the need for the efficient and judicious application of resources. The inclusion of land accounting within the sustainability framework necessitates an evaluation of extant land uses, the identification of potential conflicts therein, and the determination of optimal land use practices that serve to foster long-term environmental, social, and economic sustainability. By embedding land accounting in the decision-making matrix, policymakers are enabled to discern the trade-offs among competing land uses, thus facilitating the prioritization of actions designed to curtail adverse environmental impacts while amplifying societal benefits [6]. Effective land accounting yields sustainable development initiatives that are bespoke to specific geographical locales, considering local conditions and community requisites to ensure enduring and resilient development undertakings. In summation, the amalgamation of land use planning and sustainable development objectives through robust land accounting mechanisms is pivotal in crafting a more sustainable and inclusive prospect.

About the notion of sustainable development, the task of accounting for land assumes a pivotal position in evaluating the economic ramifications of resource exploitation and developmental tactics. The invocation of diverse methodologies, as elucidated including economic, environmental, social, and technical frameworks, facilitates a holistic appraisal of land utilization efficacy and its influence on sustainability. The economic perspective underscores the value and profitability intrinsic to land resources, affording insights pertinent to the economic merits of their employment. Nonetheless, as delineated in [7], an exclusive concentration on economic dimensions potentially neglects social and environmental repercussions. This accentuates the necessity for an

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encompassing viewpoint, as proposed by the synthesis of varied methodologies, to navigate the intricate interplay among land utilization, economic repercussions, and sustainable development objectives. By integrating findings from research such as [8], sustainable consumption and production in the context of regional advancement, land accounting can yield instrumental understandings aimed at which accentuates augmenting economic performance whilst concurrently preserving environmental and societal welfare.

3 Accounting approach for accounting for land

In the field of accounting, the accounts are the basic unit of construction. The accounting unit is the main item of accounting. This information is used for analytical purposes by various institutions. For this information to be functional, its proper structuring is necessary.

Land (and the associated natural resources) may be sold outright when the legal ownership is transferred from one institutional unit to another. Acquisitions and disposals of land should be recorded in the capital account. Land is also the type of asset most frequently subject to a lease. Commonly, farmers leasing land pay regular rent to the owner of the land, and these flows are recorded in the allocation of primary income accounts.

For land, interim classifications for both land use and land cover have been developed;

Land accounts could be divided into the following sub-accounts:

1.1 Agriculture

1.2 Forestry

1.3 Land used for aquaculture

1.4 Use of built-up and related areas

1.5 Land used for maintenance and restoration of environmental functions

1.6 Other uses of land n.e.c.

1.7 Land not in use

2 Inland waters

2.1 Inland waters used for aquaculture or holding facilities

2.2 Inland waters used for maintenance and restoration of environmental functions

2.3 Other uses of inland waters n.e.c.

2.4 Inland waters not in use

All of these sub-accounts consist of information that presents financial and non-financial information. The non-financial information consists of land coverage in square matters, the category of the land, and the specific use of the land. These accounts present the

The financial information is specific and depends on the method of evaluation. It could be used five key components of the NPV approach to make an assessment: (a) the measurement of returns on environmental assets, (b) the determination of the expected pattern of resource rents based on expected extraction profiles and prices, (c) the

estimation of the asset life, (d) the selection of a rate of return on produced assets and (e) the choice of discount rate.[9]. Using all of these methods presents the fair value of the asset at any time. In addition to them, we should keep in mind the social price that all people and businesses could pay. This payment is important to keep the land clean and healthy not only for the present nations but also for future generations.

MATERIALS AND METHODS

Within the realm of sustainable advancement, methods for land valuation that are effective hold significant importance in ensuring that natural resources are used in a manner both fair and efficient. The pertinence of evaluating ecosystem services that forests provide in places like Kosovo and North Macedonia [10] highlights the necessity of integrating all-encompassing economic valuation techniques into practices of land accounting. Such methods assist not only in appraising specific ecosystem services, but also in fostering an overall grasp on the interaction between land use, conservation, and sustainable advancement. Moreover, innovative methodologies to land consolidation initiatives, as illustrated by the progress in creating automated algorithms for handling spatial data in Poland [11], show the potential for enhancing evaluation processes of land with greater efficiency and accuracy. By incorporating such innovations into frameworks of land accounting, both researchers and makers of policy can fortify the groundwork for promoting land management practices that are sustainable, while also enhancing the long-term resilience of ecosystems within the framework of sustainable development goals.

RESULTS

Within the sphere of sustainable development, the inclusion of land accounting is pivotal for evaluating environmental consequences and fostering prudent resource administration. As indicated in [12], the development of Circular Economy (CE) inquiry accentuates the growing significance of incorporating land accounting methodologies into corporate frameworks to fulfill environmental sustainability aims. Projections in land accounting inquiry can draw from learning on innovation governance, as revealed in [13], by highlighting the intricacies of governance and the necessity for forward-thinking policy formulation to tackle issues tied to sustainable land utilization. Comprehending the fluid interaction among innovation regulations, societal demands, and ecological apprehensions can steer prospective scholarly endeavors in land accounting toward the harmonization of objectives, resource distribution, and the establishment of decision-making constructs endorsing sustainable land administration techniques. By integrating viewpoints from various academic fields and stressing the governance role in land resource supervision, upcoming tendencies in land accounting research can greatly aid in propelling sustainability goals and encouraging judicious land custodianship within the sustainable development framework.

DISCUSSION

Incorporating sustainability principles into land accounting has been shown to have a significant impact on decision-making and investment strategies. [14] By considering a broader range of financial and non-financial factors, land accounts can better inform decisions related to land management, investment, and development.

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Research has demonstrated that sustainable land accounting practices can lead to more responsible and transparent decision-making, as well as the identification of new opportunities for improving environmental and social outcomes. For instance, the analysis of a land's carbon footprint and resource efficiency can inform decisions about renewable energy investments or the implementation of sustainable land-use practices.
Additionally, the adoption of global frameworks and standards, such as the Sustainability Accounting Standards Board (SASB) and the Global Reporting Initiative (GRI), has further advanced the integration of sustainability into land accounting. By aligning with these frameworks, organizations can demonstrate their commitment to sustainable development and enhance their credibility with stakeholders.

CONCLUSION

The incorporation of land accounting in sustainable development is crucial for effective decision-making and resource management. By accurately evaluating land assets, governments and organizations can better understand the true costs and benefits of land use, leading to more sustainable outcomes. Land accounting provides a comprehensive overview of land assets, allowing for improved monitoring of changes in land quality, quantity, and value over time. Integrating environmental and social aspects into financial reporting supports sustainable land governance, benefiting both human welfare and ecological preservation. This practice enhances transparency, accountability, and long-term planning for land use, significantly contributing to sustainable development.

Research highlights the complex links between land management and environmental sustainability. Effective land use can mitigate resource depletion and environmental harm, supporting sustainable development goals. Soil management is essential for food security, and approaches like agroecology promote robust and equitable food systems. Aligning land accounting with sustainable development goals is vital for achieving a sustainable future.

Policy implications reveal that embedding land accounting in governance can foster transparent and accountable land use, aiding in the creation of effective policies against issues like land degradation and deforestation. This integration allows for tracking progress toward environmental goals and identifying areas needing intervention. Consequently, land accounting improves decision-making, supports sustainable land practices, and helps achieve global sustainability milestones.

Future research should focus on innovative information and communication systems in agriculture, examining their impact on sustainability and food security. Studies should also explore the relationship between urban expansion and land cover changes in rapidly growing cities, integrating transit policies with land use planning to promote sustainable urban development. These research areas can enhance land accounting methodologies, further advancing sustainable development objectives.

In summary, accurate land accounting is essential for managing land sustainably. It enables informed decisions that balance economic, social, and ecological goals. Comprehensive land accounting practices help evaluate the true value of land, including ecosystem services and natural capital, leading to better land use decisions and long-

term benefits. Policymakers and stakeholders must prioritize land accounting to achieve sustainable development targets and create a more accountable and resilient future.

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FINANCIAL BENEFITS OF IMPLEMENTING PAPERLESS MANAGEMENT IN MUNICIPALITIES

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ABSTRACT

The transition to paperless management in municipalities is an essential step in achieving the goals of environmental economics and sustainability. To assess the benefits of such a transition and find weaknesses, the municipality of Liepaja (Latvia), in cooperation with the municipalities of Vila Nova de Poiares (Portugal) and Mielec (Poland), implemented a joint project.

The present research evaluated the financial benefits of switching to paperless management as well as the benefits of training municipal employees to improve their digital skills. The research analysed and compared data collected in all three municipalities within one year. The research focused on the volume of paper consumed, the reduction in toner costs during the year and the effectiveness of training provided to municipal employees. Based on a previously conducted survey on self-assessment of municipal employees' digital skills, the training aimed to develop and implement appropriate courses to improve employees' digital skills and change their attitudes and habits.

The research applied a combined approach, incorporating elements of both quantitative and qualitative methods. The specific amounts of paper consumption and toner costs in each of the three countries analysed were calculated using financial data from local governments. Qualitative methods were used to interview municipal employees and get an idea of the practical impact of implementing electronic governance. A survey of municipal employees was also conducted after completing the courses.

The research developed recommendations for other municipalities in all three countries to improve employees' digital skills and reduce paper and toner costs.

Keywords: environmental economics, sustainability, paperless, benefits.

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INTRODUCTION

The transition to paperless management in municipalities is not only a step towards modernizing administrative processes but also a significant move towards environmental sustainability and economic efficiency. Despite the bureaucratic challenges and resistance to change typically observed in public administration, the implementation of digital solutions offers numerous benefits. This paper explores the financial benefits of adopting paperless management practices within municipal governments, specifically focusing on the municipality of Liepaja in Latvia, in collaboration with Vila Nova de Poiares in Portugal and Mielec in Poland.

This research, conducted as part of the Erasmus+ project Digital & Dematerialization Municipalities (No. 2021-1-PT01-KA210-ADU-000029862), aims to assess the impact of digital transformation on paper and toner consumption and the effectiveness of training municipal employees in digital skills. By evaluating data from these municipalities over the course of a year, we provide insights into the cost savings and operational efficiencies achieved through the adoption of paperless management practices. Furthermore, we examine how training programs tailored to enhance digital competencies can support this transition, ultimately leading to sustainable and economically beneficial municipal management.

The following issues are highlighted in this research:

1. Communication with the team;
2. Encourage recycling and reuse;
3. Use e-signature software.

Unlike business administration, public administrations tend to lack performance incentive systems, be overcommitted to regulations and rule-following (even if ineffective or poorly designed) and are exposed to political influences that undermine effectiveness [1]. Research on public administration implementation suggests that government employees, particularly street-level officers, implement programmes in ways fundamentally different from actors in other organisational settings. Rather than simply implementing top-down policies and programmes faithfully (as is commonly believed), street-level officers – those government officers who interact with citizens on a daily basis – possess high levels of discretion, understood as “the power or the right of deciding according to one's judgment” [2, 3, 4]. Such administrative discretion might prove a potential threat to organisational goals such as IT modernisation, or encourage the pursuit of private interests despite laid down processes to safeguard the state and public interest [5, 6].

The Erasmus+ project *Digital & Dematerialization Municipalities* (*No. 2021-1-PT01-KA210-ADU-000029862*) was implemented to assess the digital skills of municipal administration employees [7]. The goal of the project was to identify the possibilities of digital transformation and the competence of employees in various municipalities in EU Member States as well as to understand how city administrations adapt to the digital age and the problems they face, reducing paper consumption and increasing the digital skills of employees [8]. To achieve the goal, the current skills of employees were assessed in detail, and plans were designed to improve the weakest skills by taking specific courses in each municipality. Based on the previous cooperation of the municipality of Liepaja, the following municipalities were chosen for comparison with the municipality of Liepaja (ML) (Latvia): the municipality of Vila Nova de Poiares (MVNP) (Portugal) and the municipality of Mielec (MM) (Poland), which were similar in terms of population and economic activity.

The research was based on a survey of municipal administration employees and a review of the relevant literature. The survey was conducted in October 2022 by sending electronic questionnaires to the e-mail addresses of municipal employees. A total of **279 respondents** participated in the survey, answering 62 questions. The survey involved 71 men and 208 women, revealing the inequality of gender representation, as men made up 25% of the respondents. One respondent did not indicate the age, so it was impossible to include it in an age group. The distribution of respondents by municipality was as follows: 110 in **Latvia (ML)**, 78 in **Portugal (MVNP)** and 71 in **Poland (MM)**. Given that the survey represented a self-assessment, the survey results could differ from reality if the surveying process were not observed by ICT personnel asking additional questions. However, it was a suitable and quick procedure to start discussing and intensively promoting digital skills with the aim of reducing the expenditure on toner and paper in municipalities.

To further dematerialise management processes in municipalities, it is necessary to plan the build-up of digital skills in employees, considering the weaknesses identified in each municipality. Overall, it could be concluded that the situation regarding digitalisation skills was similar in all three municipalities in various countries: Latvia, Poland and Portugal. This indicated that Latvia was not in a worse situation in the transition of municipalities to paperless management than the other selected countries. Given the similar situation, the municipalities could design uniform training courses for use in each municipality. It would be necessary to supplement specific questions and consider the peculiarities of age groups. The greatest attention should be paid to cyber security.

Each municipality applied a different approach to holding the courses. MVNP provided two training courses, each 25 hours, involving 50 employees. MM implemented five training courses, 16 hours each, with 67 employees involved. Compared with the other partners, the municipality of Liepaja applied a different strategy and conducted training through two specific courses: Digicom Skills and Data Analytics. The courses were delivered online, and the duration of each course was 4 hours. Several sessions were held, and they directly reached 101 employees from the Liepaja city administration. The participants represented a variety of internal departments, with a particular focus on those working with the public.

After the implementation of the courses, an evaluation of the financial benefits was performed at the end of 2023.

MATERIALS AND METHODS

An analysis of the benefits of taking the measures by the municipality of Liepaja for the transition to paperless management in internal management processes and of delivering the courses revealed that the benefits could be seen in terms of paper, toners and ink saved. In general, financial benefits for ML were assessed in the following structural units: Office of the Executive Director, Organisational Division, Customer Service Centre, Accounting, Personnel, Legal, Development and Administrative Department, Departments of Public Procurement, Environmental Health and Public Participation, Management and Audit of Capital Companies. Table 1 gives a comparison of expenses on paper, toner and ink between 2022 and 2023. The data showed that the main benefits involved the reduction of paper consumption.

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Table 1. Comparison of paper, toner and cartridge ink consumption by the Liepaja city administration (ML) in 2022 and 2023

Item	2022		2023	
Paper size	**Number, pcs.**	**EUR**	**Number, pcs.**	**EUR**
A4	247000	1362	90000	743
A3	7500	80	500	6
Toner kind				
New, coloured (alternative)	15	278	5	79
New, black and white (alternative)	44	777	16	279
New, coloured	4	190	5	900
New, black and white	2	163	0	0
Cartridge type				
New, coloured	16	936	6	246
New, black and white	16	1004	7	352
Total	254581	3786	90532	2253

Source: authors' construction based on the Liepaja city administration data

As shown in Table 1, the number of paper sheets or printouts consumed by various organisational units decreased by 164000 sheets during the year. The largest reduction was found for the Organisational Division (50000 sheets), in the Executive Director Office (22500) and in other organisational units (15000). The reduction was not identified for the Departments of Public Procurement as well as Environmental Health and Public Participation. This could be explained by the timely transition of both departments to paperless management, and their printouts related to information required by other institutions in paper format.

An analysis of the reduction in monetary terms revealed a total saving of EUR 692. Some organisational units, e.g. the Customer Service Centre, the Public Procurement Department, the Development Department and the Department of Environmental Health and Public Participation experienced an increase in spending, which was insignificant due to an increase in paper prices.

An analysis of the reduction in toner consumption revealed a significant reduction in the number from 65 pieces to 26 pieces. The toners had not been purchased for several organisational units, e.g. the Personnel Department and LPR, while 5 new colour toners had been purchased for the Customer Service Department and the Executive Director Office. Due to the purchases, the financial savings from reduced toner consumption were small, only EUR 152. In the coming years, it is planned to continue reducing expenses on toners.

The consumption of cartridge ink by several organisational units, e.g. the Administrative Department, the Public Procurement Department and the Accounting and Legal Department had also significantly decreased. However, the consumption by several organisational units had increased, e.g. the Department of Management and Audit of

Capital Companies (KPURD). The total financial savings from the reduction of cartridge ink consumption was EUR 1312 in 2023 compared with 2022.
As shown in Figure 1, the total financial savings from the transition to paperless management in internal processes ML amounted to EUR 2155 in 2023 compared with 2022. The total reduction was 46%, which was significant. The largest savings related to ink – both colour and black and white cartridges –, followed by paper, while the least was saved on toners.

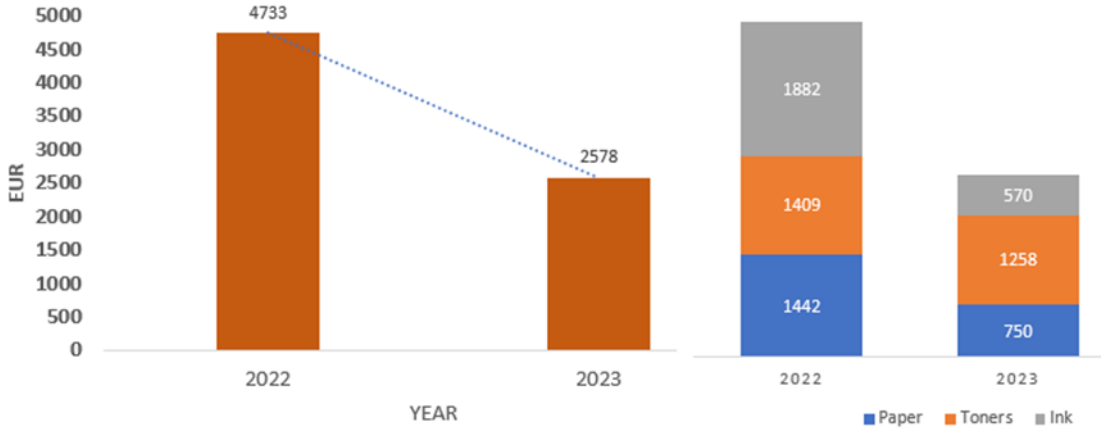


Figure 1. Total financial savings from the transition to paperless management of internal processes ML

Source: authors' construction based on the Liepaja city administration data

For the financial assessment to be complete, the authors recommend that in the following years, accurate accounting and analysis of changes in information and other technology, software purchase and maintenance costs be performed by each organisational unit and the whole institution. It is important to separately list the changes in electricity consumption, both in kwh and in monetary terms, estimating the additional consumption during the winter, if any of the rooms are heated with electricity. Remote work opportunities, which the employees referred to as a positive factor, could cause difficulty in accounting for electricity consumption. Waste management costs and the savings if the amount of paper waste is reduced should also be listed separately. Waste management costs depend not only on the amount of waste to be disposed of but also on waste management service prices; therefore, the assessment of benefits for several years requires making adjustments. The authors recommend setting archive storage costs as a separate accounting item.
Aditionally the authors used data from the available project materials to compare the total financial benefits of the transition to paperless management, digital skills training courses, and other measures with those of Vila Nova de Poiares (MVNP) (Portugal), Mielec (MM) (Poland) and Liepaja city (ML) (Latvia).

The materials showed only the total savings in each local government administration. Comparing the savings of all three municipalities, they are similar in ML (2253 EUR) and MVNP (2665 EUR), but the savings in MM are three times higher (6072 EUR). This can be explained by the older age of MM administration employees and, therefore, a smaller share of paperless management before the project implementation. The costs of preparing the courses were not included in the financial calculation, as the project funds covered them, and the prepared materials will be able to be reused in the future.

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RESULTS AND DISCUSSION

For the financial assessment to be complete, the authors recommend that in the following years, accurate accounting and analysis of changes in information and other technology, software purchase and maintenance costs be performed by each organisational unit and the whole institution. It is important to separately list the changes in electricity consumption, both in kwh and in monetary terms, estimating the additional consumption during the winter, if any of the rooms are heated with electricity. Remote work opportunities, which the employees referred to as a positive factor, could cause difficulty in accounting for electricity consumption. Waste management costs and the savings if the amount of paper waste is reduced should also be listed separately. Waste management costs depend not only on the amount of waste to be disposed of but also on waste management service prices; therefore, the assessment of benefits for comparison of expenses on paper, toner and ink between 2022 and 2023 in all structural units. The data showed that the main benefits involved the reduction of paper consumption. Furthermore, the reduction in paper and toner usage contributes to environmental sustainability, aligning with the goals of environmental economics.

CONCLUSION

The research highlights the significant financial and environmental benefits of transitioning to paperless management in municipalities. By reducing paper and toner consumption, municipalities can achieve substantial cost savings and promote sustainable practices. The study also underscores the importance of training municipal employees in digital skills, which is crucial for the successful implementation of paperless management systems.

The findings suggest that other municipalities can replicate these strategies to realize similar benefits. Future research should focus on the long-term impacts of paperless management, including changes in technology costs and energy consumption. Additionally, exploring the challenges and best practices in digital transformation can provide valuable insights for continuous improvement in municipal management.

By refining the structure and clarity of each section, our paper can effectively communicate the financial benefits and broader implications of implementing paperless management in municipalities.

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HARD COAL AS AN IMPORTANT TRANSITION FUEL IN THE POLISH ENERGY SYSTEM - THE CONTEXT OF THE CARBON FOOTPRINT

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ABSTRACT

Dynamic climate changes require large human action. One of its essential elements is the reduction of anthropogenic GHG emissions. Within the European Union, they constitute one of the two fundamental goals of the European Green Deal strategy, which assumes that Europe (EU) will remain the first climate-neutral continent by 2050. Among the nine sectors of the economy the most widely covered by these activities is the energy sector. Taking into account the assumed rate of GHG emission reduction, it seems that transition fuels will play a key role in this process, being the basis for the security and stability of the energy system, especially in the point of view of the weather dependence of a large part of renewable energy sources and the still existing lack of industrial energy storage technologies with adequate efficiency and effectiveness. This article argues in the above context that electricity based on hard coal from own deposits can be 10% less GHG-emissive than this product based on imported natural gas (taking into account the sum of all greenhouse gases and the Global Warming Potential factors determined in the IPCC AR6 report). This statement is based on an analysis of the Polish energy market.

Keywords: GHG emission, energy transformation, transition fuel, hard coal

INTRODUCTION

Climate changes, resource scarcity, changes in demography and society, technological breakthrough, rapid urbanisation - these are some samples of world megatrends [10] of last and for nearest years. They create a human approach to action, including economic activity, requiring it to be conducted in a sustainable way. From this reason the concept of Sustainable Development is becoming increasingly important for the activities of global value chains. Sustainable development is defined as such development, that meets the present needs of people without compromising the ability of future generations to meet their own needs. In order to achieve sustainable development, three key elements need to be coherent: economic growth, social inclusion and environmental protection [7]. In the context of the goals referred to as SDGs (Sustainable Development Goals), included in the "2030 Agenda for Sustainable Development" of the United Nations, it is becoming crucial to work toward responsible production leading to economic growth, while protecting the natural environment and combating climate change. These goals and related targets are global in nature and can be implemented worldwide, taking into account the different conditions of individual countries, their capacities and level of development, and their compatibility with national strategies and priorities [7]. Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU with regard to corporate sustainability reporting, referred to as the Corporate Sustainability Reporting Directive (CSRD). According to it, all large entities and small and medium-sized listed companies will be obligated to provide information on: environmental, social and human rights issues and corporate governance in their management report in 2024. This information will be

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reported according to the common European Sustainability Reporting Standards (ESRS) [3]. Undoubtedly, individual countries and communities around the world are pursuing the main objectives, thereby placing a focus on sustainable development. Thus, the European Union is a party to the 2015 Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCC). The Paris Agreement commits to reducing greenhouses gases (GHG) emissions in such a way that the increase in average global temperature compared to pre-industrial levels does not exceed 2°C. In addition, parties are to aim to limit this increase to 1.5°C. According to emission models put forward by the scientific community, including the Intergovernmental Panel on Climate Change (IPCC), this implies a halt to global emissions growth around 2030, followed by a successive reduction so as to reduce global emissions to zero in the second half of the century [8]. Recognised by researchers for years, the most serious challenges and dilemmas facing the world at this moment are: responsible consumption and production, rising GHG emissions leading to climate change, increasing energy consumption and the finiteness of the earth's resources. Sustainability, along the European Union's existing climate policy and the listed environmental challenges gave rise to the European Green Deal Strategy in December 2019. It is a set of initiatives with the overarching goal of achieving climate neutrality by 2050 for all UE member states. The European Green Deal is designed to enable a fair energy transition, ensure the supply of clean, affordable, and secure energy, and support the protection of biodiversity, efforts towards a circular economy, and the promotion and financing of green investments.

A tool to support the transition is the EU Taxonomy, which sets out the criteria that an activity must meet to be considered environmentally sustainable (and thus to be able to attract additional funding to carry it out). The EU taxonomy identifies key environmental aspects, referred to as environmental objectives, such as [6]:

- combating and adapting to climate change (reducing CO2 emissions and improving energy efficiency),
- water management,
- activities for the Circular Economy,
- non-GHG emissions,
- protection of biodiversity.

The EU Taxonomy therefore constitutes a requirement, but also an incentive for economic actors to target their activities to improve environmental performance in terms of the environmental impact of a given activity and thus to obtain 'green fund'.

The elements connecting all these environmental goals are the basic implementation directions of the European Green Deal, which are [2]:

1. Reduction of carbon footprint by 2050 (Scope 1 + Scope 2 + Scope 3) to the level of 600 million tons of eCO2/year, which will allow the European Union to remain the first climate-neutral area in the world.
2. Reducing the environmental footprint through the implementation of the Circular Economy, which, via waste reduction (including at the product design level), can achieve savings of EUR 600 billion by 2030 and reduce the carbon footprint by 450 million tons with reference to 2005.

The first goal is the most important for the context of this article. The path of its implementation is presented in Figure 1 [2].

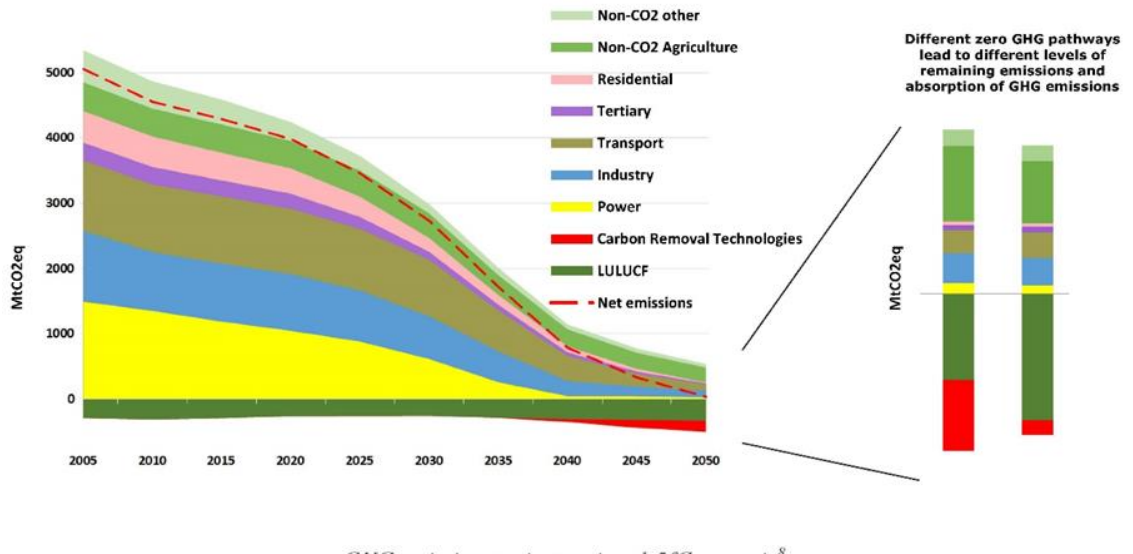


Figure 1. Reduction path of the carbon footprint in UE to 2050

One of the most important sectors of the economy to undergo such transformation is the energy sector. The following proprietary calculations help indicate what role hard coal can play in this system.

CALCULATIONS OF THE CARBON FOOTPRINT OF ELECTRICITY IN POLAND BASED ON HARD COAL FROM OWN DEPOSITS AND IMPORTED NATURAL GAS

As indicated in the previous chapter, the energy sector is to be one of the industries that are to become very low-emission in terms of GHG in the next few decades, leading the EU towards its climate neutrality goal. This will be a process, of course; a process that will gradually eliminate high-emission sources, replacing them with zero or low-emission sources. Transitional fuels are to play a significant role at this time, especially during the transition period, which is estimated to last between 2025 and 2040.

Taking into account the fact, that Poland's energy mix is still based primarily on hard coal and brown coal, accounting for 67% of the electricity generated in 2023 [3], the country must undergo extremely significant changes in the professional energy sector at that time.

Following the law implementing in Delegated regulation (EC) no. 2022/2014, included in the EU Taxonomy, European Commission has labelled nuclear and natural gas as sustainable. This was translated into the legislation of individual EU countries, creating or updating the energy policies of these countries accordingly. On this basis, Poland's energy policy [3] until 2040 assumed a gradual, although dynamic departure from coal, but with a strong use of natural gas and liquid hydrocarbons in the transitional period.

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In the paper author's opinion, the above indications are correct if direct emissions are taken into account. His analyses based on National Centre for Emissions Management (KOBiZE) [5] data show that the emission intensity of burned hard coal is approximately 40% lower than that of natural gas. The emission indicators on which these calculations were based are presented in Table 1, and the calculation results in terms of kg CO2/GJ are shown in Figure 2.

Table 1. Reduction path of the carbon footprint in UE to 2050 [5]

Fuel type	Calorific values [MJ/kg]	Emission values [kg CO2/GJ]
Hard coal	21,48	93,55
Natural gas	48,00	55,47

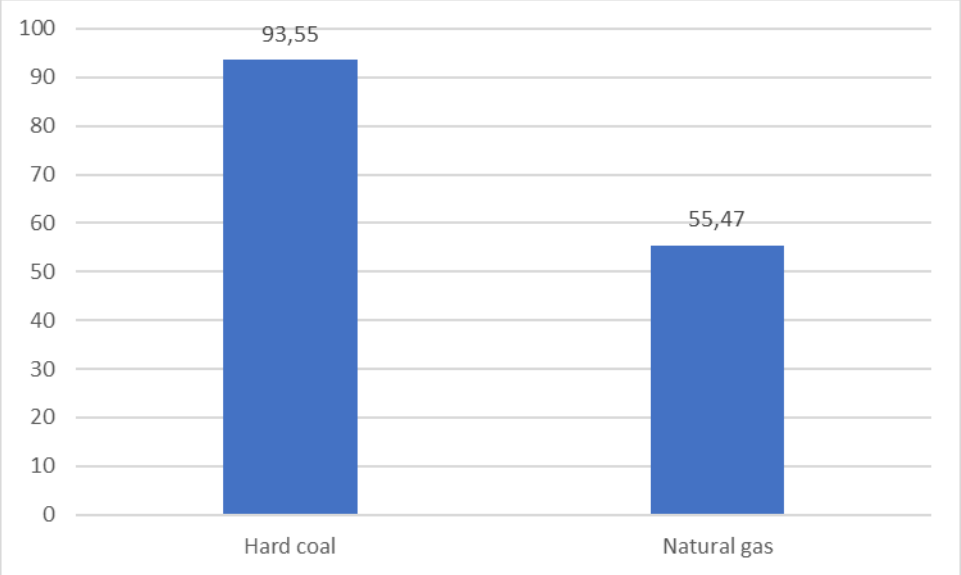


Figure 2. Emission intensity of electricity generated from burning hard coal vs. natural gas in Poland [kgCO2/GJ]

As already indicated above, a main element of the above GHG emission levels is the fact that they include the fuel combustion process.

According to the paper's author, relying solely on this element, although very important, is incomplete. The above values do not take GHG emissions related to the production and transport of combusted products into account.

The above issue becomes particularly important if we take into account, firstly, the location of sources of natural gas used in Poland, as well as the significantly higher level of the greenhouse potential index CH4 (which is the main component of natural gas) in relation to CO2, which is the main product of the combustion of both fuels.

Regarding the first issue, it should be noted that nearly 70% of the natural gas used in Poland comes from import [1]. This is primarily due to the insufficiency of the fuel's own resources. The main places of its current and planned import are Norway (deposits on the Norwegian Shelf), the Arab Countries (deposits in the Arabian Gulf) and the USA (deposits in the Gulf of Mexico). These directions are presented in Figure 3. In terms of burned hard coal, it should be noted that its deposits occur in Poland and that this fuel, in terms of demand for it, is fully saturated from these deposits.

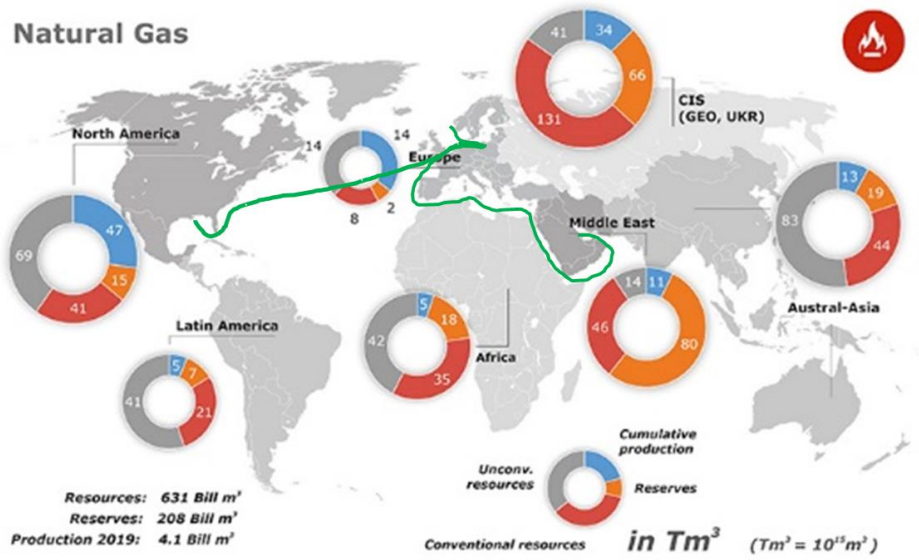


Figure 3. Directions of natural gas imports to Poland

Regarding the second issue, it should be taken into account that CH4 is almost 30 times (exactly 29.8 times, see Figure 4 [4]) more emissive than CO2. This is of particular importance mainly in relation to the CH4 emission process during the production and transport of natural gas, especially over long distances (which is the case not only for Poland, but also for a significant number of EU countries that do not have sufficient deposits of these hydrocarbons for their needs).

Greenhouse Gas	100-Year Time Period				20-Year Time Period			
	AR4 2007	AR5 2014	AR6 2021		AR4 2007	AR5 2014	AR6 2021	
	Feedback Not Included		*Feedback Included*		*Feedback Not Included*		*Feedback Included*	
CO_2	1	1	1	1	1	1	1	1
CH_4 fossil origin	25	28	34	29.8	72	84	86	82.5
CH_4 non fossil origin				27.2				80.8
N_2O	298	265	298	273	289	264	268	273

Figure 4. Global Warming Potential (GWP) index of different GHG

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As research by many scientists has shown, including detailed analyses by Taraska and Banks [9] (see Figure 5), during the above-described processes, over 30% of the total GHG emission level for this fuel may occur in terms of direct CH4 emissions.



Figure 5. GHG emissions in the production, transport and power plants operation processes concerning natural gas

If the additional emission-related elements described above are taken into account, the GHG emission levels for both fuels used change significantly, as shown in Figure 1. Adding up direct and indirect emissions (Scope 1 + Scope 2 + Scope 3), the emission intensity of natural gas imported from long distances is over 10% higher than that of hard coal extracted and burned on site. The results of these calculations in terms of absolute data are presented in Figure 6.

Figure 7 shows the emission values related to individual phases of production, transport and use of natural gas.

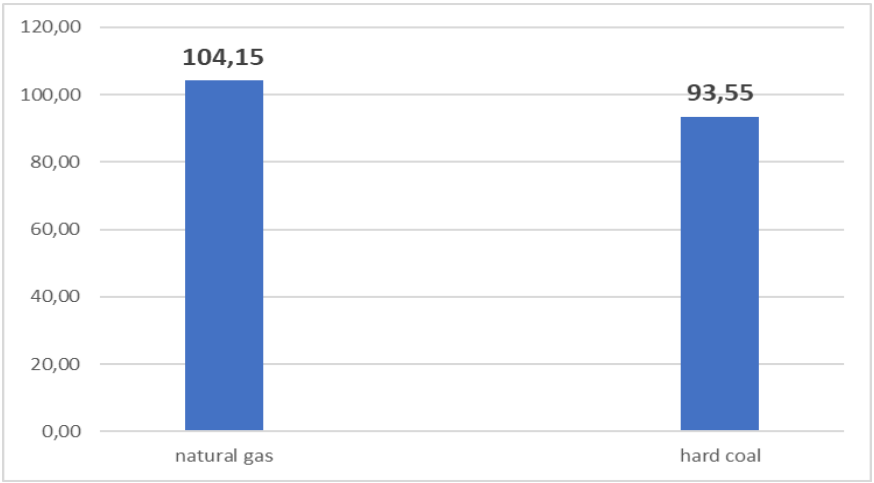


Figure 6. Total emission intensity of electricity generated from burning hard coal vs. imported natural gas in Poland [kgCO2/GJ]

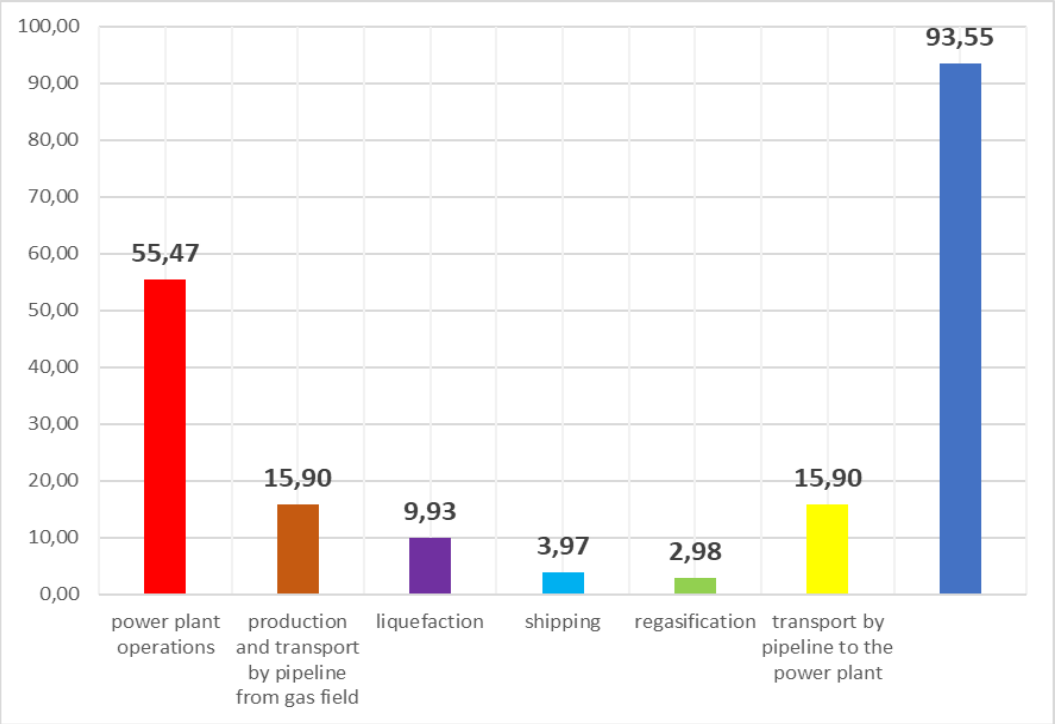


Figure 7. Total emission intensity of electricity generated from burning hard coal vs. imported natural gas in Poland, with relation to individual phases of production, transport and use of natural gas [kgCO2/GJ]

CONCLUSION

The analyses and their results presented in this article, in the author's opinion, lead to the following basic conclusions:

1. For the good of the planet, as well as humanity, we should strive to protect it, including reducing our impact on the natural environment in terms of all negative pollutants, including excessive GHG emissions.

2. The energy industry should change towards the production of energy from renewable sources. The lack of stability of these origins, combined with the lack of effective and economically efficient energy storage technology, requires finding the best transitional fuel for energy, also for Poland.

3. The European Green Deal Strategy and Poland's Energy Policy until 2040 indicated that these fuels will be natural gas and radioactive elements, excluding, and even eliminating by 2049, carbon fuels, including hard coal.

4. The results of the author's research indicate that eliminating hard coal as a transition fuel seems to be a mistake. GHG emissions generated in the process of its production and combustion in Poland are 10% lower than in the case of using imported natural gas, taking into account today's technologies.

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5. We should seriously consider defining hard coal as a transitional fuel in the process of transforming the energy industry into zero-emission industries, also developing technologies for clean combustion (or maybe not only combustion) of coal.

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INVESTMENT PROMOTION AND ATTRACTION TO BIOECONOMY INDUSTRIES IN LATVIA

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Dr. Ilze Upite[1]

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ABSTRACT

Investments made in response to climate change could help to foster environment-friendly business practices. Therefore, bioeconomy industries are considered crucial for achieving climate neutrality in Europe by 2050. Accordingly, bioeconomy strategies have been designed in many countries, including in Latvia. Therefore, the aim of the present research is to examine the investment environment and the amounts of gross investment made in bioeconomy industries, as well as foreign direct investment attracted to Latvia to contribute to the implementation of the Latvian Bioeconomy Strategy 2030. The research covered the period 2015-2022 and was based on publicly available information on investment. The research found that significant investments were made in bioeconomy industries during the period analysed; however, the amount of gross investment made and the growth rate were insufficient to achieve the target set by the strategy by 2030, i.e. to reach the total investment of EUR 20 billion in the bioeconomy industries. The most investments were made in companies engaged in the primary sector, energy generation and manufacture of wood products. In addition, compared with the rest of the Baltic countries, foreign direct investment as a % of gross domestic product (GDP) was the lowest in Latvia. Therefore, it is important that measures are taken in the country to enhance the investment environment, as well as encourage and stimulate investments – both private and public – by means of various support measures to foster growth not only in bioeconomy industries but also in the entire national economy.

Keywords: investments, bioeconomy strategy, development.

INTRODUCTION

In the European Union (EU), the bioeconomy represents all industries as well as related services that produce, use, process, distribute or consume biological resources, including ecosystem services. Thus, the bioeconomy in its various forms is an important element in the global transformation to a more sustainable economic system [1]. The EU Green Deal aims to become the world's first "climate-neutral union" by 2050, striving to be environmentally friendly in various industries, e.g. energy, food, construction and transport [2]. The transition to the bioeconomy and a broader low-carbon fossil economy requires long-term investments whose ecological and economic performance are affected by various future conditions [3]. Scientists from the USA emphasize that in addition to the important role of the bioeconomy in achieving zero carbon emissions by 2050, there is another argument for countries to invest in the

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development of the bioeconomy – it is the competitiveness of countries and the risk of losing an opportunity to revive output [4]. Investments made in response to climate change could help to encourage environment-friendly business practices, e.g. conservation of natural resources, production of alternative energy sources or implementation of other environment-friendly projects [5]. Overall, the financial sector can contribute to the achievement of sustainability goals in all industries through investment [6]. Investor capital contributes to the growth of companies because the investors change conditions for financing a company either by lowering the cost of capital or by enhancing access to finance. However, significant changes require policies that change the viability of economic activities [7]. Therefore, the leading countries of the world as well as EU Member States design bioeconomy development strategies. R.M'barek and J.Wesseler (2023) have stated that "beginning in 2023, 10 Member States have a dedicated bioeconomy strategy at national level in force and at least 6 Member States are in the process of developing their respective dedicated national strategies" [1]. The Latvian Bioeconomy Strategy 2030 was approved in December 2017. Five main interconnected and complementary lines of action have been brought forward for the achievement of the objective of the bioeconomy strategy [8]. One of them is "Attractive entrepreneurial environment", which has several sub-measure groups associated with investment promotion and attraction to bioeconomic sectors: 1) *Creation of an investment-friendly environment.* The environment should be shaped so that it would be attractive for investments (raising capital) in bioeconomy development projects, particularly if investments for further processing of biomass into products with higher added value are made, following the principle of cascading; 2) *Promotion and attraction of investments.* Attraction of foreign and national investments, including to infrastructure, pilot projects, demonstration projects, risk capital etc. should be promoted for the achievement of the objective. A complex approach is necessary for the promotion and attraction of investments, which depends on both the bioeconomy industry and product group, as well as the size of the undertaking and target markets [8]. Therefore, the aim of the present research is to examine the investment environment and the amounts of gross investment made in bioeconomy industries, as well as foreign direct investment attracted to Latvia to contribute to the implementation of the Latvian Bioeconomy Strategy 2030.

MATERIALS AND METHODS

To analyse the investment environment, the research analysed publicly available information on domestic investment and foreign direct investment made in the bioeconomy of Latvia from: 1) the Ministry of Economics (MoE) of the Republic of Latvia (LR) [9], which is responsible for investment promotion and attraction; 2) the Official Statistics Portal of the Republic of Latvia (https://stat.gov.lv), which reports on gross investment made in industries [10]; 3) the Bank of Latvia on foreign direct investments [11]. The research employed the Statistical Classification of Economic Activities in the European Community, Revision 2 [12]. The present research considers the following economic activities as bioeconomy industries: 1) primary production of bioresources – A Agriculture, forestry and fishing; 2) bioresource processing industries consuming bioresources (dependent manufacturing industries) – C10 Manufacture of food products, C11 Manufacture of beverages, C13 Manufacture of textiles, C14 Manufacture of wearing apparel, C15 Manufacture of leather and related products, C16 Manufacture of wood and of products of wood and cork, except furniture, manufacture

of articles of straw and plaiting materials, C17 Manufacture of paper and paper products; 3) bioresource processing industries in which bioresources are an alternative to other raw materials – C20 Manufacture of chemicals and chemical products, C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations, C31 Manufacture of furniture, D Electricity, gas, steam and air conditioning supply; 4) industries consuming bioresources for the provision of services – F Construction and I Accommodation and food service activities.

The research employed the publicly available Eurostat database [12] to analyse and compare the situation in the Baltic States, as a wider market is important for attracting investment. The research period was 2015-2022, which allows for a comparison of the situation before the Latvian Bioeconomy Strategy 2030 has been approved and during the implementation thereof. The research applied the monographic method and statistical data analysis.

EVALUATION OF RESULTS AND DISCUSSION

1. Investment environment and gross investments in bioeconomy industries in Latvia

Investment promotion in Latvia has always been a priority for fostering economic growth, and it has received increased attention in policy documents. Investment promotion is a complex measure and, therefore, any investment promotion policy is designed in detail. Unfortunately, an investment promotion and attraction plan recommended by the Latvian Bioeconomy Strategy 2030 for the development of the bioeconomy in Latvia has not been designed. However, fostering foreign direct investment in the areas of the Smart Specialization Strategy (RIS3) by purposefully promoting investments in knowledge-intensive sectors with high value added, including the bioeconomy, is one of the priority goals defined by the National Industrial Policy Guidelines for 2021-2027 [13]. Investment activities in Latvia have been fluctuating since 2020. Over the last three years (2020-2022), total expenses on fixed capital formation increased by an average of 1.8% per year, which was less than before the Covid-19 pandemic in 2017-2019 when the increase was on average 8.1% per year. As the economy stabilized after the shock caused by the Covid-19 pandemic, investments increased by 7.2% in 2021. However, the war in Ukraine has increased uncertainty, and this affected investment activities. In 2022, investments grew by only 0.6% and accounted for 21.7% of GDP. The investment activities were also limited by an increase in construction prices and delays in the implementation of EU-funded programmes. After three years of moderate growth, the investment activities increased significantly in 2023 [14]. Weak lending, low demand and uncertainty significantly limited private investments in Latvia, which have remained at a low level for a long period. In 2021, the amount of private sector investments increased by 10.2%, and in 2022, the amount exceeded the 2021 level by almost 8.2%. Positive changes were observed also in 2023, and in the first half of the year, the amount of private investments was 10.4% higher than a year earlier. Domestic investment in Latvia was at a relatively high level. It made up almost 1/5 of the total investment in the national economy of Latvia, and the change largely related to the cyclical nature of use of EU funding. Domestic investment increased by 7.6% in 2020. In 2021 and 2022 (in constant prices), however, it decreased and was 1.4% and 24.6%, respectively, lower than a year ago. In the first quarter of

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2023 compared with the corresponding period of the previous year, the amount of domestic investment increased by 10.2 % [2].

In 2022, a gross capital investment of EUR 1673.4 mln., which exceeded the level of 2015 by 48.6%, was made in bioeconomy companies. The most investment was made in the primary sector (38.4% of the total investment in 2022), followed by energy generation (19.1%), manufacture of wood products (17%) and construction (11.3%), while in other industries it was only 14.2%. The least investment was made in manufacture of leather products, wearing apparel and textiles (Table 1).

Table 1. Gross capital investments in bioeconomy companies in Latvia (NACE Rev.2) in the period 2015-2022, mln. EUR [10]

Indicators	2015	2016	2017	2018	2019	2020	2021	2022	Proportion in 2022, %	2022/ 2015, %
Total	1126.4	1491.8	1419.0	1343.8	1411.8	1471.3	1225.8	1673.4	100	148.6
Annual growth rate,%	100. 0	132.4	95.1	94.7	105.1	104.2	83.3	136.5	x	x
A	245.3	488.4	412.1	469.8	415.4	438.2	393.7	642.0	38.4	261.7
C10	127.9	91.4	80.0	78.3	142.4	113.2	79.3	66.0	3.9	51.6
C11	35.5	15.1	13.4	15.2	17.3	22.6	18.6	18.2	1.1	51.2
C13	6.0	3.9	3.9	3.6	5.6	4.6	4.9	4.9	0.3	81.2
C14	3.1	6.5	7.2	3.4	3.2	2.7	3.4	4.4	0.3	144.4
C15	0.1	0.1	0.5	0.1	0.1	0.0	0.2	0.2	0.0	359.4
C16	140.8	136.8	168.5	138.9	205.4	216.3	179.3	284.8	17.0	202.3
C17	6.9	6.1	5.6	9.2	12.3	5.5	8.3	8.7	0.5	125.3
C20	8.1	9.3	14.5	13.7	12.7	29.4	36.7	25.1	1.5	312.1
C21	15.3	4.9	6.9	8.4	16.5	10.1	11.3	10.2	0.6	66.6
C31	13.5	16.2	29.8	9.7	14.2	13.8	17.2	17.1	1.0	126.6
D	328.3	410.8	384.3	247.5	301.1	357.1	258.8	319.0	19.1	97.2
F	138.2	214.0	221.3	269.8	192.5	189.3	160.4	189.8	11.3	137.3
I	57.4	88.3	71.0	76.0	73.0	68.5	53.6	83.0	5.0	144.6

According to the Latvian Bioeconomy Strategy 2030, investments in the amount of approximately EUR 20 bln. Need to be made in innovations and the development of new products, expansion and modernisation of manufacturing, establishment of new undertakings, development of infrastructure as well as branding and marketing measures for achieving the target set by the strategy until 2030 [8]. After the strategy (2018-2022) has been approved, the amount of investment totalled EUR 7.1 bln., with the average amount of investment per year being EUR 1.4 bln. If this pace of gross investment continues, the target set by the strategy is not going to be achieved, reaching 92.5% of the forecast (EUR 18.5 bln.). This means that in the coming years, additional measures should be taken to foster investments in bioeconomy industries. A breakdown of gross capital investments made in bioeconomy companies in 2015-2022 reveals that the investments dominated in the following areas: machinery and equipment – 43%, existing buildings and constructions, construction and reconstruction of buildings – 30%, other fixed assets – 24% and land – 3%. The highest proportion of investments in machinery and equipment was made in the following areas: C17 Manufacture of paper and paper products – 73% and C16 Manufacture of wood and of products of wood and cork, except furniture, manufacture of articles of straw and plaiting materials – 59%. The highest proportion of investments in existing buildings and constructions, construction and reconstruction of buildings was made in the following areas: D

Electricity, gas, steam and air conditioning supply – 57% and I Accommodation and food service activities – 54%. The highest proportion of investments in other fixed assets was made in the following areas: C11 Manufacture of beverages – 43% and C14 Manufacture of wearing apparel – 38%. Due to the specifics of economic activity, the highest proportion of investments was reported for land – A Agriculture, forestry and fishing – 15% (Figure 1). This indicates the specifics of bioeconomy industries regarding making investments to ensure production, processing or providing services.

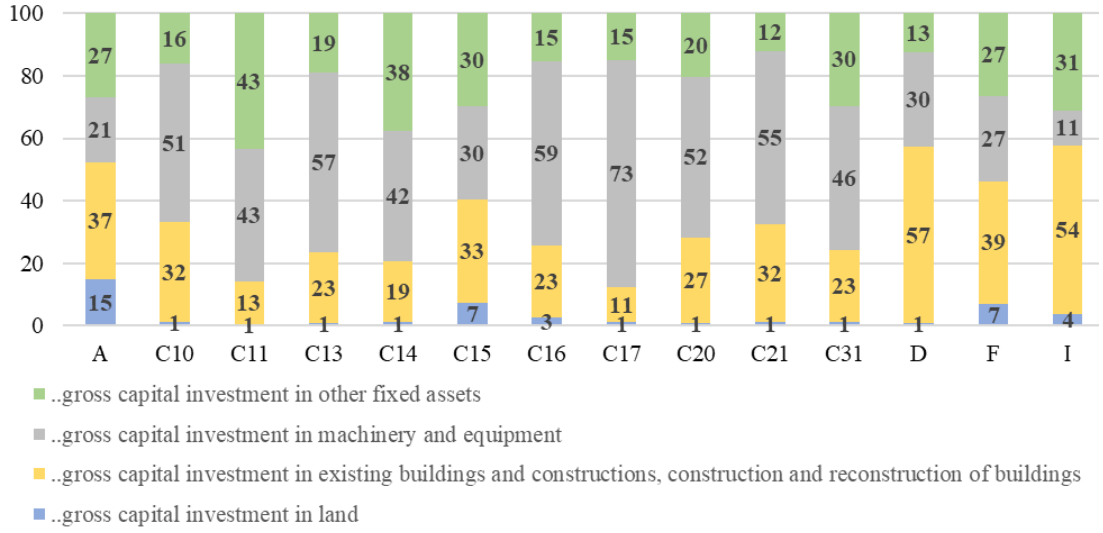


Fig. 1. Breakdown of gross capital investments in bioeconomy companies (NACE Rev. 2) in 2015-2022, % [10].

2. Foreign direct investments in Latvia, including in bioeconomy industries

The intensity of foreign direct investment (FDI) flows has been different since Latvia joined the EU. In the period from 2011 to 2016, the annual net flow of FDI into Latvia averaged 3% of GDP, while in 2017-2019, it increased by an average of 2.7% of GDP [15]. In recent years, the foreign direct investment flows have stabilized; however, the cross-border investment flows overall tend to slow down because of increased geopolitical risks and uncertainty over economic growth. In 2021, the amount of FDI transactions increased significantly, reaching EUR 2809 mln. (8.4% of GDP), which was determined by ambitious investments by the Swedish company Swedbank AB in the equity capital of its companies registered in Latvia [14].

At the end of 2022, the stock of FDI in the economy of Latvia reached EUR 22.6 bln. More than 22% of the total was invested in bioeconomy companies. In the 8 years analysed, the stock of FDI has significantly increased in the manufacturing industry by 78% and in agriculture, forestry and fishing by 53%, whereas a decrease was reported in the construction industry by14% (Table 2). A comparison of increases in the stock of FDI in the period analysed revealed that the fastest increase in bioeconomy industries was reported in 2021 and 2022 at 12% and 13%, respectively, which shows that the bioeconomy industries have become more attractive to foreign investors in recent years. This could be especially true for the processing industry, as the stock of FDI at the end of 2022 represented 56% of the total investment made in the bioeconomy sector. The second highest figure was reported for agriculture, forestry and fishing at 18%.

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Table 2. Foreign direct investments in bioeconomy companies in 2015-2022, balance at the end of the period, mln. EUR in Latvia (NACE Rev.2) [11]

Indicators	2015	2016	2017	2018	2019	2020	2021	2022	Proportion 2022, %	2022/ 2015, %
A	600	565	618	593	669	715	795	916	18.4	152.7
C	1 559	1 634	1681	1796	1906	1977	2354	2775	55.7	178.0
D	504	495	566	556	547	567	693	629	12.6	124.8
F	501	591	564	643	471	436	386	432	8.7	86.2
I	138	142	191	154	219	214	164	230	4.6	166.7
Total	3302	3427	3620	3742	3812	3909	4392	4982	100.0	150.9
Annual growth rate, %	x	103.8	105.6	103.4	101.9	102.5	112.4	113.4	x	x

Historically, the largest FDI flows into Latvia come from neighbouring countries: Sweden, Estonia, Lithuania and Russia, as well as from the Netherlands, Cyprus and Germany [11]. An analysis by industry reveals that the highest proportion of FDI stock (76% at the end of 2022) was found for 5 industries: scientific and technical services, financial intermediation, real estate activities, trade and in the bioeconomy sector – in the manufacturing industry (12.3%). However, it should be noted that in this case the research analysed the total amount of investment in the manufacturing industry, which also included several industries not related to the bioeconomy [11].

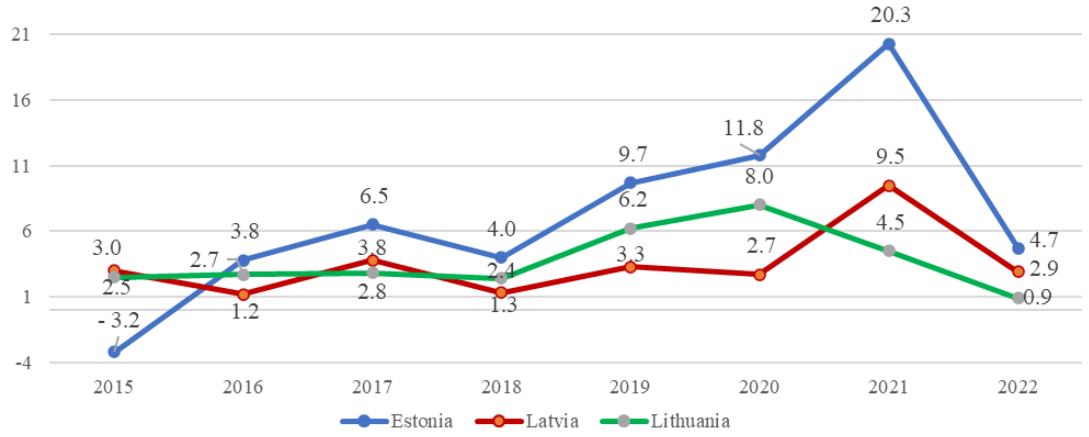


Fig. 2. Foreign direct investments in the Baltic States in 2010-2020, as a % of GDP [12].

A comparison of Latvia with the other Baltic neighbouring countries has revealed that for several years, the largest amount of FDI was reported in Estonia – on average 7.2% of GDP in 2015-2022, reaching the highest level in 2021 at 20.3% of GDP. However, the amount of FDI was relatively lower in Latvia and Lithuania. In Latvia, the average amount was 3.5% of GDP in 2015-2022, reaching the highest level in 2021 at 9.5% of GDP; in Lithuania it was 3.8% of GDP in 2015-2022, while the highest level was reached in 2021 at 8% of GDP (Figure 2). The National Industrial Policy Guidelines for 2021-2027 developed by the Ministry of Economics of Latvia have set five knowledge-intensive areas as investment priorities, in which Latvia has available resources and competence, which refer to the Smart Specialization Strategy of Latvia and which also include a knowledge-intensive bioeconomy [13]. The FDI attraction policy is aimed at increasing the competitiveness of Latvia as an attractive environment for investments,

considering the most important aspects for investors: macroeconomic performance, the business environment –simplicity of bureaucratic procedures and a stable tax policy –, availability of qualified labour, market potential, availability of necessary infrastructure, as well as support instruments and incentives. It is essential to attract foreign investments to industries that contribute to a change in the composition of the national economy in favour of foreign demand-oriented industries, especially in industries that are defined as medium-high and high-tech industries. In attracting foreign investments, a focus should be placed on geographically close neighbouring countries, where Latvia is recognizable and there is no need to invest extensive additional resources in informational measures, as well as on economically stable and developed countries, where the development potential and needs of industries meet prospective cooperation opportunities for Latvia, as well as on countries with the largest outflows of investment globally: the USA, France, Germany, the United Kingdom, Japan, China, Russia and India [14]. To contribute to a faster recovery of the national economy of Latvia from the Covid-19 crisis and improvement in the economic situation, thereby accelerating the attraction of investments and increasing the economic competitiveness of Latvia, the Cabinet regulation Regulations regarding Servicing Priority Investment Projects entered into force on 11 February 2021. The Cabinet regulation prescribes priority investment projects, qualification criteria for companies and the procedure for approving investment projects, the list of services to be supplied by state administration and cases where the authorities ensure the supply of relevant services in priority order and within the deadline. The segment of priority investment projects also represents the knowledge-intensive bioeconomy, as well as construction, transport and logistics if these industries relate to the supply of services and infrastructure to companies of the bioeconomy sector. Companies registered in Latvia, which meet the criteria established by the Cabinet regulation and make large-scale investments within a period of three years from the day of starting an investment project, are eligible to apply for priority investment project status (total amount of investment is at least EUR 5 mln., while in the administrative territory of Riga city – at least EUR 10 mln.), thereby creating at least 75 new jobs (in Riga – at least 100 jobs), contributing to a significant amount of exports (more than EUR 3 mln., in Riga – more than EUR 5 mln.) or investments in research and development (at least EUR 250 000 EUR) [9; 16].

CONCLUSION

Investments are an important driver of expansion of companies as well as industries and the entire economy of the country. However, bioeconomy industries are considered to be crucial for the global transformation to a more sustainable economic system and climate neutrality in Europe by 2050. Therefore, an analysis of the implementation of the Latvian Bioeconomy Strategy 2030 in the field of investments revealed that: 1) in 2022, a gross capital investment of EUR 1673.4 mln. was made in bioeconomy companies, which exceeded the level of 2015 by 48.6%; 2) the amount of gross investment made and the increase rate were insufficient to achieve the target set by the strategy by 2030 – to reach a total investment of EUR 20 bln. in bioeconomy industries, as the expected achievement could be 92.5%; 3) foreign direct investments play a significant role in the development of industries; in 2015-2022 in bioeconomy industries, they have significantly increased from EUR 3.3 bln. to EUR 5 bln. at the end of the respective year; 4) the largest increase in 2015-2020 was reported in the manufacturing industry by 78% and in agriculture, forestry and fishing by 53%, while

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investments have decreased in the construction industry by 14%; 5) it could be established that compared with the rest of the Baltic States, foreign direct investments as a % of GDP was the lowest in Latvia; therefore it is important to continue increasing the activities of national administration institutions aimed at enhancing the investment environment to attract domestic and foreign investments.

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LEGAL FRAMEWORK FOR ENVIRONMENTALLY FRIENDLY BUSINESS PRACTICE IN THE BIOREGION ESTABLISHMENT CONTEXT IN LATVIA

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ABSTRACT

Many UN and EU agreements binding on Latvia are aimed at sustainable development, biodiversity and mitigating climate change. In this context, one of the solutions is the development of concepts of bioregions or organic farming regions because the bioregion involves the principles and techniques of organic production and consumption and is characterised by an "organic" lifestyle, healthy nutrition, human relations, nature protection as well as the promotion of a particular area and the peculiarities thereof. Philosophically, rural development policy is based on the idea of balance. In globalised systems, small and local companies are pushed out of the market, which is distributed between large market actors; however, the bioregional approach is aimed at fostering the local economy through developing the rural environment in a particular area, protecting natural resources and biodiversity as well as preserving scenic values and the quality of the cultural environment. The development of a bioregion represents an activity, progress towards the goal and a dynamic process that is planned and evaluated using various criteria, guidelines and restrictions. Environmentally friendly business practice is a set of prerequisites that a business needs to meet in order not to cause damage to the environment. The relevant legal framework is essential to ensure the sustainable use and preservation of natural resources, as well as to promote regional cooperation and sustainable development. In view of the fact that bioregions are a new concept in Latvia, the present research aims to identify and analyse documents that govern environmentally friendly business practices in potential bioregions in Latvia.

Keywords: bioregion, environmentally friendly business practice, legal framework.

INTRODUCTION

Nowadays, man-made pollution has become critical, and the stress on the natural environment does not always contribute to economic growth. It is necessary to seek new solutions to reduce environmental pollution. Society's attitude towards the environment has also changed. Even if the consequences of such actions are not yet understood by many people, various measures regarding involving the population in environmental preservation are taken by applying strategic approaches. One of the environmentally friendly approaches is the establishment of bioregions. The bioregionalist perspective begins challenging the homogeneity of the global economy and consumer cultures, it supports a competitive pattern capable of reconciling political boundaries with ecological boundaries, thereby contributing to the output of local food and materials as

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well as sustainability owing to the bioregion. From a sociological perspective, bioregions represent not only geographical areas but also socio-ecological systems, in which humans interact with the natural environment and shape it themselves. This view emphasises interconnectedness between human communities and the landscapes they inhabit, thereby highlighting the interaction between culture, the economy and ecology [1]. From the perspective of jurisprudence, the world is most often perceived as a legal phenomenon. The role of legislators is to resolve a specific situation by using a strict system of laws, regulations and principles that are valid in the particular circumstances. However, jurisprudence is also focused on providing theoretical support for such particular decisions. Bioregionalism challenges the accepted traditional and current views of governance and decision-making, and it also affects action on the legal regulation of business in bioregions. Therefore, the present research aims to identify and analyse legal documents that govern environmentally friendly businesses operating in potential bioregions in Latvia. The specific research tasks involve the systematisation of environmentally friendly businesses and the relevant legal framework as well as the identification of the main problems.

MATERIALS AND METHODS

It is certainly difficult to imagine a bioregional system on a global or even national scale. On smaller scales, however, the practices and views of bioregionalism are visible in the ideological goals and actions of local self-sufficient producers. What bioregionalism offers is an alternative to our increasingly globalised markets. The legal acts that are mainly participatory and customised can represent critical public interests in environmental integrity and sustainable resource production. Localised economies could be better suited to achieving the outcomes. Bioregionalism identifies similar areas in transportation and trade, communication networks, natural resource dependence, culture, recreational preferences, natural ecosystems, governance and social issues [2]. It does not make sense to discuss the topic of sustainability on a global scale without considering local communities and the local scale where human life actually occurs. Applying a systems approach, the research analysed publicly available legal documents (laws, Cabinet regulations etc.) that govern environmentally friendly businesses in potential bioregions in Latvia, giving an idea of the legal framework for environmentally friendly businesses in the context of establishment of bioregions in Latvia. The present research is interdisciplinary, employing qualitative methods for social sciences and mainly applying a systems approach [3] that allows the systematisation of environmentally friendly businesses and the relevant legal framework as well as the identification of the main problems.

DISCUSSION AND RESULTS

Bioregionalism could be seen most clearly through sustainable land management practices, e.g. organic farming and permaculture. These ideologies also manifest themselves in worker and consumer cooperatives, community development finance and ecovillages. However, many obstacles should be overcome to implement a bioregional economy. The development of bioregions is also affected by various factors that interact with various processes through complex relationships, thereby shaping ecological and social development in an area as well as improving and developing the quality of life economically. Knowledge of these and other factors in a geographic region is an important aspect of effective planning for the future of a bioregion [4]. Biological areas

or bioregions represent nothing new. There are dozens of them around the world. A bioregion represents an agreement between its residents and municipalities, with everyone undertaking to observe some principles while living in this area. According to information on the Internet, there are a lot of such bioregions in the south of Europe, mostly in Italy, as well as in France and Spain, and some in Sweden and Norway. In Latvia, a bioregion established in the Gauja National Park would be the first one in Latvia and the Baltic States. The establishment of a bioregion undoubtedly shapes its municipalities' future vision and their approach to dealing with climate problems, as well as it can also help local businesses to grow and increase the tourism potential of the region [5]. After analysing businesses in bioregions in Europe, one can conclude that Germany focused on the full production cycle for organic products, while Italy on organic farming and tourism. Overall, the various kinds of bioregions might apply different institutional approaches and different agricultural approaches. In France, a bioregion produces its own energy by means of solar and water power, as well as supplies timber for infrastructure development [6]. In Latvia, the institutionalisation of the first bioregion is still underway; however, observations reveal that consumers are also offered other craft goods, e.g. cosmetics, wooden products and handicrafts. Relatively wide business opportunities could be available in bioregions, thereby fostering the creation of products that are environmentally friendly and also belong to the culture of a particular area. Therefore, the bioregional framework as a place-based approach represents a large-scale system related to nature and humans. A clear understanding of the legal framework for environmentally friendly activities is necessary to foster scientific progress, planning as well as legally regulated activities that affect communities and living natural systems. Defining one of the basic principles of the sociology of law, A.Comte has emphasised that laws should be derived from social life experience and not from concepts formulated a priori by legislators [7].

For several decades globally, and also at the European level, strategic accents have been directed towards an ecological perspective, thereby emphasising the interconnectedness and interdependence between human communities and their natural environment. The Lisbon Treaty reflects the European Commission's decision to make environmental protection an integral part of economic and social policies at the macroeconomic level and the industry level. The most important goals of the EU environmental policy are as follows: to preserve, protect and increase the quality of the environment, protect human health, prudently and rationally use natural resources and foster the implementation of environmental measures to solve regional and global problems. The UN Sustainable Development Goals and the European Green Deal represent a strategic position with solutions to make our farming more sustainable in the long term. These are global trends and strategies, yet the real implementation of the ideas requires legal regulation, which is the competence of each country. An analysis of the relevant legal framework of Latvia revealed that it could be divided into two large categories. The first is the laws and regulations directly related to environmental protection, which must be complied with in the fields of **natural environment preservation and territorial zoning**. The Environmental Protection Law (2006) prescribes state control in the field of environmental protection, e.g.: research into, extraction and use of and accounting for natural resources; polluting activities, activities involving chemical substances and mixtures, management of specially protected natural areas of national significance, specially protected species and habitats, management and protection of micro-reserves and compliance with the laws and regulations governing environmental impact

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assessments of activities intended therein. The Law on the Conservation of Species and Biotopes (2000) governs the protection, management and monitoring of species and habitats [8].

The Water Management Law (2002) focuses on establishing a system for the protection and management of surface water and groundwater, which facilitates sustainable and rational use of water resources, ensuring long-term protection thereof and sufficient supply to inhabitants with good quality surface water and groundwater, protects terrestrial ecosystems directly dependent on water as well as ensures progressive reduction of pollution of groundwater and the replenishment of groundwater resources. The Protection Zone Law (1997) prescribes a procedure for maintaining and controlling the condition of protection zones and restrictions on economic activity in the protection zones [8]. From the bioregional perspective, the Land Survey Law (2006) should also be mentioned, as it focuses on the competence of the Parliament and the Cabinet to regulate land use. The Parliament decides to establish national reserves, biosphere reserves, national parks, regional nature protection areas and cultural and historical objects. The Cabinet, in turn, makes decisions on the establishment of protected landscape areas, nature reserves, natural monuments, spas, recreation areas, cultural and historical as well as other specially protected objects. The law stipulates that local governments, within their scope of competence, take measures in their territory regarding land use, amelioration and protection [8].

The second category of legal regulation is applicable to specific activities in potential bioregions. In establishing bioregions, not only the legal acts and documents that refer to regional and territorial development but also to **organic farming and organic food production** are essential. Implementing the EU Green Deal in Latvia, organic farming also tends to expand from year to year, while consuming increasingly more material and human resources, which means that the farmers also need to supplement their knowledge of the basic requirements outlined in the relevant EU and national legal acts. In Latvia, farming, including organic, is governed by the Law on Agriculture and Rural Development (2004), which was passed based on three regulations of the European Parliament and of the Council; based on the law, the Cabinet prescribes: 1) a procedure for monitoring and controlling organic farming, 2) a procedure for trade in animals and the products derived therefrom, which are not governed by the directly applicable EU acts on organic farming, 3) requirements for the integrated growing, storage and labelling of agricultural products, as well as the control procedure [8]. It is supplemented by the Cabinet Regulation regarding the State Fee in the Field of Organic Farming, which stipulates a procedure for paying the state fee in the field of organic farming, as well as the amount of the state fee and available relief on the fee. The Cabinet regulation also prescribes a procedure for trade in animals and products derived therefrom, which are not governed by the directly applicable legal acts of the European Union on organic farming. It applies to deer, rabbits, wild boars, mouflons, ostriches, pheasants, meat pigeons, quails, snails and earthworms [8].

The second most common kind of economic activity in bioregions is tourism. Quality **ecotourism** should be specific to bioregions. In the future, tourism demand is likely to be driven by an increasing awareness of environmental problems, digital services, wellbeing and better interaction with local communities and culture. This also applies to the question of how to address the impact of tourism on climate change. The European Green Deal does not emphasise the tourism industry. Nevertheless, it is also possible to

receive tourists, relax and travel in a way that does not harm the surrounding environment. The basic law that governs the tourism industry in Latvia is the Tourism Law (1998), which aims to create a legal framework for tourism development in Latvia. The law also defines the main objectives of the tourism industry. Some of them are based directly on the principles of sustainable tourism. The law defines ecotourism as sustainable, environmentally friendly tourism, which aims to contribute to the tourists' knowledge of natural and cultural values and environmental protection as well as to environmental education and awareness in society [8]. Ecotourism and rural or nature tourism cannot be equated, although they represent the kinds of sustainable tourism. Nature tourism involves activities in nature and there are no strict criteria for environmental protection, while ecotourism is based on a responsible attitude towards the environment in which we live, as well as the involvement of local communities from which services and home products are bought. Ecotourism is managed in such a way that all the revenue generated stays as much as possible where it is provided. Ecotourism also involves comprehensive public education about the impact on nature. Therefore, when developing ecotourism, it is necessary to invest in nature protection, benefit the local population, protect endangered species and reduce waste and other negative environmental impacts. Starting up a business in the field of ecotourism requires complying with the laws related to nature protection (Environmental Protection Law (2006), Law on Specially Protected Nature Territories (1993), Cabinet Regulation No. 264 General Regulations on Protection and Use of Specially Protected Nature Territories (2010), Cabinet Regulation No.69 Regulations regarding Protected Landscape Areas (2014), Law on Protection of Cultural Monuments (1992)). In addition, the Law on Forests (2000) concerning economic activities essential for ecotourism prescribes a procedure for picking forest berries, mushrooms and nuts. It is not specified whether this also applies to the sale of the mentioned natural resources at guesthouses (B&B) or on organic farms. Ecotourism often deals with the protection and use of land, natural resources and livestock, as well as accommodation and equipment. The Civil Law stipulates that the owner of the land has the right to prohibit visitors from staying on the property, even if no damage is caused.

Over the last 30 years, **eco-, bio- or organic cosmetics** have emerged as an alternative to the chemical cosmetics industry in which huge funds have been invested. As the awareness of nature protection increases, producers and consumers as well as the general public, attach more importance to the environmental impacts of any product., Many eco-label programmes have been launched not only in Europe but also in various other countries. The organisation Ekomark © Standard sets the requirements that must be met to create and introduce the European Union ecolabel system or ecological labelling system. The organisation applies the criteria of the European Union ecolabel system [9]. Two legal acts are essential concerning compliance with the safety requirements for cosmetic products: Regulation (EC) No. 1223/2009 of the European Parliament and of the Council on cosmetic products, which envisages that every cosmetic product available on the market must meet the requirements to protect human health, and Cabinet Regulation No. 354 Procedure for Meeting the Essential Requirements for Cosmetic Products (2013), which is binding on national cosmetics manufacturers and distributors. The term home producer is not referred to in any legal act in relation to cosmetic products. Only the cosmetic products whose composition and production process comply with the requirements laid down in the laws and regulations

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and which have undergone a safety assessment, which the producer can present to the Health Inspectorate – a supervisory authority –, are allowed to be marketed.

There is an increase in the use of **ecological building materials**; however, the use is hampered by insufficient information about their advantages. Ecological building materials represent those that are: recyclable, do not have harmful environmental impacts, are produced from renewable sources, improve indoor climate, reduce harmful environmental impacts made during the extraction, processing, recycling and disposal thereof, as well as do not have negative impacts on human health. Restrictions on the choice of materials are set by the uses for the materials themselves: fire safety, sound insulation, vapour insulation etc. and the sequence of material installation. There are no specific regulations and laws regarding ecological building materials in Latvia. The requirements are general and apply to both artificial and ecological building materials because both of them they could be used in construction incorrectly. All the requirements are set by the Latvian construction standards [8]. Nowadays because of greenwashing, producers and sellers, wanting to increase their sales, do not hesitate to assign their products or services various labels and properties: environmentally friendly, ecological, sustainable etc. Consequently, this often leads to a misunderstanding of whether an environmentally friendly product is the same as an ecological product, and whether such labels are generally true for building renovation, greener production processes etc.

Energy is another area that can benefit from the concept of bioregions, thereby creating prerequisites for the use of local and renewable energy sources, the development of a safe and high-quality energy supply system and reducing the environmental impact. These objectives are consistent with those of the Energy Law [8]. In Latvia, most of the thermal energy supply systems run on local bioresources, fuelwood makes up 78.6% of total renewable energy consumption in Latvia. At the same time, the coordination of the goals of various lobby organisations is so complex that the draft Renewable Energy Law has been in the development process for 14 years [10]. For certain kinds of renewable energy infrastructure, e.g. roads for wind energy production, a simplified construction supervision process is provided based on the need for energy security and independence [11]. Of course, this will also boost other kinds of economic activity such as tourism and hospitality, which also use the newly created road infrastructure. This is just one of the benefits that a decentralised energy system could bring along with a decrease in maintenance costs of electrical energy transmission and distribution, the an increase in the power system's resilience against infrastructure damage (important in the context of the Ukraine-Russia war), and can also serve as a basis for public involvement in establishing energy self-sufficient bioregions as those in Germany [12] or Finland [13]. Currently, a relevant legal framework is still being developed, but it is clear that it is part of the political agenda.

An analysis of the relevant laws and Cabinet regulations revealed that although the laws were transparent and each law had a connection with the respective Cabinet regulation passed based on it, businesses would need clearly systematised laws specifically on environmentally friendly economic activities. Besides, from a pragmatic perspective, valuable is only what is of practical importance and what is needed by an individual or a group. Thinking is the way an individual adapts to the environment to function successfully. Bioregions are a new concept in Latvia, it currently has no relevant legal framework, yet a legal framework at any level for environmentally friendly activities is

essential for sustainable use and conservation of natural resources. After analysing the laws and regulations governing environmentally friendly activities in bioregions, the authors created a system for the legal regulation (Fig. 1). The systems approach applied allowed us to structure the legal acts by type and by purpose, which also facilitated an understanding of the main problems for environmentally friendly activities. The structure consists of a central or core system, which represents the legal framework for environmental protection and bioregions. Bioregions are often established to protect and boost economic activity in specially protected nature territories, thus preserving biodiversity and at the same time fostering economic activity there.

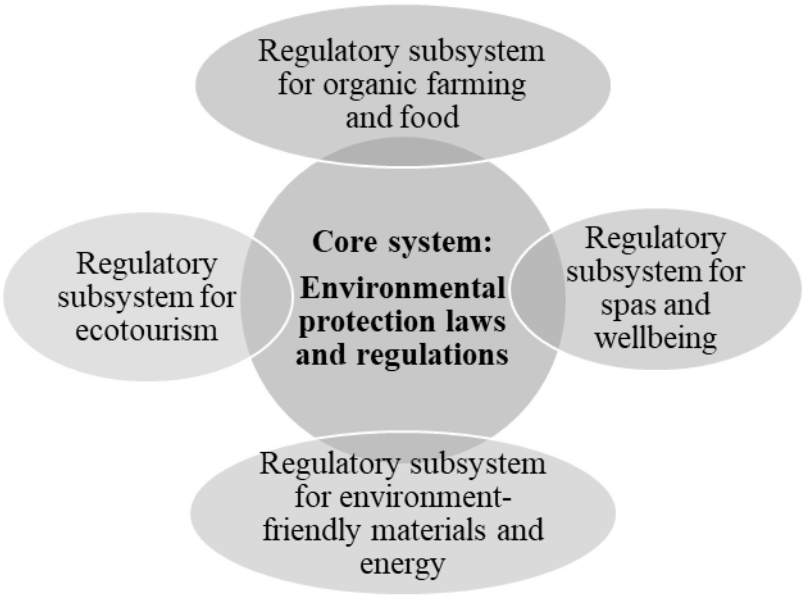


Fig.1. System of legal regulation of environmentally friendly business in potential bioregions in Latvia

The regulatory subsystems represent the main kinds of economic activity in bioregions. The regulatory subsystem for organic farming and food is quite clear, while that for ecotourism is ambiguous because the range of economic activities related to ecotourism is very wide. The regulatory subsystem for spas and wellbeing and that for the production of environmentally friendly materials and goods involve weaknesses; however, the shortcomings identified are offset by the external environment, e.g. certification systems both for the production of eco-cosmetics and for the development of environmentally friendly accommodation. An analysis of some documents revealed the activities of various business organisations in summarising the relevant legal framework and advising businesses on the legal framework for environmentally friendly business. An important element of the external environment is also the regulations adopted by the EU, which mainly affect lawmaking in the Member States. Besides, the European Green Deal is not just a nice legal document but a legally binding commitment of the EU to take actions in various areas to achieve climate neutrality. The EU seeks solutions and adopts regulations related to energy efficiency, vehicles and the transition to more environmentally friendly means of transport.

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CONCLUSION

Bioregional planning and legally regulated activities can help society to deal with environmental problems and identify solutions that would help the communities to see constraints on resources in populated areas so that they do not overestimate the capacity of their populated areas and live sustainably in the future.

Bioregions as environmentally friendly populated areas are necessary, yet for part of the population they can also create restrictive feelings; therefore, economic opportunities should be emphasised more clearly and the relevant legal framework should be made clearer, e.g. the legal framework for organic farmers must govern sustainable farming based on the natural cycle and no harm to the ecosystem.

Structuring the current relevant legal framework is one of the solutions to business diversification in bioregions so that natural and legal persons can navigate laws and other legal documents as well as the possibility of reducing greenwashing.

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MECHANISMS OF PUBLIC MARKETING IN THE SYSTEM OF POST-WAR SOCIO-ECONOMIC RECOVERY OF TERRITORIAL COMMUNITIES

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ABSTRACT

After war conflicts or crisis situations, the recovery of territorial communities becomes the most important task for ensuring stability and development. However, effective recovery requires not only material but also informational and communication efforts aimed at forming a positive image and attracting investment. Ukraine has suffered significant damage as a result of the full-scale military aggression, so there is a great need for the implementation of public administration mechanisms to attract investment for the reconstruction of territories. **Problem statement:** the problem is that the lack of a systematic approach to using public marketing mechanisms in the system of post-war socio-economic recovery of territorial communities will hinder the achievement of effective results. **Research aim**: the aim of this research is to analyze and systematize public marketing mechanisms in the context of the recovery of territorial communities after the war, in order to determine their role and importance in shaping a positive image and attracting the necessary resources. **Research object and subject**: the object of the research is the system of post-war socio-economic recovery of territorial communities, and the subject is the public marketing mechanisms used to achieve this goal. **Research methods**: the research is based on the analysis of domestic and foreign research in the field of public marketing, as well as on the author's own experience of participation in scientific conferences and publications on this topic. Analytical methods, study of practical cases of application of marketing strategies in the context of the recovery of territorial communities, statistical methods and correlation analysis were used. **Research results**: an analysis of the world experience of post-war reconstruction was carried out and the differences between the situation in Ukraine and similar processes in Europe were determined. The advantages and disadvantages of economic system management models were investigated and a grouping of KPI factors was carried out. **Conclusions and recommendations**: public marketing mechanisms are an important tool in the system of post-war recovery of territorial communities. It is

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recommended to implement individual marketing strategies, taking into account the specifics of each community, in order to ensure stable and effective development.

Keywords: environmental economics; territorial communities; sustainable development; public marketing, post-war recovery, investment attraction, Ukraine

INTRODUCTION

In the modern world, military conflicts and crisis situations often lead to the destruction of infrastructure in territorial communities and disruption of the socio-economic development of regions. Recovery after war events becomes an extremely important task, but it is usually complicated by the lack of necessary resources and an effective recovery strategy.

As of March 4, 2024, as a result of the full-scale military aggression of the Russian Federation against Ukraine, the direct damage caused to Ukraine's infrastructure during the war amounted to 63 billion US dollars, or 1.8 trillion hryvnias. This is based on an analysis conducted by the analytical department of the Kyiv School of Economics and volunteers from partner organizations, such as the Center for Economic Strategy and Prozorro.Sales, within the framework of the "Russia Will Pay" project. According to the Ministry of Economy and the KSE Institute, the total losses incurred by the Ukrainian economy as a result of the war, taking into account both direct and indirect losses (such as GDP decline, investment and labor outflow, additional defense and social support expenditures), calculated within the framework of this project, are as follows. Since the start of the Russian military invasion on February 24, at least 4,431 houses, 92 factories and enterprises, 378 educational institutions, 138 medical institutions, eight civilian airports and 10 military airfields, seven thermal and hydroelectric power plants, etc. have been damaged, destroyed or captured in Ukraine.

One of the key aspects of the recovery of territorial communities is the formation of a positive image and attracting investment through public marketing mechanisms. However, there are some challenges and problems that arise in the use of public marketing in the system of post-war recovery. First of all, the recovery of territorial communities after the war is usually a complex and lengthy process that requires a combination of effective investment attraction strategies and marketing initiatives. Additionally, modern trends in public marketing, such as the growing importance of digital technologies and social media, require new approaches and tools in this field. The research hypothesis is that the effective use of public marketing mechanisms in the system of post-war socio-economic recovery of territorial communities will contribute to a positive image and the attraction of necessary resources for sustainable development. Given the current trends and tendencies in this field, it can be assumed that digital media and Internet platforms can become effective tools for communication and marketing in recovering communities. Statistical data shows that in many countries that have gone through military conflicts, low levels of investment and economic development continue for several years after the conflict ends. For example, according to the World Bank, in conflict-affected regions, poverty rates are increasing twice as fast as in regions that have not been involved in conflict. This emphasizes the importance of using public marketing mechanisms effectively to accelerate recovery processes and stimulate economic growth in such regions.

MATERIALS AND METHODS

The article proposes a methodology and results of the analysis of literary sources aimed at developing a model for managing the economic system of nature management to ensure sustainable development, including in the period after the war, taking into account the peculiarities of recovery. The work analyzes the world experience of post-war reconstruction, identifies the differences between the Ukrainian situation and similar processes in the European post-war period. Based on this analysis, the key performance indicators (KPIs) of the economic system are determined and its strengths and weaknesses are revealed. The information and analytical basis of the model is formed on the basis of the results of research on public marketing processes. Through the analysis and generalization of these data, a methodology for calculating the weighting coefficients of KPI elements of the economic system using economic and mathematical modeling is developed. A formula is presented for calculating integral coefficients, which is the basis for assessing the efficiency of the functioning of the post-war economic system of sustainable development of territorial communities. To confirm the reliability and relevance of the model and evaluation methodology, the authors calculated the integral coefficients of the efficiency of the economic system functioning in territorial communities. Based on the research results, a map of geographic zoning of the territories of Ukraine that were most affected by the hostilities was formed and a mechanism for providing investments to these territorial communities was developed.

RESULTS

In July 2022, Ukraine together with Switzerland held the International Conference on the Reconstruction of Ukraine (URC 2022) in Luhansk. At this conference, strategies and prospects for the recovery and development of Ukraine were discussed, plans and principles of reconstruction were agreed upon, and attention was focused on the social, economic, ecological and infrastructural aspects of reconstruction and the necessary reforms. URC2022 became the international start of the process of rebuilding Ukraine. The National Recovery Plan presented at the Lugano conference is a detailed and comprehensive document containing key strategic directions and practical measures, including legislative initiatives [1]. The plan was developed over 10 years and includes 15 national programs totaling more than $750 billion. In October 2022, at an international conference in Berlin, Ukraine announced that it had decided to start a new national recovery program, which includes 38 billion US dollars to cover the budget deficit and 17 billion US dollars for the urgent restoration of social, energy and transport infrastructure. He presented a less ambitious reconstruction plan that included [2-3]. After the Second World War, many countries of the world experienced a period of post-war reconstruction. Depending on the scale of destruction, economic opportunities and political conditions, different countries used different methods of reconstruction. One of the most famous reconstruction plans is the Marshall Plan, introduced by the USA in 1948 [4]. This plan called for financial aid to European countries to support economic reconstruction and democratic rule. In many countries, special government agencies were created to take responsibility for national reconstruction. For example, the Federal Development Agency was established in Germany, and the Reconstruction and Development Commission was established in Japan [5]. The reconstruction process included restoration of industrial potential,

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construction of new housing. Based on the analysis of the blocks of the Marshall Plan and the analysis of literary sources, reports of international financial institutions and scientific journals, this work proposes to form a complex of information and analytical foundations for the model of the post-war recovery of the economy of Ukraine. The information and analytical background is presented in Table 1.

Table 1

Information and analytical provision of KPI factors of the economic system in the context of post-war reconstruction tasks

Index	Characteristic	Formula for Calculating	Parameters	Characteristic
Solvency	Evaluates the ratio of liabilities to assets liquidity. Typically ranges from 0.4 to 0.45, highlighting a balanced liquidity position for financial stability.	$\frac{Fn + Ff + CF}{CL}$	0,4 – 0,45	Fn - funds and equivalents in national currency Ff - funds and equivalents in foreign currency CF - current financial investments CL - Current liabilities
Liquidity Ratio	Assesses the ability to meet short-term or long-term liabilities. Ideally falls between 0.3 to 0.35, indicating adequate liquidity for debt repayment.	$\frac{\text{Cash}}{\text{Short}-\text{term}-\text{debt}}$	0,3 - 0,35	Ability to pay short-term or long-term debt
Fixed Assets Ratio	Measures liquidity, particularly focusing on fixed assets. A ratio greater than 1 signifies a favorable liquidity position.	$\frac{\text{current assets}}{\text{short}-\text{term debts}}$	> 1	A form of flow measurement
Ratio of Liabilities to Total Assets	Indicates the proportion of total liabilities concerning asset value. Value is expected to be around 1, showing a balance between liabilities and assets.	$\frac{\text{Debts}}{\text{total assets}}$	< 1	Ratio of total debt to asset value

** Source: developed by the authors.*

To establish the weighting coefficients, a correlation analysis was carried out for the de-occupied territorial communities Borivska settlement territorial community of Kharkiv region, Izyum city territorial community of Kharkiv region, Dvorichan settlement territorial community of Kharkiv region, Kupyansk city territorial community of Kharkiv region and Shevchenkiv settlement territorial community of Kharkiv region, the results of which are shown in Table 2.

Table 2

KPI-factors Correlation Dependence

KPI-factors	Borivska settlement territorial community	Izyum city territorial community	Dvorichan settlement territorial community	Kupyansk city territorial community	Shevchenkiv settlement territorial community	Correlation
Solvency	0,46	0,62	0,38	0,48	0,64	0,64
Liquidity Ratio	0,42	0,32	0,4	0,42	0,34	0,82
Fixed Assets Ratio	0,33	0,35	0,39	0,4	0,39	0,27
Ratio of Liabilities to Total Assets	2,3	2,6	2,4	2,9	2,2	0,78
Profitability	0,45	0,4	0,39	0,47	0,32	

** Source: developed by the authors.*

By selecting and creating KPI elements of the economic system and determining their weighting factors, this paper proposes a formula for calculating the integral coefficient of economic system performance.

$$K = \sum_i (0{,}6 * Sol \quad + 0{,}8 * Liq + 0{,}3 * FixA + 0{,}8 * RI)$$

This article considers the calculation of integral coefficients for evaluating the efficiency of the economic system. For this purpose, the proposed coefficients for the regions of Ukraine were analyzed and calculated.

DISCUSSION

As a result of the calculations, it was developed recommendations on the implementation of public marketing mechanisms for the development of the socio-economic and investment system within the framework of the post-war reconstruction of territorial communities – Table 3

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Table 3

Public marketing mechanisms for the development of the socio-economic and investment system within the framework of the post-war reconstruction of territorial communities

Parameters	Rating	Implementation of public marketing mechanisms
0-1,2	minimal	Development and implementation of effective communication programs that emphasize the need and benefits of socio-economic development in communities, which programs may include advertising campaigns, webinars, public events and other media tools to attract attention to the needs of reconstruction. Development of investment proposals and attracting investors to socio-economic projects in communities. Provision of financial and technical support for the restoration and development of infrastructure, as well as the provision of quality social services in communities. Support and stimulation of public initiatives aimed at socio-economic development and reconstruction of territorial communities.
1,3-1,6	medium	Implementation of large-scale information campaigns and educational projects aimed at increasing public awareness of the need and benefits of infrastructure restoration and development. Development of information materials and promotion of infrastructure restoration projects. Creation of special investment programs and incentives to attract investors to the community. Involvement of the private sector in projects for the restoration of infrastructure and the development of entrepreneurship. Formation and implementation of projects for the restoration and construction of transport, educational, medical and other necessary infrastructure.
1,6 - more	maximal	Implementation of large-scale information campaigns that emphasize the need and opportunities for reconstruction and development, which includes the promotion of infrastructure restoration initiatives and the stimulation of entrepreneurial activity in the territorial community. Development and promotion of investment programs and incentives to support enterprises operating in the community. Provision of social support programs for victims, in particular for people affected by the loss of housing and family support. Implementation of measures to ensure the security of investments and development by maintaining law and order and fighting crime in the region.

CONCLUSION

As a result of the conducted research, the following conclusions can be made:

Public marketing mechanisms are becoming a key tool for promoting the post-war socio-economic recovery of territorial communities. They help raise public awareness of the need and benefits of post-aggression development and mobilize diverse resources for recovery.

Public marketing aims to create a positive public perception of recovery initiatives that encourages support and participation in programs and projects aimed at improving living conditions and economic growth.

Effective public marketing mechanisms involve the involvement of a wide range of stakeholders, from non-governmental organizations and businesses to government structures and international partners, which facilitates the establishment of partnerships and joint efforts in recovery.

Public marketing can stimulate innovation and innovative approaches to recovery. By promoting new ideas and developing a positive image, you can attract attention to progressive programs and projects.

It is important to consider that the success of community restoration requires long-term efforts and constant improvement of public marketing mechanisms. The focus on stability and sustainability helps ensure long-term positive changes in post-war reconstruction and sustainable socio-economic development of territorial communities.

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OCCUPATIONAL RISK ASSESSMENT IN 400/220/110/20 kV PORȚILE DE FIER POWER SUBSTATION FROM ROMANIA

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ABSTRACT

Regardless of its type and size, any organization is faced with risks that can affect the achievement of its objectives in terms of activities, strategic initiatives, operations, processes and projects, with different consequences on strategic, operational, financial results and image and reputation. All activities of an organization involve risks, and risk management is the process of substantiating the decision, by taking into account the effects of uncertainty on the materialization of objectives and determining the necessary measures and actions. The process involves the use of logical and systematic methods for continuous communication-consultation, context-setting, identification, analysis, evaluation and treatment of risks associated with any activities, processes, functions, products, services or values, monitoring and risk review. Any work environment must be safe and healthy, and this is not always the case for too many workers. Every day many examples of workers whose health is exposed to the action of risk factors include dust, gaseous noxies, vibrations and extreme temperatures. The primary aim of this study is to assess and quantify the occupational risks at the 400/220/110/20 kV Portile de Fier power substation in Romania, identifying key risk factors and proposing measures to mitigate them. The assessment is carried out using the National Research and Development Institute of Occupational Safety – NRDIOS Bucharest method, in order to establish the risk/safety levels in a quantitative manner, based on a systemic analysis and on the assessment of risks of accidents and professional diseases. The role of Occupational Risks Assessment for power substation at very high voltage is to generate the national economy electricity, well-being, and safety work and health environment, workers and workplaces secured, and security of industrial and power process, in order to optimally operate the national economy and ensure energy security. This involves multidisciplinary and transdisciplinary knowledge from the authors: power substation, safety work, energy security and risk management (assessment).

Keywords: Occupational risks, assessment, safety, power substation

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THE ROLE AND IMPORTANCE OF OCCUPATIONAL HEALTH AND SAFETY IN THE CONTEXT OF ENSURING ENERGY SECURITY

The method developed by "National Research and Development Institute of Occupational Safety – NRDIOS Bucharest", aims to determine the quantitative level of risk/safety for a workplace, sector, section or company, based on a systemic analysis and assessment of risks of injury and occupational disease, in terms of OHS. The application of the method is finalised with a summary document – *Assessment Sheet of Workplace*, which includes the *global risk level of the workplace.* The developed assessment sheet of the workplace is the basis of the program for the prevention of accidents and occupational diseases for the workplace, sector, section or company analysis. The essence of the method is to identify all risk factors in the system analysis (workplace) on the basis of pre-established control lists and to quantify the risk dimension on the basis of the combination of the severity and frequency of the maximum foreseeable consequence. [1]

The global risk level (Nr) per workplace shall be calculated as a weighted average of the risk levels established for the identified risk factors. In order for the result obtained to reflect as accurately as possible the reality, the risk factor ranking, which is equal to the level of risk, shall be used as a weighting element. In this way, the highest risk factor will also be the highest ranking. Thus, it is eliminated the possibility for the cross-compensation effect, involved by any statistical average, to mask the presence of the highest-risk factor.

The formula for calculating the *global risk level* is the following:

$$N_r = \frac{\sum_{i=1}^{n} r_i \cdot R_i}{\sum_{i=1}^{n} r_i} \quad (1)$$

where:
N_r - the level of global risk in the workplace;
r_i - risk factor ranking „i";
R_i - level of risk for the risk factor „i";
n - number of risk factors identified at the workplace.

The level of security (Ng) at workplace is identified on the risk/security level mapping scale, built on the opposite proportionality of risk and security levels. Both the global risk level and the safety level are recorded in the workplace sheet. In the case of macro-systems assessment (sector, section, company), the weighted mean of the average safety levels determined for each workplace analysed in the macro-system component (similar workplace are considered as a single workplace) has to be calculated so that to obtain the *global level of safety at work* for the workshop/section/sector or enterprise under investigation – Ng:

$$N_g = \frac{\sum_{p=1}^{n} r_p \cdot N_{rp}}{\sum_{p=1}^{n} r_p} \quad (2)$$

where:
Ng = the overall risk level of the power substation;
rp = workplace rank p, equal to the risk level of the workplace;
n = number of workplaces;
Nrp = is the level of overall workplace risk.

The authors of the NRDIOS method recommended that the maximul acceptable risk level be 3,5. [1]

In short, the term "Occupational Health and Safety" (OSH) covers the well-being, social, mental and physical of workers. Certainly, concern for the well-being of workers should be one of the main components of the social responsibility of any economic organization. Increasing the level of security of any system involves identifying risks and establishing the means of prevention and protection intended to control them. Moreover, the key issue of access to the optimization of human integration in the system of professional requests, to the conservation and efficient use of its creative potential, is today a multidisciplinary field that integrates joint concerns of the technical and humanist disciplines interested, as well, in finding the most appropriate means specific to the functioning of the system. Knowledge of risk requires knowledge of its structure and its manifestation. Consequently, it must be penetrated into its complexity and into all areas of knowledge. This requires an ample and sometimes complex undertaking, but paradoxically, life is a continuous risk and there is no progress that increases our comfort without any risk. This progress is increasingly leading to a rejection of the “imposed” risks arising from human activities carried out in the work process. [2]

Risk management facilitates a *structured and systematic approach* to decision-making. The value and strength of the managerial approach to risk lies in the fact that it combines various *valuation and consultation techniques*, uniting them into an ensemble that gives consistency to the decision-making process. Risk management gives any organization the ability to better understand how operations are carried out and the ability to respond more effectively to changes in internal and external circumstances.

ASSESSING PROFESIONAL RISKS IN TERMS OF OCCUPATIONAL HEALTH AND SAFETY AT A 400/220/110/20 kV PORTILE DE FIER POWER SUBSTATION WITHIN NATIONAL POWER SYSTEM

The 400/220/110/20 kV Portile de Fier power substation is located in near Orsova commune, Mehedinti county, belonging to the Center for the Exploitation of Electricity Transmission Networks – Craiova Electricity Transport Unit, *according to fig. 1.*



Fig. 1. Positioning of the 400/220/110/20 kV Portile de Fier power substation (source:www.entsoe.eu)

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Table 1. Workplaces at the 400/220/110/20 kV power substation

No.	WORKPLACE	LEVEL OF RISK (Nrp)
1	400, 220 kV, 110 kV OPERATING SERVICE	X
2	20 kV OPERATING SERVICE	X
3	400, 220 kV, 110 kV PRIMARY CIRCUIT MAINTENANCE	X
4	20 kV PRIMARY CIRCUIT MAINTENANCE	X
5	SECONDARY CIRCUIT MAINTENANCE	X

The overall risk levels determined for each workplace at the 400/220/110/20 kV power substation are generally as follows *(table 1.):* [3]

400 kV Power Substation:

The 400 kV power substation is of the external type and is equipped with double bussbar systems, to which the following power cells (switchgears) are connected: *400 kV Djerdap OHL (overhead power line); 400 kV Urechesti OHL (overhead power line); 400 kV Slatina OHL (overhead power line); 400 kV – 100 MVAR Coil Compensation; 400/220 kV – 400 MVA AT (autotransformer); 400 kV Transverse Couple; 400 kV Transfer BussBar; 400 kV Measure 1; 400 kV Measure 2.*

220 kV Power Substation

The 220 kV power substation is of the external type and is equipped with two bussbar systems, to which the following power cells (switchgears) are connected: *220/110 kV – 200 MVA AT (autotransformer); 220 kV Resita OHL (overhead power line); 220 kV Turnu Severin Est OHL (overhead power line); 220 kV Cetate OHL (overhead power line); 220 kV Measures 1; 220 kV Measures 2.*

110 kV Power Substation

The 110 kV power substation is of the external type and is equipped with double bussbar systems, with connection by transversal couple, to which the following power cells (switchgears) are connected: *110/20 kV – 200 MVA AT (autotransformer) and Overhead power lines.*

A. Risk level assessment for the activity: 400, 220 kV, 110 kV Operational Service

The object of the activity is the operational service of the power installations: [4]

- *supervision;*
- *control;*
- *maneuver.*

The global risk level at workplace: 400 kV, 220 kV and 110 kV Operational Service

$$N_{\text{400kV-220kV}} = \frac{\sum_{i=1}^{7} R_i \cdot r_i}{\sum_{i=1}^{7} r_i} = \frac{2\cdot(1\cdot1)+5\cdot(2\cdot2)}{2\cdot1+5\cdot2} = \frac{22}{12} = 1,83$$

B. Risk level assessment for activity: 20 kV Operational Service

The object of the activity is the operational service of the power installations: [3]

- *supervision;*
- *control;*
- *maneuver.*

The global risk level at workplace: 20 kV Operational Service

$$N_{20\,\mathrm{kV}} = \frac{\sum_{i=1}^{11} R_i \cdot r_i}{\sum_{i=1}^{11} r_i} = \frac{11 \cdot (3 \cdot 3)}{11 \cdot 3} = \frac{99}{33} = 3,00$$

C. Risk level assessment for activity: 400 kV, 220 kV and 110 kV Primary Circuit Maintenance

The purpose of maintenance and repair of primary equipment is the following types of work: [4]

- *servicing primary equipment;*
- *mechanical activities;*
- *welding and painting activity;*
- *masonry repair;*
- *dismantling of appliances.*

The global risk level at workplace: 400 kV, 220 kV and 110 kV Primary Circuit Maintenance

$$N_{MENT.EP400/220kV} = \frac{\sum_{i=1}^{14} R_I \cdot r_i}{\sum_{i=1}^{14} r_i} =$$

$$= \frac{1 \cdot (1 \cdot 1) + 5 \cdot (2 \cdot 2) + 8 \cdot (3 \cdot 3)}{1 \cdot 1 + 5 \cdot 2 + 8 \cdot 3} = \frac{93}{35} = 2,65$$

D. Risk level assessment for activity: 20 kV Primary Circuit Maintenance

The purpose of maintenance and repair of primary equipment is the following types of work: [5]

- *servicing primary equipment;*
- *mechanical activities;*
- *welding and painting activity;*
- *masonry repair;*
- *dismantling of appliances.*

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The team of revisions-repairs of equipments and secondary circuits and prophylaxis have as object of activity:

- *revision;*
- *maintenance;*
- *repair of secondary protection and circuits;*
- *prophylaxis of power installations.*

The global risk level at workplace: 20 kV Primary Circuit Maintenance

$$N_{20kV} = \frac{\sum_{i=1}^{16} R_I \cdot r_i}{\sum_{i=1}^{16} r_i} =$$

$$\frac{5\cdot(2\cdot2)+11\cdot(3\cdot3)}{5\cdot2+11\cdot3} = \frac{119}{43} = \mathbf{2,76}$$

E. Risk level assessment for activity: 20 kV Secondary Circuit Maintenance

The team of revisions-repairs of equipments and secondary circuits and prophylaxis have as object of activity:

- *revision;*
- *maintenance;*
- *repair of secondary protection and circuits;*

prophylaxis of power installations.

The global risk level at workplace: 20 kV Secondary Circuit Maintenance

$$N_{EP} = \frac{\sum_{i=1}^{17} R_I \cdot r_i}{\sum_{i=1}^{17} r_i} = \frac{13\cdot(3\cdot3)+3\cdot(2\cdot2)}{13\cdot3+3\cdot2} = \frac{129}{45} = \mathbf{2,87}$$

F. Global risk level assessment of the 400/220/110/20 kV power substation

The risk levels, determined for each workplace in the 400/220/110/20 kV power substation are generally the followings: [3], [5]

Table 7. Workplace from 400/220/110/20 kV power substation

No.	WORKPLACE	LEVEL RISK (N_{rp})
1	400 kV, 220 kV and 110 kV OPERATIONAL SERVICE	1,83
2	20 kV OPERATIONAL SERVICE	3
3	400 kV, 220 kV and 110 kV PRIMARY CIRCUIT MAINTENANCE	2,65
4	20 kV PRIMARY CIRCUIT MAINTENANCE	2,76
5	20 kV SECONDARY CIRCUIT MAINTENANCE	2,87

The global risk level of the 400/220/110/20 kV power substation is:

$$N_{rg} = \frac{\sum_{p=1}^{n} r_p \cdot N_{rp}}{\sum_{p=1}^{n} r_p} =$$

$$\frac{(1{,}83 \cdot 1{,}83)+(3 \cdot 3)+(2{,}65 \cdot 2{,}65)+(2{,}76 \cdot 2{,}76)+(2{,}87 \cdot 2{,}87)}{1{,}83+3+2{,}65+2{,}76+2{,}87} = \frac{35{,}20}{13{,}11} = 2{,}68$$

$$\mathbf{N_{rg\text{-}power\ substation} = 2{,}68}$$

CONCLUSIONS

The most effective way to ensure safety and protect the health of workers at work is to eliminate sources of danger. It is an action whose effects are maximal if carried out in the design and construction of work systems, but which is also beneficial afterwards. On one condition: a methodology is in place to allow analysis, identification and determination of the treatment of these sources. The development of theory and applications in the field of systems security has provided a scientific basis and useful tools for the work of preventing professional risks. All methods designed to achieve system security have been taken over and adapted to determine with their help the possibilities of protecting the safety and health of workers.

After the OHS risk analysis, the following conclusions are generated:

- global risk level of the 400/220/110/20 kV Portile de Fier power substation was calculated **2,68 – low – very low risk;**
- the operative staff of the 400/220/110/20 kV Portile de Fier power substation complies with the occupational safety and health norms;
- the maintenance staff of the 400/220/110/20 kV Portile de Fier power substation complies with the occupational safety and health norms;
- the danger of injury and professional illness is very low;

The entire 400/220/110/20 kV Portile de Fier power substation works correctly and does not show OSH non-conformities and does not pose a danger to the National Power System.
Regarding *innovation and originality*, NRDIOS Bucharest method is Romanian and requires a very good knowledge of the power substation and the safety and security standards at work. This involves multidisciplinary and transdisciplinary knowledge from the authors.

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OPPORTUNITIES FOR INTRODUCING INNOVATIVE PRECISION FARMING METHODS IN ORGANIC FARMING IN LATVIA

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ABSTRACT

Modern agriculture, or precision agriculture, is a method that enables better, more efficient and smarter farming, ensuring sustainable development. Precision agriculture can combine data obtained from GPS systems with data from aerial photographs to precisely determine soil needs based on this data. Combining this with precise weather forecasts and location determination systems provides a powerful tool for more efficient agriculture. New technologies have already created a niche in agriculture. By combining detailed knowledge of the fields with automated systems, farm management becomes increasingly simple and efficient. The purpose of this paper is to provide information on research that investigated and analysed the possibilities of introducing innovative precision farming methods in organic farming enterprises in Latvia. The article summarizes data from the research phase, where organic farming enterprises in the northwestern coastal regions of the country were analyzed. The research methodology includes theoretical concepts of influencing factors and framework structure. The study includes data from expert interviews and a questionnaire survey and analyses the possibilities of developing organic farming enterprises by adopting precision farming methods. Using a case study method, a selection of organic farming enterprises was identified where the effectiveness of implemented precision farming techniques such as GPS, soil analysis, aggregate sensors and a uniform survey programme were analysed and compared. The data will be used in the next stages of the research to compare the possibilities and effectiveness of implementing precision agriculture methods in organic farming in other regions of the country.

Keywords: sustainable development, precision farming methods, organic farming, innovative entrepreneurship

INTRODUCTION

Modern economic growth is marked by the limited availability of resources in the world. Global challenges such as climate change and growing population are driving the search for new more environmentally friendly production methods. [6] The shape of the worldwide economy has highlighted the need to develop and improve how food, products and materials are produced and consumed, by introducing more sustainable farming methods. Agriculture is considered to be a basic sector of the national and global economy, mainly because it provides the population with food, which is the primary contribution of agriculture. Agricultural enterprises provide jobs in rural areas,

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which play a major role in regional development. Increasing efficiency is one of the objectives of any economic operator. This is particularly important in the agricultural sector, where efficiency is often quite low. Technological processes and the introduction of new innovative farming techniques contribute to increasing production efficiency. [5] Innovation and innovative activity are the basis for the countries' economic and social development. Innovation is also a driving force for entrepreneurship and for an enterprise to be innovative means to be competitive on the domestic or global market by producing products or services with high added value. [1]

The world is constantly changing and to be competitive and profitable in the future, businesses need to adopt modern technologies and use up-to-date machinery and equipment in their production processes. [2] Innovation and digitalisation refer to the continuous development and change of specific processes and procedures based on digital technologies to transform and improve business operations, services or processes. It involves the use of digital tools, technologies and data to streamline operations, improve efficiency and create new opportunities for innovation and growth. [7] Digitalisation plays an important role in our lives. Digital tools have evolved, such as automation that makes human work automated, the introduction of new devices that allow employees to work remotely, tools that improve internal communication, systems that enable paperless working, and artificial intelligence that facilitates digital data collection solutions. [8]

Characterisation and implementation of precision farming methods

The introduction of precision farming methods is considered one of the innovations of modern farming. The first major boom in the adoption of new technologies in agriculture took place in the second half of the last century, which led to a rapid increase in agricultural production. The focus was on technologies that already existed and were successful in other sectors of the economy but had not been widely adopted in the agricultural sector. [4] These new practices were driven by the need for data-driven decision-making and replaced the traditional approach. The global practice of precision agriculture began in the early 1980s when farmers started using GPS technology and crop monitoring to collect and analyse farm data. [3] The early 1990s also saw a large market uptake of easily portable devices that allowed farmers to track field boundaries, record soil sample locations and conduct crop monitoring. [4] However, farmers and researchers faced several challenges related to the huge amount of data to collect and process. As a result, smart technologies such as sensors, drones and mobile devices were introduced and used to collect real-time data to increase farm productivity [2]

There are several companies in Latvia that help to collect precision farming information and implement it in one place, using software and servers they have developed. Precision farming is a 21st century innovation and its emergence is linked to the introduction of GPS systems in agriculture. Precision agriculture is able to combine data from GPS with data from aerial photographs so that different sensors and sprayers can accurately determine soil needs based on this data. [4] Combining all this with accurate weather forecasting and positioning systems provides a powerful tool for more efficient farming. This technology has introduced data collection and processing practices to agriculture, such as accurate topographic maps, monitoring every centimetre of soil, nutrient balance and fertiliser needs. [6] There are various precision farming methods and tools that have been successfully integrated into agricultural enterprises. Some of

the most common precision farming methods and tools can be identified, the implementation of which will later be analysed in selected agricultural enterprises. (see Table 1)

Table 1. Most common precision farming methods (compiled by authors from [4])

Category	Method	Description
Remote Sensing	Satellite Imaging	Uses satellite imagery to monitor crop health, soil conditions, and weather patterns
	UAV/ Drones	Employs drones equipped with cameras and sensors to gather high-resolution images and data from fields.
	Multispectral and Hyperspectral Imaging	Utilizes sensors to capture images in multiple wavelengths to assess plant health and soil properties.
Proximal Sensing	Soil Sensors	Involves sensors placed in soil to measure moisture, nutrient levels, pH, and temperature
	Crop Sensors	Measures plant parameters such as chlorophyll content, growth rate, and stress indicators.
Variable Rate Technology	Variable Rate Application (VRA)	Adjusts the number of inputs (fertilizers, pesticides, water) based on site-specific data to optimize application.
	Variable Rate Seeding	Modifies seeding rates according to soil and field conditions to improve yield and resource efficiency
Data Management	Geographic Information Systems (GIS)	Uses GIS software to map and analyze spatial data for decision-making in farm management
	Farm Management Information Systems (FMIS)	Integrates various data sources and tools to support farm management decisions and operations.
	Decision Support Systems (DSS)	Provides tools and models to help farmers make informed decisions based on data analysis.
Automated Equipment	Autonomous Tractors and Machinery	Uses GPS and sensors to automate field operations such as planting, harvesting, and spraying.
	Precision Irrigation Systems	Automates and optimizes irrigation schedules and amounts based on soil moisture and weather data.
Monitoring and Forecasting	Weather Stations	Uses local weather stations to provide real-time data for weather conditions and forecasts.
	Crop Modeling	Utilizes simulation models to predict crop growth, development, and yield under varying conditions.

Precision farming techniques are becoming increasingly popular around the world. The adoption of precision farming practices is expected to increase as they allow farmers to accurately manage field changes, increase productivity and reduce production costs.

MATERIALS AND METHODS

The study consists of four consecutive phases and is divided by region. The first phase, data selection and inventory, identified the factors influencing the development and adoption of precision farming methods in Latvia through qualitative analysis of publicly available documents or secondary sources. In the second phase of the research, the identified precision farming methods were validated and complemented by selected experts in the field. In the third stage of the research, a case study approach was used to select cereal farming enterprises and to carry out an economic analysis of the largest agricultural enterprises in the region that have adopted precision farming methods. The fourth stage of the study will identify the impact factors and determine the significance of the impact of each factor. This paper presents data from the first and second stages of

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the study on the use of precision farming methods in the north-western region of Latvia. In-depth interviews with industry experts were carried out to explore the possibilities of introducing innovative precision farming methods in agricultural enterprises in Latvia. The aim of the interviews was to find out the experts' opinions on the introduction of precision farming methods in organic grain farming enterprises in the north-western region of the country. The article summarises the data from the phase of the research carried out, which analysed organic grain farming enterprises in the north-western coastal areas of Latvia (Kurzeme). Although Latvia is not large in terms of area, there is a marked difference between the development of rural areas in the southern regions of the country (Zemgale) and the north-western areas on the Baltic coast (Kurzeme). There are different climates and even very different weather conditions throughout the year, but most importantly there are differences in soil fertility and land quality. Since ancient times, the north-western territories have been said to be rich in Latvia's green gold – forests, while the southern and south-eastern territories (Zemgale) have vast, rich fields and plains. This study presents data on the possibilities of introducing precision farming methods in the north-western coastal areas.

RESEARCH RESULTS

The interviews took place with each expert individually in person. The article presents data on the experts' opinion in one of the 5 regions, factors influencing the development and adoption of precision farming methods in the North-West region. All data, once complete and fully processed across all regions, will be compared and their influencing factors identified in the next stages of the study. During the expert interviews in the North-West region of the country, the three experts were asked five basic questions on precision farming methods and their implementation.

The first question aimed to identify the experts' understanding of precision farming methods and when they first encountered these methods in their practice. Summarizing the experts' responses, Expert 1 noted that they first encountered precision farming methods during their university studies. The first expert was able to name at least five precision farming methods used on their farm. Expert 2 indicated that they first read about precision farming methods in studies on how German farmers use GPS, sensors, and soil analyses on their farms. Analysing the responses, the expert explained the historical introduction of precision farming methods. Expert 2 explained that in the early 2000s in Latvia, this was unheard of and seemed a long way off, but a few years later, in 2015, precision farming methods were introduced in the company where the expert worked. The expert was able to identify and name more than five methods. The expert could identify and name more than five methods. Expert 3 noted that, like the others, they first heard about precision farming methods at university. The expert named more than five precision farming methods. Summarising the collected data, it can be concluded that all experts first encountered precision farming methods in an academic setting, indicating that education is an important factor in the dissemination of this technology. Expert 2 particularly emphasized that their knowledge came from foreign studies, and the implementation of these methods in Latvia was delayed until 2015. This illustrates that innovations are often adopted from abroad and implemented in local practice with a time lag.

As the second question, an expanded inquiry was posed to determine which precision farming methods the experts have implemented and used in their practice. The experts'

responses were highly diverse and varied, highlighting different needs and the significance of these methods. Expert 1 indicated that on their farm, they use GPS, soil analyses, a unified management program called "Agrar Office," sensors for sprayers, and fertilizer spreaders. They plan to introduce orthophotos and expand their machinery fleet with Fendt tractors equipped with GPS. Expert 2 described their practice, noting experience working in several organic farming enterprises in the region. In the companies where they work as an agronomist, only soil analyses and GPS are used. However, on their newly established farm, they use GPS, soil analyses, and implement sensors. Expert 3 described and explained their experience, indicating that they use all the mentioned methods in their practice like GPS, soil analyses, and orthophotos. The experts' responses to the second question reveal different levels of use of precision farming methods. GPS and soil analyses are the most frequently used methods applied across various enterprises. Experts 1 and expert 3 also mentioned orthophotos, although these are less common. The use of management programs and sensors is noted only in specific cases, suggesting that these methods are not yet widely adopted. This could be related to higher costs and more complex implementation.

On the question, which precision farming method is the most useful and why, opinions were divided. Expert 3 believes that soil analyses and orthophotos are the most useful methods. He said that everything starts with the soil. If we don't know what the soil needs to be fertile for the intended crop, precise GPS and sensors won't deliver the desired results. They are auxiliary tools, but to grow a good yield, we need to identify what the soil lacks. This is crucial to determine the necessary plant protection products to maximize the situation. Expert 2 considers sensors the most useful because they can read the plant's condition and provide the necessary dose, thereby saving on the number of applied substances. He also acknowledges the importance of soil analyses, as they provide insights into soil composition, but he believes they are not needed more frequently than every three years. Expert 1 indicates that the greatest benefit of their farm comes from GPS, as it helps complete fieldwork quickly and accurately.

The farm covers a large area, requiring multiple tasks to be done simultaneously. If one link in the chain delays, all subsequent tasks and tractors come to a halt. The rapidly changing weather in Kurzeme means that slow work can leave some fields unsown or unharvested, which would result in significant losses. The responses to the third question reveal differing perspectives on the most valuable precision farming methods. Expert 3 emphasizes the foundational importance of soil analyses and orthophotos, suggesting that understanding soil needs is critical for successful farming. Expert 2 highlights the practicality of sensors in providing real-time plant care, while Expert 1 values GPS for its efficiency and precision in large-scale operations. These varied opinions underscore the diverse needs and priorities in precision farming practices.

The question asked what the main benefits are of implementing precision farming methods. All experts agreed that the primary benefits of precision farming methods are reduced production costs and increased yields. All experts agreed that reduced production costs are a primary benefit of precision farming methods. These savings come from lower fuel, machinery, and labour costs, contributing to higher profitability. All experts highlighted increased yields as a significant benefit of precision farming methods. Enhanced precision in field treatments and better resource management contribute to improved crop productivity and quality. Precision farming methods lead to substantial cost savings in various aspects such as fuel, plant protection products, and

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fertilizers. Precision farming methods enhance operational efficiency by making tasks faster, more precise, and convenient. (see Table 2)

Table 2. The benefits of implementing precision farming methods (compiled by authors)

Aspect	Expert 1	Expert 2	Expert 3
Reduced Production Costs	Precision farming has made tasks faster, more convenient, precise, and cost-effective. Highlighted the comfort and precision provided by fully equipped tractors, which allow for accurate field treatment on the first attempt, reducing costs associated with machinery, fuel, labour.	Observed financial returns from precision farming methods. Noted that small savings per hectare accumulate to significant amounts over time, contributing to substantial growth in the enterprise and improvements in harvested yields and product quality.	Noted that initial investments are high but lead to increased efficiency and revenue from produced goods, evident in balance sheet items like revenue.
Increased Yields	Precision farming methods have transformed operational practices, leading to increased yields. Noted substantial benefits in crop production efficiency.	Observed substantial growth in harvested yields and product quality due to precision farming methods. Precision farming allows working both economically and efficiently.	Highlighted increased efficiency and revenue, which indicate improved operational efficiency and higher yields.
Cost Savings	Identified significant cost savings in fuel, plant protection products, and fertilizers. Observed that initial investments pay off progressively each year.	Emphasized that precision farming methods had yielded financial returns. Noted savings per hectare, which accumulate to significant amounts over time, leading to higher profitability.	Noted that precision farming methods result in increased revenue and efficiency, contributing to overall cost savings and better financial performance.
Operational Efficiency	Precision farming has transformed operational practices, making tasks faster and more precise. Highlighted the comfort and efficiency of using fully equipped tractors for accurate field treatment.	Noted that precision farming methods allow for working both economically and efficiently. Observed improvements in operational practices leading to higher efficiency.	Highlighted increased efficiency in operations, as evidenced by improved balance sheet items like revenue.
Long-Term Investment Benefits	Although the initial investment was substantial, observed that it pays off progressively each year.	Emphasized satisfaction with the chosen equipment and noted long-term financial returns. Recommended precision farming methods to agriculture companies aiming for development.	Noted that initial investments in precision methods result in long-term benefits such as increased efficiency and revenue.

The expert interview included a question to get experts' views on the drawbacks of precision farming methods. The transition to new technologies is often met with resistance and requires substantial training efforts, particularly for older employees. In summary, the adoption of precision farming methods involves a complex balance of potential benefits and notable challenges. While the positive effects, such as increased yield and efficiency, are evident from the first year of implementation, the high initial investment and the difficulties associated with transitioning to and maintaining these advanced technologies cannot be overlooked.

The experts identified several significant disadvantages of implementing precision farming methods. The primary issues highlighted were the high initial costs, dependency on specific machinery distributors, complicated repairs, and the challenging transition and training process. The experts' responses underscore that while precision farming methods offer numerous benefits, such as increased efficiency and reduced long-term costs, they also come with significant drawbacks. The high initial costs can be prohibitive, necessitating external financing that can limit financial flexibility. (see Table 3)

Table 3. The drawbacks of precision farming methods (compiled by authors)

Aspect	Expert 1	Expert 2	Expert 3	Summary and Analysis
High Initial Costs	Noted the significant initial investment as a barrier.	Mentioned the considerable initial costs but noted long-term payback.	Highlighted the substantial initial investment, often requiring external financing.	High initial costs are a major drawback, necessitating significant investment and often external financing, which can limit the financial flexibility of farms.
Transition and Training	Described the difficult transition and training process, especially for older employees.	Observed resistance from older employees during the transition.	Emphasized the challenging transition period and the need for extensive training.	Transitioning to precision farming requires significant training and adjustment, particularly for older employees who may resist the change.
Dependency on Distributors	Highlighted the dependency on specific machinery distributors, leading to delays and higher costs.	Noted delays in repairs due to reliance on specific distributors.	-	Dependency on specific distributors can cause delays and increase repair costs, particularly during peak seasons.
Complicated and Costly Repairs	Mentioned the complexity of repairs, requiring specialized knowledge and resulting in higher costs.	Experienced delays and high costs for repairs due to distributor dependency.	-	Precision farming equipment is complex, leading to longer repair times and higher costs due to the need for specialized knowledge and services.
Overall Analysis	Despite high initial costs and a challenging transition, saw long-term benefits.	Found the long-term benefits to outweigh initial challenges, with increased efficiency.	Acknowledged the need for external financing but recognized immediate benefits in efficiency and productivity.	Precision farming methods offer significant benefits such as increased efficiency and reduced long-term costs, but these come with substantial initial investments and challenges during transition and maintenance.

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DISCUSSION

Precision farming is one of the ways to save resources, use them more efficiently and in a more environmentally friendly way. Agricultural enterprises emphasise that the introduction of innovative solutions and precision farming techniques can reduce the use of plant protection products and fertilisers and reduce water consumption. Precision farming techniques allow for increased yields and improve economic and environmental performance.

CONCLUSION

The introduction of digital technologies in agricultural enterprises is one of the most important elements of strategic development in the agricultural sector and rural areas in Latvia. In agriculture, new technological opportunities can modernise the industry, fostering innovation in the agricultural sector and creating new opportunities for the development of rural areas, ensuring their growth and population density. The analysis of the data from the research shows that the biggest disadvantage of the introduction of precision farming methods is that it requires a large initial investment. Nevertheless, experts agree that the methods are worthwhile and can improve farm performance in terms of increased output and improved quality. Opinions were divided on the most useful method, but soil analysis was considered useful by all, and methods such as GPS and technique sensors were also welcomed. It can be concluded that precision farming methods are common in agricultural enterprises in the coastal areas of the north-western region. Increased yields, reduced costs, convenient equipment, comfort and precision were mentioned as the biggest benefits of adopting precision farming methods.

The introduction of new precision farming methods reduces costs by providing accurate measurements of soil conditions, allowing an assessment of where and how much agrochemical inputs are needed for a particular sector. This avoids the over-application of agrochemicals in areas where they are not needed. There are many different factors that determine crop yield. In agriculture, these new technological possibilities can modernise the sector, encouraging innovation in the agricultural sector and creating new opportunities for the development of rural areas, ensuring their growth and habitability. The introduction of digital technologies in agriculture ensures precision of measurements, speeds up data collection and processing. The digitalisation of agricultural enterprises is an economic growth driver with multiple economic, social and environmental benefits, ensuring the economic growth of regions.

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PRODUCTIVITY IN BIOECONOMY INDUSTRIES IN LATVIA

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ABSTRACT

Bioeconomy industries play an important role in contributing to national economies and a transition to climate-friendly farming practices. This is evidenced by various policies implemented, including the United Nations Sustainable Development Goals, the European Union (EU) Bioeconomy Strategy and the European Green Deal. The increasing productivity and new technologies can have negative environmental impacts, affecting the economic framework associated with ecosystem services. To address these challenges, coordination among various sectors, stakeholders and value chains is necessary, supporting cross-sectoral strategies; therefore, the government has adopted the Latvian Bioeconomy Strategy 2030. One of the complementary lines of action to achieve the goal of the bioeconomy strategy is "increasing the efficiency and labour productivity in all industries of the bioeconomy". Accordingly, the present research aims to examine labour productivity in the national economy and in bioeconomy industries to contribute to the implementation of the Latvian Bioeconomy Strategy 2030. The research analyse the level of labour productivity achieved in Latvia and compare it with that in other EU Member States, as well as examine labour productivity in individual bioeconomy industries in Latvia in the period 2015-2022. Several indicators were used: labour productivity per person employed and per hour worked both in current prices and constant prices. The research found that in the period analysed, the highest productivity was achieved in section D Electricity, gas, steam and air conditioning supply, which significantly exceeded the national average, whereas it was significantly lower in the following sections: I Accommodation and food service activities, F Construction and A Agriculture, forestry and fishing, although significant productivity growth has been observed in the period 2015-2022. Therefore, it is necessary to continue implementing the measures begun to increase productivity in the areas where it is low.

Keywords: labour productivity, bioeconomy strategy, development.

INTRODUCTION

The bioeconomy includes industries that use renewable biological resources to produce value-added products such as food, feed, energy and bioproducts. Its importance is determined by priority in specific and related policy areas, such as the European Union (EU) Bioeconomy Strategy, the UN Sustainable Development Goals, the European Green Deal and the Next Generation Recovery Plan [1]. In 2019, the EU bioeconomy market size reached almost EUR 324 billion (approximately 14% of the total in the EU) and employed 6.9 million people… [2]. Therefore, the bioeconomy needs to embrace

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new ways of working with nature. Applying knowledge of ecosystems and services can lead to improved productivity and resilience… [3]. However, the increasing labour productivity and new technologies can have negative environmental impacts, affecting the growing economy related to ecosystem services. Coordination among various industries, stakeholders and value chains is therefore needed, supporting cross-sectoral strategies, sustainable production and biomass use as well as market development (new products and services) [4]. Therefore, a separate policy in which the European Commission (EC) defined the basic principles of the European bioeconomy was created along with the development of a bioeconomy strategy in the EU in 2012. The EU Bioeconomy Strategy was revised in 2017 and 2018 [5]. EU Member States also design their own bioeconomy strategies. For example, the Bioeconomy Strategy of Italy envisages actions to increase sustainable labour productivity, social cohesion and political stability… [6]. The Latvian Bioeconomy Strategy 2030 was adopted in December 2017, and one of the complementary lines of action to achieve the goal of the bioeconomy strategy is "increasing the efficiency and labour productivity in all industries of the bioeconomy" [7]. Scientists have found that in Eastern and Central Europe, there is significant potential for increasing labour productivity in some industries, and the development and implementation of bioeconomy strategies could shape a transition to the development of bioeconomy industries [8]. Labour productivity is often used as a measure of competitiveness and is considered by the EC to be the most reliable indicator of long-term competitiveness [9]. Therefore, the present research aims to examine labour productivity in the national economy and in bioeconomy industries to contribute to the implementation of the Latvian Bioeconomy Strategy 2030.

MATERIALS AND METHODS

At the macro level, labour productivity is measured as the quantity of goods and services produced per hour worked (value added per hour worked) or output per employee (real GDP per employee). At the level of individual industries, labour productivity is calculated by dividing the value added of the industry by the number of people employed in it [10]. To analyse labour productivity, the present research used publicly available information: 1) the Eurostat database to examine and compare productivity across EU Member States; 2) information on the Official Statistics Portal of the Republic of Latvia (https://stat.gov.lv) to identify the level of labour productivity achieved in Latvia in various industries and in the entire economy. The research used the Statistical Classification of Economic Activities in the European Community, Revision 2, which specifies the kinds of economic activities. The research considers the following economic activities as bioeconomy industries: 1) primary production of bioresources – A Agriculture, forestry and fishing (A), which includes A01 – Crop and animal production, hunting and related service activities (A01), A02 – Forestry and logging (A02), A03 – Fishing and aquaculture (A03); 2) C – Manufacturing, incl. bioresource processing industries consuming bioresources (dependent manufacturing industries) – C10 Manufacture of food products (C10), C11 Manufacture of beverages (C11), C13 Manufacture of textiles (C13), C14 Manufacture of wearing apparel (C14), C15 Manufacture of leather and related products (C15), C16 Manufacture of wood and of products of wood and cork, except furniture, manufacture of articles of straw and plaiting materials (C16), C17 Manufacture of paper and paper products (C17); 3) bioresource processing industries in which bioresources are an alternative to other raw

materials – C20 Manufacture of chemicals and chemical products (C20), C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations (C21), C31 Manufacture of furniture (C31), D Electricity, gas, steam and air conditioning supply (D); 4) industries using bioresources for the supply of services – F Construction (F) and I Accommodation and food service activities (I).

The research period was 2015-2022, which allows the situation before the adoption of the Latvian Bioeconomy Strategy 2030 and during the implementation thereof to be compared. The research applied the monographic method and statistical data analysis.

EVALUATION OF RESULTS AND DISCUSSION

1. Productivity in the entire economy and in bioeconomy industries in Latvia

Labour productivity growth plays a decisive role in economic growth in Latvia, especially if considering a decrease in the working-age population and the fast rise in labour costs. The experience of the wealthiest EU countries shows that it is an increase in labour productivity that is the main driving force on the way to prosperity. An increase in labour productivity as well as the achievement of the target set by the Latvian Bioeconomy Strategy 2030 is fostered by the creation of a respective regulatory framework and the allocation of ear-marked support, which has contributed to the increase in labour productivity also in bioeconomy companies. Nevertheless, labour productivity in Latvia still significantly lags behind the EU average.

In the period 2015-2022, labour productivity growth has been faster in Latvia than on average in the EU, as the productivity has increased by 46% (on average 29% in the EU-27), and the productivity gap has decreased by 8 percentage points in the period analysed. However, compared with the developed Member States of the EU, there are still significant disparities. In 2022, the level of productivity in Latvia was only 73.5% of the EU average (according to the purchasing power standard), and it was the fourth lowest among the EU Member States behind only Bulgaria, Greece and Slovakia. In 2022, the productivity of resources in Latvia, expressed in terms of GDP per capita, was 26 thousand EUR, which represented only 28% of the level achieved in Luxembourg and 32% of the level achieved in Ireland, lagging behind the productivity in the other Baltic countries as well (Figure 1).

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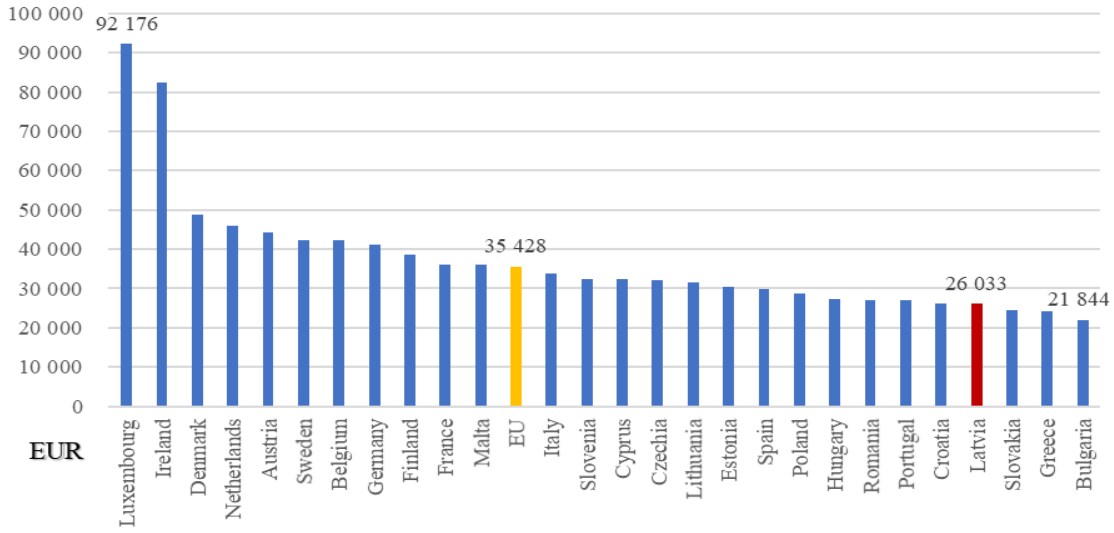


Fig. 1 GDP per capita in EU Member States in 2022, EUR [11].

According to experts, labour productivity and factors therein have been researched insufficiently in Latvia. The low level of labour productivity in the economy of Latvia is determined by the relatively weak participation of producers in global value chains and the specialization of exporters in low-tech products, as well as the slow introduction of modern technologies. An increase in labour productivity is also hampered by insufficient investment in research and development, as well as weak innovative activities and science-industry cooperation [10].

An analysis of gross value added per employee in Latvia (Table 1) reveals that in some bioeconomy industries, this indicator significantly lagged behind the average level nationally. For example, in 2022 the lowest productivity in current prices was reported in section I Accommodation and food service activities at 20.7 thou. EUR or 51% of the average in the economy and section F Construction at 26.6 thou. EUR or 68%, as well as section A Agriculture, forestry and fishing at 31.3 thou. EUR or 80%. In contrast, the highest productivity was reported in section D Electricity, gas, steam and air conditioning supply, reaching 116.6 thou. EUR or almost 3 times higher than the average in the economy of Latvia in 2022. A similar situation was observed in relation to gross investment measured in 2015 constant prices. The only exception was section A Agriculture, forestry and fishing with the second lowest productivity reported in 2022. An analysis of productivity growth in 2022 compared with 2015 in current prices revealed that the highest growth was reported in two sections: D Electricity, gas, steam and air conditioning supply and A Agriculture, forestry and fishing, 2.7 and 2.6 times, respectively, which means that the sections have had the highest price increase because in constant prices, the increase has been 7% and 37%, respectively. However, the only section in which productivity decreased in 2022 compared with 2015, measured in 2015 prices, was F Construction (Table 1).

Table 1. Gross added value per employee in the entire economy and in the main industries related to the bioeconomy in Latvia in 2015-2022, thou. EUR [12]

Section	2015	2016	2017	2018	2019	2020	2021	2022	2022/2015, %
Current prices									
TOTAL	24.3	25.0	26.6	28.2	29.6	30.0	34.1	39.1	161
A	12.3	12.3	14.7	16.1	17.5	18.3	21.5	31.3	255
C	21.7	21.7	23.8	25.6	26.9	28.5	33.8	40.5	187
D	43.0	53.8	52.3	35.8	40.4	48.9	69.1	116.6	271
F	20.0	19.7	21.7	23.2	24.3	24.7	23.6	26.6	133
I	13.5	14.2	15.7	16.9	16.2	13.5	14.0	20.7	153
2015 constant prices									
TOTAL	24.3	24.8	25.7	26.1	26.3	26.0	28.5	28.6	118
A	12.3	12.2	12.9	12.4	14.8	14.6	15.2	16.8	137
C	21.7	22.0	23.5	25.0	25.1	26.0	27.4	27.6	127
D	43.0	50.5	49.2	31.8	29.5	39.1	51.9	45.9	107
F	20.0	19.6	21.4	22.0	21.7	21.4	19.1	17.8	89
I	13.5	14.0	15.2	15.8	14.6	12.0	12.4	15.7	116

An analysis of gross value added per hour worked in Latvia (Table 2) revealed that the situation was similar to that with productivity per employee. In 2022, the lowest productivity in current prices was reported in section I Accommodation and food service activities at 11.21 EUR or 54% of the average in the economy, while the second lowest productivity was reported in section F Construction at 14 EUR or 67% and section A Agriculture, forestry and fishing at 15.63 EUR or 75%. In contrast, the highest productivity in 2022 was reported in section D Electricity, gas, steam and air conditioning supply at 60.78 EUR or 2.9 times higher than the average in the economy of Latvia. A different situation could be observed if measured in terms of gross investment per hour worked in 2015 comparable prices. In 2022, the lowest productivity was reported in section A Agriculture, forestry and fishing at 8.38 EUR, the second lowest level was in section I Accommodation and food service activities at 8.53 EUR, which represented 55% and 56%, respectively, of the average productivity in the entire economy.

An analysis of productivity growth, measured as gross added value per hour worked, in 2022 compared with 2015 in current prices revealed that the highest figure was reported in 2 sections: D Electricity, gas, steam and air conditioning supply and A Agriculture, forestry and fishing, 2.8 and 2.6 times, respectively, which means that these sections experienced the highest price increase because if measured in constant prices, the increase has been 12% and 41%, respectively. In contrast, the only industry in which productivity has decreased in 2022 compared with 2015, measured in 2015 prices, was also section F Construction.

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Table 2. Gross added value per hour worked in the entire economy and in the main industries related to the bioeconomy in Latvia in 2015-2022, EUR [12]

Section	2015	2016	2017	2018	2019	2020	2021	2022	2022/ 2015, %
Current prices									
TOTAL	12.78	13.15	14.10	14.82	15.89	16.62	18.63	20.91	164
A	5.95	6.07	7.12	7.79	8.49	9.05	10.52	15.63	263
C	11.44	11.23	12.23	13.16	14.03	15.53	17.97	21.28	186
D	21.38	28.30	26.08	18.24	20.38	24.90	35.48	60.78	284
F	10.31	10.13	11.11	11.68	12.91	13.38	12.64	14.00	136
I	6.96	7.75	8.49	9.00	9.01	8.47	8.21	11.21	161
2015 constant prices									
TOTAL	12.78	13.05	13.60	13.76	14.10	14.41	15.58	15.32	120
A	5.95	6.03	6.22	5.99	7.16	7.24	7.44	8.38	141
C	11.44	11.39	12.10	12.85	13.08	14.16	14.58	14.51	127
D	21.38	26.60	24.55	16.19	14.87	19.88	26.66	23.91	112
F	10.31	10.12	10.94	11.07	11.52	11.58	10.23	9.37	91
I	6.96	7.67	8.20	8.43	8.09	7.52	7.26	8.53	123

A more detailed analysis of productivity, measured as gross added value per employee (in current prices) (Table 3) revealed that in 2022, the highest productivity was in section D Electricity, gas, steam and air conditioning supply at 69.1 thou. EUR (2 times higher than the average in the economy), division C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations at 61.3 thou. EUR (1.8 times higher), divisions C16-C18 Manufacture of wood and of products of wood and cork, except furniture, manufacture of articles of straw and plaiting materials, Manufacture of paper and paper products at 48.4 thou. EUR (1.4 times higher) and division A03 Fishing and aquaculture at 41.5 thou. EUR (1.2 times higher than the average in the economy). Among bioeconomy industries, according to Smart Specialization Strategy (SSS) monitoring data, only the pharmaceutical industry is defined as a R&D high-intensity industry or a high-tech industry, the production of chemicals and products is considered to be a R&D medium-high-intensity industry, while the other bioeconomy industries are classified as low-tech industries [13].

In contrast, the lowest productivity was reported in section I Accommodation and food service activities, as well as in divisions C13-C15 Manufacture of textiles, manufacture of wearing apparel, manufacture of leather and related products and A01 Crop and animal production, hunting and related service activities. A similar trend has also been found by other scientists who noted that a comparison with the EU average revealed that there was a distinct productivity gap in agriculture, although the productivity varied across industries and countries [4]. In 2022 compared with 2015, the largest increase in productivity (gross added value per employee (in current prices)) has been reported in two industries: A03 Fishing and aquaculture and C16-C18 Manufacture of wood and of products of wood and cork, except furniture, manufacture of articles of straw and plaiting materials, Manufacture of paper and paper products, 2.3 and 2 times, respectively.

Table 3. Gross added value per employee in the entire economy and in the main industries related to the bioeconomy in in Latvia in 2015-2021, thou. EUR [12]

Section	2015	2016	2017	2018	2019	2020	2021	2021/2015, %
Current prices								
TOTAL	24.3	25.0	26.6	28.2	29.6	30.0	34.1	140
A01	8.9	8.3	10.8	10.1	12.3	14.2	16.3	183
A02	20.6	22.1	24.5	30.9	29.2	27.6	33.1	160
A03	17.9	20.4	22.6	22.3	30.9	33.0	41.5	231
C10-C12	21.2	20.2	21.4	23.4	24.2	25.0	24.0	114
C13-C15	10.2	11.1	12.2	13.2	13.0	13.7	14.1	138
C16-C18	24.0	24.1	27.4	31.5	33.0	34.2	48.4	202
C17	24.2	23.5	23.2	23.5	24.8	26.5	27.2	113
C20	21.8	21.0	21.4	28.4	25.7	30.2	37.6	173
C21	33.6	34.8	37.4	33.5	53.5	50.4	61.3	183
C31-C32	15.1	14.9	15.9	17.2	18.6	20.3	24.6	163
D	43.0	53.8	52.3	35.8	40.4	48.9	69.1	161
F	20.0	19.7	21.7	23.2	24.3	24.7	23.6	118
I	13.5	14.2	15.7	16.9	16.2	13.5	14.0	103
2015 constant prices								
TOTAL	24.3	24.8	25.7	26.1	26.3	26.0	28.5	117
A01	8.9	8.3	8.7	7.4	9.2	8.3	8.4	95
A02	20.6	21.7	23.0	24.7	27.7	30.9	31.9	155
A03	17.9	22.0	25.0	22.9	28.9	26.6	37.2	207
C10-C12	21.2	20.5	20.4	22.3	20.8	22.2	23.6	111
C13-C15	10.2	10.7	11.6	12.3	12.0	12.2	13.1	128
C16-C18	24.0	24.3	26.9	30.2	32.0	32.3	28.9	121
C17	24.2	24.0	23.3	22.1	24.5	28.2	21.4	89
C20	21.8	20.6	20.3	27.6	23.2	28.1	32.3	148
C21	33.6	35.8	37.2	32.6	51.3	45.5	52.9	158
C31-C32	15.1	14.8	15.8	16.9	17.6	17.7	21.4	142
D	43.0	50.5	49.2	31.8	29.5	39.1	51.9	121
F	20.0	19.6	21.4	22.0	21.7	21.4	19.1	96
I	13.5	14.0	15.2	15.8	14.6	12.0	12.4	92

An analysis of gross added value per employee (2015 constant prices) (Table 3) revealed that in 2022, the highest productivity was reported in division C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations at 52.9 thou. EUR (1.8 times higher) and section D Electricity, gas, steam and air conditioning supply at 51.9 thou. EUR (1.8 times higher than the average in the economy). The lowest productivity was reported in division A01 Crop and animal production, hunting and related service activities at 8.4 thou. EUR, which made up only 29% of the average in the economy of Latvia, and in section I Accommodation and food service activities at 12.4 thou. EUR, which accounted for only 44% of the average nationally. A significant increase in productivity – slightly more than 2 times – was achieved only in division A03 Fishing and aquaculture. However, labour productivity has decreased in 4 industries (C17 Manufacture of paper and paper products, I Accommodation and food service activities, F Construction and A01). According to the SSS monitoring report, the dominance of low value-added industries in the economy of Latvia and the low R&D expenditure of the private sector, which largely relate to the structure of the national economy and institutional barriers, were identified as the most significant structural barriers to economic transformation [13].

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The Latvian Bioeconomy Strategy 2030 has set various objectives to achieve higher efficiency and labour productivity in bioeconomy industries, including increasing the production of higher value-added products and niche products, promoting the substitution of imports with domestic products, implementing energy efficiency measures, promoting investment attraction for biomass processing and ensuring stable biomass streams for processing purposes. However, the forest industry needs to take measures to increase forest productivity [7]. The goal of achieving a transformation in the economy of Latvia to higher value-added activities is set by the Guidelines for the National Industrial Policy for 2021-2027. The Smart Specialization Strategy of Latvia has set five areas of knowledge, incl. a knowledge-intensive bioeconomy, and the national government has allocated most of the public funding for innovation to research in these areas, the development of innovative technologies and products, as well as business support [14]. Consequently, the national and EU support instruments are aimed at fostering higher value-added activities in priority industries by using funding from the EU Structural and Investment Funds. This is especially important in areas where productivity is lower. Besides, there is clear evidence that agricultural productivity growth responds to research and development efforts. The goal of agricultural research and development should have two subordinate objectives: agricultural productivity and environmentally friendly management [15].

CONCLUSION

Latvia should focus on increasing labour productivity because the productivity is crucial for economic growth and prosperity. By taking proper measures and making effective regulation, the gap between the EU average productivity and that in the economy of Latvia could be reduced. The level of productivity and an increase therein are of fundamental importance in the bioeconomy sector. In 2022 in Latvia, the lowest productivity, regardless of prices (current or constant) or per employee or hour worked, was in sections I Accommodation and food service activities, F Construction and A Agriculture, forestry and fishing. In contrast, the highest level of productivity in 2022 was achieved in section D Electricity, gas, steam and air conditioning supply sector and in some processing industries.

In the period 2015-2022 in Latvia, the highest productivity growth in current prices was reported in sections D Electricity, gas, steam and air conditioning supply and A Agriculture, forestry and fishing, while in constant prices – in section A Agriculture, forestry and fishing. In 2022, significantly higher productivity was reported in division C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations, while the highest productivity in primary production was reported in division A03 Fishing and aquaculture, which had the fastest growth rate in the period 2015-2022. This means that the levels of labour productivity in bioeconomy industries are different, and further efforts should be made to increase the productivity in the industries where it significantly lags behind the average in the national economy.

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ROMANIA - AN INTEGRATED PART OF THE EUROPEAN ENERGY TRANSITION PROCESS

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ABSTRACT

In the period 2010-2022, Romania has seen a continuous increase in the share of renewable energy in gross final energy consumption, promoting and using green energy sources. In 2019, more than 24% of energy consumption came from renewable energy, ranking 10th in the EU, surpassing the European average, and by 2030, Romania aims to reach a share of 49.4% renewable energy in gross final consumption of electricity.

In this perspective, climate change is the most discussed topic, and from the analysis of CO_2 emissions for the same period, a decreasing trend can be observed, signalling a positive impact on the environment. The intensity of greenhouse gas emissions, as measured by the amount of gases emitted per unit of GDP, is decreasing, indicating increased economic efficiency.

It is essential for the sustainable development of Romania to invest in the development of the energy sector, the main issue will be to identify the best ways to align the state with the EU directives and to become climate neutral by 2050, being a goal assumed by the EU and its states when signing the Paris Agreement in 2015. This paper contributes to this field by providing information on Romania's evolving landscape by harnessing multiple sources of renewable energy and at the same time, the financial opportunities granted by the state to key actors.

Keywords: energy transition; renewable energy; Romania; greenhouse gas emissions.

INTRODUCTION

Recently, climate change management has become an important national issue in Romania, as severe weather events have caused substantial economic losses in various industrial sectors. If global warming increases, the country's economic situation is expected to deteriorate considerably due to the effects of climate change (Chitu et al., 2022) [1].

Difficulties in the energy sector are often debated by authorities and institutions at global, regional and national level. As a member of the European Union, Romania adopts the best initiatives in the field of energy and energy security, while complying with the "Green Energy for All Europeans" legislative package and the European Green Pact. These framework documents aim to create an innovative, developing, digital and secure energy system. In order for Romania to make a successful transition to green energy, it is crucial to prioritise efficiency in linking investments, technologies and policies to the climatic and geopolitical characteristics of the country. Investments in enhancing energy

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efficiency, encompassing production, transport, distribution, and end-use, will yield significant environmental benefits, reduce greenhouse gas emissions, improve energy security, alleviate energy poverty, and boost the competitiveness of economic activities across all sectors of the Romanian economy (Tanțău, A., Șanta, A.M.I, 2019) [14].

The review of the scientific approaches of researchers on the transition from energy to renewable energy sources revealed that recently strategies, policies and regulations are being addressed for each country to increase the share of renewable energy in gross final energy consumption.

The literature is approached in this study from two perspectives. On the one hand, the approach of the literature that reflects the pillars of the energy development process in Romania, and on the other hand, the approach of the literature that addresses the provisions, clear directions and defines the benchmarks that Romania should consider for the implementation of the European Green Pact directives and that require the transformation of the energy sector into another system model, based on clean, innovative technologies, which can face competition in an integrated electricity market.

EU-wide policy on renewable energy production and the promotion of the use of renewable energy is laid down in EU Directive 28/2009. The European Commission has published a proposal for a revised directive on renewable energy with the aim of making the EU a world leader in the renewable energy market by 2030.This directive aims to set national renewable energy targets for each Member State, based on the specific renewable energy potential of each country (European Commission, 2023) [3].

During 2016, the EC presented two packages of proposals to reform European energy policies, anticipated in 2015 through the Energy Union Framework Strategy. These packages are defining for the European energy sector, and implicitly for the Romanian one, in the period 2020-2030, being aimed at accelerating the energy transition in the EU. In July 2016, a first package of proposals was published, regarding: the reduction of non-ETS emissions in each Member State for the period 2021-2030 (Romania has been allocated a 2% reduction quota), the accounting of GHG emissions from land use, land-use change and forestry, as well as a communication on a European strategy for decarbonisation of the transport sector (European Parliament, 2015)[4].

At the end of 2019, the EC presented a new proposal to address climate and environmental challenges in the form of a growth strategy, with the objective of transforming the EU into a fair and prosperous society with a modern, competitive and resource-efficient economy with no net greenhouse gas emissions in 2050 and with economic growth decoupled from resource use.

The European Commission announced at the end of 2019, through the Green Deal, that the EU proposes to position itself as a world leader in combating the effects of climate change and to become the first continent with a net zero level of greenhouse gas emissions in 2050[2]. In essentially, it aims for a lasting and sustainable transformation of the economy by phasing out fossil fuels, encouraging clean and renewable energy and developing a circular economy.

Romania has achieved significant progress in its renewable energy strategy through the Integrated National Climate Change Plan 2021-2030, which is in the process of being updated to increase renewable energy to 30.7% by 2030[11]. of various energy resources renewable energy such as biomass, geothermal, wind and solar energy, which will be

increasingly used as technological advances improve. The transition to renewable energy is expected to reduce greenhouse gas emissions, diversify energy sources, reduce dependence on fossil fuels and potentially create new jobs in green technologies, especially in the context of conflict. which is still burning between Ukraine and Russia (ITA, 2021)[6].

MATERIALS AND METHODS

In order to assess Romania's alignment with EU energy targets, we will first analyse the share of renewable energy in gross final energy consumption from 2010 to 2020, based on data from the Romanian National Institute of Statistics and Eurostat. We will measure the share of allocated renewable energy in total gross final energy consumption as defined by the Renewable Energy Directive. Gross final energy consumption includes energy used by final consumers, grid losses and self-consumption by power plants.

According to the Romanian National Institute of Statistics (2023)[12], this indicator analysed by the authors is part of the EU Sustainable Development Goals (SDGs) and the EU 2020 Strategy. The SDGs we will discuss include targets on affordable green energy (SDG 7), ensuring sustainable energy consumption and production (SDG 12) and climate action (SDG 13). SDG 7 focuses on universal access to clean energy, improving energy efficiency and increasing the share of renewable energy. SDG 12 promotes resource efficiency and waste reduction, while SDG 13 focuses on climate agreements. The EU 2020 strategy aims to increase renewable energy in gross final energy consumption to 20% by 2020 and at least 27% by 2030. This aligns with the Energy Union Strategy, which supports decarbonisation in the energy system. The EU Cohesion Policy (2014-2020) has allocated €29 billion for sustainable energy projects, including energy efficiency, renewable energy, smart infrastructure and low-carbon innovation, investments that are being seen in Member States.

We also used the Eurostat database to collect information on the share of renewable energy in gross final energy consumption for the whole decade from 2010 to 2020 to provide a long-term perspective in EU member states. These data were analysed through a comparative analysis between Romania and other EU Member States using comparative graphs and tables.

RESULTS

The data highlights fluctuations and trends in this share over a decade, providing insight into the progress and challenges Romania has faced in adopting and integrating renewable energy sources. These details are essential to understand the national context of the transition to a circular economy and to make relevant comparative analyzes with developments in other EU member states (Khan, A.M, 2021)[7].

The values in the analyzed table refer to the annual shares of renewable energy, highlighting both constant increases and possible decreases, thus indicating the need to introduce effective policies and measures to stimulate the use of green energy. This research is essential to assess and record Romania's progress towards national and European renewable energy targets and to identify areas where further improvements are needed.

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Table 1. Share of renewable energy in gross final energy consumption in Romania 2010-2019

Year	Share of renewable energy in gross final energy consumption in Romania 2010-2020 (Percentage)
2010	22,8 %
2011	21,7 %
2012	22,8 %
2013	23,9 %
2014	24,8 %
2015	24,8 %
2016	25 %
2017	24,5 %
2018	23,9 %
2019	24,3 %
2020	24,5%

Source: National Statistical Institute of Romania, http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table

In the period 2010-2020, with the exception of the years 2011, 2017, 2018, there is a continuous increasing trend of the share of renewable energy in the gross final energy consumption, which demonstrates the promotion of renewable energy sources, encouraging the production of energy from less exploited renewable resources.

In 2020, more than 24% of energy consumption came from renewable energy sources, placing our country in 10th place in the EU and above the EU average.

By 2030, Romania aims to achieve a share of renewable energy in gross final consumption of electricity (RES-E) of 49.4%, up from 41% in 2020 (Mediu, 2020).

Also for the same period of time, 2010-2020, we will analyse the CO2 emissions intensity at the Romanian level, as well as the greenhouse gas emissions by economic activities, in order to intensify Romania's efforts to achieve the transition to a green, low-carbon, climate resilient economy and to integrate climate change adaptation measures in vulnerable economic, social and environmental sectors, in line with EU policies.

Table 2. CO_2 emissions intensity in Romania 2010-2019

Year	CO_2 emissions intensity in Romania 2010-2019 (thousand tonnes CO_2 equivalent/thousand lei)
2010	0,13
2011	0,14
2012	0,13
2013	0,11
2014	0,11
2015	0,11
2016	0,1
2017	0,1
2018	0,09
2019	0,08

Source: National Statistical Institute of Romania, http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table [9]

Greenhouse gas emissions intensity shows how much gas was emitted to produce one unit of GDP (constant 2010 prices), with a decreasing trend, this shows a positive aspect in terms of the environmental impact of economic activity.

The energy sector development activity is part of Romania's sustainable development process. The vision of the country's Energy Strategy is one of expansion of the energy sector in conditions of sustainability, economic growth and affordability, in the context of the implementation of the new legislative package. Clean energy for all Europeans in 2030, with targets set for reducing greenhouse gas emissions, renewable energy sources and energy efficiency, and the prospect of Romania implementing the European Green Pact 2050.

The EU targets an 80-95% reduction in GHG emissions compared to 1990 levels by 2050, with targets of 40% for 2030 and 60% for 2040. With the European Green Deal, it is proposed to revise this target, i.e. a 50% reduction to 55% in 2030 and to reach "net zero" emissions in 2050 (Mediu, 2020).

Using the aggregate form of greenhouse gas emissions, the evolution of the global warming potential of greenhouse gases in industry and households is tracked, in 2016 in industry 85.4% of greenhouse gas emissions were distributed and in households 14.6% (NIS, 2018)[10].

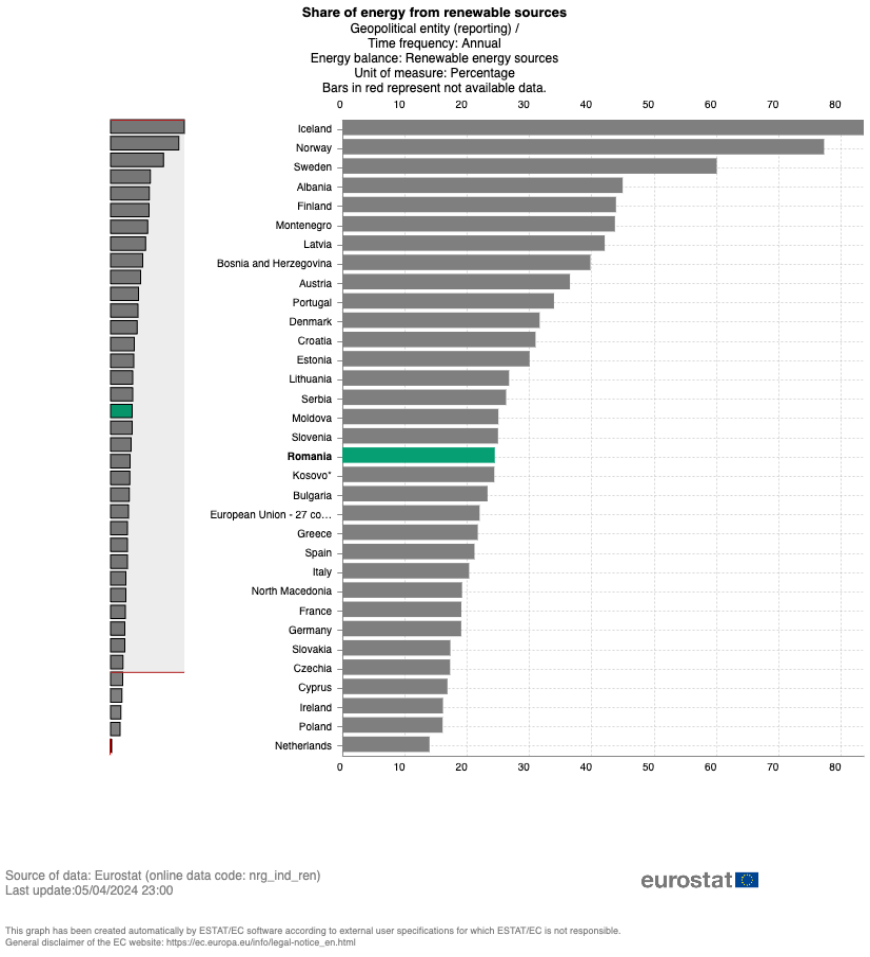


Figure 1. Share of renewable energy in final energy consumption in Europe
Source: Eurostat,
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/bar?lang=en [5]

https://doi.org/10.5593/sgem2024/5.1/s21.75

Figure 1 shows the share of renewable energy in final energy consumption in various European countries and in Europe's neighborhood, providing a clear comparison between countries and highlighting each nation's progress in combating climate change through the adoption of green energy.

DISCUSSION

From the graphs and figures presented above, it can be seen that the leaders in renewable energy are Iceland with a share of approximately 80% reflecting the intensive use of geothermal and hydropower resources. Norway and Sweden demonstrate a strong commitment to this approach, in particular using hydropower and biomass in a share of more than 50%. Other high performers include Finland, Latvia, Albania with semi-significant shares of almost 40%, supported by biomass and wind energy, also indicating an efficient use of available renewable resources. The average of the European Union (27 countries) in 2020 is 22.038%, which reflects the efforts of the Member States to achieve the energy and environmental targets already set at European level.

Although there are leaders who have successfully integrated green energy production and use systems in their states, there are also countries that are still struggling in this area, with fairly small shares such as Ireland, Poland, the Netherlands, Luxembourg and Hungary [13].

Romania ranks slightly above the European average, but efforts to increase the share of renewable energy must continue in order to achieve the proposed objectives of sustainability and reducing the carbon footprint. In addition, in 2020, we can mention that Bulgaria is just below Romania and exceeds the EU average regarding the share of energy from renewable sources in the final gross energy consumption, with a share of 23.319%, which means that it has realized the importance of the transition and uses natural resources for hydropower and biomass. This is also due to natural resources such as the numerous rivers and significant hydropower potential, which thus contribute to the production of renewable energy, but also uses biomass in energy production, especially in rural areas. Bulgaria has also benefited from investments through European funds for the development of clean energy production capacity, including wind and solar park.

Romania is in an honorable position in this ranking, with a weight of 24.5% in 2020, and among the reasons for placing above the EU average we mention the considerable hydropower potential, due to the mountainous relief and the extensive hydrographic network; exploiting the Dobrogea area, in particular, for their high wind potential, where numerous wind farms have been built. In recent years, there have been significant investments in solar energy, even if it currently represents a smaller share in the energy mix. Romania has also implemented various support schemes, such as green certificates, to encourage investments in green energy. In addition, there are significant investments in the modernization of energy infrastructure to facilitate the integration of renewable energy sources into the national grid (Ministry of Economy, 2020)[8].

As limitations of the paper, we can point to the availability and accuracy of the data that were available on official national and European websites, such as INS or Eurostat, but there are also external and political factors that may influence the share of renewable energy, which are not necessarily reflected in the statistics.

CONCLUSION

This paper highlights the importance of efficient energy policies and investments in green infrastructure to boost the share of renewable energy in final energy consumption.

To maintain and increase performance, European countries need to continue to invest in infrastructure and new technologies, improve support policies and promote the use of renewables at national level. This will not only ensure compliance with European targets, but also long-term sustainable development, reducing dependence on traditional energy sources and contributing to environmental protection.

Romania is committed to aligning with EU policies by adapting its legislative framework to promote renewable energy and energy efficiency, aiming for a 30.7% share of renewable energy in its total energy mix by 2030, thus promoting the decarbonisation of its energy sector and contributing to the broader goal of climate change mitigation.

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SIMULATION OF URBAN HEATING SYSTEMS' RETROFITTING PROJECTS: FROM CONCEPT TO INSTRUMENT

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ABSTRACT

Updated normative documents within the *Fit for 55* legislative package envisage increased dynamics in achieving European *Green Deal* goals, which are obligatory for EU countries. This directly applies to over 65 million energy-inefficient buildings in EU27 urban areas as well as heat supply systems. However, unified funding for long-term renovation programs is not planned. To respond quickly to diverse financing options with distinct conditions and target variables, a costly and time-consuming elaboration of detailed renovation projects becomes ineffective.

The article outlines the functional algorithm developed for the innovation sandbox, which is intended for the simulation of various renovation/modernization options in the overall urban heating system including heated buildings, district heating network and heat sources. The aim is crafting the application/project that meets the specific conditions to the maximum and provides high performance-price ratio. The algorithm is founded on the previously developed methodological concept.

Created sandbox's algorithm:

- encompasses the analysis of all components of the overall heating system;
- is applicable to the requirements of relevant projects and available funding options;
- offers a flexible pre-design assessment of the benefits to be achieved by the project;
- capable to consolidate many individual projects;
- provides objective and sufficiently precise results for the initial simulation and evaluation of project variations;
- does not necessitate specific knowledge in building physics and economics;
- utilizes a limited set of input indicators.

Through the sandbox, both central and local governments, as well as building owners, can effectively adapt to evolving funding and/or project tender rules.

Keywords: fit for 55, urban heating system, energy efficiency, renovation, simulation.

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INTRODUCTION

The normative documents within the *Fit for 55* package [1] underwent updates in 2023, envisioning heightened requirements [2, 3] for achieving European *Green Deal* goals, which are obligatory for EU countries. This directly applies to over 65 million energy-inefficient buildings across EU27 urban areas, as well as heat supply systems. The need for massive, deep, and dynamic renovation programs becomes imperative. However, unified funding for long-term renovation programs is not planned. Consequently, a prompt and convincing response to project calls becomes essential for the retrofitting process of buildings, district heating (DH) networks and heat sources (HS).

To respond to vary financing options with different conditions and target variables, a costly and time-consuming elaboration of detailed renovation projects becomes inefficient. A flexible pre-design assessment of the benefits to be achieved by the project is needed. Existing methodologies for evaluating renovation solutions fall short in facilitating pre-design simulations for specific projects. This is primarily because:

- most of them are suitable for detailed calculating individual buildings (e.g., [4, 5]);
- retrofitting blocks of buildings is less commonly addressed (e.g., [6]);
- studies focusing on specific aspects related to DH and HS are limited (e.g., [7, 8]).

The developed methodology offers insights into key aspects, such as achievable heat energy consumption and primary energy savings, reductions in dominant CO_2 emissions, changes in heating costs, and required investments. A restricted set of core indicators are applied, making the methodology accessible without the need for specific knowledge in building physics and economics. Methodology is based on direct computing of the changes of abovementioned target parameters. It enables flexible, rapid and at the same time sufficiently accurate simulations at the pre-design stage, assessing the potential of various renovation projects and their variants within a designated area. This paper delineates the methodology crafted founded on the concept published in [9].

MATERIALS AND METHODS

General settings

The EU's *Green Deal* documents primarily focus on reducing heat and primary energy resource consumption, along with lowering CO_2 emissions and heating costs. This focus enables direct simulation of changes, excluding aspects unaffected by the recovery from the algorithm. The methodology does not necessitate specialized information; all required data is available in the existing documents:

- city-level indicators are furnished by regulatory documents, (e.g., [10]);
- energy performance certificates provide essential data for evaluating building energy performances [2]; their supporting documents are also available;
- DH network configuration and piping data are maintained by network operators;
- centralized heat source (CHS) operator hold data on heat production, whereas building manager possess the necessary data concerning local heat source (LHS).

The methodology is designed to analyse various project variants and determine the optimal one. It facilitates the integration of multiply potential projects, enabling the formation of a long-term renovation program and the search for the overall program optimum. This process can be conducted at the pre-design stage adhering to the principles of innovation sandbox.

To illustrate the methodology, Fig. 1 demonstrates its application in simulating a virtual urban heating system retrofitting project. The project involves renovating a block of buildings comprising seven buildings labelled B_1–B_7. Each renovated building achieves a reduction in heat energy demand by ΔQ_B [MWh]. Building B_7 will not be renovated, so $\Delta Q_{B7}=0$. Local heating is utilized in buildings B_1 and B_4, supplied by LHSs. Buildings B_2, B_3, B_5, B_6 and B_7 are connected to the DH network via inlet pipes, which nominal diameter is D_B [m] and length L_B [m]. Notably, number of buildings, connected to the DH network, will not undergo renovation in this specific project. The network is connected to the CHS; heat loss from pipes Q_{pipe} [MWh] occurs in each network section, and the total amount of losses is Q_{net} [MWh].

After the project implementation, HSs generate the necessary amounts of thermal energy reduced by ΔQ_{sup} [MWh] and emit correspondingly decreased amounts of CO_2 [t]. ΔQ_{sup} for LHS, which are equal to heat energy savings ΔQ_{B1} and ΔQ_{B4} respectively, are not factored in centralized heating calculations; they are included, when computing the overall reduction in the project's thermal energy consumption, denoted as ΔQ_{proj}.

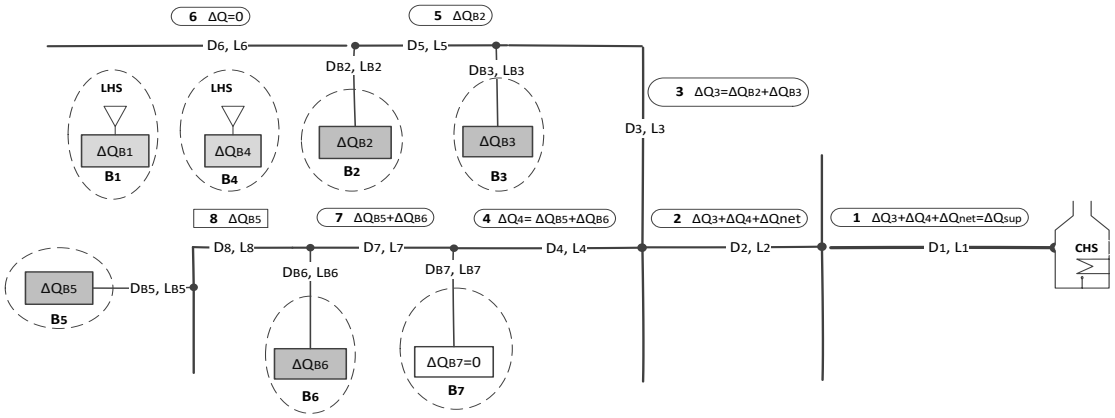


Fig. 1. Virtual urban heating system's retrofitting project: thermal energy consumption/flows.

Buildings

The heat balance of a building is determined by numerous factors, and the multitude of characteristic parameters, required for precise calculations poses a significant obstacle to the desired objective: enabling swift pre-design calculations by non-specialists.

Casual relationships between the indicators of different constructive elements are non-existent, in many cases they are very week even within a single element. Consequently, identifying the key drivers of heat consumption for the entire building through mathematical modeling methods is impossible. Instead, evaluations are conducted on an element-by-element basis to exclude less significant entities from the calculations:

- Aspects that remain unchanged during the renovation process, are omitted from the calculations. This includes solar heat gain (as building orientation and windows size remains constant), as well as internal heat gain and hot water consumption (as the renovation does not alter functionality of the building).
- Thermal bridges in an insufficiently insulated building can be neglected due to high total losses. Conversely, well-insulated buildings that adhere to technological recommendations from material and structure manufacturers, coupled with high-

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quality construction work, tend to have minimal thermal bridges. Therefore, thermal bridges are excluded from the calculations as separate entities.

- Thermal conductivity λ [W/(m·K)] of commonly used insulation materials differ only slightly. Additionally, factors such as manufacturing discrepancies, joints/fastenings and humidity influence the heat flux locally. The same holds true for building insulation costs and market volatility. Consequently, calculations assume an average λ for insulation materials and renovation costs. Only the thickness of the thermal insulation material *d* [m] is utilized as a driver.

The renovation process for external walls, roof/ceiling and basement involves covering them with thermal insulation materials (mineral wool, polystyrene, etc.); their thermal transmittance $U_{ins}=\lambda/d$ [W/(m^2·K)] is incomparably lower than the value of constructive materials U_{constr} (concrete, bricks, wood, etc.). U_{constr} calculation for different foundation/basement constructions (unheated/heated basement, slab-on-ground, etc.) is complicated, but the results are relatively consistent. To simplify this process, users are provided with a typical values for U_{constr}, but they can also set U_{constr} values if known.

Renovation of windows and/or exterior doors is planned by replacing them with higher-quality windows/exterior doors, which boast lower *U*-values compared to the old ones. It is assumed that dimensions of windows and exterior doors remain unchanged during the renovation.

Retrofitting ventilation system is a component of building renovation projects aimed at enhancing both building thermal efficiency and air quality within the premises. Calculating the thermal energy savings from ventilation upgrades, two factors are considered: the reduction of gaps resulting from the replacement of old windows, and the building's functionality, which determines the choice between a centralized mechanical air handling system and local wall-mounted heat recovery ventilation units.

Improvements to the technical building system encompass technologies that optimize thermal energy consumption within the building – smart sensors for monitoring temperature, humidity, CO_2 and VOC concentrations within the premises for internal climate control, as well as equipment for remotely controlling heating and ventilation systems in specific areas of the building. Given the wide range of potential upgrade operations, quantitative assessments rely on expert-estimations regarding the achievable reduction in heat energy consumption in various buildings by optimizing technical building systems, (e.g., [11, 12]). Additionally, it is assumed based on practice that modernization of technical building systems in Latvia is often incomplete.

The total reduction in annual heat energy consumption ΔQ_B obtained from building renovation is calculated as the sum of reductions from the renovation of all building elements. Furthermore, the peak heat load Q_{peak} [MW] of the building at the minimum temperature of the heating period decreases by ΔQ_{peak} [MW].

DH network

The massive and deep renovation of buildings leads to a significant reduction in thermal energy consumption, consequently alleviating the strain on DH networks. This presents a potential opportunity to save heat by reconstructing the network and reducing losses. Since the overall configuration, topography, and technical parameters of a specific DH network are determined by the unique conditions of the real city, the simulation of the thermal regimes in the network is organized on a section-by-section basis.

A simplistic algorithm has been developed for expedited pre-design simulation of the thermal regimes in the pipelines of individual network sections, which ensure the flow of heat carrier to the buildings to be renovated. The following assumptions were made:

- the configuration of the DH network remains unchanged during reconstruction;
- sections are constructed using pre-insulated pipes in accordance with regulatory standards (e.g., [13]);
- the dimensions of existing pipes (incl. pipe inner diameter) are chosen based on the required peak load; it could not be provided by a smaller standard diameter pipe;
- calculations of hydraulic and thermal regimes of DH networks are not included;
- the flow of heat carrier in the network section is assumed to be constant, corresponding to the heat energy load.

Heat loss from pipeline Q_{pipe} [MWh] is determined by the temperature difference between the heat carrier and surroundings, as well as by constructive dimensions of the pipe (diameter, length and thickness) and thermal conductivity of the insulation. However, the reduction in heat demand by ΔQ_B [MWh] and associated ΔQ_{peak} [MW] result in a respective decrease in the flow rate of the heat carrier, which does not significantly impact Q_{pipe} through the insulation.

The sum of Q_{peak} [MW] of the buildings supplied with heat through the specified section, determines the required pipe diameter. In case of deep and large-scale renovation of buildings, the required peak heat load in a particular section of the DH network may decrease to a level that could be met by a thinner pipeline with lower Q_{pipe}. Reducing pipe size during the reconstruction of the DH network is the only feasible means of reducing heat loss ΔQ_{pipe} in the relevant section.

The algorithm for calculating the potential ΔQ_{pipe} in the network section is as follows:

1. identify the sections, through which heat is supplied to buildings to be renovated;
2. determine the reduction of heat supply for each of these sections, calculated as the sum of ΔQ_B for buildings supplied with heat through the specific section;
3. calculate the reduction in peak heat load for each section;
4. evaluate the possibility of optimizing (resp., choosing the smaller) pipe diameter D_{nom} for the relevant network section assuming an optimal heat load of the specific pipe before reconstruction;
5. calculate the ΔQ_{pipe} obtained from the replacement of the pipe in the specific section for the entire time, while there is a hot heat carrier in the pipes.

The total heat energy savings in the DH network ΔQ_{net} are calculated by summing up the ΔQ_{pipe} in all specific network sections.

Heat sources

CO_2 emissions attributed to building heating, are not generated within buildings themselves. Instead, CO_2 is produced as a by-product in HSs, obtaining supplied thermal energy Q_{sup} [MWh] from primary energy resources in CHSs or LHSs.

In the case of district heating, Q_{sup} equals the total amount of heat energy produced in CHSs, as indicated by measuring instruments, transferred to the network, and consumed by both the buildings to be renovated in the specific project (B_2, B_3, B_5, B_6 in Fig. 1) and buildings not undergoing renovation (B_7 and unlisted buildings). For LHS (B_1, B_4),

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typically heating a single building, there is often no such meter; the heat consumption fixed in the energy performance certificate of the relevant building is used as Q_{sup}.

In both cases two drivers determine the volume of emissions: the amount of supplied heat energy Q_{sup} and the emission factor of the primary energy resource. The greatest reduction in emissions can be achieved by purposefully combined manipulations related to both drivers: renovating buildings and reconstructing inlet pipes to reduce the required amount of thermal energy for heating by ΔQ_{sup} and transitioning to a higher-quality (*greener*) primary energy resource with a lower emission factor.

It is assumed that the cost of heat production in the HSs is primarily determined by the type and prices of the primary resource. Partial loading of the HS has minimal impact on its efficiency and fixed production costs.

RESULTS

To objectively assess the accuracy of the proposed simplified method of building heating consumption calculations, a comparative analysis was carried out. For this purpose, the heat balance of 3 buildings – single family home (95 m^2), 2-story office building (490 m^2) and 5-storey residential building (2577 m^2) was created with the detailed calculation program PHPP and the developed simple method. The results obtained from both calculation models are summarized in Table 1 – as it is seen, the difference in heat energy consumption does not exceed 10% for energy efficiency improvement measures.

Tables 1. Comparison of heat energy demand from detailed (D) and simplified (S) calculations.

	Single family home			**Two-story office**			**Residential building**		
Calculation method	*(D)*	*(S)*	*%*	*(D)*	*(S)*	*%*	*(D)*	*(S)*	*%*
Current state	18,1	19,1	-6%	95,5	101	-6%	331,9	349,9	-5%
+ 15 cm wall insulation	13,9	14,5	-4%	75,0	77,9	-4%	254,6	274	-8%
+ 20 cm roof insulation	10,5	10,8	-3%	73,1	75,9	-4%	318,2	335,9	-6%
+ 10 cm basement insulation	15,4	16,0	-4%	72,7	75,0	-3%	319,8	335,8	-5%
+ New windows (U=1,6)	11,9	12,3	-3%	57,0	59,9	-5%	249,4	268,6	-8%
+ New windows (U=0,8)	9,7	9,9	-2%	45,9	48,7	-6%	210,0	229,1	-9%
+ Central ventilation	9,9	9,2	7%	58,5	54,2	7%	200,9	192	4%
+ Local ventilation units	10,9	10,4	5%	61,2	56,2	8%	215,5	210,2	2%

Fig. 2 illustrates the influence of chosen thickness of thermal insulation materials (d) on the achieved reduction of heat consumption (ΔQ_{wall}) and renovation costs (C_{wall}) illustrates the significant potential offered by the methodology, acting as an innovation sandbox, in selecting the optimal renovation variant.. The pattern of performance-price ratio, caused by variations in d, suggests the existence of its optimal value. Similar iterations are feasible in the renovation of each element, as well as in the execution of projects and programs.

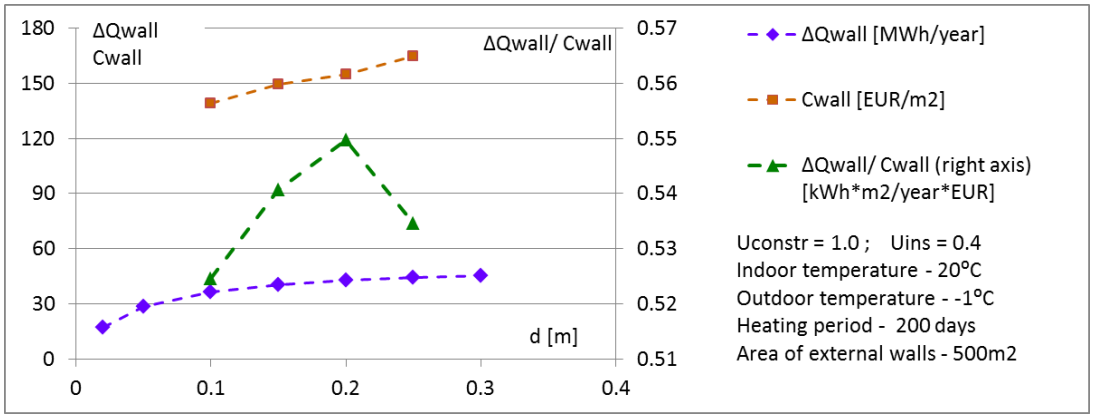


Fig. 2. Insulation of external walls: performance price ratio (authors calculation)

DISCUSSION

Several aspects need to be discussed. Primarily, only the inlet pipelines of the buildings to be renovated can be wholly attributed to the building renovation project. Additionally, due to relatively lower benefits, large investments and lengthy investment payback periods, a decision must be made regarding the timing of inlet pipeline reconstruction: either concurrently with the building renovation, or as necessitated by the deterioration of existing pipes. In the trunk sections of the DH network, heat carrier typically flows also to other buildings not targeted for renovation in the specific project. The reconstruction of such sections could be undertaken within the framework of dedicated optimization projects. Naturally, the described methodology can be used for pre-design calculations. Transitioning to a *greener* primary energy resource entails replacing HS equipment and requires huge investments. These investments could only be included into the renovation costs of buildings with LHS. In this case, a decision must also be made regarding whether and when to proceed with the transition. Only reducing heat production in CHS would be possible in building renovation projects.

CONCLUSION

The referenced methodology has been developed for simulating retrofitting projects of urban heating systems, boasting the following characteristics:

- comprehensive coverage: it manages all components of the urban heating system;
- applicability: designed to meet the requirements of relevant projects and available funding options;
- project integration: capable of combining multiple individual projects, facilitating a holistic approach;
- objective results: provides objective and sufficiently accurate results for initial simulation and evaluation of project variants;
- accessibility: requires no specific knowledge in building physics or economics, ensuring user-friendliness;
- minimized indicators: utilizes a limited number of indicators to streamline the simulation process.

Number of outcomes is available:

- achievable savings: shows the reduction of thermal and primary energy;
- emissions reduction: illustrates the reduction in dominant CO_2 emissions;
- financial implications: indicates changes in heating costs.

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- investment requirements: provides insights into the necessary investments.

The major end users of the methodology would be: (1) municipalities and government institutions to streamline the sustainable planning and management of urban heating systems and interaction with owners of infrastructure and local heating systems enabling balanced actions and priority identification, and (2) national authorities for monitoring the national *Fit for 55* implementation, strategic planning and management.

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SUSTAINABLE DEVELOPMENT AND ENERGY TRANSITION IN TURBULENT TIMES: THE CASE OF RUSSIA

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ABSTRACT

According to the Global Sustainable Development Report 2023, achieving many SDGs is becoming increasingly difficult. In conditions of turbulence and ongoing challenges for the society, increasing attention is being paid to ensuring technological sovereignty of regions and countries. Countries with advanced technologies have advantages, among which energy supply technologies occupy a special place. The type and quality of energy sources is of particular importance. The energy complex and its resource supply, as well as everything related to the production and consumption of electricity, play a major role in this regard. The transportation is of great importance as well.

The purpose of the paper is to consider some promising areas that contribute to the energy transition and to evaluate their benefits. In particular, attention is being paid to energy storage devices, which can solve problems hampering the development of RES and use of electric cars. Some measures are proposed to increase the attractiveness of electric cars for consumers and manufacturers. The proposed study could be of interest for policymakers in other countries to develop some measures promoting energy transition.

Keywords: Low-carbon development, industrial policy, transportation, energy transition, electric cars, energy storage systems (ESS).

INTRODUCTION

Environmental risks as the main ones for humanity and the economy were highlighted in the Report of the World Economic Forum in Davos (2023) [11]. In the next ten years, six out of ten global risks will be environmental, surpassing economic, geopolitical, social and technological risks. Top 4 global risks (by likelihood) are environmental in the long term. Environmental risks occupy the first four positions in terms of their danger among other risks. There are: Failure to mitigate climate change, failure to climate change adaptation, Natural disasters and extreme weather events, Biodiversity loss and ecosystem collapse. Large scale involuntary migration, Natural resource crisis, Erosion of social cohesion and societal polarization, Widespread cybercrime and cyber insecurity, Geoeconomic confrontation, Large-scale environmental damage incidents follow them. Among these risks one can also see two environmental risks.

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Table 1. Top Global Risks by Likelihood

1	Failure to mitigate climate change
2	Failure to climate change adaptation
3	Natural disasters and extreme weather events
4	Biodiversity loss and ecosystem collapse
5	Large scale involuntary migration
6	Natural resource crisis
7	Erosion of social cohesion and societal polarization
8	Widespread cybercrime and cyber insecurity
9	Geoeconomic confrontation
10	Large-scale environmental damage incidents

Source: World Economic Forum. Global Risks Report 2023 https://www.weforum.org/publications/global-risks-report-2023/in-full/

According to the Global Sustainable report (GSDR)2023 of United Nations "Times of crisis, times of change: science for accelerating transformations to sustainable development" the current state of progress toward the sustainable development goals based of select targets as far from desired.

It is easy to see that the substantial progress/on track one can observe only for indicators 9.c.1 "Increase access to mobile networks" and 17.8.1 "Increase internet use". For all other indicators there are Deterioration, Limited or no progress, Fair progress but acceleration needed. The regress is for air pollution, greenhouse gas emissions, biodiversity [4].

In 2009, a group of researchers led by Will Steffen of the Australian National University and Johan Rockström of the Stockholm Center for Sustainable Development at Stockholm University proposed the concept of planetary boundaries. These are the boundaries of the sustainability of the natural Earth-Man system, the basic global parameters within which the long-term safe existence of humanity on the planet is possible [8]. As for 2023, 9 boundaries were assessed, 6 crossed. Simulations using the Earth-3 system dynamic model showed that if current trends continue, SDGs are not achievable within planetary boundaries. The goals will remain out of reach. Qualitatively new ways of developing society are needed.

MATERIALS AND METHODS

In our previous research we assess the competitiveness of a Russian electric car and an ICE car, using the method of estimating the total cost of ownership (TCO) taking into account external costs associated with climate change (see also [2]).

The formula for the total cost of ownership a car, taking into account external costs, is as follows:

$$TCS = TCO + EC, \quad (1)$$

where TCS –*Total Cost for Society*, TCO – *Total Cost of Ownership*, EC – *External Costs*.

We use the following formula:

$$TCO = IC + \sum_{t=1}^{N} \frac{OC}{(1+r)^t} - \frac{RS}{(1+r)^N}, \quad (2)$$

where IC– *Initial Costs*; OC – *Operating Costs*; RS – *Resale Price*; r – discount rate; t – year; N – vehicle ownership period [2]. We've calculated some part of external costs of vehicles in order to calculate the total costs for society and came to a conclusion that it is necessary to incorporate them into costs of ownership.
For the development of electric transport and alternative energy sources, energy storage systems are necessary. To assess the economic feasibility of their implementation, we use the LCOS (levelized cost of storage) formula.

RESULTS
Taking into account new challenges, it is necessary to update technological and technical re-equipment of industry [5]. Of particular importance is the quality of energy sources. The energy complex as well as everything related to the production and consumption of electricity, play a major role in this regard. In Russia, there is an annual increase in demand for electricity due to increased economic activity and household use of electricity. The most important component of the successful working condition of an electricity supply system is maintaining a balance between the volume of generated and consumed energy. To ensure a guaranteed balance, the required amount of reserve electricity is extremely important, which is currently replenished through traditional generation. A potential solution to the electricity storage problem in Russia is the use of energy storage systems (ESS). Using such systems, electricity generation stations will be able to optimize the operating mode of equipment, and networks and consumers will be able to regulate the load and accumulate electricity for further use [7]. Recent decades have shown that the presence of renewable energy sources (RES) in Russia's electricity structure is increasing. Taking into account the difficulties to predict amount of electricity generation from renewable energy sources, depending on the level of technology development and weather conditions, we can say that the use of ESS will become an incentive to expand the use of RES [3]. The use of energy storage systems seems especially relevant in regions not connected to the Unified Energy System.
The economic efficiency of ESS will be determined by the cost of charging the battery (the minimum purchase price from the network, taking into account restrictions or the alternative price of selling excess energy to the network), the cost of discharging the battery (equivalent to the cost of the replaced resource), as well as the levelized cost of energy storage LCOS [6].
LCOS (Levelized Cost of Storage) is used to make relevant comparison between different types of ESS. It is calculated as the ratio of costs for an ESS to the volume of electricity supplied by the ESS over its entire service:

$$LCOS = \frac{\text{CAPEX} + \sum_n^N \frac{OPEX_n}{(1+r)^n}}{\sum_n^N \frac{Wh_n}{(1+r)^n}} \quad (3),$$ where

CAPEX – capital costs,
$OPEX_n$ - operating costs,
Wh_n – volume of electricity supplied by ESS in year n,
N – number of years,
R – discount rate.
The most promising ESS are electrochemical ones due to their compactness, speed, and scalability. The advantages of Li-Ion batteries such as long service life, compactness, and high energy density allow them to be used in portable electronics and electric

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vehicles. In recent years, the global demand for lithium-ion batteries has increased significantly [1].
In Fig. 1 one can see that until recently there were not enough energy storage devices in Russia. However, in March 2023, Russia adopted the ESS "road map", according to which the planned volume of financing for their production until 2030 will be about 127 billion rubles; 76% of it is planned to be obtained from investors.

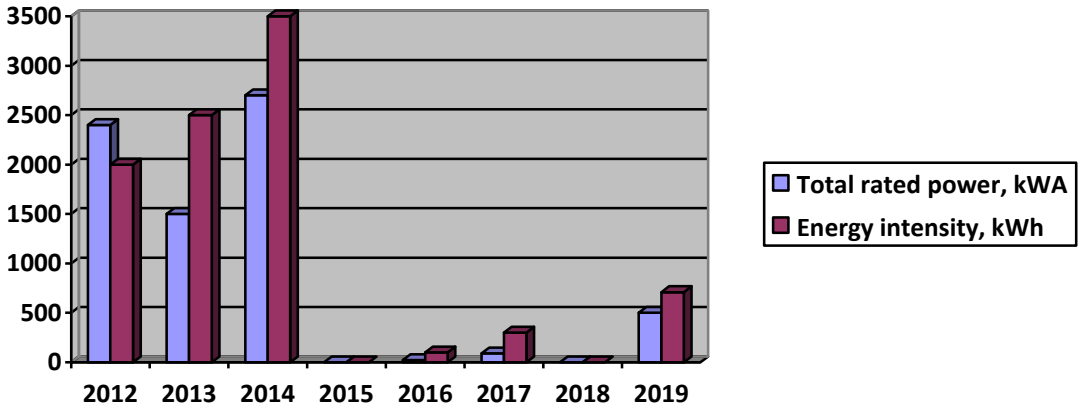


Figure 1 – Total rated power and Energy intensity of *Li-Ion* storage systems in Russia (2012-2019)
Source: compiled by the authors using data from [12]

We evaluate the economic feasibility of electricity storage devices in industrial enterprises. To do this, one need to track the dynamics of changes in the LCOS indicator depending on the estimated cost of lithium-ion batteries (Figure 2). Such an assessment may be useful for enterprises interested in using ESS to be able to independently change the parameters of electricity consumption, taking into account tariffs, reliability indicators of the power system and needs of enterprises [9].

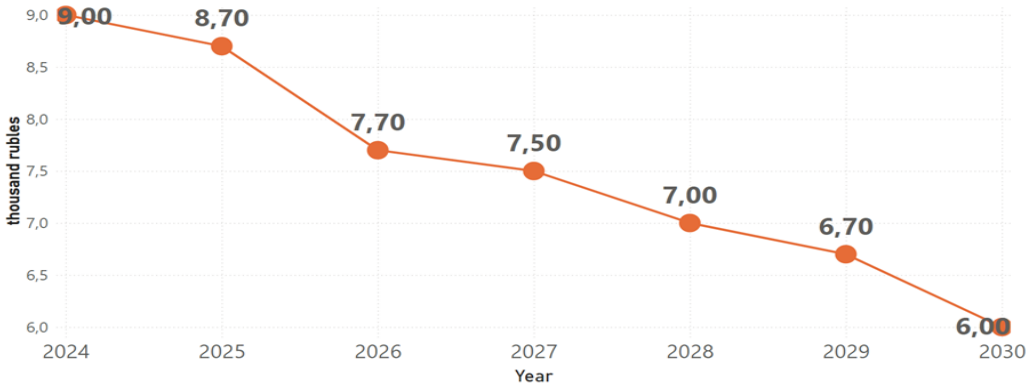


Figure 2. The estimated cost of lithium-ion batteries in Russia, thousand rubles.
Source: compiled by the authors using [10]

We apply the following assumptions:

- the cost of lithium-ion batteries is included in the CAPEX indicator (CAPEX = CAPEX1 + Li-ion-price);

- CAPEX1 and Wh are constant;

annual maintenance costs for OPEXn will be reduced by 10% compared to the previous year due to the development of technologies for operation and repair of ESS.

Parameter values for calculating LCOS for 2024 are:

CAPEX1 = 20,000 rubles, OPEX = 48,000 rubles, Wh = 2.7 MWh. (Source: U.S. Department of Energy, Imperial College London, Vygon Consulting).

Taking into account the above, formula (3) is:

$$LCOS = \frac{(\mathrm{CAPEX}_1 + Li\text{-}ion\ price) + \sum_n^N \frac{OPEX_n}{(1+r)^n}}{\sum_n^N \frac{Wh_n}{(1+r)^n}} \quad (4)$$

Let's calculate LCOS for each year, taking into account five years of project implementation (N=5). This amount was chosen due to the average service life of a lithium-ion battery, during which significant processes of degradation of the materials do not occur.
As it can be seen from Fig. 3, the purchase and use of lithium-ion battery-based ESS is proving to be cost-effective for some companies.

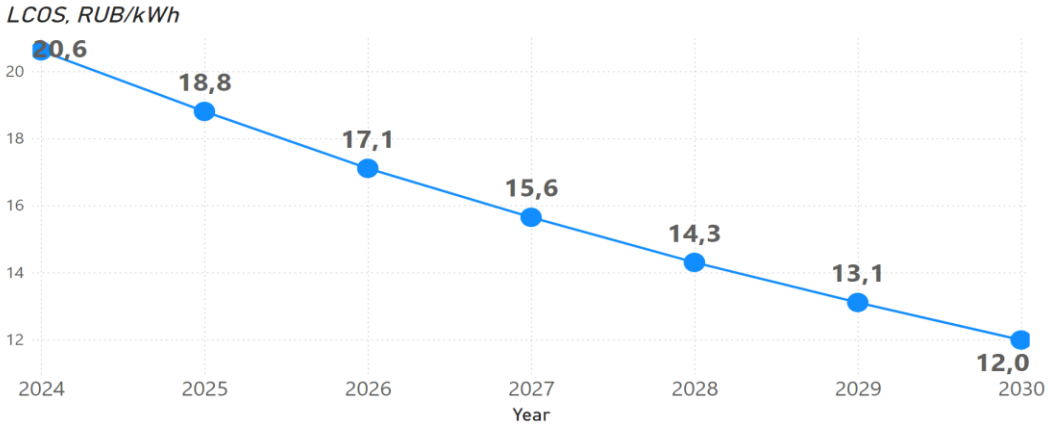


Figure 3. LCOS predicted value, Rub/KWh.
Source: compiled by the authors.

DISCUSSION

Today, lithium-ion batteries are the leaders in performance characteristics among the most common energy storage systems, but they are inferior in cost, and therefore in LCOS.

We can observe at Fig. 4 LCOS of different ESS types when using 250 cycles of charge per year. LCOS of lithium-ion batteries depending on CAPEX is estimated in 2019 as 38 rubles/KWt*h, but by 2030 it is expected to be 17 rubles/KWt*h [10].

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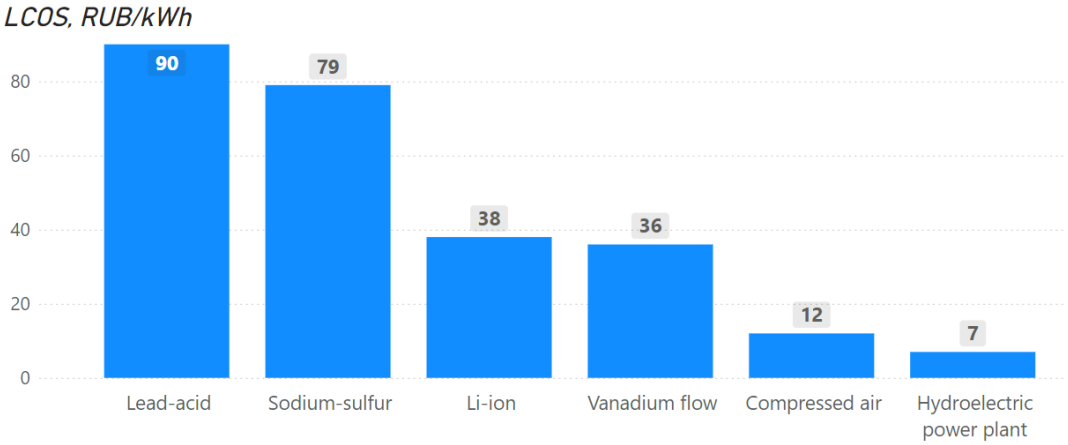


Figure 4 – LCOS of different ESS types.
Source: [10]

It is expected that until 2030, electric vehicles will be the main driver of the development of lithium-ion batteries. The share of electric vehicles in total sales in Russia can reach 15% by 2030 according to the "Concept for the development of production and use of electric road transport in the Russian Federation for the period until 2030." In 2024, the Rosatom State Corporation and the Avtotor company entered into an agreement on the prefabricated production of batteries for electric vehicles based on lithium-ion battery modules.
Russia, along with exporting lithium from Bolivia, is going to develop its own deposits (Trans-Baikal Territory, Murmansk Region). There are no such environmental risks as in other countries, since there are mines for lithium and Russia is a country supplied with water.
To overcome key barriers hindering the development of electric vehicles in Russia, it is proposed to use some tools presented below.
It is necessary to provide the buyer of an electric vehicle with an additional subsidy, to use the "bonus/malus" system, to stimulate the transition of companies to electric vehicles, to ensure the development of a charging infrastructure network in areas of high demand using public-private partnership mechanisms. For producers the program similar to the "double credit" policy pursued in China may be effective.

CONCLUSION

In this paper we estimated the development of energy storage devices in Russia as a tool for successful energy transition and an important factor for moving closer to achieving the SDGs.

Li-Ion Energy Storage Systems (ESS) are well known for their advantages such as compactness, high energy density, long service life, scalability. They can be used in portable electronics and electric vehicles. We evaluated LCOS (Levelized Cost of Storage) of lithium-ion battery-based ESS till 2030 and came to the conclusion that the purchase and use of such ESS is proving to be cost-effective. ESS are necessary for further successful development of Renewable Energy Sources (RES) as well as for electric cars. Some economic measures are necessary to increase the competitiveness of electric cars and development of RES in Russia in order to provide the green transition. Some measures to increase the attractiveness of electric cars for consumers and manufacturers are proposed in this paper. We have made conclusion that Russia has

everything necessary to create a complete technological chain for the production of Li-Ion Energy Storage Systems, opening up great prospects for further development in the field of energy transition as well as technological sovereignty.

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SUSTAINABLE DEVELOPMENT OF TERRITORIAL COMMUNITIES: MANAGEMENT OF ECONOMIC PROCESSES AND TOURIST RESOURCES

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ABSTRACT

The problem of sustainable development of territorial communities and the management of their economic processes and tourist resources is important in the modern world, as it requires a balanced approach to ensuring economic growth, preserving the environment and meeting the needs of society. The research is aimed at studying the management strategies of economic processes and tourist resources in territorial communities in order to ensure sustainable development. **The aim of the study.** The purpose of the study is to analyze the current trends in the management of economic and tourism aspects of the development of territorial communities, to identify key problems and to offer recommendations for their solution. **Object and subject of research.** The object of the research is territorial communities, and the subject is the management of their economic processes and tourist resources. **Research methods.** The research uses methods of analysis of scientific literature and documents, empirical research. With the help of statistical methods, the main trends and transformations of the issue of sustainable development of territories, taking into account the requirements of the economy of nature use, were analyzed. By using methods of correlation analysis, the key influencing factors on ensuring the sustainable development of territories in the conditions of modern global challenges were determined. The author analyzed modern approaches to managing the economic and tourism aspects of the development of territorial communities, identified key problems and proposed specific recommendations for improving management to achieve sustainable development. **The conclusion** of the study is the need to develop an integrated approach to the management of economic and tourist processes in territorial communities, which will take into account the needs of society and the preservation of the environment.

Keywords: environmental economics; territorial communities; sustainable development; tourism

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INTRODUCTION

The issue of sustainable development of territorial communities and the management of their economic processes and tourist resources is pertinent and crucial in the modern world. The steady growth of the economy and the facilitation of tourism development require a comprehensive approach to resource and process management at the local level. In this context, the role of sustainable development of territorial communities becomes crucial for ensuring economic stability and preserving natural and cultural values. Society faces a myriad of complex challenges related to maintaining ecological balance, fostering economic growth, and addressing social issues. The growing need for sustainable development and preservation of natural resources presents government bodies, businesses, and communities with significant tasks that demand a comprehensive approach and innovative solutions. This article examines the issues of managing economic processes and tourist resources in the context of ensuring the sustainable development of territorial communities, providing analysis and recommendations for practical implementation.

Current trends and tendencies indicate an increased focus on sustainable tourism development, the expansion of tourist attractions, and the growth potential for local economies. However, along with tourism growth, new challenges arise, such as environmental pollution, overcrowding of tourist destinations, and the loss of authenticity of local cultures.

The research hypothesis posits that effective management of economic processes and tourist resources can contribute to the sustainable development of territorial communities, balancing economic and sociocultural needs while preserving natural resources. Statistical data show an increase in the volume of tourism business in various regions, but also highlight issues related to environmental conservation and socio-cultural tension.

According to the World Tourism Organization, the annual volume of international tourism grew to 1.5 billion international tourists in 2023 compared to previous years. However, simultaneously, there is an increase in CO2 emissions from transportation and energy consumption, threatening ecological balance and sustainable development. Therefore, there is a pressing need to actively seek effective management strategies aimed at balancing the interests of tourism development with the importance of preserving the environment and cultural heritage. This article aims to study and analyze these issues with the goal of developing practical recommendations that can contribute to the sustainable development of territorial communities.

MATERIALS AND METHODS

The study employed a multidisciplinary approach to investigate the influence of globalization on territorial management and environmental economics. It involved gathering and analyzing primary and secondary data to understand how globalization impacts organizations and their management strategies regarding sustainable development like a part of environmental economics. This analysis uncovered causal relationships and established a structured hierarchy of factors influencing sustainable development management, considering economic utilization of natural resources, environmental economics and sustainable tourism. Various management models and theories in the context of globalization were explored through the analysis, comparison, and synthesis of diverse literature, defining globalization's influence on development.

By employing methods like accumulation, grouping, and comparative analysis, the study identified best practices for sustainable development, adaptation to globalization challenges, and innovative management approaches. Case studies of sustainable development in environmental economics ventures entering the global market, enhancing intercultural competence, and devising strategies like tourism development were examined to extract practical principles. Statistical analysis methods and correlation relationships were also employed to provide mathematical support for formulated hypotheses.

RESULTS

As a result of the analysis of literary sources, the theoretical and methodological aspects of the research were determined. Analysis of the sources used indicates a wide range of studies in the field of environmental economics development, environmental economics, and tourism. Article [1] examines the issue of sustainable tourism in the European context. The authors explore current trends and strategies to ensure the sustainable development of tourist destinations in Europe [2]. In the study by Thongdejsri, M. and Nitivattananon, V., the impact of a low-carbon tourism program on sustainable tourism in a world heritage city is evaluated. The authors investigate the effectiveness of measures to reduce CO2 emissions and preserve cultural heritage [3]. The research by Wai-chung Lai, L. is dedicated to analyzing the relationship between private property rights, culture, property management, and sustainable development. It emphasizes the importance of effective property management for achieving sustainability [4]. Ingulfsvann, A.S., Jakobsen, O. and Nystad, Ø. propose a dialogical network perspective on sustainable development in environmental economics. The authors study the interaction between various actors within a network to achieve sustainable development [5]. Cifuentes-Faura, J. and Noguera-Méndez, P. (2023) examine the role of economics and business in shaping attitudes towards sustainability. The authors analyze the impact of education and educational programs on fostering sustainability in business and society [6]. Authors Uhodnikova, O., Viatkin, K., Gordiienko, S., Viatkin, R., Moroz, N. (2023) have developed a study on territorial planning and sustainable development in refugee areas. They investigate the challenges and opportunities of planning to ensure sustainable development and integration of refugees into new conditions [7]. These sources contribute to understanding the wide range of aspects influencing sustainable territorial development, including economics, tourism, property management, and sociocultural aspects.

It is advisable to determine the presence of various methods of quantitative assessment of factors influencing the sustainable development of territories. One of them is the use of econometric models. Environmental economics models allow for assessing the impact of various factors on the sustainable development of territories. To confirm the hypotheses regarding the cause-and-effect relationships of the influences of global factors on the sustainable development of territories, taking into account the factors of tourism development and environmental economics, correlation dependencies were analyzed. The results are presented in Table 1.

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Table 1. Model of factors influencing the sustainable development of territories and environmental economics

Coefficient	Components of the Evaluation System	Characteristic
Democracy	Political rights encompass freedoms such as the right to a free and autonomous press, equality under the law, efficient governance, and involvement in decision-making processes.	The Democracy Index is rated on a scale from 0 to 10, with 10 being the highest level of democracy and 0 being the lowest. countries scoring 8 or higher are considered full-fledged democracies. countries scoring 6 to 7 are considered hybrid regimes. countries scoring 4 to 5 are considered authoritarian regimes. countries scoring 0 to 3 are considered totalitarian regimes. Countries scoring 0 to 3 are considered totalitarian regimes.
Trade	Trade protection measures Infrastructure development Market accessibility Extent of environmental economics globalization	The TI measures each country's level of openness based on 12 different indicators, including trade protection, infrastructure, market access, and degree of economic globalization. Ratings are on a scale of 1-100, with 100 being the most open and 1 being the least open. Countries with a score of 70-100 are considered very open to trade; countries with a score of 50-70 are considered moderately open. Countries with a score of 30-50 are considered less open to trade. Countries with a score of 1-30 are considered very low in trade openness.
Corruption	The Corruption Perceptions Index (CPI) is an annual assessment of the extent of corruption in 180 countries around the world. the CPI was developed by Transparency International (TI), an international non-governmental organization dedicated to fighting corruption.	The Corruption Perceptions Index (CPI) assesses corruption using data from 13 diverse sources, including surveys of businesspeople and experts, as well as official records. The index ranges from 0 to 100, where 0 represents the highest corruption level and 100 the lowest. Nations scoring 0-30 are classified as highly corrupt, those scoring 31-50 are also considered highly corrupt, while scores of 51-70 indicate moderate corruption levels. Countries with scores of 71-90 are seen as having lower corruption levels, while those scoring 91-100 are deemed very corrupt.
Tourism development Index	Number of tourists who visited the territory over a certain period of time. Variety of tourist attractions in the territory. Level of satisfaction of tourists from visiting the given territory. Level of advertising and marketing efforts aimed at attracting tourists. Level of accessibility and infrastructure for tourists in the territory.	The developed index of tourist visitation territories is a comprehensive indicator that assesses the attractiveness level of a particular territory for tourists. It takes into account several key parameters that influence tourists' decisions to visit a specific location. Each of these parameters can be measured on a scale or in percentages, allowing for a comprehensive assessment of the tourism attractiveness of the territory. For example, the index can be calculated as the arithmetic or weighted average value of each of these parameters.
Investment	Economic stability Environmental economics Extent of corruption Effectiveness of government Education level Market accessibility	The Investment Attractiveness Index (II) evaluates countries' investment appeal using 12 diverse indicators, including economic stability, corruption level, government efficiency, education level, and market accessibility. The index ranges from 1 to 100, where 100 indicates the highest level of investment attractiveness and 1 the lowest. Nations scoring 70-100 are classified as highly investment-attractive, those scoring 50-70 are considered moderately investment-attractive, and those scoring 1-30 are deemed very low in investment attractiveness.

* Source: developed by the author.

Analyzing the territory (using statistical data, the CI for the territorial communities of the Zakarpattia region of Ukraine has been determined, with initial data for the calculation taken from open sources of the State Statistics Service of Ukraine) – table 2.

Table 2. Calculation of the correlation dependence of the Sustainable Development Index

	positive influence	positive influence	negative influence	irreversible
DI (Democracy Index)	10-8	7-6	5-4	3-0
TI (Trade Index)	100-70	69-50	49-30	29-0
CPI (Corruption Perceptions Index)	30-0	50-31	70-51	100-71
TDI (Tourism Development Index)	10-8	7-6	5-4	3-0
II (Investment Attractiveness Index)	100-70	69-50	49-30	29-0

* Source: developed by the author.

Therefore, the table presents four gradations of factors influencing the processes of sustainable development of territories and environmental economics based on the ranking results: positive influence, average influence, negative influence, irreversible.

DISCUSSION

The conducted study aimed to assess the factors influencing the sustainable development of territories, focusing on the Zakarpattia region of Ukraine. The research utilized various quantitative methods, including econometric models, to analyze the impact of different factors on territorial sustainability. The data were sourced from the State Statistics Service of Ukraine. The analysis revealed several key findings:

1. Democracy Index (DI): The region demonstrates a moderate level of democracy, with a score ranging from 6 to 7. This indicates that while democratic processes exist, there may be some limitations or challenges in terms of political rights and governance efficiency.
2. Trade Index (TI): The region exhibits a moderate level of openness to trade, with a score ranging from 50 to 70. This suggests that there are opportunities for trade and environmental economics globalization, but there may be room for improvement in terms of infrastructure development and market accessibility.
3. Corruption Perceptions Index (CPI): The region faces challenges regarding corruption, with a score ranging from 50 to 70. This indicates a moderate level of corruption, which could potentially hinder sustainable development and environmental economics efforts and investment attractiveness.
4. Tourism Development Index (TDI): The region shows promising potential for tourism development, with a score ranging from 7 to 8. This suggests a diverse range of tourist attractions, high levels of tourist satisfaction, and effective marketing efforts to attract visitors.
5. Investment Attractiveness Index (II): The region demonstrates moderate investment attractiveness, with a score ranging from 50 to 70. This indicates favorable conditions for investment, including environmental economics stability, government effectiveness, and market accessibility.

In conclusion, the study highlights the importance of addressing corruption and improving governance efficiency to enhance the region's sustainable development and

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environmental economics prospects. Additionally, leveraging its tourism potential and maintaining economic stability are crucial for attracting investment and fostering long-term growth.

CONCLUSION

Based on the results presented in the correlation dependence calculation of the Sustainable Development Index (SDI), the following conclusions can be drawn:

1. Positive Influence (DI 10-8, TI 100-70, TDI 10-8, II 100-70): Factors within this range indicate a strong positive influence on sustainable development. These include high levels of democracy, openness to trade, tourism development, and investment attractiveness. Territories falling within this category are likely to experience robust environmental economics growth and social progress.
2. Average Influence (DI 7-6, TI 69-50, TDI 7-6, II 69-50): Factors in this range suggest a moderate impact on sustainable development. While there may be room for improvement in certain areas such as governance and market accessibility, these territories still exhibit potential for growth and development.
3. Negative Influence (DI 5-4, TI 49-30, TDI 5-4, II 49-30): Territories falling within this range face challenges that negatively affect sustainable development. These may include corruption, limited trade opportunities, underdeveloped tourism infrastructure, and low investment attractiveness. Addressing these issues is crucial to overcoming obstacles to development.
4. Irreversible (DI 3-0, TI 29-0, TDI 3-0, II 29-0): Factors categorized as irreversible indicate significant barriers to sustainable development. Territories in this range experience severe challenges such as totalitarian regimes, minimal trade openness, poor tourism potential, and low investment appeal. Special attention and comprehensive reforms are needed to initiate positive change and promote sustainable development in environmental economics.

In summary, understanding the correlation between various factors and their impact on sustainable development is essential for policymakers and stakeholders to implement targeted interventions and strategies. By addressing challenges and leveraging opportunities, territories can work towards achieving long-term prosperity and resilience. The developed model of influencing factors on ensuring the sustainable development of territories and environmental economics can be used in practice for a number of purposes. Using the model allows you to assess the current state of the territories and identify the main factors that affect their sustainable development, which helps to develop strategies and programs aimed at improving the economic, social and ecological state of the territories. The model provides an objective assessment of various aspects of impact, which helps in making effective decisions regarding the allocation of resources and the development of territorial development management policies. Once strategies and measures are implemented, the environmental economics model can be used to monitor and assess their impact on the sustainable development of territories. This allows early detection of problems and adjustments of strategies according to needs.

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THE IMPACT OF SUSTAINABILITY ON ACCOUNTANCY PROFESSION

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ABSTRACT

The United Nations' Sustainable Development Goals have recently challenged organizations to start consistent transformation in order to foster sustainability in future economy and society. One of the key enablers of this transformation was the European Union's Corporate Sustainability Reporting Directive, which amended non-financial reporting with sustainability reporting. As a result, the first global sustainability standards have been developed, which gave the accountancy profession a key role in helping organizations navigate through this new challenge. Sustainability reporting presents a great responsibility for professional accountants to create and communicate comprehensively and transparently the long-term value of organizations. Due to their genuine integrity, backed with ethical behavior and professional expertise, many believe that accountants are best positioned for that role. However, to be able to understand and quantify the environmental, social and corporate related risks, to identify materiality and to prepare quality disclosures for sustainability-related information, professional accountants need to develop their professional skillset. This paper aims at outlining the main effects of sustainability development over the accountancy profession and to highlight the new competences, needed in accountant's professional profile through the lens of the new sustainability reporting framework. Main implication is that the new elaborate roles within the sustainable organization will enhance their skillset and will place new development opportunities in front of professional accountants. A combination of interpretive and critical scientific research methods has been applied to this study.

Keywords: sustainability reporting, accountancy profession, competences

INTRODUCTION

In 1987, the United Nations defines sustainability as meeting the needs of the present without compromising the ability of future generations to meet their own needs. In his research "Why All Businesses Should Embrace Sustainability" Knut Haanaes interprets sustainability as a business approach for creating long-term value by taking into consideration how a given organization operates in the ecological, social, and economic environments [1]. Main implication in both definitions is the long-term nature of sustainability and its impact on corporate and social longevity. According to a research, conducted in 2020, companies with high ratings for environment, social, and governance (ESG) performance enjoyed higher operating margins [2]. In the McKinsey 2020 survey, 83% of investors expected organizations with a positive record for ESG issues to contribute more shareholders value over those with a negative one in the following years [3]. It is important to draw a distinction line between ESG and sustainability, because ESG looks at how the world impacts a company or investment, whereas sustainability

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focuses on how a company impacts the world [4]. Nevertheless, they are both strategic considerations for organizations and investors, and are put together on the current sustainability agenda. In today's global and ever-changing world sustainability impact is required to be reported by companies, regardless of size, industry or location, because stakeholders demand sustainability-related information more than ever. They need to be aware of companies' management potential in terms of resources, risks and opportunities, as well as their ability to build and maintain sustainable culture. Moreover, they need to be well aware to what extent business profits are delivered at the expense of the environment or society [5]. Increased demand for sustainability-related information is further amplified by regulatory requirements on business organizations for sustainability reporting. In this respect, IFRS Sustainability Disclosure Standards – S1 and S2 mark a milestone in companies' sustainability performance reporting. The main idea behind these standards is to provide a framework for reporting the core aspects of sustainability in a relevant, transparent, coherent and comparable manner. Hence, their goal is to ease investors and stakeholders in their decision making in reply to the growing demand for complete evaluation of company's sustainability performance.

In sustainability context organizations are required to be public trusted corporate figures. Not only investors and stakeholders, but the whole society needs their transformation towards sustainability as a proactive response to all the global economic dynamic changes. But to be sustainable in the long term is challenging. Organizations have to produce quality products by making mindful investment decisions and trade those products by mitigating the ESG risks. Meanwhile, organizations should also contribute to society development and environment protection. This imperative for creating value transparently, then protecting it mindfully and finally communicating it comprehensively is not just a great challenge, bringing new opportunities for the accountancy profession, but it is considered the new role of professional accountants [6]. A transformation process is taking place and the generic role of the accountant as performance communicator through traditional financial reporting is now upgraded to a value communicator by the need of a more holistic approach to report sustainability. Finally, the role of bringing public trust in organizations becomes a priority for professional accountants and they need to demonstrate compliance with sustainability and its implementation in the overall organizational strategy.

Motivated by the continuously evolving sustainability landscape, this paper aims at analyzing its effects on the role of the accountancy profession. This new role will be discussed through the lens of the new reporting framework, shaped by Corporate Sustainability Reporting Directive (CSRD). Core capabilities and competences, which will further develop accountant's professional portfolio will be outlined as they are needed for taking advantage of the future career opportunities.

PRESENT SUSTAINABILITY REPORTING LANDSCAPE – A CALL FOR MORE HOLISTIC, TRANSPARENT AND COMPREHENSIVE CORPORATE REPORTING

In the last three decades a number of global initiatives have marked the sustainability reporting landscape. The first to provide organizations with standards to guide them in reporting sustainability was the Global Reporting Initiative (GRI). It is also one of the most used frameworks by organizations. According to a KPMG survey, four out of five companies globally report sustainability with GRI [7]. Further, the Taskforce for Climate-

Related Financial Disclosures (TCFD) developed a framework for consistent climate-related financial disclosures taking into account the financial implications of the climate risk and its importance for strategic planning decisions. Meanwhile, the Sustainability Accounting Standards Board released the SASB Standards, which contain specifications on disclosing financially material sustainability information and are widely used in the USA. These together with a few other initiatives presented a plethora of non-financial reporting frameworks, which shaped the sustainability reporting landscape of the past decades. However, the constant attempts to collectively address the Sustainability Development Goals made it extremely important for organizations to start speaking the same way about sustainability [7]. Thus, in April 2021 as a result of the ambitious Green Deal the European Commission adopted a proposal for developing of a new directive aiming to revise and strengthen the rules in the existing Non-Financial Reporting Directive (NFRD) (EU) 2014/95/EU. In December 2022 the European parliament has adopted the new Corporate Sustainability Reporting Directive (CSRD) (EU) 2022/2464, which amended the old NFRD. The main changes (Table 1), introduced by the CSRD are significant in terms of scope of liable companies, reporting requirements, mandatory third-party audit assurance and even the way of submission [8].

Table 1. Main changes, introduced by the CSRD

Main changes	Non-Financial Reporting Directive (NFRD) (EU) 2014/95/EU	Corporate Sustainability Reporting Directive (CSRD) (EU) 2022/2464
When will it be applicable?	FY2018	January 2024 • Reporting entities already subject to the NFRD report in 2025 on 2024 data January 2025 • Large reporting entities not currently subject to the NFRD report in 2026 on 2025 data January 2026 • Listed SMEs, small and non-complex credit institutions and captive insurance entities report in 2027 on 2026 data
To which companies will it be applicable?	Large public interest entities with > 500 employees Public interest entities are: • Listed companies • Banks and Insurance companies	• All (listed or non-listed) large companies (two of three criteria met): > 250 employees and/or > €40M Turnover and/or > €20M Total Assets • All other (small/medium) listed companies get an extra three years to comply
How many companies are subject to the new directive?	EU: 11.600	EU: 49,000 Covering >75% of total EU companies turnover
What is the scope of reporting requirements?	Companies are to report on: • Environmental protection • Social responsibility and treatment of employees • Respect for human rights • Anti-corruption and bribery • Diversity on company boards (in terms of age, gender, educational and professional background)	Overall requirements: • Inclusion in the Annual Report • External (limited) assurance (as from FY2024) • Reporting principles • Format and timing General disclosures: • Business model, strategy and policies • KPIs and targets (forward looking information) • Company and sustainability governance • Double materiality assessment and due diligence • Risk and opportunity management Topic-specific disclosures: • Environmental (incl. EU Taxonomy) • Social • Governance • Sector-specific standards
Is independent third-party assurance mandatory?	Non-mandatory (for most countries)	Mandatory – limited level of assurance Including: • Integration in Auditor's Report • Involvement of key audit partner • Scope to include EU Taxonomy information and process to identify key relevant information
Where should companies report?	Included in the Annual Report	Inclusion in the Management Report
In what format should companies report?	Online or PDF version	To be submitted in electronic format

Source: KPMG [9]

Main goal of the new Directive is to ensure improved transparency, reliability and comparability of sustainability information, reported by the organizations, which will eventually enhance investors' decision-making on capital markets. The substantially increased number of companies, subject to the Directive and the fast approaching deadline for mandatory disclosure reporting caused a number of concerns while the preparations

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for the big change were ongoing. One of the main concerns and a subject of focused research in the extant literature since the Directive was adopted was the concept of "double materiality". Further, this materiality concept should be used as a criterion for the disclosure of certain information in sustainability reports. According to some practitioners difficulties may arise when trying to make a distinction between impact materiality (company's impact on people and environment) and financial materiality (how sustainability issues might create financial risks for the company). Another challenge, imposed by the new CSRD, is the third-party mandatory limited assurance. Availability of independently audited and certified sustainability information is expected to enhance investors' confidence, yet among auditors some concerns are emerging about preparing for that engagement. It is one thing to develop an assurer's opinion on financial statements, where estimates are based on historical information, but to provide assurance for sustainability, where estimates are often based on hypothetical scenarios would be completely different and more challenging engagement [10]. Another major concern about the progress against sustainability reporting and implementation of the CSRD requirements is related to the costs for ensuring compliance of companies with limited resources. The whole process of preparing sustainability information for disclosure implies higher costs, although the benefits from investing time and resources are still uncertain from organizational perspective [11]. Undoubtedly, sustainability reporting will bring many challenges for both companies and practitioners. Nevertheless, recent researchers proof that organizations have already started preparing for the big change towards sustainability by gathering teams with the needed expertise in reply to the new CSRD requirements [8].

On June 26, 2023, the International Sustainability Standards Board (ISSB) issued its first two inaugural sustainability reporting standards - IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information and IFRS S2 Climate-related Disclosures. The two standards complement each other and have to be applied together. They both require the companies to prepare disclosures on the following four content areas [12]:

Governance - the governance processes, controls, and procedures used to monitor and manage sustainability-related risks and opportunities;

Strategy - approaches to manage sustainability-related risks and opportunities;

Risk management - processes to identify, assess, prioritize, and monitor sustainability-related risks and opportunities; and

Metrics and targets - performance relative to its sustainability-related risks and opportunities, including progress towards any targets the company has set or any targets it is required to meet by law or regulation.

IFRS S2 requires the disclosures for the same areas, but in the climate-related context. Furthermore, IFRS S2 requires assessment of company's climate resilience, based on cross-industry metric categories, company's climate-related targets or targets, required by law.

Both S1 and S2 standards require disclosure of "material" information. In that respect, in IFRS S1 it is clearly stated that in order to ensure investors understand sustainability risks and opportunities relevant to their investment decisions, the definition for "material" is the same as it is in the IFRS: "Information is material if omitting, misstating or obscuring

it could reasonably be expected to influence investor decisions". This final decision regarding the definition of material information should bring some clarity in the long debates on double materiality concept. Another important point to be mentioned is the fact that third-party assurance is not currently part of the new standards. However, the ISSB assures that S1 and S2 are designed to make the reported information verifiable, hence the sustainability related information will be more reliable and of higher value for the interested stakeholders. The new standards have also addressed the other major concern about the companies with limited resources by indicating that they should report "reasonable and supportive information that is available to the entity at the reporting date without undue cost or effort"[12]. Interoperability is another key point in the new issued standards as it is expected that the consolidation of the variously used existing frameworks, such as the GRI standards, the TCFD architecture and others will allow companies to migrate with ease from previous sustainability disclosure framework to a more consistent one.

The ISSB admits that apart from focusing on the impact of the social and environmental issues over financial risks and opportunities for the companies, there are more future topics to be added to sustainability reporting. Meanwhile, on July, 31, 2023 the European Commission adopted the European Sustainability Reporting Standards (ESRS) for use by all companies subject to the CSRD. The 12 draft ESRS are based on technical advice from the European Financial Reporting Advisory Group (EFRAG) and are covering the full range of sustainability issues. The ESRS and the first two standards of the ISSB have been developed in parallel and the Commission has worked to ensure a very high level of alignment between them. Although it is quite early to assess the success of the new sustainability standards, there is no doubt that they aim to create a common language for sustainability, which will enable companies to provide comprehensive, transparent, comparable and decision-useful information, to meet the information needs of investors on global capital markets.

DISCUSSION

The new role of accountants in the heart of sustainable organizations

The described sustainability reporting landscape and the growing need for comprehensive and transparent sustainability-related information sends a clear message that sustainable development is not an option anymore. It is a necessity and each and everyone in the organization should take responsibility for their sustainable behavior and should be accountable for creating sustainability-related information. However, it is the accountant in the organization, who will take major responsibility for sustainability reporting. This is a paramount shift from preparing financial statements for company performance to building in sustainability disclosures for the wider stakeholders' needs.

Long before the start of preparing the reports in line with the new sustainability reporting framework, accountants have an important role to play in incorporating the new regulations for the specific organization and its environment. Professional accountants should be aware of the company's business model, its corporate strategy and organizational goals. This will give them understanding to how the company creates value and delivers sustainability. Since the accountants have to communicate how the organization is addressing sustainability risks and opportunities, it is important that they take part in the process of setting the business targets. They need also to prepare metrics and evaluation strategies, in order to ensure that those business targets are compliant with

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the sustainability development goals and that different ESG risks related to this strategy could be measured, verified and finally transparently reported.

Another important engagement for professional accountants in pursuit of successful sustainability reporting is to identify what is important and to determine material information about sustainability. Disclosures for sustainability are designed to meet multiple internal, external and legislative needs and in this sense materiality assessment is crucial. A strong judgmental capacity is required by the accountants, who should apply the appropriate approach to determine which information if omitted, misstated or obscured, could reasonably be expected to influence investors' decisions. Accountants have to play an important balancing role among different stakeholders in the investment community. The more this balance is achieved and the more internal and external purposes are aligned, the more efficient the reporting process will be. Moreover, the reporting burden for the organization could be reduced and aligned with the proportionality implication of the new sustainability standards. Furthermore, for the purpose of creating and reporting sustainability-related data for the organization, accountants need to leverage technologies and efficiently apply them to establish the appropriate data collection methodology in agreement with the new reporting requirements.

The role of professional accountants does not end with setting up the sustainability reporting organizational strategy and sustainability risk management. The importance placed on sustainability disclosures to bring reliable information requires accountants to produce verifiable reports. They should consider different levels and methods for assurance and verification of sustainability-related data. A proactive attitude for further seeking of continuous development of the reporting process will ensure that accountants will communicate the organization's value with high-quality sustainability-related disclosures.

Sustainability reporting landscape requires new competences in the accountancy professional profile

The accountancy profession is crucial to meeting the evolving sustainability imperative for economy and society. Professional accountants are called to take many new roles in responding the dynamic changes in sustainability reporting. For the purpose of taking proactively those new roles, they should enhance their skillset with a number of new competences. Recent reports of ACCA have identified seven main areas of new capabilities (Fig.1), required by professional accountants, engaged with sustainability reporting [6].

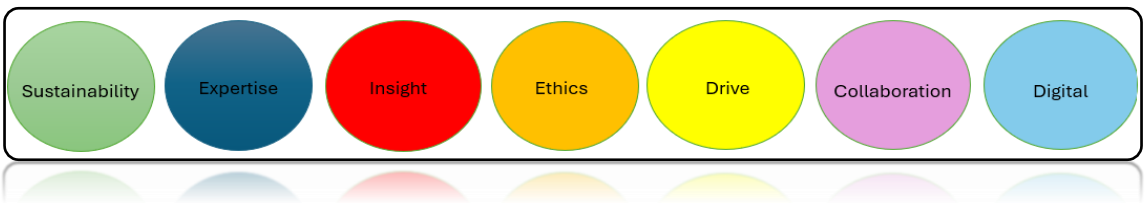


Fig. 1. Areas of capacities for accountants, undertaking sustainability reporting Source: ACCA [6]

Sustainability area encompasses understanding of what sustainability implies, skills for applying ESG metrics and ability to perform sustainability analysis. This capability area requires a shift to a more integrative mindset, which will allow accountants to create,

protect and communicate the long-term value not only for the organization, but also for society. The **Expertise** area covers consultancy and advisory competences, which are strongly backed up by traditional accountancy expertise such as financial reporting, performance management, financial and risk management, taxation, audit and assurance. Materiality assessment capability, technical skills and interdisciplinary knowledge for important ESG topics are to be added to the know-how of the accountant's professional profile, but most importantly professional accountants should acknowledge growth mindset and lifelong learning attitude as main prerequisites of high-performance and successful career. **Insight** competence area is about business acumen, critical thinking, decision making, innovation and governance. This is maybe one of the most challenging development areas for accountants, yet, it is an area which will bring them to the business leadership table. **Ethics** and integrity are the backbone of accountancy profession and doing the right thing is imperative for professional accountants. However, a deficit of public trust, data privacy and corruption concern still prevail in global society. Moreover, the fast-emerging digitalization processes raise new ethical challenges in the accountancy domain, and this is a call for action for accountants to improve and strengthen their ethical principle to recover public trust and to promote responsible business behavior. **Drive** development area is about authenticity, leadership, determination and again lifelong learning. Professional accountants should be determined to ask the right questions, to be curious about new ideas and to inspire others to achieve organizational goals, while doing the right thing in a sustainable way. **Collaboration** competence area requires from accountants an improved interaction with internal and external stakeholders, which means ability to communicate clearly what is important in order to build trust and maintain sustainable partnerships. Adoption of diversity, equity and inclusion (DEI) mindset is not just a necessity, but a cornerstone opportunity for accountants to contribute for a sustainable diverse workplace by recognizing and accepting different opinions, by creating an inclusive environment, by avoiding any kind of bias and by promoting equitable practices. Last but not least is the **Digital** area of capability, which in sustainability context requires awareness and competence to use modern technologies, platforms, tools and models to interact, to gather and interpret data, to make analysis, to optimize reporting processes. Nowadays, being digitally literate is a must for the professional accountant and it is not only in sustainability context, but it is rather a whole separate factor, causing powerful influence over accountancy profession and its future role in society.

CONCLUSION

Sustainability development is an important journey for the whole society. The effect, caused by the new sustainability reporting framework over the accountancy domain is enormous. The new role of professional accountants is far beyond simply embedding CSRD requirements in the organization. They should embrace the new challenge and proactively participate in building the corporate sustainability strategy for creating, protecting and communicating organization's long-term value. Underpinned by their generic obligation to act with integrity and in an ethical manner, professional accountants are best positioned to navigate organizations through this dynamic transformative process towards a sustainable future. Taking many elaborate roles within the sustainable organization will place new career opportunities for professional accountants. To play these essential roles and to take advantage of the new opportunities in front of them, accountants need to accept the lifelong learning attitude and continuously adapt

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themselves to the dynamically changing environment, in order to reply successfully to the demand for sustainable future.

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THE INFLUENCE OF MEDIA ECOSYSTEMS ON CONSUMER BEHAVIOR AND DECISION-MAKING FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

The European Union's planning documents for 2040 clearly outline the importance of an environmental economy, which focuses on the economic impact of environmental policies and the sustainable management of natural resources, emphasising the need to integrate ecological principles into economic systems. The planning documents at all levels pay particular attention to the circulation of information, to keeping the public informed about the promotion of green thinking and sustainable development. The media ecosystem, which focuses on the media environment and its impact on people's behaviour, perception and understanding, plays a crucial role in shaping public opinion on environmental and sustainable development issues. Contemporary economics researchers argue that effective environmental governance requires a synergistic approach through the media ecosystem to raise public awareness of sustainable development issues. The media have become an integral aspect of everyday life, providing information and serving as a basis for people to make choices and decisions. This paper presents the results of a study carried out on the behaviour of young people in the media ecosystem and the factors influencing the decision-making process. The study was based on theoretical research of documentary sources and digital materials, analysis of statistical data. The analysis of survey data was used to analyse the factors influencing the behaviour and decision-making of young people in Latvian comprehensive schools in the digital environment, including their perception of factors influencing sustainable development. The findings show that the contemporary media ecosystem plays a significant role in people's lives, influencing their behaviour and decisions. The data will be used in the next stages of the research, where the behaviour of all age groups in the media ecosystem, factors influencing decision-making and perceptions of sustainable development will be explored.

Keywords: sustainable development, media ecosystem, consumer behaviour, decision making

INTRODUCTION

In environmental economics, environmental quality is seen as a commodity for which demand and supply can be determined. Market goods may be valued by consumers through market transactions, but people also value goods such as clean air, clean water, a safe climate for people, healthy ecosystems that have an impact on human life, which are an integral part of everyday life. [7] The media ecosystem has become an integral part of modern life, operating in all spheres of human life. It is therefore clear that the development of the media ecosystem must be geared towards enhancing the quality of life through sustainable development. [2]

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The contemporary media transition and operation in the digital environment is analysed as a key element of sustainable media development. Media ecology addresses the question of how media and the digital environment influence human perception, understanding, feelings and values today and how our interaction with media contributes to or hinders our survival. In a general sense, ecology is the study of the environment, its structure, content and impact on people. The environment is a complex system of messages that convey certain ways of thinking, feeling and behaving. The media ecosystem shows how media structure what we see, why media make us feel the way we do, act the way we do, make the decisions we make. Media ecology explains the media ecosystem as a systemic entity and an integral part of the contemporary environment. [4]

The world's major challenges are global developments and their impact on the development of the media ecosystem. In the media ecosystem, this refers to the interconnected network of media technologies, platforms and content that make up a dynamic and constantly changing environment for communication and information dissemination. The technologies and innovations produced create a blurring of the boundaries between the physical, digital and biological worlds. [7]

Like the natural ecosystem, the media ecosystem is characterised by a complex interplay of different elements, ranging from traditional media such as newspapers, television and radio to modern forms of media such as websites, social media platforms, blogs and podcasts. Each element plays a specific role in shaping the overall landscape of the media ecosystem and influencing the production, consumption and dissemination of information for sustainable development. A key aspect of the media ecosystem is convergence, which refers to the merging of different forms of media onto a single platform or device. This convergence has been facilitated by technological advances that allow users to access media content through a single device, such as smartphones or tablets. As a result, the boundaries between different forms of media have become increasingly blurred, giving rise to new forms of content creation and consumption. [9]

In addition, algorithms and artificial intelligence play a crucial role in shaping media consumption patterns in the media ecosystem. Social media platforms and online services use algorithms to personalise content for users based on their preferences and past behaviour. In turn, the media ecosystem explains the broader cultural, social and environmental context in which media operate. The concept of the media ecosystem was popularised by media academic Marshall McLuhan, who builds his theory on the thesis that media today act as an extension of our senses, shaping how we perceive and interact with the world and ensuring sustainable development. [9] By highlighting the interconnectedness of media technologies, human behaviour and the physical environment, media ecology emphasises the complex relationships between these elements. In media ecology, supply emerges as a key concept, referring to the characteristics and affordances of media that influence its use and perception by users, thereby influencing the decisions made by individuals. [3] An example is the wide availability of social media platforms and their unquestionable influence on public opinion and perception of sustainable development. The availability of Twitter and Instagram clearly demonstrates how user-generated content and online quick effect messages can operate and interact in real time, facilitating the spread and rapid inclusion of the public in the reception of generated content. Each participant could instantly

express an opinion, which can be positive or negative, thus reacting to the content message of interest and making a decision on the offer made.[5]

Analysing the contemporary world of technology and information, the media ecosystem and media ecology serve as valuable frameworks and help to clarify how media technologies and platforms shape the everyday lives of societies and influence their perception of the world, changing decision-making habits and ensuring sustainable development. The interrelationship between media technologies, audiences and their contextual environment helps to better understand the challenges and perspectives posed by the changing media environment.

Evolution of the media ecosystem and impact on consumer decision-making

The media ecology tradition is linked to the concept of ecosystem, which is mainly used in business economics discussions. [2] In recent years, researchers in media ecosystem studies have explained that the media ecosystem nowadays updates public opinion and understanding of the basic principles of communication and explains how different sectors of society, such as private and public, work and leisure, as well as different regions, different forms of business and different sectors, start to interact with each other because of the proliferation of electronic and digital media.

The media ecosystem explains that, thanks to the availability of the internet, online media are increasingly penetrating all areas of society and becoming an integral part of everyday life. Digital communication has changed the understanding of communication in its traditional context, requiring all factors of sustainable development to be analysed and included. [5] Technological progress and development have created a new dynamic between the media ecosystem and users, where speed and response time are the key factors in this transformation. The digital world offers a constant flow of information. However, easy and immediate access to information does not guarantee its relevance and does not contribute to a critical understanding of the content. [1] Digital media use is becoming increasingly important. It defines everyday needs and triggers new habits. The digital media environment has created a paradox where any user can instantly become a participant in any event without being physically present in the environment. Online offers and opportunities have become an integral part of life. The list of formats will continue to expand and change as devices, applications, social media and platforms evolve and users extend, adopt and adapt them. In this context, it is important to understand how and to what extent the new media ecosystem influences and contributes to sustainable development indicators. [5]

The historical development of the media ecosystem follows the work of the founders of media ecology theory, media pioneers H.A. Innis, M. McLuhan and N. Postman. The concept of media ecology was applied to media research. As the name suggests, media ecology broadened the understanding of the definition of media and changed the approach from understanding a narrow medium of communication to a whole life communication system that shapes both the inner world of each individual and the social environment of society, ensuring sustainable development. Innis, McLuhan, Postman and other scholars were interested in how different media technologies offer a social environment to society and influence public opinion, changing the way the world is perceived and therefore how existence is lived, including through the selection of more environmentally friendly resources and the promotion of a greener approach to the use of consumer goods. [6] According to World Bank analysis, the decline in the use of

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traditional forms of media such as newspapers and magazines reduces overall paper consumption in direct paper categories by almost 60%, the paper used for printing newspapers and magazines. [8]

As the internet becomes more common, the perspective of media as a living ecosystem and social environment is more relevant than ever. The media ecosystem is changing and evolving fast, and media ecology theory explains media as the structure in which society and culture develop - as the environment in which people operate and live their lives, and through which reality is perceived and decisions are made. Culture and social and societal relations are shaped through human communication. Therefore, the media technologies of each age, i.e. the ways in which people communicate, fundamentally shape culture, mindsets, values, social and power relations, explain human existence and the continuous evolution of the environment. [5] Today, it is argued that culture is not shaped by technology, but by the communication that takes place in particular media. Media ecology observations blossomed from the 1960s to the 1980s, when electronic media became increasingly widespread and filled everyday life with information. However, as Paul Levinson argues, the tradition of media ecology has only become truly applicable with the advent of the Internet. Understanding and promoting sustainable development goes along with media development as an integral part of research. [2]

According to Levinson, this is for three reasons. Firstly, the Internet brings together all the previous media historically shaped by classical speech, classical written and printed text and electronic audiovisual multimedia. The Internet is thus a richer and more versatile medium than previous media. The Internet provides a more versatile technological communication and is able to cover a greater part of the human experience. Secondly, the Internet is essentially an interactive medium in which sender and receiver are not clearly distinguishable. Because of this interactivity, people can act on the Internet in a very similar way to in physical reality. Thirdly, due to its associative, hypertext structure, the Internet resembles human thought processes and the original medium, speech, and is thus almost fully integrated into all human activities. [6] This demonstrates that the modern media ecosystem has fundamentally changed public communication and decision-making. In addition to the characteristics of the Internet described by Levinson, a fourth can be added. With the increasing computing and storage capacity of chips, the Internet has significantly reduced the cost of producing, distributing and processing information. As a result, information and the cultural content produced have been blended and have become a kind of shared resource. Accessible information can be seen as the main reason for the media saturation of contemporary reality. Mobile devices have ensured the constant presence of media content and environments. The computational environment, which fragments and democratises knowledge, has created a digital media ecosystem. [5]

MATERIALS AND METHODS

The purpose and nature of the media ecosystem is to shape the everyday life of society, ensuring sustainable development. It has changed decision-making habits and patterns of use and enjoyment of many things. (for example, use of consumed and recycled paper) As the media ecosystem has become a part of everyday life, it becomes particularly important to understand how much time is spent online. This means not only studying where time is spent, but additionally studying how time is spent and what influences certain decision-making.

This paper presents the results of a study carried out on the behaviour of young people in the media ecosystem and the factors influencing the decision-making process. The study was based on theoretical research of documentary sources and digital materials, analysis of statistical data. The analysis of survey data was used to analyse the factors influencing the behaviour and decision-making of young people in Latvian comprehensive schools in the digital environment, including their perception of factors influencing sustainable development. This paper presents data from a study conducted to analyse the behaviour of young people (16-20 years) in the media system, including an analysis of how young people spend their time in the digital environment and what media they choose. The aim of the study was to understand what influences young people's decisions in the digital media world and their perception of the factors affecting sustainable development.

RESEARCH RESULTS

The study used theoretical research of documentary sources, including texts, articles and digital materials, statistical data analysis and survey data analysis to analyse the factors influencing the behaviour and decision-making in digital environments of young people (16-20) of the same age group, from mainstream schools. The survey was completed by 1553 young people, with an average age of 18.3 years. The study included a 45-question survey to explore young people's perceptions of the impact of the media ecosystem on their daily habits, as well as their understanding of sustainable development. All young people responded that they are currently unprepared and unable to move away from the digital media environment in their daily lives.

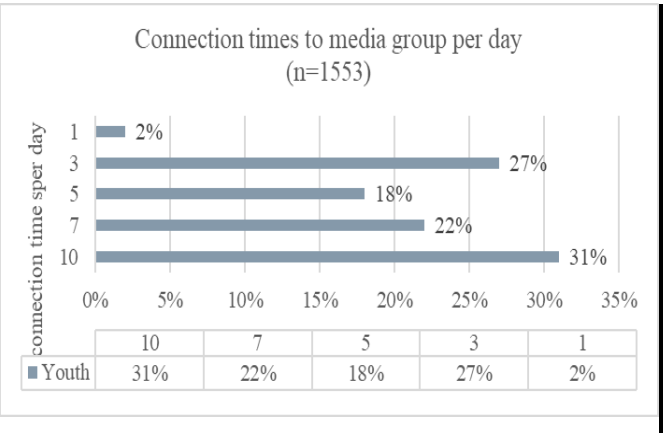


Figure 1. Connection times to media per day (compiled by authors)



Figure 2. Favourite online shops of young people. (compiled by authors)

At the beginning of the survey, young people identified the purpose and frequency of their media use. The survey data shows that 31% (482) of the young people surveyed log on to a social media site 10 or more times a day, 22% (341) log on to a social media site at least 7 times a day and only 2% (31) of the young people surveyed indicated that they use a social media site 1 time a day. When asked about the purpose of their use, young people indicated that in 44% of cases they access media groups only for entertainment (music, social dialogue, blogs of popular people, etc.). 58% of the respondents indicated that they log in to shopping portals on a daily basis. 18% indicated that they follow news portals to find out the most important information in the country. Only 11% indicated that they log on daily for study purposes. (see Fig. 1)

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Media consumption behaviour of young people indicates that they are frequently involved in shopping portals. Therefore, this paper will provide an in-depth look at data on young people's digital shopping habits. All young people (100%) indicated that they have access to money to make purchases. Young people were additionally asked whether they had to coordinate their shopping choices with their parents. Only 12% of young people indicated that they always have to coordinate purchases with their parents. 70% of young people indicated that they only coordinate purchases with their parents for purchases above €50. 18% of young people indicated that they do not coordinate purchases with their parents. It can be concluded here that young people make their own decisions when shopping in a media group, relying on their own opinion and vision of the necessity of the product. Jauniešiem tika uzdoti papildu jautājumi par mediju izvēli iepirkšanās gadījumā. 44% no aptaujātajiem, kas kaut reizi iepirkušies interneta veikalos, norādīja, ka mīļākā interneta veikala tiem nav. 56%, ir norādījuši savus mīļākos interneta veikalus, kurus apmeklē digitālajā vidē regulāri.

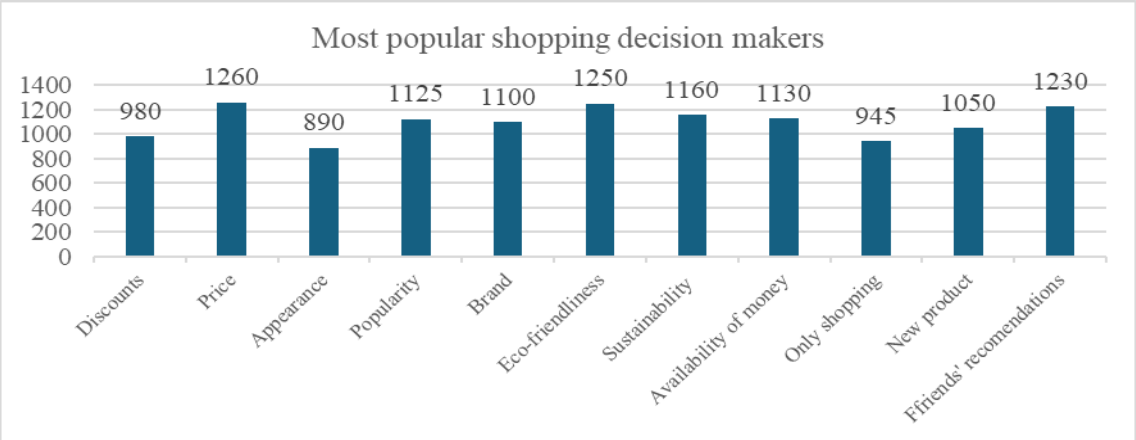


Figure 3. Most popular shopping decision makers. (compiled by authors)

As you can see, Asos, H&M, Shein, About You, Zara, Pull&Bear, Sinsay and Reserved are the most popular online stores among young people. The most popular online shop for young people is Asos. Young people have their own distinct factors for choosing an online shop. One of these is certainly the style range of goods and another is the quality of service offered by the store. Young people were asked to select and rate more than 20 criteria. The data shows that young people consider recommendations from friends, price and popularity, environmental friendliness and sustainability of the product (clothing), availability of money, simply buying a new product and the desire to shop to be important when shopping. Similarly, many young people (68%) indicated that choosing and using media is simply a leisure activity. (see Fig. 3)

Media choice is often subjective and it does not matter in which order media are chosen. The survey data show that the average time spent on digital media as a form of leisure is 4.4 hours per day. The longest time spent is more than 10 hours per day in daily media use, while the least time spent is no less than 2 hours per day. This shows that the media ecosystem plays an important role in the daily lives of young people today. (see Fig. 4) Young people were asked about buying goods digitally and whether they remember exactly what it was like. Most respondents (64%) say that they made their last purchase without a particular need for a specific item of clothing. 37.0% say they were prompted to make a purchase by a digital marketing activity, while 26% say they would not have focused on a particular product if they had not received digital information about it.

Young people also indicated that it was the digital content, repeated several times both in email and other media, that influenced their decision to buy the product. (see Fig. 5)

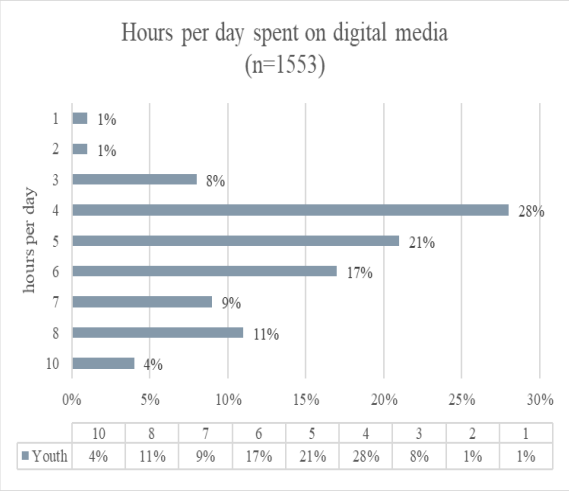


Figure 4. Hours per day on digital media. (compiled by authors)

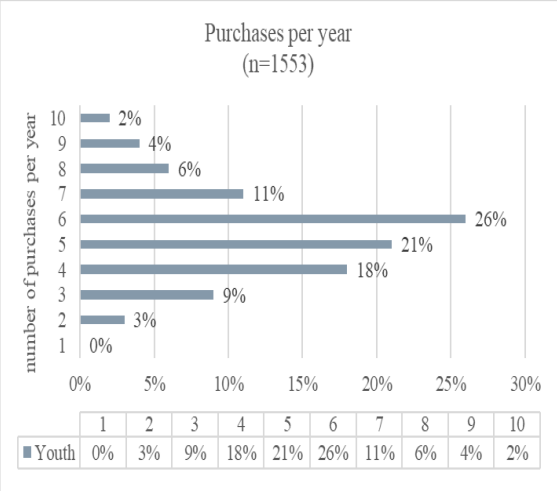


Figure 5. Purchases per year. (compiled by authors)

It should be noted here that often at the age of 16 the content chosen is not under parental control. 99% of young people indicated that they do not receive specific guidance from their parents in their choice of media. The responses (86%) show that parents discuss generally accepted safety norms in the use of digital environments, but rely on young people's choices and personal preferences

The survey asked young people about the benefits of accessing the digital media ecosystem. 97% of respondents identified quick access to information and reduction of paper use (in the media context) as key to the sustainable development of the media ecosystem. All young people indicated that they pay a lot of attention to environmental issues in their lives and believe that the digitalisation of media has a direct impact on green thinking by reducing certain types of waste. All young people indicated that they see a major problem in the availability of consumer goods, the freedom to buy goods and the excessive use of non-organic packaging (especially when transporting goods).

DISCUSSION

The concepts of media ecosystem and media ecology are essential to explain the complex relationship between media technologies, target audiences and contextual environments. These concepts are essential for understanding the interplay between media and the world around them in decision-making and the role of media for sustainable development. According to the Media Ecology Association, the term "media ecology" can be defined as the study of the media environment, the idea that technologies and techniques, forms of information and codes of communication play a leading role in people's lives. [4] Media ecology theory is based on the principles that technology not only has a profound impact on society, but also controls virtually every aspect of life.

CONCLUSION

Media ecology is a complex and systemic meta discipline that studies the changes and consequences that have occurred in society as a result of technological and media developments throughout history and their impact on sustainable development. The

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media have become a central aspect of everyday life, providing information and serving as a basis for people's consumption. This study used a theoretical approach to documentary sources, including texts, articles and digital material. The findings show a shift from simple, vertical and linear communication systems to networks that enable horizontal and personalised consumption. It is concluded that technology has redefined structures and concepts. In the digital media environment, news consumption is increasingly subject to algorithmic manipulation. While many studies have explored how algorithms affect people's everyday lives, little is known about how young people themselves perceive, learn and cope with the personalisation of news. The results of this study suggest that the frequency and engagement of young people with media needs to be further investigated separately. The contemporary consumer spends more and more time in the media environment, and the younger the consumer, the longer the time spent in the media ecosystem. The younger the consumer, the longer the time spent in the media ecosystem. As the media ecosystem becomes increasingly embedded in the fabric of everyday life, it is possible that engagement could be a more meaningful way to assess young people's behaviour in the digital media environment in order to explore what motivates young people to engage more in digital activities in order to meet important needs, including social needs such as social needs and interaction, information sharing and self-expression. The data from the study will be used in the next steps to analyse the behaviour of different age groups and to compare the three main challenges of the digital media ecosystem. Analysing the impact of the media ecosystem on human behaviour cannot ignore the importance and potential of the media ecosystem not only to disseminate relevant information but also to promote social values and understanding of sustainable development.

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THE INFLUENCE OF SPATIAL, ECONOMIC AND SOCIAL TRANSFORMATION IN THE DEVELOPMENT OF A LANDSCAPE VALORISATION STRATEGY

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ABSTRACT

The aim of this paper is to assess the impact of spatial, economic and social transformation and their influence on the development of a landscape valorization strategy, in terms of the possibilities for implementing structural changes in the territory of a country, through which structural changes to support the introduction of new technologies and innovations, resulting in a change in the sectoral structure of a country's economy. On the other hand, by assessing the impact of social transformation, an explanation will be sought for a number of processes related to the motivation to upskill the workforce in different regions, and possible ways of stimulating them will be sought by creating opportunities to improve the existing business environment in lagging regions in developing countries. An assessment of the role of spatial transformation is necessary in view of creating the conditions to stimulate investment in lagging regions, and to achieve sustainable development through a balanced use of available resources. On the other hand, the need to develop a strategy for the valorisation of the landscape should be highlighted in the light of an assessment of spatial, economic and social transformation, in the context of the objectives set by a number of countries to achieve the transition to a low-carbon and digitalised economy. This process, on the other hand, implies considerable efforts to increase the digital skills of the population, which will have an impact on the development of personal and collective incentives for the development and application of innovation in the socio-economic life of the population in the regions. On the other hand, the need to develop a valorisation strategy for the landscape is underlined by the search for opportunities to increase investment in green technologies in productive activities.

Keywords: landscape valorisation strategy, economic transformation, green technologies, spatial planning and transformation, low carbon economy.

INTRODUCTION

The need for all professionals who are responsible for landscape planning and management should be familiar with both existing new concepts and the characteristics of the environment and available natural resources in order to provide quantitative measures of the environmental benefits of natural resources. The identification of the advantages of an individual region is essential at all levels of government, both on the part of the local authorities and on the part of the central executive and all other interested parties involved in decision-making, with strict regard and consideration of the costs and benefits of the proposed measures and pre-proposed actions.

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The main differences in the use of the term "value" by economists and ecologists relates to the interrelationships of price formation methods and human preferences, with the result that "the functionality of economic value is between one entity and a set of human preferences"[1]. Or, assuming that a region is degraded and in decline, it will be assumed that this same regionhas the presence of a lower abundance of organisms, with the result that this same degraded region will be valued less for the existence of organisms than another region that is undegraded and relatively ecologically clean with a preserved landscape. From an economic point of view, a polluted region will have a lower value, but provided that an equivalent non-polluted area is available and exists, and provided that there are also consumer preferences of different social strata of society for non-polluted over polluted areas. In other words, demand influences supply and hence the determination of the value of the non-polluted region. Different layers of society exhibit different preferences towards their surroundings. Economic value is defined as the maximum amount of a good or service for which an individual is willing to give up other goods and services in order to obtain the desired good, service, or the desired state of the environment in the region they wish to inhabit. "A measure of welfare is formally expressed in a concept called willingness to pay (WTP), where "the value lost from a degraded environment is the maximum amount people are willing to pay to have a state in which that same area is free of pollution."[1] The problem, or rather the difficulty, relates to the way in which natural assets and the state of the environment are valued by individuals and the way in which the real economic value of a region can be determined. Again, a number of issues arise related to the determination of the value of pollution landscapes that might not provide the necessary added value to local populations, relative to regions that are non-pollution all other things being equal.

1. THE ROLE OF ECONOMIC VALUATION IN IMPLEMENTING TRANSFORMATION AND DETERMINING ITS IMPACT ON THE DEVELOPMENT OF A LANDSCAPE VALORISATION STRATEGY.

In carrying out an economic evaluation relating to the value of a proposed or implemented policy or in developing a development plan for a particular region, any economist is interested in assessing how the welfare of society or, in particular, of an affected community or the individuals specifically affected will change, and carrying out an economic evaluation of a strategy involves answering the following questions:

- by what percentage the well-being of society or affected individuals decreases with the anticipated loss of a natural resource when a process of regional degradation occurs, or by what percentage the well-being of society will increase if a new natural resource is discovered and the managed area simultaneously improves the quality of life in that region. As an example, we can cite the rapid development of the Co-operative Republic of Guyana with In Guyana, whose population is just over 800,000, per capita production is already higher than in Saudi Arabia and is mainly on the discovery by the US oil company ExxonMobil of one of the largest oil fields with a capacity of up to 11 billion barrels of oil, and the targets set by ExxonMobil are linked to the company's desire to have the country producing 1.2 million barrels of oil by 2027. By 2020, the country is aiming to produce 2.2 billion barrels per day.

When conducting an assessment of the economic value of a region, economists also look for answers to the following two questions:

- What is the proportion of the population willing to give up certain goods and services for the sake of owning some particular natural resource or having access to some particular resource service?

- In what ways will the well-being of local people be affected if a planning and/or implemented policy, or a planned and/or implemented measure of the developed management plans and strategies for a given region affects and increases the quantity, resource availability and quality of a resource or resource service in the region?

It is a well-known fact that all resources are scarce, and the formation of the demand for scarce resources is related to their availability at a given time, so choices have to be made about how society will use the available n owned resources. The complexity of the choice is also determined by individual and collective demand, which is very often based on multiple complex trade-offs by individuals and society, with the result that the decisions made can determine and reveal the value of how individuals and society collectively choose and allocate the resources they possess relative to the need to satisfy scarce demands. Determining the value of the natural environment is objectively a complex process, as there are different ways of using it, which are also related to the change of the environment and climate change, and in addition to the trade-offs that society will make in terms of giving up something to get something else.

The valorisation of landscapes and the assessment of transforming environments should be seen as an ever-growing set of techniques depending on the evolution of societies over the centuries. From an economic point of view, the concepts of producer surplus and consumer surplus are applied to natural resource and environmental issues in the determination of well-being, where the basic question is:

- Is it better for society today and will it lead to an increase in society's well-being tomorrow in the context of environmental protection?

It is argued that the implementation of environmental assessment as a process of applying welfare economics provided that the production activity is related to the use or condition of natural resources. And the process of assessing benefits to society implies the existence of two states:

- No change - no change is observed on the basis of the implemented policy and released measures;

- With change - when a change in value occurs;

There is a lot of talk about assessing processes in terms of 'before' and 'after' they occur, and very often attempts are made to weigh the social benefits occurring from changes in commercial activity against the benefits and consequences of environmental change. Undertaking a social accounting analysis will involve calculating all the real costs associated with a commercial activity, and should include the costs of lost or damaged environmental assets and the costs of improving or reducing the quality of life of local people in the region.

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2. THE ROLE OF SPATIAL TRANSFORMATION IN CREATING THE CONDITIONS FOR STIMULATING INVESTMENT IN LAGGING REGIONS.

In essence, we can view the implementation of economic impact analysis as a methodology for determining the ways in which changes in regulations, planned and implemented policies, and the application of new technologies affect regional income on the one hand, and all economic activities on the other, as well as revenues, expenditures, employment, and unemployment. It is the economic impact analyses carried out that target different hierarchical levels, such as:

- existing local environmental groups in a region may wish to assess the impact of environmental regulations and the ways in which they affect the rate of population growth/decline and the determination of the tax base in the region;

- formed local communities or regional groups, on the other hand, might need to increase their understanding of the impact of a national regulation on their specific economic conditions in the region, in order to plan future economic activities in the context of environmental protection and in line with the fight against climate change.

- subject could also be various international agencies that are directly interested in the efforts being made in different regions of the world related to reducing carbon dioxide emissions, as well as seeking opportunities to influence the relative growth rates of both rich and poor countries.

In defining the role of spatial transformation, we also need to present some of the methods for assessing future risks for different regions, but in general this process is complex given the determination of the complexity of the existing urban environment and the existence of a diversity of urban conditions in different regions of the country. Such an analysis implies that cities should be systematised into different groups, for example, according to population size they should be classified and goped into large, medium and small cities. In addition, it is also appropriate to group them according to their location, such as coastal cities along the Danube and seaside cities along the Black Sea coast. Next, they should be divided into lowland, mountain and semi-mountainous areas, as the consideration of urban vulnerability implies that settlements should be considered according to historical development patterns, zoning and specific land use. It is the economic valuation and valorisation of the landscape that needs to address the existence of a wide range of likely interrelated impacts in urban areas that may be caused by the occurrence of future climatic events leading to damage to buildings and urban infrastructure. Also leading to the occurrence of impacts on the health of local populations, reduced mobility and accessibility in water use. I.e. the occurrence of negative climate events have negative consequences for the population and at the same time bring increased financial pressures on local governments related to the ability to restore, maintain and build new appropriate infrastructure in response to climate change. Undoubtedly, climate change will have a huge impact on large cities, with central urban areas characterised by higher densities, the presence of heavy traffic, significantly reduced green and open spaces and extremely old depreciated infrastructure with limited capacity to absorb the water runoff of a tributary river as a result of the occurrence of an extreme meteorological event being more vulnerable to extreme climate events. It is also to be expected that extreme weather events will affect vulnerable groups, especially social groups living below the poverty line, the homeless, the elderly and the sick.

The need to implement spatial transformation implies looking for opportunities to restructure the landscape to respond to potential extreme temperatures, as:

- Higher temperatures will lead to the formation of heat islands, and we will see an increase in their intensity and impact on large cities characterised by increased density and intensity of development.

- Low temperatures and cold waves are rarely to be expected, but as a result of climate change we can expect them to combine with heavy snowfall then rapid snowmelt, leading to risks to the delivery of vital services to the population, such as the restriction of food supplies as a result of blocking access to individual settlements.

On the other hand, serious attention should be paid to intense rainfall events, as:

- We can expect an increase in the number of floods and the number of affected settlements, with neighbourhoods located near watercourses and those of large cities built illegally on their periphery in flood-prone areas being particularly vulnerable.

- In combination with the intense rainfall, we can expect an increase in the frequency of hailstorms, which will further damage buildings, vehicles, public transport and infrastructure.

- Prolonged rainfall, and the resulting increased groundwater levels will be a catalyst for landslides to occur.

In addition, climate change not only impacts the urban environment and people's lives, but will require further in-depth analyses related to the need to take appropriate measures for possible and expected water resource scarcity on the ground, as:

- High temperatures, which imply drought, will increase tensions in settlements, especially where there are water shortages and where there are outdated water networks, implying losses of large quantities of water.

In this regard, the key vulnerabilities to these climate hazards in different regions and localities of the country should be identified by assessing:

- The current state and preparedness of infrastructure;

- Human, operator or user preparedness;

- Hydroelectric power plants - vulnerable to drought operation;

- Water services (water supply, sanitation, land reclamation) - vulnerable to land.

- The main risks for the managed systems;

- Possible damage from improper operation;

- Risks to hydropower plants due to low or high river streams.[2]

As regards the Republic of Bulgaria, we should note the ongoing process of ageing of the population leading to a decrease in the share of persons under 15 years of age and an increase in the share of persons aged 65 and over. And bearing in mind that UN forecasts state that by 2050, one in three Bulgarians will be over 65 years of age, and only one in two Bulgarians will be of working age. Any objective analysis will have to be made on the share of the working population, as this is a key factor in the level of income of a country. The process of managing a country's demographic challenges is linked to the demand for raising productivity levels in the country, and to reach the EU average income

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levels productivity will need to grow by at least 4 per cent per year until 2050. Furthermore, the need for landscape transformation and valorisation will imply further analysis of the macroeconomic implications of climate change. It should be borne in mind that by distributing foreign funds evenly across economic sectors, up to 30 percent reduction in climate change damages could be optimised and citizens' welfare improved. In this regard, the more vulnerable regions should implement and develop plans and strategies to attract private investment, while making a significant effort to apply blended finance instruments more widely, as a changing climate represents not only a threat to economic activities, but also an opportunity to develop new business ventures and investments in modern technologies that respect and protect the environment. Definitely, we can note that a new approach is needed for the country in the implementation of the process of transformation and valorization of the landscape, in order to highlight the potential for value creation that will not only support regional economic expansion in lagging regions, but also stimulate the economic growth of the country in general. Such an approach should be linked to increasing the share of investment in 'smart' and innovative solutions. We must definitely conclude that the valorization of the landscape does not depend only on the horizontal actions by the involved stakeholders, but also on the undertaking of the vertical actions that must be directed to the processes of valorization from ecosystems to society [3].

3. FEATURES IN THE DEVELOPMENT OF LANDSCAPE VALORIZATION STRATEGIES.

Looking at the particularities of developing valorisation strategies for landscapes will need "in response to questions from policy makers, landscape economics provides answers largely inspired by theoretical models of reference in economics. The cost-benefit approach, acclaimed by public economic calculus, therefore finds a place in all the instruments of analysis suggested by landscape economics. However, in relation to the specificity of landscape, the many costs and/or benefits are non-market, heterogeneous and context specific. Valuation studies to validate the effectiveness of a project require the use of methods capable of reconstructing monetary indicators of these non-market costs or benefits. The economic valuation of landscapes is based on use and non-use values of visitors to their places of leisure, residents in living spaces and the entire population. The question of the value of the landscape emerges in particular when the changes affecting the space are perceived as threats by certainagents. This recognises the existence of a social demand for landscape through an active attitude of economic agents to projects with an impact on the landscape and the heterogeneity of perceptions and judgments on proposed projects [4]".

In this regard, given the climatic variability and in the context of determining the vulnerability of different regions of the country, changes in the hydromorphological regime and water flow of the water body should be monitored, as they may lead to the loss of repositories or loss of natural habitats, habitats of water-dependent species and species, which in turn will affect the valorization of the landscape, so that the strategies developed should reflect, respect and provide for policies and measures related to:

- "The expected deterioration of habitat;

- The expected loss or deterioration of protected natural habitats in or along the river channel;

- Alteration and destruction of river habitats, aquatic and coastal fauna;

- Habitat destruction and fragmentation; barrier effect of rivers types;

- Impact on fauna due to erratic river flow;

- Operation of the hydropower plant;

- Change in the ecological status of surface waters and associated ecosystems due to the effects of water withdrawals and barriers in rivers without established or well-functioning fish passages [5]" .

On the other hand, serious attention should be paid to the process of deforestation of water catchments, as this process leads to a number of changes in both the availability of water resources and the emergence of problems related to flooding and changes in water quality due to erosion processes in the catchment.

DISCUSSION

The existence of different approaches in the implementation of landscape valorization, as well as in the implementation of the process of planning and management of landscape transformation processes imply a number of difficulties and raise a number of questions related to the issues discussed and presented in this paper. Such as how the key indicators and indicators representing landscape transformation and valorisation are defined. In addition, a series of questions can be asked about the framework defining the advantages and disadvantages of landscape management plans and strategies. Using the cost-benefit method, what are the key indicators reflecting the financial projections in carrying out the current landscape valorisation assessment that can be used to identify potential growth opportunities in the study region.

CONCLUSION

In conclusion, it should be noted that in assessing the impact of spatial, economic and social transformation in the development of a valorisation strategy for the landscape, the implementation of cost-benefit analysis is central, despite the fact that there are many limitations such as the determination of discounting of future costs and benefits, discounting and future generations. Also a series of issues related to distribution, uncertainty and risk as well as irreversibility as factors that have a substantial impact on the development of regions. Cost-benefit analysis is seen as the main tool through which an economic evaluation of the implemented public programmes in the field of natural resource management as well as environmental protection is carried out. It is used in flood control, irrigation planning, and hydropower planning and alternative energy supply projects. The need to 'place a value on natural resources and environmental assets', both within the framework of sustainable development and in terms of realising the process of valorisation and transformation of the landscape, is necessary and useful as it assists:

- The national and regional income reporting process;

- Carrying out a strategic benefit-cost analysis;

- Carrying out a benefit-cost analysis at project level in a given region.

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By carrying out an assessment and comparison of environmental values, opportunities can be achieved to implement a change in the national income accounts to reflect both the improvements made and the reduced volume of natural and environmental resources.

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THE ROLE OF INVESMENT FOR THE DEVELOPMENT OF ENVIRONMENTAL ECONOMICS IN LATVIA

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ABSTRACT

One of the objectives of the research is to identify the factors influencing the implementation of environmental economics and green governance principles in Latvia. The study focuses on the strategic allocation, implementation and impact of investments, including EU structural funds, on environmental sustainability initiatives in Latvia. The research methodology includes theoretical concepts and research on the development of the environmental economics in the regions of Latvia. In order to achieve the objectives, the study was structured in several parts and carried out in different stages. The study is planned to be carried out over the period 2022-2025. This paper summarises the findings of the study, which explored possible financial solutions for the development of the environmental economics in the country using statistical data analysis, in-depth interviews and a survey method. In order to gain a deeper insight into the implementation of green governance principles and the factors contributing to the development of the environmental economy, data on the opinion and experience of entrepreneurs in attracting external financing, including EU funds for the development of the environmental economy, were researched and analysed. The study surveyed more than 100 entrepreneurs in both rural and urban areas, and obtained their perceptions of the factors influencing the development of the environmental economics. Data from interviews with municipal leaders were analysed to identify the development prospects of the territories and the factors influencing the implementation of green economy principles. The results of the study show that investment plays a key role in the development of the environmental economics and the implementation of green governance principles, and that attracting EU structural funds often plays a crucial role in the implementation of sustainable principles and the successful development of the environmental economics in Latvia. The data from the study will be used in the next stages of the study, where the development of the environmental economics and the implementation of green governance principles in all municipalities of the country will be studied and the data will be compared.

Keywords: environmental economics, green governance, sustainability, investments

INTRODUCTION

The environmental economics and green governance are a change in thinking about development and growth that can improve people's lives and the environment, while contributing to environmental and economic sustainability. [9] The role of

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environmental economics in the economic development of a modern country is immense. In order to understand the trends in environmental economics, it is necessary to understand that environmental economics is a sub-discipline of economics in modern economic theory that uses the analytical techniques of economic theory to study the efficiency of environmental resource use, taking into account the present and future costs and benefits of ecosystems, human well-being and biodiversity. Although environmental economics is one of the newest sub-fields of economics, it has developed rapidly since 2000. Green economy is a broad concept that has sparked debate among economists and environmentalists. [4] The green economy routinely uses energy to improve environmental performance while reducing climate risk. [8] Climate pressures and brain drain pose challenges for long-term growth and economic stability. As World Bank research indicates, this should make environmental economics and green thinking the foundation of national economic development and a strategy for achieving long-term development. The development of an environmental economy should promote innovation and the use of the latest technologies in all sectors of the economy, ensuring national competitiveness, growth and sustainable development. [10]

Environmental issues including global warming, drinking water quality, access to renewable energy, development of degraded areas, biodiversity conservation and other environmental development issues are becoming extremely pressing, and globalisation and increased global trade in commodities are further exacerbating the situation. While environmental challenges are more focused on reducing diffuse emissions from various sources, including roads, the sea, aviation and agriculture, diffuse pollution spreads over large regions. [9] In order to maintain ecological balance and at the same time ensure successful national economic development, public policies must be focused and open to stimulating an environmental economy that is geared towards sustainable development.

The implementation of the principles of environmental economics and green governance must become an integral part of national development efforts, which can contribute to economic development and improve people's lives while promoting environmental and social well-being. Promoting the development and implementation of sustainable technologies is an important component of the environmental economy strategy. [8] The overall aim of this paper is to analyse a number of challenges that are faced in implementing sustainable change and that need to be properly understood by policy makers and practitioners at different levels of society.

According to the OECD Global Report, five challenges are involved in the development of an environmental economy: a) the increasingly global environmental risks; b) the introduction of radical rather than incremental sustainable technological change; c) the availability of financing for the environmental economy and the uncertain business scenario; d) the role of government and the development of appropriate policies and financial support; e) the implementation of green and environmentally friendly governance principles at all levels. [5] Sustainable technological change requires a reassessment of the roles of the private sector and the state respectively, and that future research should increasingly address the challenges of identifying and implementing new combinations of policy instruments in different institutional contexts.

METHODS AND MATERIALS

The aim of this research is to identify and investigate the factors influencing the implementation of environmental economics and green governance principles in Latvian regions. This paper summarises the findings of in-depth interviews with public administration and local government leaders on possible solutions and availability of funding for the development of the environmental economics and the implementation of green governance principles in the country. In order to gain a deeper insight into the implementation of green governance principles and the factors contributing to the development of the environmental economy, research and analysis of data on the opinion and experience of entrepreneurs in attracting external funding, including EU funds for the implementation and development of the environmental economic principles in business was carried out. In total, more than 100 entrepreneurs in both rural and urban areas were surveyed and their perceptions of the factors influencing the development of the environmental economics were obtained. Data from interviews with municipal leaders were analysed to identify the development prospects of the territories and the factors influencing the implementation of green economy principles

The general data profile shows that Latvia has laws and regulations that provide for vertically and horizontally coordinated development planning documents for the period up to 2030. Latvia's Sustainable Development Strategy 2030 is the highest-level and longer-term development plan and is broadly in line with the sustainable development goals. [3] The Foreign Investment Climate Index survey indicates that more attention needs to be paid to investment security and attracting investment specifically to address environmental issues and stimulate the green economy. Foreign investors continue to make a significant contribution to the national budget, and with all the challenges ahead for Latvia, we need to look more at how we will also provide the necessary resources to implement our environmental economic plans. The EU's Green Deal objectives are at the top of this list, with a particular focus on energy independence and security of supply. The public, as well as investors, need to see concrete changes that can increase trust in public sector actors, including politicians. [7] It should also be noted that EU funding for environmental issues plays an important role in driving the country's green agenda and the development of the green economy as a whole.

Data show that in Latvia, direct EU Structural Fund investment for environmental protection and resource efficiency is available for the promotion of the environmental economy, amounting to EUR 1 million from the ERDF, CF, EAFRD and EMFF. [2] The ERDF is the most widely used, followed by the EAFRD and the CF in third place in terms of funding received, but the JNI Fund is the least used. The largest share of funding is devoted to promoting the competitiveness of SMEs, with funding of EUR 1.23 million from ERDF, EAFRD and EMFF, and to developing network infrastructure in transport, with funding of EUR 1.05 million from ERDF and CF. It can thus be concluded that EU funding currently represents more than 32% of the total EU funding.

The available external funding for the development of the environmental economics is substantial and the Ministry of Economy has repeatedly pointed out in its reports that without this funding, municipalities would have insufficient financial resources to address environmental development issues and this would not contribute to the achievement of the EU's objectives. [6] It is therefore important to study the factors influencing the development of the environmental economy and to seek the views of

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both municipal leaders as policy implementers and business leaders on issues hindering the development of the environmental economics.

RESEARCH RESULTS

In order to find out about the factors influencing the development of the environmental economy, the study carried out in-depth interviews with municipal leaders to find out about possible solutions and the availability of funding for the development of the environmental economics and the implementation of green governance principles in the country. As of 2022, there are 43 municipalities in Latvia (previously there were 119 municipalities) [1], but there are a number of municipalities where both urban and rural areas are under management. Initially, 86 municipalities at different levels were approached. The study involved interviews with 55 municipal managers from all regions of the country. All interviews were carried out individually and interview responses were coded.

The study asked Latvian municipal leaders in interviews to assess the government's current efforts to implement one of the key objectives of the European Green Deal strategy, the introduction of green governance principles in Latvia. The rating was to be given on a scale from 1 to 5, where "1" means failure, "3" - average and "5" - excellent. The municipal leaders gave a score of 2.3, which is a low score. (see Figure 1)

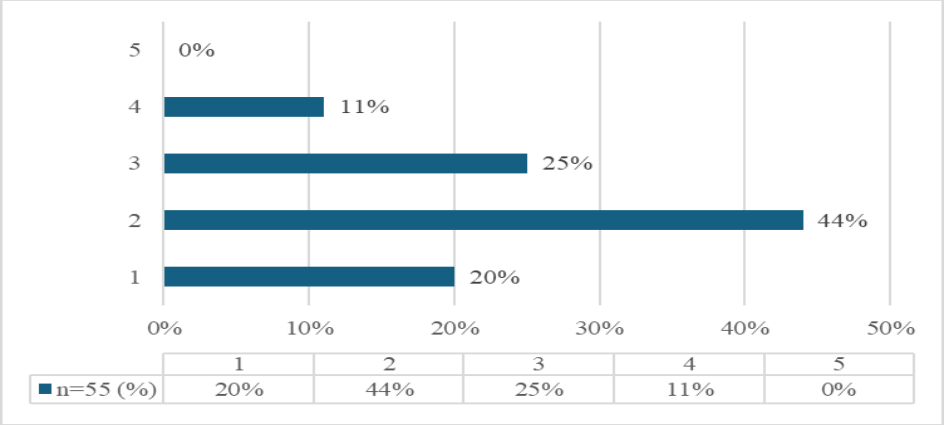


Figure 1. Implementation of green governance principles. (compiled by authors)

A significant number of municipal leaders (88%) who took part in the survey are also dissatisfied with the tax reform and the changes to the Green Deal legislation. Responses pointed to a lack of clarity about what it is and what will be done, a lack of a clear strategy, a lack of consistency in the decisions taken, a lack of progress in addressing the issue of the mandatory purchasing component (MPC), and a number of other decisions or policy initiatives to implement environmental economic issues.

Importantly, municipal leaders draw attention to the fact that there is a clear underfunding of the national budget to implement green governance principles in the country and to ensure the development of the environmental economics. All leaders pointed out that the introduction of the principles of the environmental economy and green governance is necessary to improve the attractiveness of Latvia for investment. Further analysis is needed on the use of all available investment in Latvia, provided by EU structural funds. Financial data show that, for various reasons, not all the allocated

funding is received and implemented accordingly for the development of environmental issues and the environmental economics.

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Municipal leaders were asked to identify the top priorities for implementing green governance principles and to identify at least 5 priorities per priority. Table 1 summarises the municipal leaders' assessment and the priorities identified. (see Table 1)

Table 1. Key priorities for developing an environmental economics and implementing green governance principles (compiled by athors)

No	Priority 1	Priority 2	Priority 3
1	Engaging investors to promote the green economy and the green deal	Develop incentives for advanced green technologies, and provide funding	Public sector education and financing
2	Plan for the implementation of green governance principles, ensuring continuity and finance	Define a strategy for the creation of infrastructure to promote the development of green energy companies (wind farms, solar energy, etc.)	Implementing green financing principles
3	Not to discontinue implementation of green governance principles due to financial difficulties	A strategy to curb major emitters by ensuring the rapid uptake of environmental economic principles	Investment and financial support for environmental research
4	Reducing bureaucratic obstacles	Unified and effective monitoring of the implementation of the principles of environmental economics and governance	Joint coordination of all activities related to the implementation of green governance principles
5	Clear laws on green transition to encourage investment and ensure stability	Data-based decisions and planned funding to implement the principles of the environmental strategy	Involving experts in decision-making

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Analysing the answers of municipal leaders, it can be observed that the lack of financial resources for the implementation of environmental issues and green governance principles is one of the most important factors. Asking respondents whether they think that attracting EU funding has become a leading influence factor in the development of the environmental economy in their municipality. 91% of the respondents indicated that EU funding is essential and that without EU funding available, the municipality would not be able to support entrepreneurs in implementing the principles of the environmental economy from its own resources. Municipalities would only be able to meet the minimum requirements for environmental issues from the budget allocated to them.

All the municipal leaders indicated that they were looking forward to attracting external investment in their municipalities to address environmental issues. The most important issues identified by the leaders were renewable energy issues such as solar parks, wind parks, transport networks and the use of environmentally friendly transport, cleaning up the road transport network and introducing environmentally friendly vehicles, and waste management. (see Figure 2)

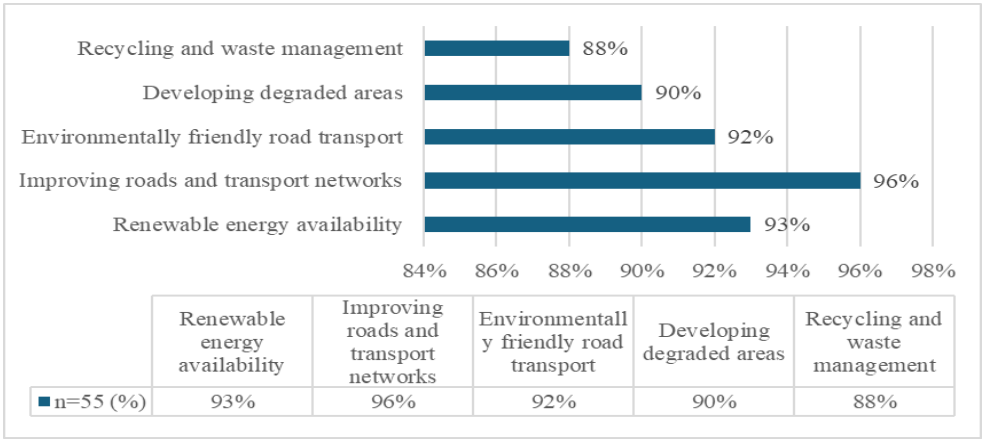


Figure 2. Attracting external investment (compiled by authors)

100 entrepreneurs from different sectors were surveyed to find out their views on opportunities for developing the environmental economics and attracting external funding. Entrepreneurs were asked whether they were aware of the availability of funding to address environmental issues in business. 67% of the respondents indicated that they were aware of EU Structural Fund projects, 30% said they had heard of but did not know what EU funds were and 3% indicated that they were not aware of the availability of EU Structural Fund funding for these purposes and had never enquired.

The survey asked how many companies have received financial support from an EU fund. 74 out of 100 respondents indicated that they had not received support. Only 26 companies indicated that they had received it. Most of the organisations surveyed have received support from the ERDF - 54% of all respondents. The second most used fund is the ESF, 27% of all those that have received some support. A further 12% of organisations received support from the CF, 4% from the EAFRD and 4% from the EMFF. Only 38% of the companies surveyed said that the purpose of receiving funding was also to address environmental issues. Only 1 business indicated that EU funding was received for the specific purpose of purchasing electric buses and 1 business indicated that the purpose of the funding was to address environmental issues.

All businesses indicated that they would have liked to have received support from EU funds to address environmental issues. When asked why they do not use external funding to implement environmental economic practices, entrepreneurs pointed to several factors - too much bureaucracy (88%), high EU criteria for funding (91%), companies not meeting the EU beneficiary criteria (96%), insufficient EU funding for environmental infrastructure projects (98%), insufficient EU funding for developing degraded areas for business purposes (89%). (see Figure 3)

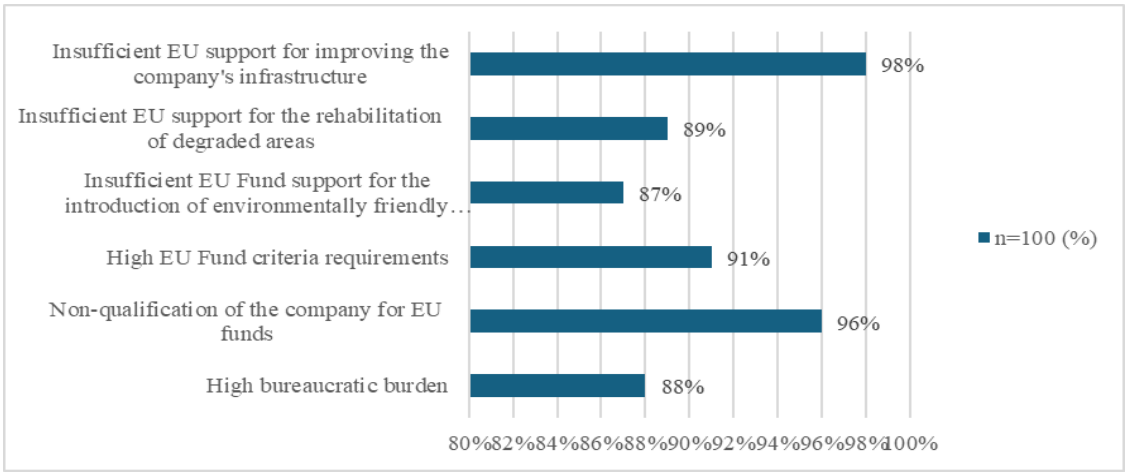


Figure 3. Factors hindering EU funding (compiled by authors)

Entrepreneurs noted that there is more soft than hard lines in the highly redundant EU funding for environmental issues. The business community would encourage funding for soft items, especially those related to the production of printed visual material and environmental education, to be channelled to the public sector and educational institutions. On these points, entrepreneurs, especially manufacturing companies, would prefer to be recipients of the service and not implementers. Entrepreneurs indicated that they would prefer to receive state-supported services to educate their employees on environmental education rather than to develop their own programmes and ensure access to qualified environmental specialists. They would recommend that this funding should be redistributed and that more EU funding should be channelled to companies to improve their infrastructure, e.g. energy efficiency, heating of buildings, use of environmentally friendly transport, management and recycling of industrial waste (especially construction waste), etc.

DISCUSSION

For Latvia, a country with a rich natural environment and significant environmental challenges, access to EU funds can play a crucial role in developing an environmental economy and promoting sustainable development. According to the Ministry of Finance, the development of the environmental economics and the Green Deal lack ambition. The country will need around €16 billion to implement this green transition. There is no clear policy on where this funding will come from and what tools will be used.

CONCLUSION

The survey shows that both municipalities and entrepreneurs consider the availability of finance to be a factor affecting the development of the environmental economics and the

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implementation of green governance principles. The entrepreneurs' survey shows that additional investment is needed to promote the green economy. The availability of EU funds could be one of the main sources of investment in business development in the region. Entrepreneurs expect to use EU funding to address environmental issues in order to improve their business infrastructure, e.g. energy efficiency, use of renewable energy, introduction of environmentally friendly vehicles. As barriers to the use of EU funding, entrepreneurs note that the criteria for using EU funds are too high for entrepreneurs, insufficient availability of funding for upgrading business infrastructure to modern requirements, and too much bureaucracy and paperwork. In addition, entrepreneurs point to the fragmentation of the objectives of EU funding and the mismatch with business objectives especially in the soft and hard headings. The conclusions of the interviews with municipal leaders indicate that municipalities are aware that without attracting external investment it would be impossible to introduce green governance principles and develop an environmental economy in the country. In particular, municipal leaders note the availability of EU funding. But additionally they point to the attraction of other investments, including private investments, especially for the implementation of renewable energy projects, such as wind farms and solar energy companies. Additional municipalities point to insufficient funding for the development of degraded areas. Environmental economics is key to promoting inclusive environmental sustainability and global adaptation to climate change within national and global economic structures. Environmental economics and green governance recognise that long-term economic growth and development depend on the efficient and responsible use and conservation of natural ecosystems so that they continue to provide resources essential for prosperity and the economy. The principles of the environmental economics approach minimise emissions of greenhouse gases, use resources efficiently and reduce or eliminate waste; it combats climate change and is based on sustainable development and green economic growth. The data from the research will be used and compared in the next stages of the research.

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THE ROLE OF SEARCH ENGINE OPTIMISATION IN CUSTOMER DECISION MAKING IN DIGITAL MARKETING FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

Search engine optimisation as a separate concept has not been researched extensively compared to other digital marketing tools in Latvia. The aim of this study is to analyse the decision-making process of custumers in the choice of services placed on the internet market for sustainable development. The study is planned to be carried out in five phases, analysing and structuring the offer of companies in different sectors and the choices made by consumers on websites. This article summarises data from the first phase of the study, which analysed companies in the tourism sector. The data reflects the offer of the tourism sector's green deal leisure and sports entrepreneurs on websites and consumer preferences for sustainable development services. The research methods have been chosen to gain insight and analyse the data on the availability of the offer of tourism enterprises on their websites for sustainable development. Using a case study approach, the study data is collected from consumer surveys. Expert interviews have been carried out to gather information on the understanding of business managers on the conditions of consumer decision-making processes for sustainable development. Search engine optimisation could be one of the most effective tools that entrepreneurs can use for sustainable business development and to encourage customers to make a decision on the choice of service. The data from this study will be used in the next stages of the study to compare consumer decision-making in the online marketplace for sustainable development across different sectors.

Keywords: sustainable development, customer decision-making, search engine optimisation, digital marketing, sustainable entrepreneurship

INTRODUCTION

Modern technology has created a unique opportunity for entrepreneurs to promote the sustainability of their businesses, thereby reducing their direct impact on the environment. The growth promotion strategy of the European Union lists a series of goals focused on increasing the competitiveness of environmental technologies and increasing Europe's innovative potential. Several of these goals can be directly and indirectly linked to the environmental dimension of sustainable development and the development of the digital business environment. [6] In recent years, digital marketing in general has been rapidly growing in importance for every company and is considered

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as one of the drivers of sustainable business. Marketing experts note that the internet has visibly changed the business world in recent years, making it possible to promote and sell products without intermediaries on any continent. The internet is like a big gorge, because people often search for something on it without knowing exactly where to find it, using search engines. Research shows that most of these consumers will visit sites that search engines show on the first page to make their decisions. So whether the goal is to sell something or simply to get more readers for a blog, if you need to attract visitors to a particular site, then you need website optimization. [2]

Search engine optimisation is considered one of the digital or internet marketing tools that aim to promote the sustainable development and competitiveness of a business. It is a process that is carried out with the aim of obtaining better positions in search engines. Website optimisation could be one of the most effective tools that companies can use to market their business on the Internet, increasing the number of visitors to their website and driving as many of them as possible to their desired destinations, influencing the sustainable development of the company. [2]

Optimisation can have a positive impact on the sustainability of a business by changing consumer behaviour and decision-making habits, noting that the website is the place where potential customers learn about a company's services or products and make a decision to buy a service. It is noted that the website needs to be developed in order to increase the number of customers and continuously influence customer decisions and contribute to the sustainable development of the business. Marketing researchers explain that nowadays, when people want to buy a product, the first place they look for it is often the internet, and the decision to buy is directly influenced by the information available about services and products. People use the internet to check and compare offers, find answers to questions they want to ask and make a decision about whether to buy a product or service. [8]

Today's digital marketing challenges and opportunities are based on the adoption of technology and changes in marketing efforts to build relationships and support consumer well-being. [3] The term "search engine optimisation" is in itself a way of saying that it is the optimisation or improvement of a website for search engines. The first search engine, Archie, was created in 1990. Today, these types of programmes are an integral part of the World Wide Web, designed to help Internet users find the information they want, based on the keywords they use, and make decisions about whether to buy or process further information. The studies explain that they are defined as tools that search the web for sites that match a real-time question, word or phrase entered by users, which we call keywords. Depending on the keyword used, search engines display a list of results called a search engine results page. [11]

Marketing experts explain that as the number of different websites and online documents increased, search engines realised the value of organic or unpaid results and started working to show users the best and most relevant sites. [10] Both Clarke and Sfetcu define search engine optimization as a process or set of methods aimed at improving a website's position in search engine results such as Yahoo, Google, etc. [2] [10] Although the experts' definition is clear and captures the essence of optimisation, it is arguably not precise enough because it does not include a very important thing - keywords. David Reske has given a more advanced definition, calling it the art and science of making a website look the way search engines such as Google, Bing, Yahoo,

etc. want it to look, so that it appears in as good a position as possible when searching for specific keywords that consumers use to make decisions. The first and foremost focus of search engines is to rank websites based on their content and keywords. [9] Search engines evaluate websites according to a specific algorithm. Most of the factors included in the algorithm are kept secret from the search engines. Search engines have created so-called 'spiders' or 'bots' that review all websites on the internet according to a specific algorithm and rank them in certain positions. [4]

Thinking about optimisation, it is important to realise that it is a time-consuming and continuous process due to the constant changes in the algorithm already mentioned. Researchers note that many people do not achieve their desired goal for this very reason, because they stop optimising their website soon enough without seeing significant results. Website optimisation is a long-term strategy that needs to be continuously refined for a business to benefit, as search engine algorithms change regularly and what worked well three months ago may not be as relevant now. One of the main advantages of search engine optimisation is that it reaches the target audience. Search engines show the website to users who are searching for keywords, so an optimised website reaches more potential customers, who can be more easily guided to conversion, or taking the desired action and making a decision.[2]

Website optimisation factors are divided into two groups, internal and external. Experts also distinguish between good website optimisation practices and bad ones. Goulas notes that it is very important to understand that both techniques can deliver results, but while one can improve a website's ranking and encourage more visitors and positive decisions, the other can lead to penalties from search engines, such as the suspension of indexation, which will also have a negative impact on the website's visitor traffic and therefore on the business as a whole. [5] Shenoy and Prabhu remind us that what matters in search engine optimization is not quantity, but quality, which positively influences consumer decision-making and loyalty, which undoubtedly results in a successful sustainable business. [11]

MATERIALS AND METHODS

This article summarises the data from the initial stage of the study, which analysed tourism event companies in Latvia, looking at what the companies offer and what consumers choose on their websites. The data reflects the analysis of the offer of the tourism sector's green course leisure and sports event organisation companies on the websites and the consumers' choice of services for sustainable development. The research methods have been chosen to gain insight and analyse the data on the accessibility of the companies' offer and sustainable development on the companies' websites. In the beginning of the study, the research hypothesis was that tourism companies in Latvia do not make sufficient use of the opportunities offered by search engine optimisation to facilitate the consumer decision-making process and, therefore, do not contribute to the sustainable development of the company. In order to find out the perception of the specialists of the tourism industry event organisation companies about the optimisation of websites for search engines and the optimisation potential, in the practical part of the study the established research methods were used and the website analysis, survey, expert interviews, as well as data processing and statistical data analysis and other methods were carried out.

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To find out the use of search engine optimisation of websites in event management companies in Latvia, a research design for website analysis was developed based on the analysis of scientific literature, as well as a questionnaire for a survey of managers of event management companies and an expert interview. The design for the website analysis was developed by the members of the research group, based on an analysis of the scientific literature, including the main optimisation conditions and factors. This website analysis allows us to look at trends in the optimisation of websites of event organisers in the Latvian tourism industry, reflecting not the possibilities of optimising the website, but assessing the influencing factors. Tourism managers were asked to fill in a questionnaire which included questions to determine both the use of search engine optimisation and the perception of the managers of event companies. As there is currently no accurate information available on the number of event organisers in Latvia, all 2085 enterprises [1] that have indicated NACE 93.2 code 'entertainment and recreation activities' as their activity type were considered for the survey. In order to obtain the survey data, a questionnaire was sent to all selected enterprises, inviting them to participate in the survey and to fill in the questionnaire. [7] The managers of the companies responsible for the website activities were asked to complete the questionnaire. The questionnaire was sent to the managers of the companies responsible for the website activities. Of all the companies selected, 83% (1731) completed the questionnaire. The questionnaire consisted of a total of 27 questions designed to gauge understanding of the use of search engines in business and their impact on business sustainability and consumer decision-making. To find out the potential of search engine optimisation activities in agencies, experts in search engine optimisation were interviewed. The criteria for the selection of the experts were at least 5 years of experience in website optimisation, as well as work experience in website optimisation in at least three different areas. The experts were asked questions to find out the main advantages and benefits of optimisation for consumer decision-making, as well as the potential of optimisation for sustainable development in tourism event organisers in Latvia. The data from the study are summarised from the surveys carried out. Additional expert interviews have been carried out to gather information on business managers' understanding of the consumer decision-making process and the conditions for sustainability.

RESEARCH RESULTS AND DISCUSSION

As mentioned before, in order to find out the perception of the managers of the companies about website optimisation and to investigate the use of optimisation, a survey of the managers of the event management companies was carried out. In addition, an in-depth analysis of the companies' websites was carried out. The survey included 27 questions. It was important to find out the location of companies by region. The majority of the company representatives who took part in the survey, or 81%, indicated that their company was located or based in the Riga region, 6% in the Kurzeme region, 5% in the Vidzeme and Latgale regions, and 3% in the Zemgale region. The high share of event organisers in the Riga region can be explained by the fact that it is very suitable for event organisers, as it is located in the central part of the country and has an international bus station and an international airport, which is a significant advantage. The possibility to provide services outside the location where the company is based, for example in other cities and even other countries, is one of the advantages of this type of company. 19% of the respondents indicated that their

company did not have a website, which immediately suggests that they do not use search engine optimisation and its possibilities. These companies participated in the survey but were excluded from the next stages of the study, where it is necessary to find out the use of search engine optimisation and its impact on consumer decision-making Most of the representatives (39%) who participated in the survey are from companies with more than 10 years of activity, 34% of respondents indicated that they work for an event organisation company with 2-5 years of activity. 16% of the respondents represent relatively young companies with less than 2 years of operation and 11% represent companies with 6-10 years of operation. (see Figure 1)

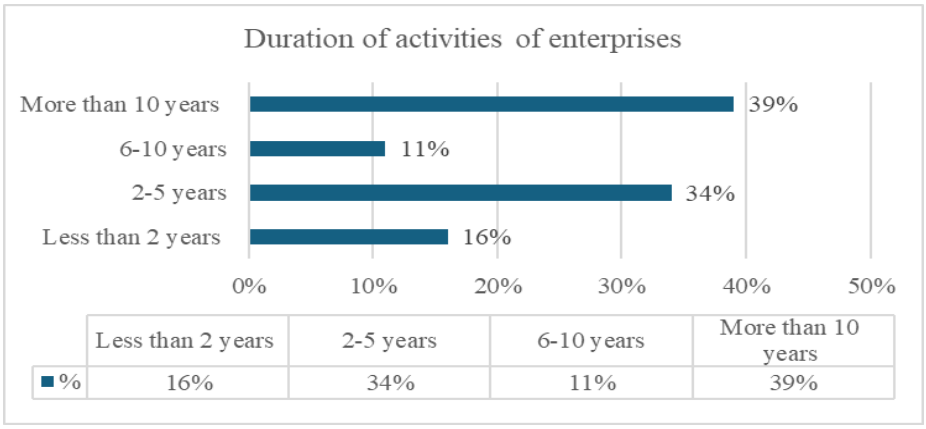


Figure 1. Duration of business activity (compiled by authors)

In summary, the survey results show that the most of the event management agencies surveyed do not have a good understanding of website optimisation. This is evidenced by the fact that some of the respondents honestly admitted that they did not know what search engine optimisation was, while a large proportion of those who indicated that they did know or partially knew it, did not know how to describe it or described it incorrectly. In a number of relatively simple questions, some respondents also chose "I cannot say", which also indicates a lack of understanding of optimisation-related issues. It should be noted that some respondents indicated that they did not know what terms such as robots.txt file and XML sitemap meant in relation to website optimisation. 51% of the respondents whose company has a website do not know what a robots.txt file is and 37% do not know what an XML sitemap is. The fact that some respondents said that keywords are considered when creating content for websites is also an indication of the lack of understanding among agency representatives, although 88% of respondents' company websites have too little content to successfully include keywords. Website optimisation was described more precisely by 20% of respondents, indicating that it is the process of improving a website in order to get better positions, or the process of making the information offered on a website easy to find on the internet. And this contributes to consumer decision-making. However, 33% of those who indicated that they knew or had some knowledge of what search engine optimisation was, were unable to define or describe it, saying that they could not say or had no opinion on what it was, while 13% described it as improving a website to make it easy for customers to use, which was considered to be inaccurate. This indicates that, overall, of all respondents whose companies have websites, only 18% understand the term 'search engine optimisation', while 29% understand it partially, knowing that keywords and content are

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important and have a direct impact on attracting customers and, consequently, on consumer decision-making.

As mentioned before, an in-depth analysis of the websites of the first five companies was also carried out to better understand the situation and assess the optimisation. The in-depth analysis was carried out on the websites of the companies that were first in Google search results for the sector-specific and one of the most searched keywords "event management company" at the time of the launch of the study. The analysis of these top five sites on the Google results page for this keyword also allows an understanding of the competition in the field in terms of search engine optimisation. In addition to the factors already discussed, the analysis of the websites using various specially developed tools also provided an opportunity to assess specific factors that cannot be determined simply by looking at the website superficially. The titles and descriptions of the five websites selected and analysed in depth, as well as the titles and descriptions of the internal pages, were assessed taking into account the recommendations of the experts in terms of their preferred length, content, use of keywords, etc. The names of the homepages of three of the five sites are classified as compliant with the recommendations and two as partially compliant, while the names of the homepages of four of the five sites are compliant with the recommendations and one is not. The descriptions on these sites are more likely to be non-compliant with the recommendations. The description of the homepage on one site is assessed as compliant and on four as partially compliant with the recommendations, while the descriptions of the homepages on three sites are not compliant, one partially compliant and one compliant (see Table 1)

Table 1. Analysis of websites according to recommendations (compiled by authors)

Criteria	Company 1	Company 2	Company 3	Company 4	Company 5
Website Name	In line with recommendations	In line with recommendations	Partially with recommendations	Partially with recommendations	In line with recommendations
Website Description	Partially with recommendations	Partially with recommendations	In line with recommendations	Partially with recommendations	Partially with recommendations
Page Titles	In line with recommendations	Not in line with recommendations	In line with recommendations	In line with recommendations	In line with recommendations
Page Descriptions	Not in line with recommendations	Not in line with recommendations	In line with recommendations	In line with recommendations	Not in line with recommendations
Header Usage	Not in line with recommendations	Not in line with recommendations	Not in line with recommendations	Not in line with recommendations	Partially with recommendations
Content Volume	Partially with recommendations	Not in line with recommendations	Not in line with recommendations	Not in line with recommendations	In line with recommendations
Content Originality	In line with recommendations	In line with recommendations	In line with recommendations	In line with recommendations	In line with recommendations
Keyword Usage	Partially with recommendations	Not in line with recommendations	Not in line with recommendations	Not in line with recommendations	Partially with recommendations
Link Quality	Not in line with recommendations	Not in line with recommendations	Partially with recommendations	Partially with recommendations	Partially with recommendations
Image Optimisation	Not in line with recommendations	Not in line with recommendations	Partially with recommendations	Partially with recommendations	Not in line with recommendations

The analysis also looked at other optimisation factors that have not been considered before, such as link quality, website speed, size, broken links, social media activity, domain authority and publications on the website. To explore the potential of using website optimisation for event organisation, three experts in search engine optimisation were interviewed who met the criteria, i.e. had at least five years of experience in optimisation and had worked on at least three company websites in different fields. The experts were initially asked what they considered to be the main advantages of search engine optimisation and what they considered to be the main benefits for companies or individuals whose websites had been optimised. According to the experts, the major advantage is that by ensuring that their website ranks well for the most searched keywords on Google, companies also ensure that they are visible and findable, contributing to consumer decision-making. Experts have pointed out that paid advertising does the opposite, as users who might be interested in a company's product are offered it wherever and whenever they can, rather than when they decide to search for it. Experts cite return on effort as an important advantage of optimisation. They explain that although it is not immediate and it takes time to achieve the desired results, if the most important optimisation work is stopped, the return will not stop completely and the optimised site will continue to generate new visitors, while for paid advertising the return depends on the advertising budget - as soon as the budget runs out, so does the return. As regards the potential for the development of search engine optimisation in Latvia, it is acknowledged that the relatively low competition is positive, but the difficulty is that Google's algorithm is not yet able to recognise and process content in Latvian as well as in other languages, such as English, which can cause difficulties in optimising content.

However, this is not impossible, but optimisation needs to be done with much less information about the keywords used by users. Experts pointed out that there are fewer sites in Latvia related to different fields from which inbound links can be obtained, which play an important role in the optimisation process. However, this can also be seen as a plus, because in this case, competitors will have few inbound links and will not need to acquire a large volume to achieve good positions. Experts point out that although the Latvian market is relatively small, it has the potential to develop website optimisation, as a very large number of internet users use the Google search engine to find the goods and services they want. Experts say that with the right and creative approach, and by following all the optimisation points, it is possible to achieve very good positions and also attract visitors in the long term. Experts cite the low search volume for certain long keywords as well as the seasonality of searches as a negative factor. A study of the results for keywords related to the sector shows that there is not much competition in this area, so it should be relatively easy to reach the first page with a well thought-out optimisation strategy. The experts' answers confirm the earlier work that search engine optimisation has various important advantages and benefits. An optimised website attracts new visitors and influences their decisions to purchase a particular product or service.

CONCLUSION

Website optimization could be one of the most effective tools that companies can use for sustainable business development and to influence customers in making decisions about service selection. To determine if the hypothesis proposed in the introduction is

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true, research methods such as scientific literature analysis, surveys, website analysis, interviews, as well as data processing and analysis methods were used. 83% of event organizing agency representatives from the contacted companies agreed to participate in the study. A challenge during the research was that the field of event organizing in Latvia has not been studied so far, hence the exact number of companies is unknown. In the study, more than 2000 different companies listed in the database, which indicated the NACE code 93.29 as their type of activity, were examined to estimate the approximate number of event organizing agencies and obtain contact information of their representatives, significantly prolonging the research process. To perform an analysis of various factors related to search engine optimization, the study utilized more than five different internet tools, each allowing the assessment of different factors. Overall, the initial stage of the research can be characterized as successful. The initial phase of the study was conducted within the planned time frame, and the objective of exploring the usage of website optimization for search engines in tourism companies in Latvia was achieved. Website optimization for search engines is defined as the process of enhancing websites to achieve better positions in search engine results when users search using relevant keywords. Website optimization for search engines is significant because statistics show that in the world's most popular search engine, Google, used by 96% of internet users in Latvia, more than 8 billion searches are performed daily, and 75% of searchers only look at results on the first page. Therefore, websites that are not easily found in search engines lose potential customers, which can negatively impact the development of a company or individual. Surveys and website analysis results reflect that only a few optimization factors on event organizing companies' websites are positively rated – originality of content and the presence of mobile versions of websites. Other factors are evaluated more negatively, such as insufficient content volume, image optimization, website security, speed, and keyword usage. This not only negatively affects website optimization but also influences user decision-making. Most surveyed event organizing company managers lack understanding of the concept of website optimization for search engines and the associated factors. From the perspective of event organizing companies, there is weak competition in website optimization for search engines, meaning that companies not currently easily found on the first page of Google for industry-leading keywords may have relatively faster, cheaper, and easier opportunities to optimize their websites and appear there compared to companies or individuals operating in areas where websites are already well-optimized.

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THE ROLE OF SOCIETY IN ENVIRONMENTAL AUDITING

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ABSTRACT

In the goal of environmental sustainability, society's essential role in conducting environmental audits emerges as critical. This abstract investigates the multiple significance of society involvement while reading environmental audits. To begin, societal scrutiny serves as a powerful force for accountability, ensuring that stakeholders are held accountable for environmental deterioration. Concurrently, by looking into audit reports, society obtains essential insights into environmental concerns, cultivating a collective awareness of sustainable practices. Furthermore, societal engagement acts as a catalyst for lobbying, accelerating calls for legislative reform and corporate responsibility. The distribution of audit findings educates the public, promoting informed decision-making and increasing environmental literacy. Also, societal participation in audit processes encourages openness and inclusivity, raising the voices of communities affected by environmental degradation. Thus, society's active participation in reading environmental audits is critical for designing a sustainable future by promoting accountability, advocacy, awareness, education, and inclusive environmental governance.

Keywords: environmental audit, nonfinancial information, ESG audit

INTRODUCTION

The activity known as environmental auditing holds substantial importance in the evaluation and enhancement of an entity's environmental influence. This involves a methodical assessment of organizational activities and routines to pinpoint possible environmental hazards and pathways for enhancement. By carrying out environmental audits, entities can assure adherence to regulatory stipulations, mitigate ecological impacts, and improve sustainability metrics. Additionally, society emerges as a pivotal stakeholder within the context of environmental auditing. Public anticipations and priorities bear upon how companies handle their environmental duties. As societal alertness and apprehension regarding environmental matters amplify, entities find themselves with mounting obligations to validate their dedication to sustainability. Consequently, societal attitudes can compel organizations to perform more exhaustive environmental audits and enforce more rigorous environmental governance practices. The symbiotic relationship between society and environmental auditing is crucial for fostering ecological stewardship and sustainable advancement.

The realm of environmental auditing serves an important function in evaluating, managing, and enhancing the environmental performance of entities and industries. It entails a rigorous examination of operations, methodologies, and activities to ensure adherence to environmental laws and sustainability criteria. Yet, the scope of environmental auditing surpasses mere regulatory compliance; it also embraces proactive initiatives to avert environmental damage and foster prudent use of natural resources. To thoroughly grasp the importance of environmental auditing in a societal context, comprehension of its fundamental concept and consequences is necessary.

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Content: Environmental auditing, as indicated by [1], entails assessing the repercussions of economic undertakings on the environment and pinpointing opportunities for enhancement in land use planning. This evaluation not only scrutinizes prevailing practices but also aids in formulating strategies for future sustainable growth. Additionally, the involvement of society in environmental auditing, stressed in [2], highlights the necessity for greater participation of allied health experts in endorsing environmentally friendly practices within medical frameworks. These observations highlight the extensive applications of environmental auditing beyond conventional limitations, signifying a wider societal impact on environmental conservation and resource regulation. Scrutinizing the varied facets of environmental auditing and its link with societal duties, a comprehensive insight surfaces regarding the interrelation of environmental stability and societal welfare. Integrating various fields, such as allied health professions, into environmental auditing unveils avenues for novel solutions to tackle intricate environmental and social issues. The findings from this scrutiny can guide policy formulation, educational curriculum, and community involvement schemes aimed at nurturing a more sustainable and robust society. Conclusion: In summation, the definition of environmental auditing goes beyond simple regulatory surveillance to include foresighted actions that aid in sustainable development and eco-conservation. The involvement of society in environmental auditing is pivotal in cultivating a shared responsibility for environmental management and supporting sustainable methodologies across numerous sectors. By utilizing the perspectives offered by diverse fields and adopting collaborative strategies, society can effectively confront environmental dilemmas and work towards a more sustainable tomorrow. Through relentless assessment, modification, and adoption of exemplary practices, environmental auditing can act as a driving force for beneficial societal and environmental transformation.

1. Society's influence on environmental auditing

In exploring society’s involvement in environmental auditing, it becomes evident that societal demands and consciousness significantly influence audit practices and results. As revealed in the study mentioned [3], the rising importance of environmental, social, and governance (ESG) factors in corporate performance has pressured auditors to take these into account when forming opinion decisions. The study illustrates that auditors are more inclined to give unmodified opinions to companies showcasing superior ESG performance, signifying a rise in the acknowledgement of sustainability’s significance in financial reporting. Moreover, the urgency to tackle climate disruption and achieve sustainability, accentuated by the IPCC report mentioned in [4], further stresses the need for auditing practices to resonate with societal concerns and environmental mandates. Society's demand for sustainable methods and accountability is, hence, propelling auditors to factor in ESG considerations within their evaluations, showcasing the changing impact of societal norms on environmental auditing methodologies.

In the domain of environmental auditing, the roles of public cognizance and societal pressure are pivotal in instigating change and ensuring accountability. As the general populace gains greater understanding of environmental concerns and the ramifications of negligent corporate behaviors, a concomitant rise in the call for transparency and ecologically sound practices is observed. This augmentation in awareness often triggers societal pressure upon corporations to comply with environmental statutes and moral guidelines. For instance, consumer boycotts or protests against environmentally detrimental activities necessitate that companies reassess their operational

methodologies to preserve their status and market presence. Moreover, heightened public examination can incite regulatory bodies to impose more stringent environmental regulations and to enforce compliance among offenders. Consequently, public awareness and societal pressure are fundamental in advancing corporate responsibility and cultivating a milieu of environmental guardianship. As the populace continues to emphasize sustainability and principled business conduct, firms will be driven to respond to these expectations to sustain their competitiveness and social accountability.

As societal awareness regarding environmental challenges escalates, advocacy collectives along with non-governmental organizations (NGOs) assume an integral function in urging transformations and compelling both governmental entities and corporate bodies to uphold their responsibilities. These entities operate as the populace's voice, championing regulations and practices conducive to sustainability while safeguarding natural resources. Through conduits like research, education initiatives, and grassroots mobilization, advocacy collectives and NGOs augment consciousness about environmental concerns and galvanize community action. Illustratively, entities such as Greenpeace and the Sierra Club have been pivotal in molding public sentiment and swaying policy determinations pertinent to climate change and contamination. By forging alliances with scientists, policymakers, and assorted stakeholders, these collectives are proficient at effectuating substantive change and fostering a sustainably-oriented future for the collective populace. Nonetheless, impediments persist concerning monetary support, public endorsement, and political antagonism, underscoring the necessity for ongoing advocacy undertakings within the ambit of environmental assessment.

Society functions importantly in influencing environmental auditing practices via several approaches, notably government regulations. As entities endeavor to incorporate societal questions into their processes, the notion of corporate social responsibility (CSR) has ascended in recognition. The repercussions of CSR on financial outcomes and company value remains a current subject of discussion. This essay explores the link between CSR, corporate performance, and the influence of government regulations on environmental auditing. Content: The scrutiny of the relationship between CSR and financial outcomes must contemplate the regulatory context within which organizations function. Government rules substantially inform corporate actions concerning environmental duties [5]. The regulations' bearing on company performance and value can be profound, emphasizing the necessity for firms to synchronize their activities with societal norms . By observing CSR tenets and adhering to regulatory demands, enterprises can boost their standing and minimize hazards linked to environmental wrongdoing. Results: The interaction among CSR, government mandates, and financial performance highlights the intricate dynamics inherent in environmental auditing. Firms that emphasize CSR efforts while conforming to regulatory structures may gain in esteem and durability. Nonetheless, the link between CSR and firm value might differ based on variables such as industry landscape and stakeholder anticipations. Government rules act as a controlling framework that shapes organizational conduct and impacts the effectiveness of environmental auditing methods.

2. Challenges Faced by Society in Environmental Auditing

Within the domain of environmental auditing, society presently grapples with challenges that are complex and require ingenious solutions. The utilization of Business

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Analytics (BA) in the assessment of environmental performance proffers critical insights and assists in the deliberative processes. By implementing BA methodologies, organizations can ameliorate data integrity, contend with convoluted issues, and exploit technological progressions to enhance the outcomes of environmental auditing. Nevertheless, the integration of such technologies requires cautious evaluation of elements such as upper management endorsement, organizational preparedness, and external assistance, which is underscored in [6]. Furthermore, societal imperatives for diversity and inclusion permeate into marketing practices, underscoring the significance of responsible consumption and production, as mentioned [7]. As entities maneuver through the dynamic sphere of environmental auditing, they must conform to societal aspirations for inclusivity, sustainable operations, and ethical behavior to advance environmental stewardship and responsibility. Integrating these societal requisites into environmental auditing protocols can engender more rigorous and transparent evaluations, thereby supporting a comprehensive strategy toward sustainability and corporate uprightness.

Environmental auditing holds significant importance in evaluating the repercussions of human undertakings are often disregarded. Furthermore, public involvement can contribute to the environment. Nonetheless, a prominent impediment encountered in this undertaking is the deficiency of public involvement. In the absence of active public participation, the efficacy of environmental audits can be markedly diminished. Public engagement stands as a crucial factor for accumulating local expertise, pinpointing environmental concerns, and executing sustainable resolutions. When communities are not actively involved in the auditing process, vital insights and viewpoints accountable of organizations and policy-makers regarding their environmental actions. (Great Britain: Parliament: House of Commons: Environmental Audit Committee, 2010-03-25) To tackle the issue of insufficient public engagement in environmental auditing, it becomes crucial to foster awareness, disseminate accessible information, and establish avenues for substantial participation. By incorporating the public into environmental auditing processes, we can bolster transparency, and accountability, and ultimately strive towards a more sustainable future.

Within the contemporary realm of environmental auditing, a significant issue necessitating attention is the widespread occurrence of greenwashing and misinformation. The term greenwashing denotes the deceptive act of promoting a product or entity as eco-friendly despite its non-compliance with such standards. This deceitful information may prompt consumers to make choices predicated on erroneous assertions, thereby exacerbating the lack of accountability observed among enterprises. Consequently, the trustworthiness of environmental audits is compromised, and the efficacy of sustainability programs is brought into doubt. Misinformation, intentional or otherwise, exacerbates this predicament by obfuscating the populace’s comprehension of environmental challenges and remedies. To surmount these obstacles, it is essential for auditors to meticulously authenticate the environmental assertions put forth by corporations and to inform the general public on differentiating between authentic sustainability initiatives and greenwashing strategies [8]. Promoting transparency and accountability, environmental audits can thus play an instrumental role in alleviating the detrimental repercussions of greenwashing and misinformation within society.

Within the scope of environmental auditing, the notion of limited resources presents a notable obstacle to auditors alongside society broadly. As referenced in [9], the

involvement of Panchayat Raj Institutions (PRIs) in poverty reduction in Karnataka, India, encounters obstructions such as corruption and unawareness, problems amplified due to constrained resources. Additionally, accentuates the significance of financial accounting and reporting in the proficient administration of resources, particularly amidst economic volatility. Understanding the ways in which limited resources affect environmental auditing practices is fundamental to tackling sustainability issues and fostering responsible resource stewardship.

Confronting the problem of limited resources in the field of environmental auditing necessitates an all-encompassing strategy encompassing methods from multiple disciplines, as indicated in [10]. The hurdles faced by PRIs in poverty alleviation schemes, including corruption and insufficient capacity, parallel the intricacies encountered in environmental audits wherein the accurate collection and analysis of data are pivotal. Likewise, the financial management principles outlined in highlight the necessity for efficacious resource allocation and utilization within environmental auditing processes to maintain transparency and accountability.

Upon amalgamating the insights from (Ramya Krishnappa et al., 2023) and , it becomes clear that addressing the challenge of limited resources in environmental auditing demands a varied approach. Implementing strategies to boost transparency, accountability, and community engagement, as proposed in (Ramya Krishnappa et al., 2023), can aid in diminishing the influence of resource constraints on audit effectiveness. Furthermore, adopting financial accounting and reporting methodologies, as explored in , can assist auditors in optimizing the use of resources and promoting sustainable practices within the environmental auditing sphere.

Within the purview of environmental auditing, political interference is found to present a substantive challenge to both the integrity and efficacy of the process. Often, individuals in government positions or involved in policy-making may attempt to manipulate the results of these audits for political benefit, either by pressuring auditors to modify findings or by deliberately withholding essential information. This form of interference is liable to undermine the credibility of audit reports and obstruct endeavors directed at confronting environmental matters in a manner marked by transparency and objectivity. Notably, certain studies have indicated that political interference in the realm of environmental auditing can result in insufficient enforcement of regulations as well as deficient monitoring of environmental repercussions. Consequently, the health and well-being of various communities, alongside ecosystems, may be jeopardized. It is imperative for auditors, to resist such political interference, retain their independence and adhere to stringent standards of professionalism and ethical behavior. Solely through the adherence to these principles can environmental audits effectively fulfill their essential function of fostering sustainability and accountability within society [11].

In concordance with the swiftness of technological progression in contemporary society, the domain of environmental auditing has witnessed considerable transformation. Such progressions have facilitated the enhancement of precision in data accumulation, scrutiny, and continuous observation of environmental determinants. For instance, the deployment of unmanned aerial vehicles outfitted with advanced sensor systems can yield granular insights concerning atmospheric quality and terrestrial utilization patterns. Furthermore, the strides in artificial intelligence have fostered the generation of more precise prognostications about environmental trajectories and prospective

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hazards. These technological contrivances not only augment the efficiency of the auditing protocol but also render a more exhaustive comprehension of ecological concerns. Consequently, enterprises and institutions are empowered to undertake decisions that are more judicious concerning their ecological practices and regulatory frameworks, consequently engendering an elevation in environmental custodianship [12]. To conclude, it is evident that technological advancements constitute a pivotal influence in enhancing the efficacy of environmental auditing and in advocating for sustainable practices within the societal sphere.

MATERIALS AND METHODS

Environmental auditing is a complex and multifaceted process that requires a systematic approach to assess the environmental impact of corporate activities [13]. The methodology typically involves a series of steps, including data collection, impact assessment, and reporting. Data collection involves gathering relevant information on the organization's resource consumption, waste generation, and other environmental metrics. Impact assessment then analyzes this data to identify the organization's environmental footprint and pinpoint areas for improvement [14]. The final step involves reporting the audit findings, which can serve as a basis for stakeholder engagement, policy development, and sustainability initiatives. Throughout this process, the active involvement of society is crucial, as it promotes accountability, fosters awareness, and catalyzes advocacy for environmental protection.

RESULTS

The effective integration of societal involvement and technological advancements can play a crucial role in enhancing the efficacy of environmental auditing. By broadening the inputs and opening up the outputs of the impact assessment process, environmental audits can become more inclusive and transparent, amplifying the voices of affected communities and promoting informed decision-making [15].

The incorporation of big data analytics, remote sensing technologies, and other digital tools can improve the veracity and timeliness of environmental audits, providing more robust and up-to-date information to guide sustainability initiatives. Furthermore, the development of standardized reporting frameworks and the mitigation of greenwashing can strengthen the credibility of environmental audits, ensuring that stakeholders and the public can trust the findings and use them to drive meaningful change.

DISCUSSION

The investigation into environmental auditing reveals its crucial role in enhancing sustainability and environmental stewardship. The findings support the hypothesis that integrating societal involvement and advanced technologies significantly improves the efficacy of environmental audits. Public awareness and pressure compel organizations to adhere to stricter environmental standards, while technologies like big data analytics and remote sensing enhance audit precision and timeliness.

To address these challenges, the study suggests increasing public engagement, developing standardized reporting frameworks, optimizing resource use, integrating advanced technologies, and ensuring auditor independence. By adopting a multi-disciplinary and inclusive approach, environmental auditing can effectively promote sustainability and drive meaningful societal and environmental transformations.

CONCLUSION

Environmental auditing remains pivotal in scrutinizing and enhancing the sustainability protocols within organizations. The involvement of society in the realm of environmental auditing proves essential in guaranteeing transparency, accountability, and the comprehensive efficacy of environmental management systems. By delving into the societal engagement's effect on environmental audit endeavors, invaluable perspectives can be derived, illustrating how stakeholders can contribute towards fostering environmentally responsible organizational practices.

The conversation on society's role in environmental auditing accentuates the significance of stakeholder engagement and transparency in the advocacy of sustainable practices. By weaving societal insights into environmental audit structures, organizations can foster enhanced environmental performance and accountability. The referenced studies provide critical perspectives on societal engagement's impact on environmental auditing, accentuating the necessity for a comprehensive approach that considers environmental, social, political, and economic facets. Ultimately, society's proactive participation in environmental auditing stands crucial in propelling positive strides toward a sustainable future.

In the context of contemplating society's role in environmental auditing, noticeable insights surface from the confluence of accountability, education, and action. Primarily, society's involvement is pivotal in ensuring that businesses and governments remain accountable for their environmental repercussions. Public pressure and heightened awareness among stakeholders can lead to demands for transparency and adherence to environmental regulations. Furthermore, education assumes a critical role in enabling individuals to make knowledgeable choices about their consumption habits and environmental conduct. Enhancing awareness about sustainability challenges can stimulate societal demand for environmentally friendly practices and commodities. Additionally, societal actions such as endorsing sustainable enterprises and engaging in environmental initiatives can generate a cascading effect that potentially influences policy and industry norms. Through proactive participation in environmental auditing processes, society plays a part in fostering a more sustainable and accountable future for everyone. Collectively, society’s engagement in environmental auditing is multifaceted, necessitating a unified effort to achieve significant progress.

In the current swiftly evolving world, the exigency for escalated societal involvement in environmental auditing has scarcely been more critical. Communities globally are confronted by the tribulations of climatic alterations, contamination, and ecosystem obliteration; hence, a compelling necessity arises for individuals to undertake an active role in preserving the planet for posterity. Engagement in local cleansing endeavors, endorsing eco-friendly initiatives, and promoting sustainable methodologies are avenues through which citizens can exert a palpable influence on environmental wellness. Empirical evidence has substantiated that when individuals foster a sense of connectivity to their community and the encompassing natural milieu, the propensity to engage in protective activities is heightened (Hugh Barton et al., 2014-01-14). Via concerted endeavors and a communal dedication to environmental custodianship, progression towards a more enduring future for the entirety can be actualized. The juncture has arrived for society to amalgamate and heed the summons for amplified participation in environmental auditing.

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THE ROLE OF WORKPLACE DIGITIZATION IN ACHIEVING SUSTAINABILITY

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ABSTRACT

Using data from the Eurostat datasets on employee computer and internet use (ISOC_CI_CM_PN2, measured as a percentage of total employment) and resource productivity (ENV_AC_RP, measured in Euro per kilogram) across the European Union between 2014 and 2022, this paper investigates the potential effects of these technologies on sustainability efforts within companies. Using the economic value produced per kilogram of material used as a proxy for resource utilization efficiency, the study seeks to establish a relationship between the level of technology use in operations and resource utilization efficiency. Through an analysis of these connections, the study aims to highlight how workplace digitization and resource efficiency as a strategic priority might support the larger goals of sustainable development. It specifically looks into whether an improvement in resource productivity is correlated with a higher rate of employee adoption of digital tools, implying that digital technology can lead to more environmentally friendly business practices. The results are anticipated to show that businesses who embrace digitalization and place a high priority on resource efficiency not only increase their economic performance but also their sustainability profile, underscoring the dual advantages of these approaches.

Keywords: sustainability; environmental responsibility; resource efficiency; workplace digitization; technology.

INTRODUCTION

In the contemporary interconnected business landscape, the significance of sustainable practices is gaining traction both in academic discourse and across various industries. Corporations are increasingly relying on technological advancements to integrate sustainability into their strategies, driven by escalating concerns about environmental deterioration and dwindling resources. Among these innovations, workplace digitization emerges as a prominent solution, offering a feasible route to achieve economic objectives while addressing environmental challenges.

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This paper seeks to explore the relationship between workplace digitization and sustainability, particularly focusing on how the integration of digital technologies can lead to enhanced resource productivity.

The recognition of Sustainable Development Goals (SDGs) as drivers of economic transformation alongside their social importance has prompted this investigation. Recognizing the significance of digital tools in achieving sustainable outcomes is essential for shaping future policies and business strategies, particularly for the European Union, a leader in environmental advocacy.

This study, therefore, investigates the potential of workplace digitization to improve resource utilization efficiency, using data from the Eurostat datasets on employee computer and internet use and resource productivity across the European Union from 2014 to 2022. This study highlights the complex relationship between digital adoption and resource productivity. It accomplishes this by calculating the economic value of materials produced per kilogram, which serves as a proxy for resource efficiency.

The hypothesis is that higher levels of digital tool adoption in workplace operations correlate with improved resource efficiency, suggesting that digitalization could be a key lever for businesses to enhance both their sustainability profiles and economic performance.

In addition, it is expected that the findings will be of value to both companies and governments interested in understanding the relationship between technological progress and sustainability goals. From this perspective, this study aims to identify the complex relationships between the use of technology and sustainable business models and improve our understanding of how technology can contribute to sustainable improvement.

WORKPLACE DIGITIZATION AND SUSTAINABILITY

Organizational sustainability goals can be significantly advanced through the use of digital technologies in the workplace. By allowing for remote work and decreasing resource consumption, recent studies show how digitization helps with environmental sustainability. In Poland, Bartosz Orzeł and R. Wolniak [1] investigated the effects of remote labor made possible by digitalization in the design and construction sectors. They discovered that because remote work is flexible and reduces electricity use and commuter emissions, both owners and employees favor it. However, despite these advantages, legal barriers and challenges in client collaboration persist as obstacles.

A. Kuzior, Karolina Kettler, and Ł. Rąb [2] investigated the long-term impact of digitization on human resources procedures at a Berlin-based IT company. They show that digital processes and organizational sustainability are positively correlated, with advantages including lower CO2 emissions and more diversity in the workplace.

In their study, Xu, She, and Liu [3] demonstrate the application of smart systems and big data in addressing sustainability issues. Their aim is to foster discussions and aid in the realization of sustainable development goals. They highlight the potential of digital technology in enhancing public welfare initiatives and promoting environmental sustainability.

V. Parida, D. Sjödin, and W. Reim [4] address how digitalization needs to be accompanied by business model innovation in order to fully realize its sustainability

potential. While digital technology enhances creativity and efficiency, realizing its full benefits requires aligning it strategically with sustainable business practices.

According to research conducted by Accenture [5], European businesses that adopt the strategy of becoming "Twin Transformers," integrating digital technologies with environmental goals, are positioned to gain a competitive advantage. These businesses are regarded as pioneers in using digital technology to improve sustainability practices, which are becoming more and more acknowledged to be both a social need and a commercial opportunity. Such revolutionary tactics aren't being used as widely as they could be, though, suggesting a mismatch between promise and real-world application.

THE IMPACT OF DIGITAL TOOLS ON RESOURCE PRODUCTIVITY

Sandra E. Black and L. Lynch [6] studied IT use and business productivity in 1997. Their research shows that digital technologies, human capital, and modern workplace practices boost American company productivity. Employee productivity rises in incentive-based pay and collaborative decision-making environments.

J. Nagy, J. Oláh, Edina-Timea Erdei, D. Máté, and J. Popp [7] examined how Industry 4.0 technologies like the Internet of Things (IoT) affect Hungarian businesses' business strategies in 2018. Digital tools throughout a company's value chain improve logistical service, efficiency, and market competitiveness, according to research. Comprehensive digital integration improves resource production and economic sustainability.

In 2022, Shen, Tao, and Song [8] examine how digitization affects Chinese worker productivity. They find that digital expansion boosts labor productivity mostly through human capital improvements. Their findings suggest that digitalization's productivity benefits increase nonlinearly with its advancement.

Philipp Klimant, H. Koriath, Marco Schumann, and S. Winkler [9] study machine tools and forming in 2021. Digitalization creates sustainable machine tools by reducing lifecycle resource consumption in manufacturing, according to their study. They demonstrate using a single method that digital technologies improve data management and predictive maintenance in smart factories, resulting in resource efficiency.

T. Marion and S. Fixson [10] examine how digital technologies affect product development. Digitization accelerates and improves innovation quality and changes job roles, collaboration, and organizational structure. They stress that knowledge management has moved from being beneficial to essential for competitive advantage. Transformation leads to a more comprehensive innovation strategy with efficient resources.

Ludivine Martin, Laetitia Hauret, and Chantal Fuhrer [11] examined how digitally enhanced home offices affected employee productivity during the 2022 COVID-19 lockdowns. Although digital collaboration tools can boost productivity, their research shows that they often lower job satisfaction. The study notes that these tools can increase productivity, but information overload and workplace stress must be considered.

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METHODOLOGY

Data is selected by taking in consideration the best variables that represent the use of computers and the internet by employees and the resource productivity. In this perspective, recent studies in the field used few common variables that best represent use of computers and the internet by employees, from which we have proposed the percentage of total employment that make use of computers and the internet, data taken from Eurostat, and being representative for 34 countries. For the resource productivity, we have considered resource productivity in euro per kilogram. We know, in theory, that the usage of computers and the internet by employees may boost the resource productivity at company level, thus we are arguing if this is applied also to the national level. For that we are proposing the next hypothesis:

H1: The level of usage of computers and internet can predict the level of resource productivity.

The statistical approach started by exposing the data description indicators, such as maximum value, minimum value, medium value, kurtosis and skewness. Afterwords, graphics with the data were plotted. The Augmented Dickey-Fuller test for stationarity was applied, along with tests for heteroskedasticity. In order to test the hypothesis, many types of regressions were performed, using ordinary least square method (OLS), with an α of .05

RESULTS

In table 1, the descriptive statistics are presented, and it can be observed that the mean value for the computers and internet usage is 45.93%, while the maximum usage for the computers and internet usage is 100%.

Table 1. Descriptive statistics of computer and internet usage and resource productivity

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Use of computers and the internet by employees by size class of enterprise as Percentage of total employment	324	.0000	100.0000	45.934259	20.4901932
Resource productivity in Euro per kilogram	324	.0000	5.4385	1.652589	1.2489857
Valid N (listwise)	324				

The correlation matrix

The results of the Pearson correlation matrix show us a positive, and significant correlation among the computers and internet usage and the resource productivity, as shown in table 2.

Table 2. Correlational matrix of computer and internet usage and resource productivity

Correlations

		Use of computers and the internet by employees by size class of enterprise as Percentage of total employment	Resource productivity in Euro per kilogram
Use of computers and the internet by employees by size class of enterprise as Percentage of total employment	Pearson Correlation	1	.446**
	Sig. (2-tailed)		.000
	N	324	324
Resource productivity in Euro per kilogram	Pearson Correlation	.446**	1
	Sig. (2-tailed)	.000	
	N	324	324

**. Correlation is significant at the 0.01 level (2-tailed).

Unit root test

We have performed the unit root test for the resource productivity, using the Augmented Dickey-Fuller procedure.

Table 3. Unit root test of resource productivity

Null Hypothesis: RESOURCE_PRODUCTIVITY_IN_EURO_PER_KILOGRAM has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.549747	0.0000
Test critical values:	1% level	-3.450553	
	5% level	-2.870330	
	10% level	-2.571523	

The results in table 3 show that the p-value is lower than the significance value, thus we adopt the alternative hypothesis and the series in stationary.

Secondly, we tested the use of computers and internet, for unit roots, using the Augmented Dickey-Fuller procedure.

Table 4. Unit root test of computer and internet usage

Null Hypothesis:
USE_OF_COMPUTERS_AND_THE_INTERNET_BY_EMPLOYEES_BY_SIZE_CLASS_OF has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.259279	0.0000
Test critical values:	1% level	-3.450617	
	5% level	-2.870359	
	10% level	-2.571538	

The results in table 4 show that the p-value is lower than the significance value, thus we adopt the alternative hypothesis and the series in stationary.

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Heteroskedasticity

We tested the relationship among usage of computers and internet and resource productivity using the White test, and concluded that, because the p-value is lower than the significance value, the null hypothesis of homoskedasticity is rejected, as seen in table 5.

Table 5. Heteroskedasticity test of computer and internet usage and resource productivity

Heteroskedasticity Test: White

F-statistic	15.99099	Prob. F(2,321)	0.0000
Obs*R-squared	29.35606	Prob. Chi-Square(2)	0.0000
Scaled explained SS	31.16381	Prob. Chi-Square(2)	0.0000

Therefore, we have decided to transform the data using logarithmical transformation. After the data transformation we have retested for heterockedastivity and concluded that, because the p-value is hoghet than the significance value, the null hypothesis of homoskedasticity is adopted, as seen in table 6.

Table 6. Heteroskedasticity test of computer and internet usage and resource productivity, logarithmical transformed data

Heteroskedasticity Test: White

F-statistic	1.383850	Prob. F(2,320)	0.2521
Obs*R-squared	2.769692	Prob. Chi-Square(2)	0.2504
Scaled explained SS	2.179595	Prob. Chi-Square(2)	0.3363

Regressions

Table7. Regressions of computer and internet usage and resource productivity

Model Summary and Parameter Estimates

Dependent Variable: log_res

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.368	157.546	1	271	.000	-2.397	1.522		
Quadratic	.435	104.120	2	270	.000	-13.180	14.439	-3.848	
Cubic	.440	106.050	2	270	.000	-9.884	8.248	.000	-.792

The independent variable is log_use.

We have estimated linear and nonlinear regressions, from which the cubic one has the highest R square, of 0.440, as shown in table 7. The results of the linear regression show us a positive modification of the resource productivity based on the usage of computers and internet, thus the usage of computers and internet can predict the resource productivity, as shown in table 9 and figure 1.

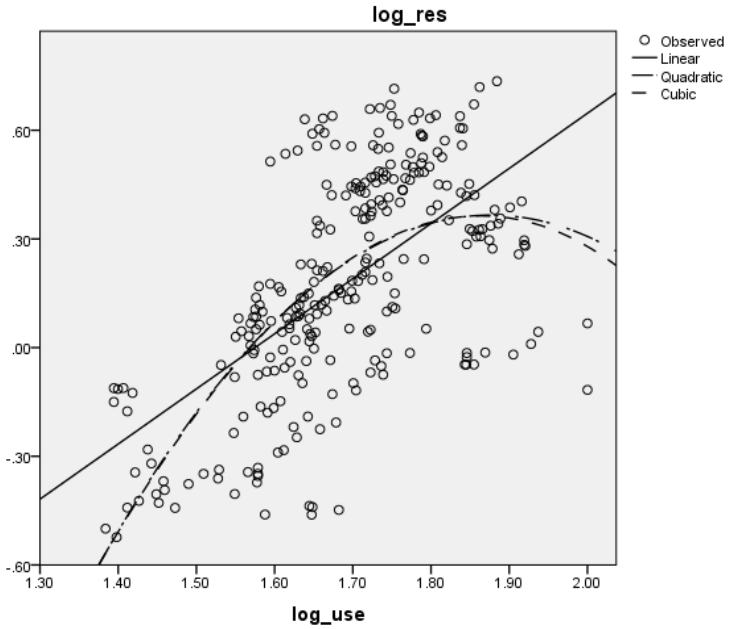


Figure 1. Regressions of computer and internet usage and resource productivity

DISCUSSION

Our study demonstrated a positive association between digital tool use and resource production, supporting the literature. Numerous studies support our conclusions. For example, Orzeł and Wolniak [1] examined the impact of digitization-enabled remote work in design and construction in Poland. Remote work greatly reduces electricity use and commuting emissions, improving environmental sustainability. Kuzior, Kettler, and Rąb [2] examined the long-term effects of digitization on HR operations in a Berlin IT company. Their research showed that digital procedures improve corporate sustainability by reducing CO2 emissions and increasing workplace diversity.

Demartini, Evans, and Tonelli [12] created a conceptual framework showing how digital technologies might improve manufacturing system efficiency, resilience, and sustainability, validating our findings. Their findings show that digital technologies can considerably improve industrial sustainability. Digitization in logistics improves supply chain sustainability by providing real-time transparency and resource management, according to Kayikci [13]. These findings confirm our conclusion that higher digital tool use increases resource productivity, showing that digitalization can boost economic performance and sustainability.

Despite the promising results, there are several limitations to our study. Our analysis was limited to data from the Eurostat datasets on employee computer and internet use and resource productivity across the European Union. Expanding the dataset to include more diverse regions and industries could provide a more comprehensive understanding of the global impact of digitization on sustainability. Additionally, we used economic value produced per kilogram of material as a proxy for resource utilization efficiency. While this metric is useful, incorporating additional measures of sustainability, such as carbon footprint or energy consumption, could provide a more holistic view of the environmental impacts. Moreover, the study period from 2014 to 2022 may not capture long-term trends and the full impact of digitization on sustainability. Future studies should consider longer time frames to better understand the evolution of these effects.

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Future research should aim to address these limitations and explore additional dimensions of the relationship between digitization and sustainability. Expanding the scope of the research to include diverse geographic regions and sectors can help generalize the findings and identify sector-specific strategies for leveraging digitization for sustainability. Incorporating a wider range of sustainability metrics, including environmental, social, and economic indicators, will provide a more nuanced understanding of the impacts of digitization. Conducting longitudinal studies can help capture the long-term effects of digitization on resource productivity and sustainability, providing insights into the sustainability trajectory of digital transformations. Investigating the impact of emerging digital technologies, such as blockchain, artificial intelligence, and the Internet of Things, on sustainability can uncover new opportunities and challenges in achieving sustainable development goals.

CONCLUSION

The study aimed at establishing the relationship between the modern workplace digital environment and resource efficiency by analyzing the data of Eurostat's employee Computer & Internet usage and resource productivity in the European Union in the period between 2014 and 2022. This research shows that the use of digital technologies is associated with better resource utilisation, which points to the fact that digitalisation might lead to enhanced economic productivity and resource efficiency, which are both key aspects of sustainability.

The analysis indicated that the process of leveraging more digital tools in employments leads to higher resource efficiency, as measured by the economic value generated per kilogram of material. These results provide evidence for the notion that digital technologies should be seen as a means to help businesses gain more sustainable positions in the course of achieving economic objectives.

However, there are also some potential limitations in the current study that should be noted. A key limitation of the study was the exclusion of data from countries outside the EU, while the timeframe of the study might not reflect long-term trends. Also, the focus on economic value per kilogram only as the indicator of resource efficiency indicates the possible deficiency of future studies, which should take into account a larger spectrum of sustainability criteria.

For the future research, more focus should be given to widen the geographical and industry coverage of the studies, include the full spectrum of sustainability indicators, and investigate the differential consequences of digitalization for the long-term. It will also be important to examine the effects of other technologies that are on the rise including blockchain, artificial intelligence, internet of things among others with the view of establishing how digital transformation can advance sustainable development.

In conclusion, our study provides empirical evidence that workplace digitization can enhance resource productivity and contribute to sustainability. These findings have important implications for policymakers and business leaders seeking to integrate digital technologies into their sustainability strategies, thereby supporting the dual goals of economic performance and environmental responsibility. By continuing to explore and address the complexities of digitalization and sustainability, we can develop more effective strategies for achieving sustainable development in the digital age

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THERMAL INSULATION FOR WALLS BUILT WITH 3D TECHNOLOGY

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ABSTRACT

Construction using 3D printer technology seems to be not just a passing trend and a growing number construction companies are approaching this new construction methodology. Although construction processes with printers are becoming standardized, it is also true that many other aspects must be considered in the design phase. Better this construction methodology becomes known, more architects and engineers will have to learn how to design these constructions, in the methods of statics, systems, etc. A very important point is the issue of thermal insulation. The designer must be able to ensure that these houses are correctly insulated, respecting all the canons required by the local laws because, like all constructions, this technology is also subject to obtaining the appropriate permits to be built. The research aims to provide an understanding of the correct thermal insulation methods so that the right standards can be ensured that are necessary and already in place for other types of construction.

Keywords: Contour crafting; raw concrete; regulation; thermal insulation for 3D printing House; 3D printing House

INTRODUCTION

Humans are born as explorers, which is their nature. In exploring, he was able to discover new cultures and new ways of life. Curiosity is what accompanies man on the most challenging adventures, and at the same time, he manages to evolve by creating ever more sophisticated tools that make his job easier.

Many people talk about the technology of 3D printers for the home, and we can admire an increasing number of constructions made by this method. The trend of using printers is gaining momentum and a new world in construction is opening up before our eyes. In terms of technology and machines, whether it is a printer with robotic arms or a gantry system, the market now presents us with many options, there are all types and for all budgets. What research is focusing on most and what it is trying to improve are the materials with which we can print houses.

Many companies, such as Italcementi, Lafarge, Cemex, etc., have specific products in their portfolio for building printed houses. Depending on the manufacturer, the properties of these materials vary.

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The designer, who will have to analyze the project and draw up the documentation for the relevant permits, will have to take into account the intrinsic properties of the material to be used.

The dynamics do not change mainly because engineers think differently if they are building a house in reinforced concrete, ytong, phorotherm, or wood.

So when we talk about houses built with printers, we must not only be concerned with the construction of walls using these machines, but we must also take into account that these houses must comply with all the regulations necessary to obtain permission to build them.

Two important points must be defined for their construction: one is stability, and therefore the load-bearing structure, and the other is the thermal insulation point.

Not all architects or engineers can carry out projects for these constructions, because they need to know not only the technology but also the way the printers work, the properties of the materials used, the construction methods, the insulation materials that can be installed in the cavities, etc...

Indeed, one of the strengths of this technology is the space (cavity) that is created when printing between the outer and inner layers of the house.

Printers are able to build both inner and outer walls simultaneously, this method of design creates a cavity between the outer and inner printed element and this cavity becomes the key point for the many benefits of this technique.



Fig. 1: Wall made by 3D printer (source: author's archive from PERI Group Germany)

PRINTING PRINCIPLES AND WALL MATERIALS

The research, which we will show below, was carried out by Arch. Andrea Palazzo (Faculty of Civil Engineering, CTU in Prague), who, after traveling and personally inspecting the main buildings built using 3D printers, specialized in designing such buildings, together with Dagmar Richtrova (Faculty of Architecture, CTU in Prague), who is also an energy specialist. They decided to carry out a study of the heat transfer calculation of multilayer walls built with 3D printers to verify how these walls should be constructed to meet the heat transfer coefficient parameters required by law, specifically for the Czech Republic as specified in the technical standard ČSN 73 0540-2:2011 [1].

One of the characteristics of the material used for printing is an extremely high drying rate. In addition, it must also have the ability to bond with the previously printed layer, so it is necessary to add plasticizers that can ensure the correct consistency. The addition of fibers to the mix also helps to eliminate the risk of cracking and splitting.

The premise of this research is that we decided to use conventional concrete with the addition of an additive produced by COBOD and CEMEX called D.fab. Therefore, the mix is composed of cement, water, gravel, and sand with the right percentage of additive (plasticizer) that allows the cement to be fluid enough for pumping, but with a quick grinding property for laying.

On the other hand, although we have a wide range of materials available for thermal insulation that can be installed in the cavity, such as polystyrene polyurethane foam, Supafil cavity wall, Hyperlit, expanded clay, blown granulated mineral wool, polyester pellets (Glueporas), we used the most easily available material on the Czech market: EPS with a declared value of the thermal conductivity coefficient λ_d = 0,039 W/m^{-1}K^{-1}.

As it is a sandwich construction, the two load-bearing printed concrete layers are connected by steel anchors. The axial distance of the steel anchors with a diameter of 3 mm is 300 mm in both the horizontal and vertical directions. These anchors create thermal bridges and reduce the effectiveness of the thermal insulation. Their influence is very important for the calculation of the final value of the heat transfer coefficient of the wall.

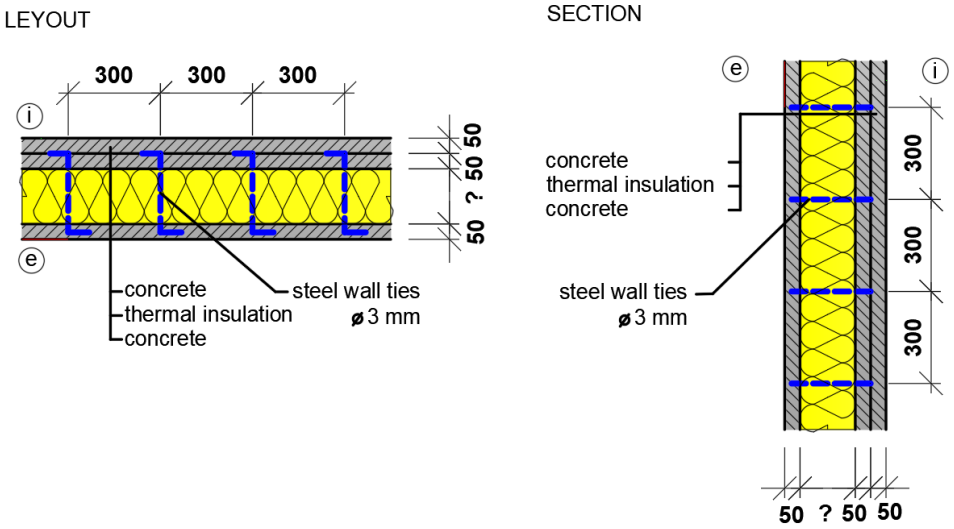


Fig. 2: Wall composition (source: author's archive)

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THERMAL INSULATION DIMENSIONING

The design of the thermal insulation thickness respects the requirements of the mentioned standard ČSN 73 0540-2 [1]. This technical standard specifies the required and recommended values for passive houses. The required values are basic values which guarantee that mould and condensation will not occur on the surface of the structures. These values are hygienic. Due to the environmental and energy rating of buildings, the requirements recommended for passive houses must be used in the design and construction of buildings. To these requirements for buildings with an interior temperature of 18°C - 22°C, the thermal insulation design will be carried out.

Tab. 1: Requirements.

Construction	Required heat transmittance coefficient U W/(m^2.K)	Heat transmittance coefficient U recommended for passive houses W/(m^2.K)
Wall	0,30	0,18 – 0,12

The calculation of the heat transfer coefficient of the wall is performed using the Teplo 2017 Svoboda Software [2]. This program evaluates one-dimensional heat conduction in a steady-state environment. In the program, the thermal conductivity coefficient of the EPS thermal insulation is adjusted for the effect of incorporation into the wall structure.

Tab. 2: Coefficient of thermal conductivity.

Value type	Mark	Value W/(m.K)
Declared	λ_d	0,039
Design	λ_{ds}	0,040
Equivalent	λ_{ekv}	0,044

The equivalent value takes into account the incorporation of the insulation into the structure, humidity and the influence of steel anchors. The number of anchors per 1 m^2 is 12 with a point thermal bridge area of 7.1 mm^2.

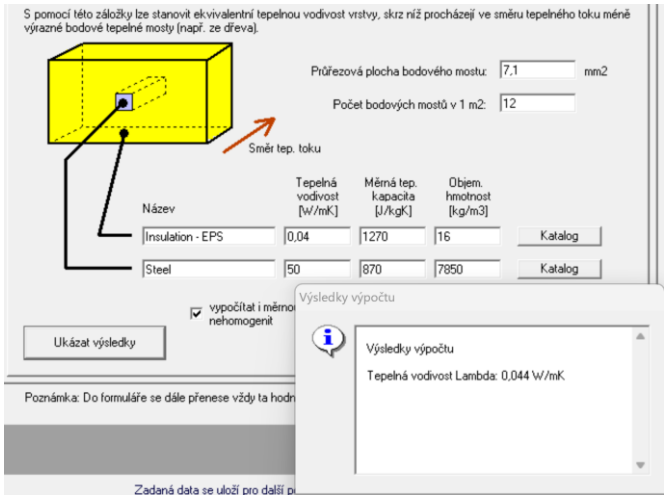


Fig. 3: Calculation λ_{ekv} (source: author's archive)

The calculation of the resulting value of the heat transfer coefficient of the wall, taking into account the steel anchors in the insulation, gives the resulting required thickness of thermal insulation to meet the value recommended for passive houses. **For**

a requirement of U_{rcph} = 0,18 W/m^{-1}K^{-1} , the thickness of the EPS thermal insulation must be at least 240 mm. This value is advantageous from an energy and environmental point of view.

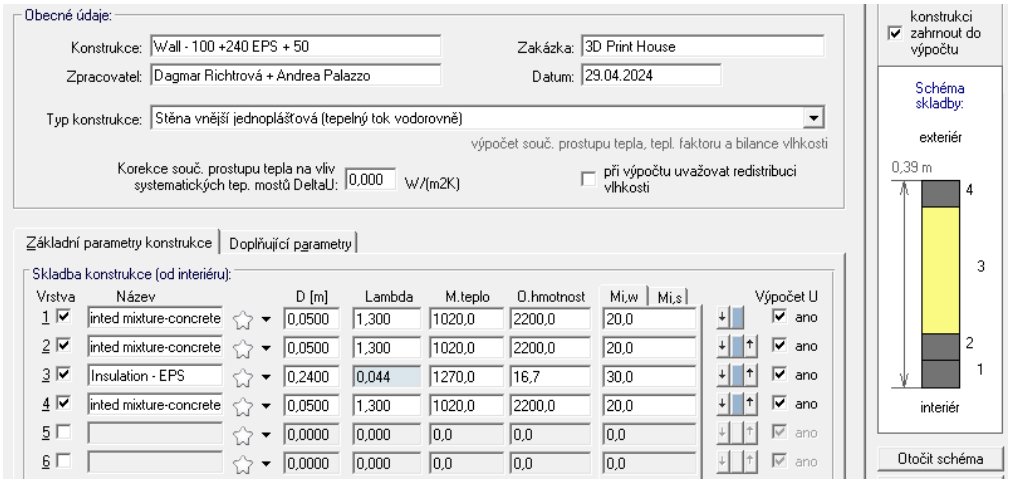


Fig. 4: Calculation U (source: author's archive)

CONNECTING THE WALL TO OTHER STRUCTURES

The heat transfer through the structure is only one part of the thermal engineering assessment. In buildings, however, the structure is in contact with other structures and elements. And it is this connection that can lead to large thermal bridges, where the surface temperature of the structures in the interior could drop below the critical temperature. If the surface temperatures fall below the critical temperature, mould and condensation will form in the structures at these points.

Evaluating the potential connection of the printed perimeter wall is another area of our investigation. We selected 3 types of details for evaluation. The first detail is the connection to the supporting column of the building. The second detail addresses the connection of the wall and foundation to the ground and the third addresses the connection of the wall and roof.

The evaluation is performed using the Area 2017 Svoboda Software program [3]. This program evaluates two-dimensional heat conduction in a steady-state environment. It evaluates the temperature progression at the detail of the contact between two structures, identifying the location of the lowest surface temperature.

The requirements for surface temperatures of structures are given in the Czech Republic in the technical standard CSN 73 0540-2 [1] in the form of the dimensionless quantity of the critical temperature factor $f_{Rsi,cr}$ (-).

For the internal boundary conditions of the house for living (temperature +20°C, humidity 50%) and for the external boundary conditions of the temperate zone of the Czech Republic (temperature -15°C, humidity 84%) the critical value of the temperature factor $f_{Rsi,cr}$ = 0.747 (-). This value corresponds to a critical surface temperature of 11.598°C.

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A) Detail of the connection to the load-bearing column

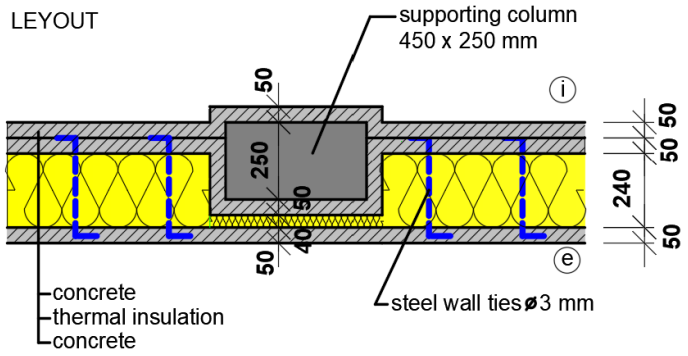


Fig. 5: Connection to the supporting column. (source: author's archive)

The lowest internal surface temperature of this structure is 15.88 °C and this corresponds to a temperature factor of 0.867 (-). Therefore

$$f_{Rsi} = 0{,}867 > f_{Rsi,cr} = 0{,}747 \text{ (-) … verified}$$

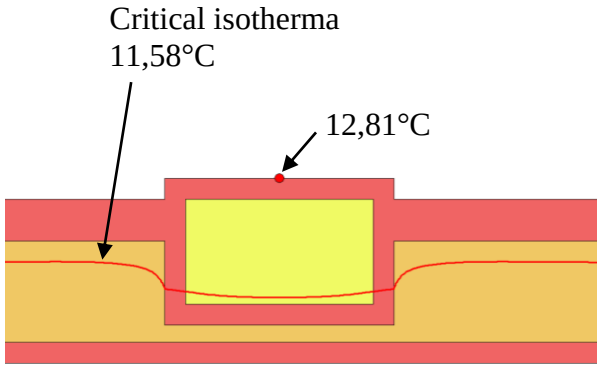


Fig. 6: Isoterma 11,58°C. (source: author's archive)

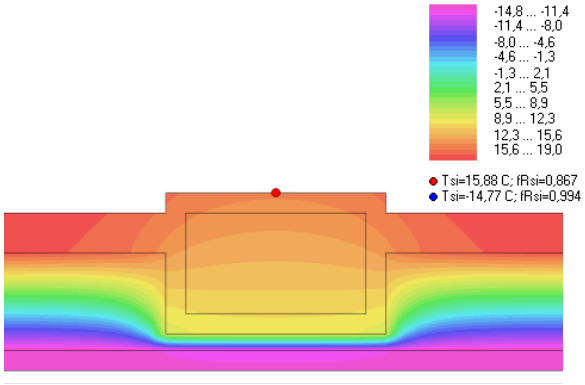


Fig. 7: Temperature field. (source: author's archive)

B) Wall and floor detail

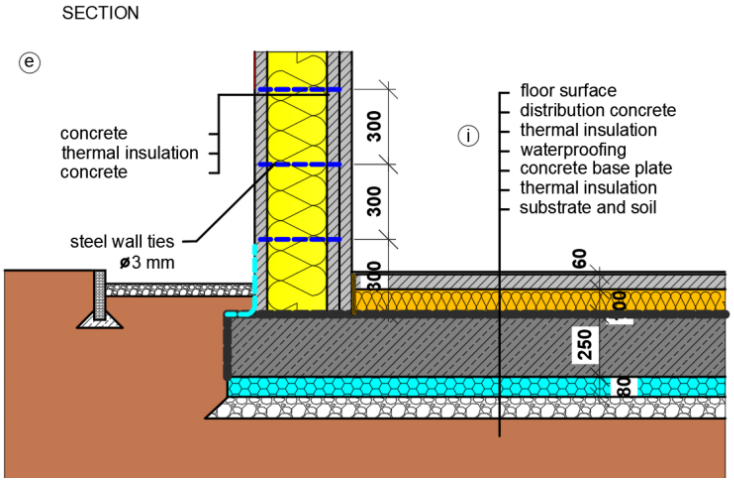


Fig. 8: Wall and floor connection on the ground. (source: author's archive)

The lowest internal surface temperature of this structure is 12.81 °C and this corresponds to a temperature factor of 0.781 (-). Therefore

$$f_{Rsi} = 0{,}781 > f_{Rsi,cr} = 0{,}747 \text{ (-) … verified}$$

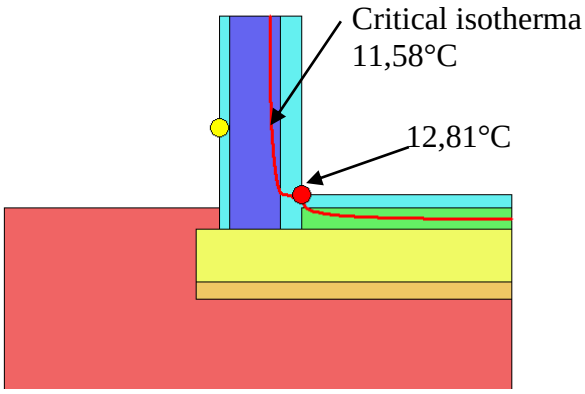


Fig. 9: Isoterma 11,58°C.
(source: author's archive)

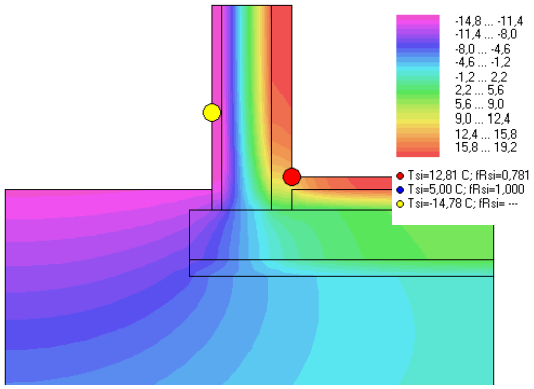


Fig. 10: Temperature field.
(source: author's archive)

C) Wall and roof detail

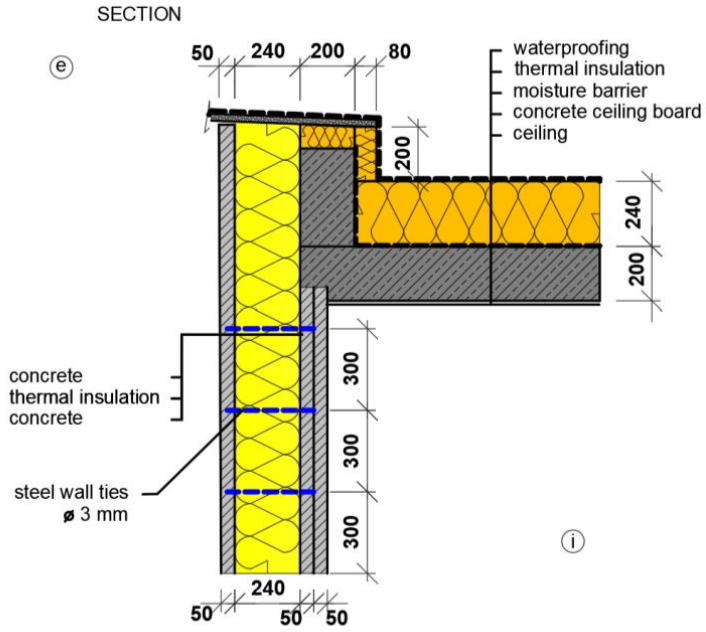


Fig. 11: Wall and floor connection. (source: author's archive)

The lowest internal surface temperature of this structure is 15,50 °C and this corresponds to a temperature factor of 0.857 (-). Therefore

$$f_{Rsi} = 0{,}857 > f_{Rsi,cr} = 0{,}747 \text{ (-) … verified}$$

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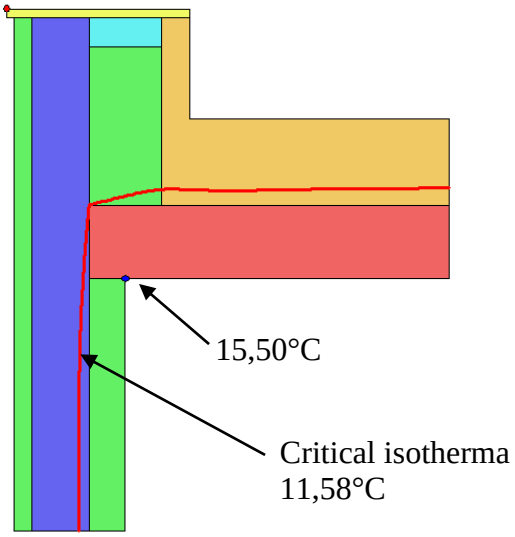


Fig. 12: Isoterma 11,58°C.
(source: author's archive)

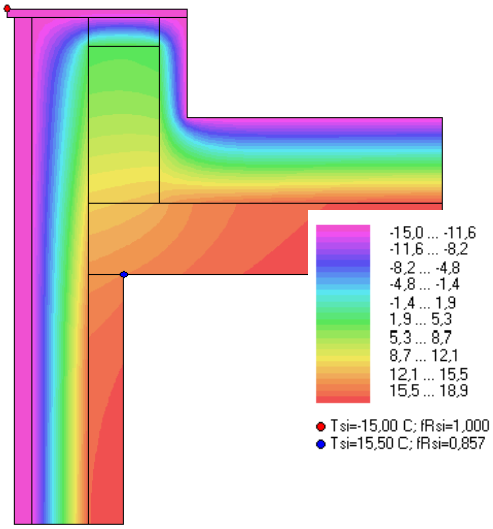


Fig. 13: Temperature field.
(source: author's archive)

CONCLUSION

The article focused on solving the optimal thickness of thermal insulation for construction conditions in the Czech Republic for housing and ordinary civil buildings, with reference to energy-saving and environmentally oriented construction. As been proven, walls build with 3D technology fully satisfy the conditions requested by the Czech technical standard ČSN 73 0540-2:2011 [1].

Another important point of the article is to emphasise that the solution of joints and continuity of 3D-printed wall structures with other structural elements cannot be neglected. If this problem it will be underestimated, significant thermal bridges will be created at the interfaces of the structures. These significant thermal bridges will have to be further treated by insulation to avoid mould and condensation on the surface.

Poorly executed details will have consequences for users in increased energy consumption and worsening the environmental impact of the building.

A further important consideration is that thanks to this technology, if well executed, we would be able to have less thick walls and thus be able to make better use of the available square metres with the economic advantage of having ‘’bigger‘’ houses. This makes us realise that if we use insulation materials with higher coefficients than EPS, the benefits may be more tangible.

ACKNOWLEDGEMENTS

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And also by Czech Technical University in Prague, Faculty of Archutecture reseaech project SGS22/195/OHK1/3T/15 and with financial support from the Faculty of Architecture and Faculty of Civil Engineering of Czech Technical University in Prague.

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TOOLS FOR DECISION-MAKING IN THE FIELD OF REGIONAL DEVELOPMENT FOCUSED ON THE NEEDS OF CLIMATE CHANGE THROUGH BLUE-GREEN INFRASTRUCTURE

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ABSTRACT

In the present, regional policy faces the demanding task of developing suitable decision-making tools for regional development that will effectively take into account the need to mitigate climate impacts. Blue-green infrastructure (BGI) emerges as one of the most promising tools in this field. BGI represents an integrated approach that harnesses the synergistic effect of natural and civic systems to manage water, regulate climate, and protect biodiversity. This comprehensive approach not only helps reduce the risks of floods, soil erosion, and drought but also contributes to improving the environment and the quality of life of residents. In our contribution, we focus on the agricultural landscape interconnected with the urbanized part of the Nitra region. In the Nitra region, which includes not only the city of Nitra but also 12 urban districts with 39 surrounding municipalities and a total population of 164,820, the construction of an extensive BGI network is proposed as a crucial part of measures to adapt to climate change. This network of natural and semi-natural measures is to be closely integrated into regional development plans with the aim of supporting sustainable development and increasing the region's resilience to ever-growing climate challenges. Our contribution informs the reader about the benefits of BGI in the design of the concept of regional development as a requirement set by the state based on the strategy of building elements to mitigate climate change with an emphasis on landscape activities and the urbanized landscape.

Keywords: Blue-green infrastructure, regional development, climate change, regional policy, land use

INTRODUCTION

In the European Commission's communication on green infrastructure, this infrastructure is described as an effective tool for delivering ecological, economic, and social benefits through natural solutions. This approach helps us to gain a deeper understanding of the value of the benefits that nature provides to human society while also mobilizing the investments needed to maintain and enhance them [1]. Green infrastructure represents a comprehensive network of natural and semi-natural areas, as well as urban green spaces, which together provide various ecosystem services. These services include climate regulation, improvement of air and water quality, biodiversity enhancement, provision of recreational spaces, and support for people's mental and physical health [2]. Among the main priorities for mitigating and adapting to climate

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change must be the restoration, creation, and protection of green infrastructure. It is essential to restore and increase the share of vegetation in cities as well as in agricultural landscapes, which includes the planting of trees, establishing flowering meadows, and creating wetlands. This aligns with the July 2021 report by the United Nations Environment Programme, which highlights that land-use change significantly impacts the Earth's climate system. Deforestation and the increase of arable land and built-up areas lead to the disruption of the water cycle, resulting in a reduction of the natural cooling effect provided by vegetation. These changes have a direct impact on microclimate, air quality, and overall ecosystem health, which in turn affects human health and quality of life [6]. As a result of climate change in Slovakia, changes in the distribution of precipitation and water availability, changes in the thermal conditions for plant production, changes in wintering conditions, and many other impacts can be expected [3]. The average global surface temperature from 2012 to 2021 was 1.11 to 1.14 °C higher than the pre-industrial level. This makes it the warmest period in history [4]. The implementation of green infrastructure is crucial for improving the well-being and quality of life of residents. These green solutions also contribute to the resilience of cities and municipalities to climate change and natural disasters, helping to create more sustainable and viable communities. Investments in green infrastructure can lead to the creation of new jobs, improved public health, and support for local economies. The European Commission calls on member states to integrate green infrastructure into their policies and planning, ensuring long-term development and protection of natural resources. This initiative also supports collaboration between different sectors and levels of governance, enabling coordinated and effective use of available resources [5]. The Strategy for Adaptation of the Slovak Republic to Climate Change (2018) focuses on selected areas such as the natural and built environment, health, transportation, and tourism, and proposes adaptation measures. In tourism, it recommends collaboration between businesses, the development of off-season products, and environmentally innovative forms. Ecotourism and geotourism have adaptive and mitigative effects, a low impact on ecosystems, and support nature conservation and local communities. Typical ecotourism activities include cycling tourism, wildlife observation, and hiking. Geotourism preserves and develops natural, cultural, and historical values, with activities such as visits to old quarries, mines, and geoparks [7].

MATERIALS AND METHODS

Adaptation to climate change in Slovakia has so far occurred mainly spontaneously, as a reaction to extreme weather events and risk management. Instead of a systematic set of preliminary and planned measures to minimize losses and damages, adaptation is mainly addressed within sectoral strategies and programs, often without significant systemic support. This situation is due to the technical complexity of the topic, uncertainty in modeling future scenarios, and the complexity of the necessary scientific, technical, and economic knowledge, which currently no institution in Slovakia is addressing.

The area under study, which we address in our publication, is located in western Slovakia and focuses on the agricultural landscape connected to the urbanized part of the Nitra region (Figure 1).

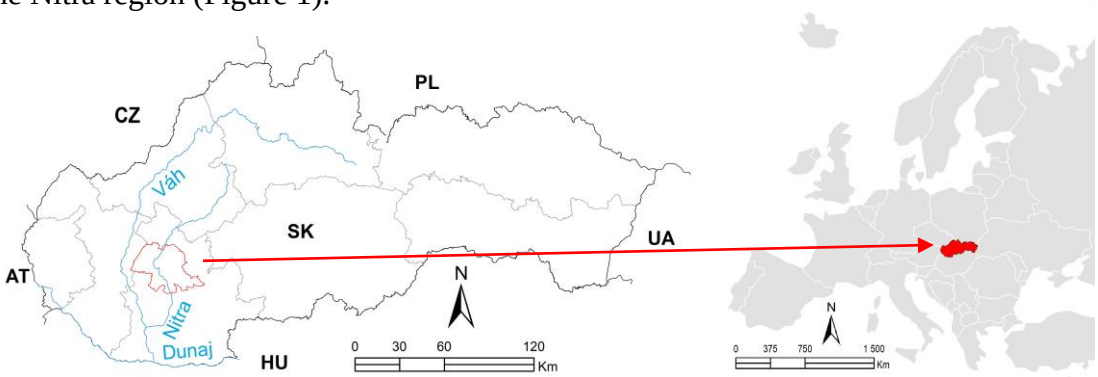


Figure 1 Location in the territory of Slovakia

The city of Nitra is the oldest city in Slovakia and also serves as a significant cross-regional center fulfilling administrative, economic, and cultural functions. The total agglomeration of the Nitra region consists of the city of Nitra itself with 12 urban districts and 39 surrounding villages. The total population of this region is 164,820, which represents approximately 3% of the total population of Slovakia. The Nitra region is also known for its agricultural importance. The surroundings of the city are cultivated for agricultural purposes, including the cultivation of cereals, fruits, vegetables, and vineyards. One of the significant natural features in the region is the Nitra River. Originating in the Tribeč mountain range, the river flows through the city of Nitra and its surroundings, providing local residents and visitors with opportunities for diverse recreational activities and walks along its banks. Overall, the nature and landscape in the Nitra region are impressive and diverse, with a combination of rivers, meadows, forests, and fields, making this region attractive to nature lovers and tourists. The current vegetation in the Nitra region (87,044.08 ha) is categorized and represented as landscape - outside built-up areas (8,443.28 ha) and urban - within built-up areas (78,600.81 ha). In the landscape category, arable land predominates at 81.8%, followed by forests at 8.8%, and built-up areas at 3.8% (Figure 2).

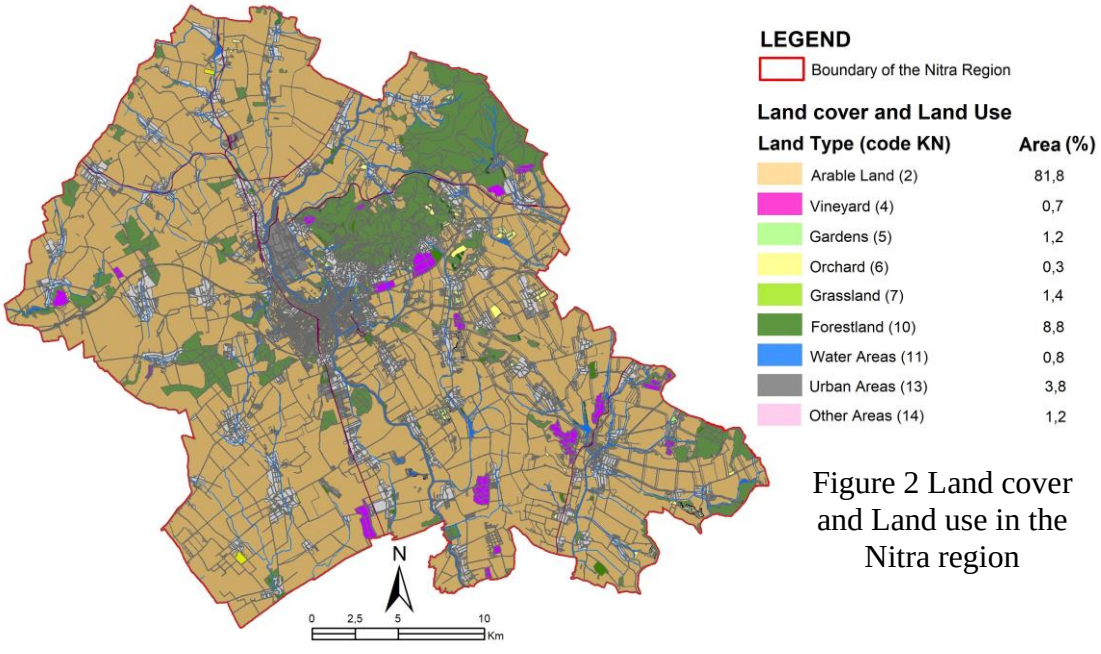


Figure 2 Land cover and Land use in the Nitra region

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Based on the Slovak Republic's Climate Change Adaptation Strategy from 2018, which focuses on selected areas such as natural and built environments, public health, transportation, tourism, and more, various adaptation measures are proposed. Within recreation and tourism, the strategy suggests closer collaboration among tourism businesses, the development of off-season tourism products, and shifting the focus of tourism activities towards environmentally innovative forms such as ecotourism and geotourism, which have both adaptation and mitigation effects. Unlike mass tourism, these forms of tourism not only have relatively low impacts on ecosystems but also actively support nature conservation, local community development, and tourism growth. Typical ecotourism activities include cycling, wildlife observation, hiking, and photography of both living and non-living natural subjects. Based on the proposal of Natural Green Infrastructure (BGI) measures for mitigating climate impacts, integrated with the Slovak Republic's Climate Change Adaptation Strategy, the primary goal is to ensure long-term perspectives by implementing protective and developmental measures. These measures were selected from a catalog of adaptation actions addressing the adverse effects of climate change in relation to landscape use [8].

For the analysis of the study area, we utilized data from the Slovak geodatabase, including the cadastral map (VKM), basic maps at 1:10,000 scale, georeferenced orthophoto map, updated BPEJ map (Mapping of the Environment and Its Components), water management map at 1:50,000 scale, land use planning maps, and digital elevation model. Based on these datasets, we developed the following mapping resources: a map depicting the current state of the area, a map of ecological stability of the area, and a map showing the strategic placement of adaptation measures for mitigating climate impacts.

RESULTS AND DISCUSSION

The aim of the proposal is to establish a network of blue and green infrastructure based on the strategic plan of the Slovak Republic to mitigate climate impacts and promote rural and urban landscape development. Currently, there is no trend in Slovakia to connect rural landscapes with urban areas. Generally, a significant challenge in building landscape features outside built-up areas lies in ownership relationships concerning individual plots suitable for implementing BGI. As of the end of 2021, Slovakia has recorded 8.4 million ownership parcels, 4.4 million landowners, and 100.7 million co-ownership relationships, with an average of 11.93 co-owners per parcel and 22.74 parcels per owner [9]. The Slovak Republic has secured €750 billion in financial resources from European Union structures for the period 2021 to 2027 for the recovery and resilience plan post-COVID-19 pandemic. One of the main priorities of this recovery plan is the green economy, encompassing topics such as climate change adaptation and sustainable transportation [10].

Here are some suitable elements for the proposal of building a network of blue and green infrastructure to mitigate climate impacts in the landscape:

- Greenery along constructed and existing cycle paths outside built-up areas offers numerous benefits, including climate mitigation. Ecological benefits include biodiversity conservation, providing habitats for various plant species, insects, and birds, thereby enhancing biodiversity. Additionally, plant root systems

stabilize soil, preventing erosion and improving soil quality, ensuring soil protection. Climate benefits include temperature reduction; trees and plants along cycling paths provide shade, helping to lower surface and ambient temperatures. This cooling effect can be significant, especially during hot summer months. Vegetation also helps retain rainwater, reducing flood risk and facilitating natural groundwater replenishment. Improved air quality occurs as plants absorb CO2 and release oxygen, contributing to cleaner air. Moreover, vegetation can trap dust particles and other pollutants. Social and recreational benefits of greenery along cycling paths enhance environmental attractiveness, potentially attracting more cyclists and promoting outdoor activities. Spending time in nature and green areas is associated with improved mental health and overall well-being. Cycling routes with accompanying greenery offer relaxing and refreshing environments. Practical benefits include wind protection; trees and shrubs act as windbreaks, reducing gusts and creating more pleasant conditions for cyclists. Vegetation absorbs and disperses noise, which can be beneficial near busy roads or industrial areas. Implementing greenery along cycling paths not only enhances aesthetics and quality of life but also contributes to a more sustainable and healthier environment.

- Building hedgerows and ponds is an effective way to adapt to climate change and mitigate its negative impacts. One of the main benefits is the improvement of microclimates. Hedgerows and ponds help regulate temperature and humidity in their vicinity, contributing to a more pleasant microclimate. Ponds retain rainwater, helping to prevent droughts and floods. During dry periods, they retain soil moisture, thereby enhancing agricultural productivity. Hedgerows and ponds provide shelter and food for various wildlife species, contributing to biodiversity conservation. Within hedgerows, trees can also be planted as windbreaks, reducing soil erosion and enhancing soil fertility.
- Another significant component of BGI are water retention facilities, which can be either of a technical nature or natural features. Their task is to retain rainwater and help distribute it evenly throughout the landscape. These facilities include dry reservoirs, retention basins, ponds, wetlands, dams, and irrigation systems. Their main goal is to improve the water regime in the landscape, prevent floods, and retain water during dry periods. Building these facilities in the landscape helps prevent floods by storing excess rainwater, thereby reducing the risk of flooding and damage caused by excessive water. They ensure water supply during dry periods by storing water that can be used when needed, ensuring a stable water supply for agriculture and other needs. They support biodiversity through wetlands and ponds, which provide habitats for various plant and animal species, contributing to biodiversity conservation and support. Water retention facilities assist in filtering and cleaning rainwater, thereby improving water quality in the landscape.
- Creation of a network of biocorridors connecting fragmented natural habitats to facilitate the migration and movement of wildlife and plants. These corridors can be composed of various elements such as forest strips, riparian zones, wetlands, and meadows. Biocorridors also include elements of blue infrastructure such as rivers, streams, and other watercourses, which play a crucial role in maintaining ecological balance. Building biocorridors brings many benefits to the landscape and society by enabling species migration, thereby contributing to the

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preservation and enhancement of biodiversity. Improving ecological stability through the connection of natural habitats enhances ecosystem resilience to climate change and other environmental stresses. Protecting water resources with the help of blue infrastructure within biocorridors helps improve the quality and availability of water resources. Biocorridors create pleasant natural environments that can be utilized for recreation and enhance the quality of life for local residents. Sustainable development integrating biocorridors into spatial planning supports sustainable management of landscape resources and environmental protection.

When planning and designing the construction of blue and green infrastructure network in the Nitra region, we proceeded based on the insights from strategic documents, spatial plans, municipal needs, and current agricultural policies aimed at mitigating the negative impacts of climate change (figure 3).

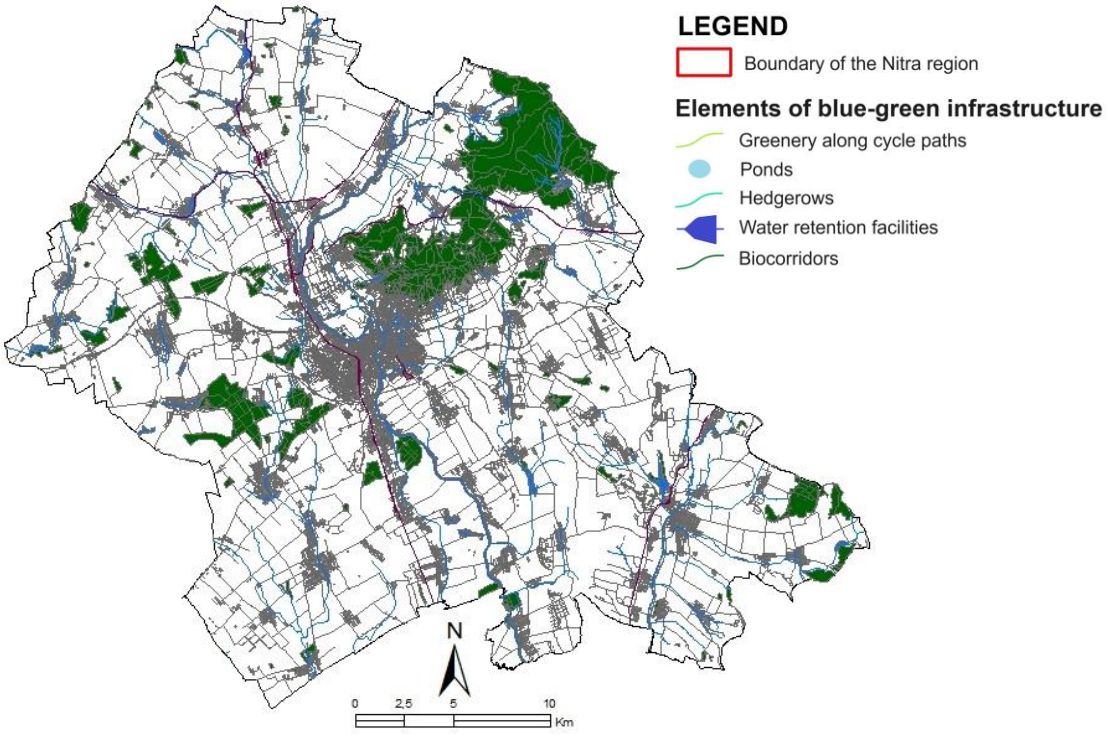


Figure 3 Proposed elements of blue-green infrastructure

The proposal involves the construction of 27.4 km of greenery along existing or proposed cycling routes. The greenery consists of double-sided tree-lined avenues to ensure the full functionality of the measure. In cases where this was not possible due to technical reasons, terrain slope, unsuitability of terrain features, or protective zones of power lines, a single-sided strip of trees or shrubs was proposed. This occurred in 3.2 km of the total proposed route. The width of these green belts ranged from 3 m to 5 m depending on land availability. The construction of hedgerows and windbreaks was locally focused, mainly on wet fields, and hedgerows were applied to fragment large agricultural fields. A total of 126 windbreaks and 484 hedgerows of meadow character were proposed. We proposed water retention facilities as small technical reservoirs, whose main role is to protect the village from flash floods and prevent local floods in

built-up areas. The secondary function of these reservoirs is to improve the water level in local streams during dry periods, provide recreation, and increase biodiversity in agricultural landscapes. Biocorridors were connected to all proposed water bodies, linking these local habitats with regional and sub-regional biocenters. Overall, 23 water retention facilities and 36.4 km of biocorridors were proposed.
One of the potential negative indicators of building Green and Blue Infrastructure (BGI) in agricultural landscapes is the loss of agricultural land. However, when comparing the benefits obtained and improvements in hydrological indicators in the fight against climate change, this land use change is necessary and essential. At the end of the day, supporting adaptation measures in the landscape ultimately increases the efficiency of agricultural land management.

CONCLUSION

Implementation of green infrastructure is crucial for the future of sustainable development, biodiversity protection, and improvement of quality of life. In Slovakia, particularly in the Nitra region, this infrastructure is designed as a response to the challenges posed by climate change, ensuring resilience against extreme weather conditions and bolstering ecological and social stability. Building a network of blue and green infrastructure, such as cycle paths with accompanying greenery, hedgerows, water retention facilities, and biocorridors, provides numerous ecological, social, and economic benefits, including biodiversity conservation, microclimate improvement, water regime regulation, and support for recreational activities. Integrating these elements into spatial planning and policies promotes sustainable development, contributes to the conservation of natural resources, and enhances community resilience to future climate challenges.

The proposal for constructing a blue and green infrastructure network in the Nitra region focuses on mitigating climate impacts and supporting sustainable development of rural landscapes. The project includes 27.4 km of green buffers with double-sided tree-lined alleys along cycling routes, 126 tree belts and 484 hedgerows for microclimate regulation and biodiversity protection, as well as 23 water retention facilities for flood protection and water quality improvement, connected by 36.4 km of biocorridors. The proposed measures are based on strategic plans and leverage available European funding effectively. The project combines environmental benefits such as biodiversity conservation and climate change mitigation with practical outcomes like flood protection and support for sustainable agriculture in the region. Despite agricultural land use, the project brings significant benefits to the local environment and residents, enhancing landscape resilience against environmental risks and providing opportunities for recreational activities and improved quality of life.

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SECTION EDUCATION AND ACCREDITATION IN GEOSCIENCES

A METHODOLOGICAL FRAMEWORK FOR IMPLEMENTING DESIGN THINKING IN THE TRAINING OF FUTURE GEOGRAPHY TEACHERS

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ABSTRACT

One of the priorities in professional education, including the training of future geography teachers, is related to ensuring a quality and innovative educational process based on the competence approach and modern innovative educational technologies.

In this regard, the present study aims to investigate the pedagogical effectiveness and educational potential of design thinking in the professional training of future geography teachers. The main goal is to enhance the academic performance of students by providing a learning process that stimulates the development of their design thinking skills. At the current stage, over 46% of young people are at risk of social exclusion, as the education system in our country fails to prepare their teachers and provide them with practical and authentic skills. This means that students lack guidance on how to develop their creative thinking and how to solve problems collaboratively.

In this context, the study steps on the notion that design thinking as an approach to learning in higher education will encourage the creative thinking of students and future teachers, by helping them develop to empathy. Also lead them to action and metacognitive awareness, improve their skills to solve problems, and develop their imagination. In other words, design thinking will expand the pedagogical repertoire of future teachers.

Based on the above, the study offers a methodological framework for implementing design thinking in the preparation of future geography teachers, by the example of Sofia University "St. Kl. Ohridski". The development of this framework envisages the implementation of the following tasks: identification of interested parties; defining design thinking skills; analysis of available competencies among students, future teachers; construction of a methodological framework for fostering design thinking among students at the Faculty of Geology and Geography of Sofia University, future teachers of geography.

Keywords: didactics of geography, learning, thinking, design thinking, teacher training

INTRODUCTION

One of the key objectives in professional education, particularly in the training of future geography teachers, is to deliver a high-quality and innovative educational experience based on the competency-based approach and contemporary innovative educational techniques. In this regard, the present study aims to investigate the pedagogical effectiveness and educational potential of design thinking in the professional development of future geography teachers. The primary goal is to enhance the academic

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achievement of students by providing a learning process that nurtures the development of their design thinking abilities.

METERIALS & METHODS

This research examines the proposition that employing design thinking as an educational method in higher education can foster students' creative thinking, cultivate empathy, motivate action, and promote metacognitive awareness, in addition to sharpening their problem-solving abilities and stimulating their imagination. In essence, design thinking is expected to broaden the pedagogical toolkit of future educators.
Considering the aforementioned, the study presents a methodological framework for cultivating design thinking in the preparation of future geography teachers, specifically at Sofia University "St. Kliment Ohridski." The development of this framework entails the execution of the following tasks: identifying the interested parties; defining design thinking competencies; analyzing the current skill set of students and prospective teachers; and creating a methodological framework for fostering design thinking among students at the Faculty of Geology and Geography, future geography teachers.
The study is the first step of a comprehensive research project of Sofia University "St. Kliment Ohridski" - "Projecting design thinking in the training of geography teachers in the Faculty of Geology and Geography". The full methodological framework is to be published. Some key primary results are presented here in response to the following questions: What is design thinking?; What are the advantages of using design thinking in a didactic environment?; What skills are needed in the 21st century?; Is there creativity in the design thinking approach?; How to project creativity in future teachers?

What is design thinking?

"Methodology that imbues the full spectrum of innovation activities with a humancentered design ethos" [2]. This is how the founder of design thinking describes the method [3]. Design thinking can be understood as a culture of thinking and activity that serves to generate innovation oriented to customer or user needs. The design thinking approach enables embracing diverse perspectives, transcending existing constraints, and creating innovative solutions. It is centered on comprehending or analyzing the needs of people in each situation and generating relevant solutions based on that understanding. Therefore, design thinking is fundamentally people-oriented and focuses on their needs [7]. Additionally, design thinking serves as a method for boosting creativity and innovation, enabling the resolution of complex problems through an interactive, integrated innovation process [14]. Consequently, the absence of a unified definition of design thinking in the literature is not surprising.
Regarding the design thinking process, different variations of the design thinking cycle can be found in the literature, with more or less phases through which it passes. The phases that are found are always problem definition, needs analysis and assessment, and idea generation. These phases are followed by prototype development [14]. For the purposes of the present study, we refer to the Sanford model [7].
As a method of private didactics, design thinking presents a promising approach for addressing complex issues in geography education, such as adapting to climate change. This method involves active engagement with the subject and can generate ideas and solutions for difficult problems. Despite its potential, there is no comprehensive study on its application in geography didactics, making it a relatively new but promising tool [4].

What are the advantages of using design thinking in a didactic environment?

„Emerging trends in education are interdisciplinary study methods, problem-based learning, student/ trainee centred approach, team based learning, experimental learning, and the changing role of the teacher/trainer as a facilitator of a process. All of these are very similar to what is the base of a Design Thinking approach: multi-disciplinarity, creative problem solving, human-centredness, collaboration, experimentation and the need for a process facilitator. It can therefore be acknowledged that Design Thinking can be used to uphold any challenge in education, such as improving the curriculum, spaces, teaching and learning processes and tools, as well as shaping educational systems." [13]. Design Thinking allows learners to develop their creativity without initially encountering many constraints and rules. However, there are clear structures throughout the different work phases that build on each other. This enables purposeful work.

In the university context, design thinking can be incorporated through comprehensive training or individual courses, as well as integration into curricula [10]. Recent publications have highlighted the lack of clear structure in project work and interdisciplinary learning, which design thinking can help address [5], [11]. By providing a holistic, practical methodological approach, design thinking can support teachers in fostering a positive attitude towards holistic design learning [8]. This publication focuses on developing the individual's creative potential, with design thinking serving to enhance creative personality.

What skills are needed in the 21st century?

According to Lor, they are related to globalization and new technologies, namely: (1) handling of information, media and technology; (2) learning and innovation and (3) communication: *"critical and creative thinking, problem solving, innovation and collaboration. With this is the need to adopt a teaching methodology that supports the implementation of 21st Century Learning, specifically in teaching creativity and innovation and integrating technology in the context of collaboration."* [5].

Design Thinking addresses the aspects mentioned in the quote and is therefore suitable for use in education. Design thinking uses the mindset of designers to approach new solutions and thereby generate ideas separate from existing solutions. Educators who use design thinking in education say the method fosters problem-solving skills, creativity and collaboration. It also encourages the motivation to discover and solve problems, as well as openness to new ideas. Therefore, design thinking is the ideal method to address the challenges of 21st century education [11].

Is there creativity in the design thinking approach?

The latin word "creare" means to bring forth, to create [1]. As for design thinking, there is no single definition for creativity. There are different approaches and different opinions, since almost every discipline in psychology, but also in other fields such as physics, chemistry, biology or sociology, has its own understanding of creativity [9]. This already points to a problem regarding the scientific measurability of creativity. Mayer [6] examined the different definitions of creativity from Sternberg's [12] series of creativity studies and found two key aspects that make up the majority of definitions. On the one hand, originality is important, and on the other, usefulness or applicability in the social environment. Conversely, this means that not every new idea is necessarily creative. A new idea must gain social acceptance and be seen as useful or practical [17]. However, given the many different understandings of creativity, five aspects under

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which creativity can be considered are repeatedly mentioned. These are: to solve the problem creatively; the creative process; the creative product; the conditions of the micro- and macro-environment; the creative person himself [16].
The primary objective of this publication is to explore the development of individual creativity. In this regard, the methodological framework of design thinking is utilized in the training of geography teachers at the Faculty of Geology and Geography of SU "St. Kliment Ohridski" to foster the creative potential of future geography educators.

How to project creativity in future teachers?

Below are 17 characteristics that make up "homo creativeus" [9]. The first characteristic is a *flexible mind*, which means that the creator can switch between different potential possibilities. It also involves choosing the right idea and pursuing it further. The second characteristic is *sensitivity to problems*. A creative person recognizes problems that others may not. The third characteristic is *curiosity*: the creative person has the desire to understand and explore the unknown. The fourth characteristic is *openness to new ideas*. The fifth characteristic is the presence of *high motivation*. Intrinsic motivation is more important than extrinsic incentives. The sixth characteristic involves *persistence and concentration*: creative people can give their full attention to one thing and not allow themselves to be distracted from their goal. The seventh characteristic of "homo creativeus" is *the tolerance of ambiguity*: the creative person can deal with contradictions. The eighth characteristic is the *ability to distinguish and separate*. The goal is to get to the heart of the problem and identify the relevant aspects, which also leads to a better understanding of the connections. The ninth characteristic is *fundamental knowledge*: the creative person has broad general and specialized knowledge. Trait 10 includes *decision-making independence*. Characteristic 11 is *unconventionality*: the creative person is ready to break taboos; it is important to break away from the previous one in order to take a new direction and thus arrive at new solutions. Trait 12 – creative personality can play with ideas and *enjoy experimenting*. Trait 13 includes *less anxiety*, the creative personality has great personal stability. Characteristic 14 includes a *complex personality*: the creative personality often combines contradictory characteristics such as primitive and cultivated, destructive and constructive personality traits. Characteristic 16 concerns the *attitude towards authority*, which means creative judgment of things, regardless of the source from which they come. Trait 16 also means that the creative person neither likes to command others nor likes to be commanded. Characteristic 17 is *humor*, a creative person appreciates humor and often has his own sense of humor.
Various highly specialized tests of creativity have been developed over the years, for example in the fields of science, engineering, technology and mathematics [15]. A test for contemporary creativity research was developed by Ripke, whose FAKT-test defines creative personality by answering questions about habits, behaviors and attitudes [9]. This results in creative value for the participant. The result can provide information about the creative potential of the test subjects, as it allows comparison with the results of other people. It is important to note that measuring creativity has both advantages and disadvantages. There is still no clear evidence for the validity of this form of testing. The results of creativity tests have been known to be limited in their external validity and may not accurately reflect real-world creativity. Although a person may perform well on a test, it does not necessarily mean they are creative in other aspects of their life [17]. Currently, there are no better methods for assessing creativity, so it is widely accepted as the standard [1]. However, it is important to recognize that creativity is a

multidimensional construct and should be assessed using at least two different tests to gain a comprehensive understanding of an individual's creative abilities.
The main research questions of the current study are derived from the above in the research on the issue, emphasizing two points: (1) the Design Thinking method has great didactic potential and (2) in a rapidly changing world, creativity is becoming increasingly relevant in search of solutions to problems. The target group of this publication are students from undergraduate programs in Geography (full-time and part-time), Geography & Biology and History & Geography at SU "St. Kliment Ohridski", future teachers. The research was carried out under the project "Design thinking in the training of geography teachers in the Faculty of Geology and Geography". The task is to identify stakeholders as the first step of a comprehensive study, the results of which are to be published. In the attitude of learning about design thinking, they intensively developed the task "How to form geographical competences in a traditional educational environment?". This task assumes a change in students' creativity, even in a one-time learning situation. The aim is to determine to what extent the approach of design thinking influences the creativity of students in the generation of proposals for innovative solutions in the conditions of the traditional educational environment in the Bulgarian secondary school. There are currently no valid studies on this. *The first research question:* Is there a change in selected aspects of participants' creativity in a design thinking learning environment? The aim of this study is to investigate if there is a change in specific aspects of participants' creativity in a design thinking learning environment. Six aspects of creativity, including flexibility, problem sensitivity, curiosity, tolerance for ambiguity, ability to separate and distinguish, and unconventionality, are particularly relevant to design thinking. Before the start of the learning intervention, students complete the FAKT-test developed by Ripke. Answers from the test show the attitude towards the participants' own creativity. Further analysis is based on these initial values. *The second research question:* To what extent are the selected aspects changing? aims to analyze how the selected aspects of creativity described in the first research question are changing. This change is estimated using SPSS. *The third research question* deals with determining the “background” for change in creativity. The task here is not to show the change in aspects of creativity itself, but the background that led to the change. This research question aims to determine which aspects promoting creativity play a role in the design thinking learning environment. To this end, participants are randomly selected and asked about Design Thinking training settings using self-developed qualitative interviews so that they can elaborate on any changes.

RESULTS & DISCUSSION

Further research work on the issue should be based on a reflection of the results of the research questions presented above. Based on the obtained results of the initial modified FAKT-test completed before the start of the training situation, the participants are divided into two groups: group 1 consists of participants who achieved a higher creativity score in the test (>114 points); group 2 consists of participants who scored below 114 points. The following qualitative and quantitative evaluation is based on this distribution of participants. Only the most important results of the three research questions are summarized here:
"Flexible mind" aspect: group 1 and group 2 stated that a flexible mind is a basic requirement in the professional environment. However, the results of this test were not

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sufficient for further analysis as the quality of the data was not sufficient for qualitative assessment. It is recommended that future research utilizes more valid survey instruments to combine both qualitative and quantitative data effectively.

"Curiosity" aspect: in both groups it is defined as a basic requirement in the professional sphere. Both groups commented negatively that curiosity cannot be satisfied in a design thinking learning environment or that almost no new knowledge is acquired, only existing knowledge is used. Curiosity was there, however, and was mostly related to understanding the problem, solving problems, and generating ideas. When it comes to curiosity, qualitative results are intertwined with quantitative ones. Statistically speaking, no significant effect could be found in the self-rated change in curiosity in group 1. Group 2 was also related to the quantitative results. Here again no statistically significant effect could be detected. One consideration is that Group 2 may be better trained because they rated themselves as less creative in the pretest. There is wide scope for research here to generate additional results.

Regarding the *aspect "sensitivity to problems":* there are different positions in the two groups when it comes to sensitivity to problems in the everyday life of the school. Participants must ensure that they complete the activities and tasks correctly. Therefore, problem sensitivity plays a central role in both groups. When compared, it can be said that both groups identified different aspects that contributed to fostering creativity in terms of sensitivity to problems in the context of the design thinking learning environment. Further research that includes the development of a valid survey instrument is recommended.

Regarding the *aspect "tolerance of ambiguity"* in the usual learning environment: participants from both groups believe that it has no significant role. The reason for this is that the participants were not involved in making such decisions. Due to this fact, after the first interviews conducted in the pilot phase, the topic of the tolerance of ambiguity in the daily life of the school was not continued. For both groups, the question was rated as difficult and unclear.

Aspect "ability to distinguish and separate" refers to the recognition of interrelationships. Both groups admit that they are not yet intensively engaged in dealing with real problems, but for them the ability to distinguish and separate, as well as to recognize interrelationships, plays a central role. This aspect of creativity is especially important to recognize the actual problem and identify the root cause. The two groups also have very similar views on task prioritization. There is room for maneuver, but for the most part pre-assigned tasks must be completed.

Regarding the *"unconventional" aspect:* for both groups, the problem-solving mentality of those who have been working for a long time in the field of education is very rigid. In this regard, the most common are the conventional solutions. However, this should not be viewed only critically. If the old things have proven themselves, they can be preserved and continued. Both groups did not identify specific traits or characteristics for the creativity aspect affecting unconventionality in a scholarly design thinking environment. Therefore, further research with a larger number of participants is also recommended here.

CONCLUSION

Despite the growing research interest in design thinking in an educational context, there are still no comprehensive publications on the target group of learners and students, especially in the field of geography didactics. Therefore, we consider the study to be

pilot. The research emphasizes the link between design thinking in learning environments and the stimulation of creativity. It proves that creativity cannot be specifically measured using a simple toolkit. As a result of the modified FAKT-test and the conducted qualitative interviews with the students, future teachers of the Faculty of Geology and Geography, it was established that it was impossible to comprehensively answer the set research questions. In response to the above research questions, change in selected aspects of creativity in design thinking conditions is identified, and the need for further research and larger-scale studies is also identified. Even if the quantitative data cannot demonstrate any promotion of creativity, the participants' statements from the interviews show that creativity is fostered through a unique design thinking learning environment. An interesting result is the presentation of various arguments for the promotion of creativity. This leads to the need for further research, e.g. developing appropriate recommendations for using design thinking in geographic education so that creativity can be stimulated to the maximum. This development provides initial evidence of this.

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GPT MODELS IN HIGHER EDUCATION: CHALLENGES AND OPPORTUNITIES

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ABSTRACT

This article explores the challenges and opportunities presented by the integration of GPT (Generative Pre-trained Transformer) models in higher education. It examines the implications for teaching methodologies, student engagement, and the potential risks associated with the reliance on AI tools in academic settings. It highlights the benefits of AI in providing personalized, efficient and flexible learning environments, enhancing student engagement, and supporting individualized learning. However, it also addresses significant concerns regarding the potential oversimplification of academic tasks, the decline in students' critical thinking skills, and the challenges educators face in effectively incorporating AI tools without causing distractions. The article emphasizes the need for a balanced approach in integrating AI into academic education, ensuring that technology enhances rather than undermines the learning experience, and aligns with contemporary educational demands. Future research directions are suggested to better understand the direct impacts of AI tools like ChatGPT on student learning and academic integrity.

Keywords: GPT, Students, Higher education, Artificial intelligence, Smart Learning

INTRODUCTION

In November 2022 OpenAI introduced ChatGPT, an artificial intelligence (AI) system that uses a comprehensive language model to generate responses based on textual inputs provided by users. This groundbreaking development drew significant attention across various sectors. Although AI has been a subject of research and development for several decades [7], the release of ChatGPT represented a pivotal moment in the field. This sophisticated AI model demonstrated a remarkable ability to perform an array of tasks with high competence. It wasn't only capable of generating text and retrieving search results, but also of processing and comprehending complex information. For instance, ChatGPT can analyze scientific data, summarize academic papers, and offer nuanced responses to specific queries. It aids in drafting well-structured documents, performing intricate calculations, translating languages with contextual accuracy, and even providing personalized learning assistance. Given these capabilities, it is evident that GPT (Generatative Pre-trained Transformer) has significant implications for educational contexts, both in terms of opportunities and challenges.

The primary research question this article seeks to address is: How does the integration of GPT models into higher education impact academic processes, student learning, and educational integrity? As indicated by the authors of an article that analyzed scholarly works on ChatGPT in the context of higher education [7], the utilization of GPT encompasses a wide array of applications; however, numerous scholarly articles highlight

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potential risks associated with its educational use. Specifically, concerns have been raised that AI tools, such as ChatGPT, may simplify assignments excessively, thereby circumventing the educational value derived from grappling with challenging material. Several studies argue that reliance on AI for assignment completion may lead to a decline in students' critical thinking abilities, as the focus shifts from understanding the material to merely achieving high grades. A common theme alongside academic integrity concerns is the effort to dissuade students from relying on ChatGPT. Numerous articles indicate that universities are revising their curricula, syllabi, and assignments to mitigate the influence of AI-generated content. A prevalent strategy involves reinstating supervised examinations, wherein students are required to complete assessments in controlled environments devoid of internet access and technological aids. This approach aims to ensure the authenticity of student work and preserve the integrity of the educational process [7].

SMART EDUCATION FRAMEWORK

In a fast-changing world, avoiding technology and reverting to the exclusive use of paper and pen is unfeasible. Instead, we should consider how to thoughtfully integrate new technologies into the teaching process. Embracing technological advancements can enhance the educational experience by making learning more dynamic, interactive, and accessible.

As indicated by the authors in the article [5], Smart Learning represents a progressive educational approach that integrates the latest technologies, including the Internet, mobile applications, virtual reality, and artificial intelligence, to foster interactive, personalized and efficient learning environment. The primary objective of smart learning is to offer flexible and customized learning methods, which facilitate innovative and interactive skill development. Through the application of advanced technologies, smart learning seeks to improve the teaching and learning process, enhance student engagement, and optimize educational outcomes. Key applications encompass cloud-based education, distance learning, interactive online research platforms, and VR applications [5]. Essential features of smart learning include intelligent learning management systems that streamline instructional processes, personalized instruction tailored to individual learner needs, robust assessment tools for tracking progress, and sophisticated library management systems for resource accessibility [4].

GPT's capacity to personalize the learning process can further support individual learning needs by providing tailored guidance and feedback, thus enhancing the overall educational experience and fostering self-directed learning. Using ChatGPT could alleviate anxiety in students who are beginning an assignment, particularly those with limited academic backgrounds or lacking positive help-seeking behaviors. For instance, an AI tutor could make students feel less hesitant to seek assistance, reducing feelings of embarrassment associated with needing help [7]. Text-generating AI platforms offer precise responses to students' questions, providing flexibility and resistance to various factors compared to human responses. Research validates that AI-based tutoring systems enhance individualized learning, self-assessment, and personalized feedback, which collectively improve the behavioral intention and actions of tertiary-level students to engage with AI technology [6].

Smart Learning approach includes also training educators to use these tools effectively and continuously developing students' digital competencies to ensure they can navigate

and leverage technological resources proficiently. Educators play a crucial role in guiding the learning process, with technology serving merely as a supporting tool [9]. In intelligent educational environments, students must also effectively utilize technology to create optimal learning conditions. While it is assumed that daily users of digital technology possess high digital skills, research emphasizes the continuous need for both students and educators to develop digital competencies, noting the discrepancy between the assumed level of digital skills and their actual state. This includes not only device operation but also effective use of various digital tools for learning, information analysis, content creation and critical thinking approach. [8], [1].

What gives AI a distinct advantage is its unlimited availability. AI is not constrained by time; it can be queried at any hour, day or night, providing continuous access to information and assistance whenever needed. Moreover, AI is highly efficient in processing and delivering information quickly, enabling students to obtain rapid responses and solutions to their queries. This efficiency can significantly enhance the learning experience by allowing students to progress through their studies without unnecessary delays, ultimately fostering a more flexible and responsive educational environment. Integrating AI into academic education is not only practical but also essential in addressing contemporary educational challenges. AI technologies, such as GPT, can assist in adapting teaching methods to the rapidly changing needs of students and the job market. AI enables a more personalized and flexible approach to education, which is difficult to achieve with traditional methods.

However, the increasing allowance for students to use technology during lessons presents significant challenges, as many educators struggle with integrating these tools without causing distractions. Both students and academic staff have highlighted these issues. They face the need to adapt to new technology, cater to varying student ability levels, and manage unwanted distractions effectively. Additionally, they have observed that AI tools have altered the traditional modes of communication between students and teachers, introducing new interaction methods that necessitate improvements in classroom communication strategies. Students have also shared their experiences, noting that while AI tools can be beneficial for research purposes, they sometimes make it harder to concentrate on assignments. One student mentioned doing well with AI for research but tending to procrastinate when using it for assignments [2].

DISCUSSION

As indicated by the authors of an article that analyzed scholarly works on ChatGPT in the context of higher education [7], the utilization of GPT encompasses a wide array of applications; however, numerous scholarly articles highlight potential risks associated with its educational use.

These themes included university responses, academic integrity issues, the limitations and weaknesses of AI tool outputs, and opportunities for student learning. The analysis found that discussions were predominantly centered on academic and institutional perspectives, with minimal focus on student views. This absence highlights the need for surveys and focus groups to better understand student engagement with ChatGPT and similar AI tools. Future research should also consider academic staff perspectives, the extent of ChatGPT's use in teaching, and adjustments to assessment tasks to prevent misuse [7]. Despite previous studies exploring AI's relationship with students, there is a significant gap in quantitative research on factors influencing students' intentions to use

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GPT. Although interest in this area is growing, research is still in its early stages and requires rigorous empirical study. Notably, only 25% of existing studies have utilized quantitative methods, with most relying on qualitative approaches. While some recent qualitative studies have identified potential factors, a comprehensive and structured examination is still lacking, raising concerns about the validity of these claims and the existence of additional influential factors [6].

The ability of ChatGPT to generate content indistinguishable from human-created material makes it highly appealing for academic purposes. Its use is particularly attractive to non-native English speakers, as it enables them to produce better essays in English, and its ability to address technical queries and check errors appeals to STEM students. Additionally, ChatGPT facilitates creative writing, such as developing plots for novels, short stories, and poetry. However, several authors have raised concerns about the impact of ChatGPT on academic integrity, suggesting that it may increase instances of content replication, diminish critical thinking, promote academic laziness, and reduce the emphasis on memory retention. The primary reasons for students' intention to use ChatGPT include technical knowledge of GPT. Its most significant impact is its capacity to generate competent initial drafts of typical written tasks, which motivates many students to utilize it [6].

Additionally, the ability to critically evaluate available online resources is increasingly important in the digital era. The GPT performs a complex summarization task by extracting pertinent information from retrieved documents. This process places the GPT between the user and the original web results, shifting the responsibility of evaluating information relevance, trustworthiness, and context from the user to the GPT. Consequently, factual errors and inconsistencies can occur between the GPT's output and the original documents. These errors, sometimes anthropomorphically referred to as "hallucinations," can be technically viewed as noisy translations similar to the children's game of telephone [3]. This potential for producing misinformation is particularly dangerous in an educational context, as students might rely on inaccurate information, leading to misconceptions and faulty knowledge construction.

Concerns about the accuracy of GPT outputs extend to their impact on various academic disciplines. There have been discussions regarding the susceptibility of certain subjects to the influence of ChatGPT, although there is no consensus on which disciplines are most at risk. For instance, some argue that the social sciences and arts are particularly vulnerable. Conversely, an academic in one article asserted that within the English department, the nature of required writing does not align well with the capabilities of these AI services. Similarly, perspectives differ in the sciences; one academic noted that ChatGPT is less effective for computer science assignments, which emphasize problem-solving over information recall. However, a student mentioned using ChatGPT for both computer science and statistics classes, indicating varied experiences and applications across disciplines [7].

The widespread adoption of GPT models has raised significant concerns about the oversimplification of tasks and the possibility of students using AI to bypass the learning process without truly understanding the material. The ease with which AI can perform tasks has sparked fears that educational processes might be undermined, as students may rely on AI tools to complete assignments without genuinely engaging with or understanding the content. This scenario poses substantial risks to the development of

critical thinking and problem-solving skills. Excessive reliance on technology can lead to a dependency where students are unable to function effectively without the support of AI. This dependency may significantly weaken their abilities to think independently and learn autonomously. Furthermore, this over-reliance on AI can impede the development of essential skills such as perseverance, resilience, and the ability to tackle complex challenges without immediate external assistance. Consequently, while AI has the potential to enhance educational processes, it is crucial to strike a balance to ensure that students maintain and cultivate their intrinsic cognitive abilities and do not become overly dependent on technological aids.

These issues present new challenges for the education sector, necessitating a comprehensive shift in teaching models. Educators must adapt their approaches to incorporate AI responsibly, ensuring that technology enhances rather than detracts from the learning experience and aligns with the demands and realities of contemporary society.

CONCLUSION

In conclusion, the integration of GPT models and other AI technologies into higher education presents both significant opportunities and considerable challenges. While AI has the potential to revolutionize learning and teaching by providing personalized and efficient educational experiences, it also raises important concerns regarding academic integrity, the potential for oversimplification of tasks, and the need for critical thinking skills. Consequently, the role of academic teachers would be evolving, probably from traditional knowledge transmitters to facilitators and mentors who guide students in navigating and critically engaging with AI tools, thereby enriching the educational experience and preparing students for a technologically advanced future.

Addressing the gaps in research concerning the minimal representation of student perspectives on the use of AI in education [7], a group of students from the Sociology Student Research Club at AGH University of Krakow has initiated a comprehensive study through an online survey. The primary aim is to determine the types of tasks for which students most frequently use GPT and to understand the factors that influence their decision to use or not use GPT. Notably, there is a significant gap in existing research regarding the factors that drive students to utilize GPT, and this study aims to fill that void [6]. This investigation seeks to uncover the motivations behind their engagement with AI tools and the specific academic needs these tools fulfill. By gathering detailed data on student interactions with AI, this study aims to provide a nuanced understanding of how AI technologies like GPT are integrated into the daily academic routines of students, shedding light on their benefits and potential drawbacks.

Aditionally, another research group comprising faculty members and students from our department has planned an extensive study using focus group interviews with academic staff to explore the application of AI tools in research and teaching. This study aims to gather insights on how these tools are perceived and utilized in scholarly work, such as conducting research or writing academic papers, as well as in teaching and interacting with students. The focus is to identify potential applications of AI in enhancing research productivity and improving educational outcomes, thereby understanding the broader implications of integrating AI into academic practice. This qualitative research will delve into the experiences and perspectives of educators, examining the practicalities and challenges of using AI in academic settings.

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STREAM-TECHNOLOGY FOR DEVELOPMENT OF CRITICAL THINKING IN FOREIGN LANGUAGE TEACHING

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ABSTRACT

Critical thinking skills are considered as a core competency development issue for future professionals who are preparing to carry out their professional activities in the context of information society and digitalization. It is believed that the role and specificity of critical thinking among future foreign language teachers has not been sufficiently explored. We consider it to be an innovative approach that implies a different understanding of the goals and implementation of the educational process and is related to the general trend of integration in the contemporary educational environment. The specific application of this technology is a new iteration of the already known STEM approach, which at this stage has evolved into the STREAM approach. Following the logic of the STREAM approach in education, the STREAM technology developed by the authors of this study is based on strengthening the role of thinking skills embodied in the arts and reading/writing in the humanities. The introduction of natural sciences, technology, engineering and mathematics content in education, and the combination of interdisciplinary STREAM technology techniques is crucial in the represented research. The differences between STREAM technology and traditional technologies are also shown. The interdisciplinary nature of the developed techniques is represented by how these techniques are fulfilled in terms of content, which is directly related to the logic of the STREAM technology teaching material content. The figures represented precisely show the visual side of the procedural part of technology and author techniques developed.

Keywords: critical thinking, foreign language students, STREAM-technology, information society, integration.

INTRODUCTION

Critical thinking skills are considered as a competence subject to mandatory development in a future specialist who is ready to carry out professional activities in the conditions of the information society and digitalization [4, 11, 13, 15]. At the same time, in our opinion, there are some theoretical reasons associated with insufficient attention to the role and specifics of critical thinking not as a universal competence, but as a component of the professional activity of an individual specialist. Thus, the role and specificity of critical thinking of a future foreign language teacher remains, in our opinion, insufficiently studied.

One of the promising and debatable areas in modern education is the use of STREAM technology, which means an innovative approach and a different understanding of the goals and methods of implementing the educational process, which, in our opinion, is

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associated with the general trends of integration in the modern educational environment. Based on the analysis of the studied concepts and scientific works, it seems possible to conclude that in most cases the technological aspect of integration within the framework of the integral approach was achieved, as a rule, on a priority basis of subjects of the natural science cycle. We, in turn, are convinced that this kind of bias should not take place, therefore, it is necessary to focus on the humanitarian, and moreover, on the possibly equivalent interdisciplinary component of the integral approach in education. In this regard, this study is aimed at developing a technology for the development of critical thinking as one of the factors for the success of the professional activity of a future foreign language teacher.

MATERIALS AND METHODS

The methodological basis of the study is the provisions of the systemic (P.K. Anokhin, I.V. Blauberg, G.N. Serikov, E.G. Yudin), integral (A.V. Bukalov, K. Wilber, T. Asher, etc.).), interdisciplinary (M.N. Berulava, N.V. Popova, G.K. Selevko, etc.), synergetic (V.G. Budanov, M.A. Basin, V.V. Vasilkova, G.N. Dulnev, Kurdyumov S.P., Kureychik V.M., G. Haken and others) [2, 8, 17] scientific approaches, the combination of which made it possible to carry out a comprehensive study of the research problem.

In order to solve the set tasks and test the initial assumptions, a set of complementary research methods was used that are adequate to its subject: theoretical and constructive methods: analysis, synthesis, abstraction, generalization, analogy, comparison, opposition, idealization, modelling, classification, functional and process design; empirical private methods: observation, testing, analysis of written works; empirical complex methods: monitoring, experiential learning, ascertaining and shaping experiments.

RESULTS

Such scientists as Sibgatullina T.V., Kosaretsky S.G., Leung A., Mulnix A.B., Tytler R. and others have been studying the features of the development and implementation of the STREAM approach at the present stage. We also note that the STREAM approach in education has appeared relatively recently, about 5-7 years ago, representing a new round of the STEM approach in education. The use of such technologies gives rise to a new problem - the training of teaching staff who will be able not only to effectively implement such technologies, but also be able to independently develop them.

The STREAM technology developed by the author of the study in accordance with the logic of the STREAM approach in education [1, 3, 5, 9, 16] is based on strengthening the role of the humanities Arts and Reading / wRiting - thinking skills embodied in reading and writing with the introduction and interdisciplinary combination of the content of natural sciences, technology, engineering, mathematics in education.

The essence of technology also makes it possible to focus on the content of the integrative language picture of the world and the influence of the interdisciplinary lexical field, which are specific factors that determine the effective development of critical thinking of the future teacher of a foreign language.

The differences between STREAM technology and traditional technologies are revealed, which determine its relevance for this study:

1) integral approach as the basis of STREAM technology. It is noted that due to the educational potential of the integral approach, it becomes possible to create the necessary conditions for the integration of the components of the personal sphere of the future teacher of a foreign language. Integration of the components of the personal sphere of the future teacher of a foreign language, which also includes critical thinking, allows you to have a positive impact on the professional and personal development of the future teacher of a foreign language;

2) the critical fullness of the content of STREAM technology as a qualitative characteristic of STREAM technology. It has been established that this characteristic implies an integral combination of material from various disciplines, which requires critical reflection;

3) non-linearity of the educational process within the STREAM technology. It has been determined that STREAM technology allows for a non-linear educational process, since it makes it possible to use the material of various disciplines, the content of which does not contradict the content of a foreign language course. In turn, the content based on the material of various disciplines allows you to model a situation that requires the use of critical thinking;

4) the presence of activities Reading and Writing (reading and writing), expanding the benefits of STREAM technology. It was revealed that STREAM technology uses two types of speech activity, the emphasis on which is absent in STEM and STEAM technologies - reading and writing. These types of speech activity make it possible to update and apply critical thinking through the author's methods of STREAM technology.

The algorithm of the procedural part correlates with the functional model of critical thinking. This model illustrates the sequence of actions performed by the teacher and students during the development of this type of thinking as critical. We believe that it can be considered as the basis for developing an algorithm for the procedural part of the described technology, which aims to develop this type of thinking as critical, since the content and sequence of the phases mentioned in the model demonstrate the visibility and reproducibility of pedagogical actions, while the phases are filled with the specifics of the process critical thinking as such. Along with the standard phases "information challenge", "reasoning", "reflection", we added the "control" phase, which, if the result is positive, precedes the "reflection" phase, and if the result is negative, it transfers the interaction to the level of "information challenge". This change allows us to avoid straightforwardness and introduce a certain variability into the logic of the development of the type of thinking under study. The stage of actualization of critical thinking of students is also added to the algorithm of the procedural part of the STREAM technology. This stage denotes the subsequent improvement of critical thinking on the part of the students themselves during their life. The algorithm of the procedural part is shown in Figure 1.

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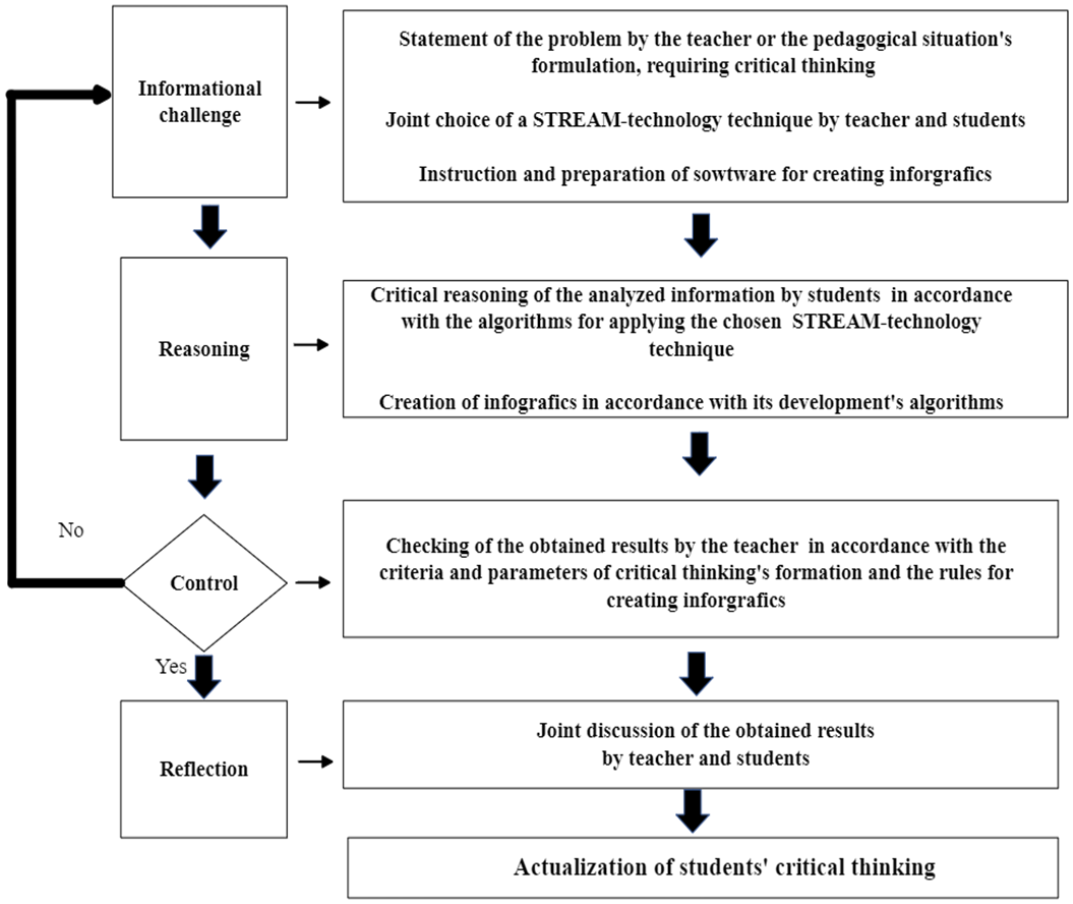


Figure 1. The algorithm of the procedural part of STREAM technology

Special results of using STREAM technology techniques will be achieved precisely in the process of teaching future foreign language teachers, because this type of students has the peculiarity of having several language pictures of the world, depending on the number of languages being studied [7, 10, 14]. When filling the techniques with the necessary content of the educational material, reliance was placed on the different sections of science mentioned in the previous paragraph. At the same time, the essence of the described techniques of the developed technology, associated with their "infographic nature" [12], makes it possible to show how, within the framework of using these techniques during critical analysis of the material of a particular field of scientific knowledge, information blocks consisting of textual and visual information are integrated and connected.

A single technique of STREAM-technology does not have the characteristics of a full coverage of interdisciplinary issues, only the complex application of the techniques of this technology makes it possible to develop this type of thinking as critical in terms of the success rate of a professional in the informational society. Let us show only several examples of the techniques mentioned.

"Start the mechanism" is the author's technique, the idea of which comes from the understanding of the self-completion's principle by the author of the study, which is a logical component of the phenomenon of pedagogical self-organization [6]. The principle of self-completion as applied to the technology described in this study means bringing the proposed object of information to the appropriate content. The gears

symbolize the image of an integral mechanism that unites the content of the information object. Activation of the mechanism means the practical implementation of the principle of self-completion. (Fig.2).

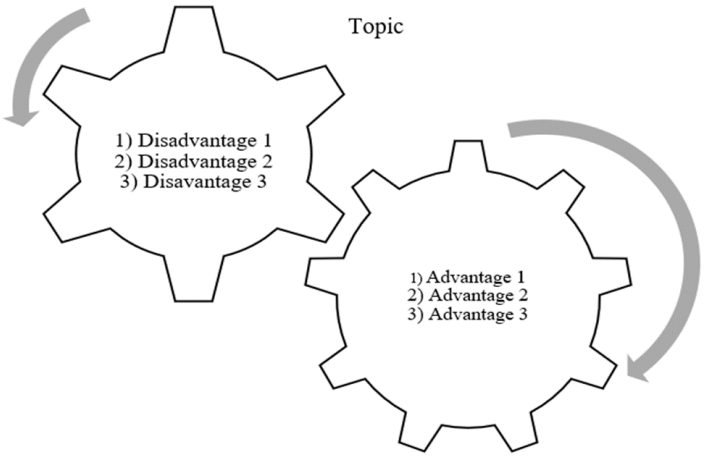


Figure 2. Visualization of technique “Start the mechanism”

On the left side, the reverse side of the topic under consideration is displayed, previously explained by the teacher. On the right side - positive arguments, advantages formulated by students in the course of working with admission. Pre-selected negative aspects of a certain problematic aspect or phenomenon stimulate a positive critical reflection of those in the necessary direction, as a result, forming a common understanding of the topic under discussion, as presented in a specific example.

The "Human" technique (Fig.3) is a schematic model of a person. This technique, in terms of its practical significance, according to the author of the study, can be aimed at a critical analysis of problematic situations or issues. The idea of integrity is the theoretical basis of the described technique. General philosophy interprets this idea in this way: it is the interconnectedness of the internal components of a certain object. When applied to the learning process, this idea reflects the high degree of logical relationships that are established.

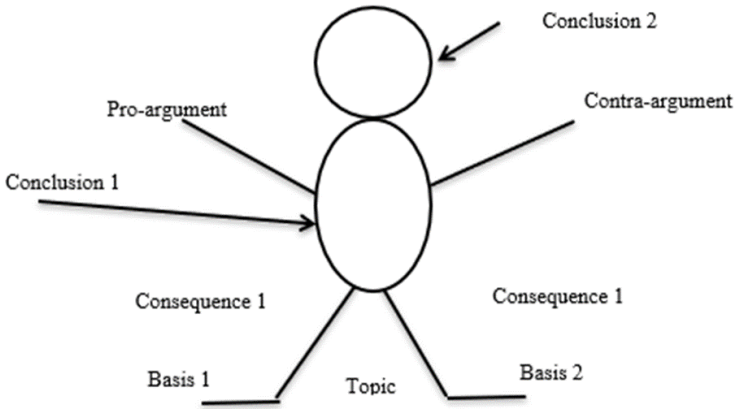


Figure 3. General infographics as a result of technique "Start the mechanism"

The presented model consists of the following components. The basis of the problem under consideration is indicated in the feet, the conclusions from the basis of the

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problem under consideration are fixed in the area of the actual legs of the model. Further, the main point of view is indicated in the torso of the model. Arguments and counterarguments are fixed in the area of the model's hands. The final point of view and the result of the critical analysis are indicated in the head of the model.

Such a process of critical problem analysis gives students the opportunity to comprehend, it would seem, absolutely dogmatic, transparent at first glance, a problem or phenomenon. The technique actualizes critical thinking, which generates the logical components of the described model.

The author's technique "The Glass Bead Game" is theoretically based on the idea that became the basis of the work of art, bearing the same name, written by G. Hesse. Thus, the mentioned idea enabled the author of the study to develop a technique aimed at analysing a work of art from the point of view of the associations that appear after reading. Below are the main components of the described technique.

To conduct an associative analysis, five main components are distinguished: literature itself, music, mathematics, painting, architecture (Fig.4). The general associative-analytical scheme is supplemented by the listed components, which contributes to obtaining a versatile system of associations. During this associative analysis, students give examples of musical works, mathematical expressions, architectural monuments, painting objects with which the analysed work of art is associated.

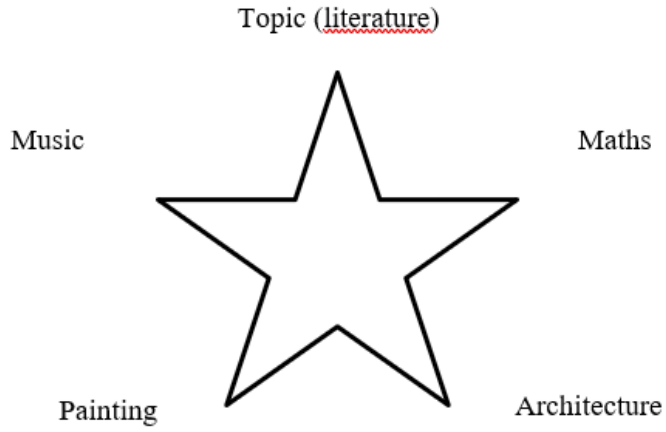


Figure 4. Technique "The Glass Bead Game"

Filling this star with the necessary content requires “strong” critical thinking and a high level of erudition and motivation to reach the essence of the work. At the same time, the mentioned symbol can also be considered as a figurative visualization of the final result of associative critical analysis, which is expressed in the achievement of new and sometimes previously unknown knowledge.

The essence of this technique lies in the associative analysis of a literature work, in identifying associative interdisciplinary correlations between the presented components, discussing the associations obtained and the relationships between them, as well as visual representation of the associative interdisciplinary model of a literature work.

DISCUSSION

Thus, when using STREAM technology, it's algorithm of procedural part and it's authoring techniques, it is possible to stimulate the mental activity of students and develop their skills to make arguments, make assumptions, make inferences, interpret information and draw conclusions in the process critical thinking's development. The high necessary level of development of such a type of thinking as critical thinking among students as prospective professionals in the field of a foreign language can only be achieved through the integrated development of the above-mentioned skills, as the results of experimental use have shown.

CONCLUSION

In summary, this article presents the main ideas on the STREAM technology for the development of critical thinking skills in foreign language teaching. The methodological basis of the research is the identification of a systematic, interdisciplinary and synergistic scientific approach, the combination of which made it possible to conduct a comprehensive study of the research question. The algorithm of the procedural part is related to the functional model of critical thinking. This model shows the sequence of actions that teachers and students take when developing critical thinking. STREAM technology authoring techniques "Start the Mechanism, Human, Glass Bead Game" etc. play especially strong part in the process of development of critical thinking, the use of them encourages students and effectively develop critical thinking skills. These skills serve as indicators of the level of formation of critical thinking. Therefore, it is highly recommended to use STREAM technology for the development of critical thinking, especially in foreign language teaching.

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THE SELECTION OF DIDACTIC RESOURCES IN THE GEOGRAPHY LESSON - AN EXPRESSION OF THE TEACHER'S DESIGN THINKING

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ABSTRACT

From a scientific point of view, the origins of design thinking can be traced back to the late 1960s. The very concept of "design thinking" appeared in the late 1980s and 1990s, when Rolf Faste began teaching design thinking as a "method of creative action" at Stanford University. Since then, various definitions of this concept have been added to the literature. Although design thinking is a business methodology, today it is widely used in the public, non-governmental, health and education sectors. With a view to stimulating efficiency in training, today more and more educational institutions are turning to it. This is not surprising, given the applicability of design thinking in several main areas: teachers, students, parents, administration. In education, it follows certain stages and methods: understanding needs, forming teams, dialogue, generating solutions, using a structured and facilitated learning process.

On a global scale, numerous effective practices have been amassed for the implementation of design thinking in the realm of education. The incorporation of design thinking principles extends to Bulgaria as well. Our country primarily focuses on formulating programs for the advancement of design thinking within the framework of international and regional projects, primarily in the field of ICT, which are directed towards secondary education. In this regard, the present study proposes that the selection of didactic resources in a geography lesson is an expression of the teacher's design thinking. The research is grounded in the understanding that presenting the interrelationships between natural features and social activities in the various spaces of the Earth is a significant challenge in geography. Therefore, the subject equally demands a multitude of didactic resources. To fulfill the objectives of the study, three categories of didactic resources are presented, their functions in the lesson are outlined, their features are delineated, and the competence of the teacher for their appropriate application in lesson planning is emphasized.

The comprehensive didactic-methodical description of didactic resources in geography education is based on the constructive framework for planning the geography lesson proposed by Schaal in 2012. The fundamental categorization of didactic resources by Fuchs in 1980 has been supplemented and modified.

Keywords: didactics of geography, learning, thinking, design thinking, didactic resource

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INTRODUCTION

As a result of the study, a checklist is recommended for the judicious use of didactic resources in the geography lesson in the context of the teacher's design thinking. The present study suggests that the selection of instructional tools in geography lessons reflects the teacher's design thinking.

METERIALS & METHODS

The research is based on the understanding that for geography, the presentation of the interrelationships between natural features and social activities in the different spaces of the Earth is a great challenge. Therefore, the subject also needs an abundance of didactic resources, even more so in the context of design thinking. For the purposes of the study, three categories of didactic resources are presented, their function in the lesson is described, their features are characterized, the competence of the teacher for their adequate application in lesson planning.

The comprehensive didactic-methodological description of didactic resources in geography education is based on the constructive framework for planning the geography lesson of Schaal from 2012. The used fundamental categorization of didactic resources of Fuchs from 1980 is supplemented and modified. As a result of the research, a checklist for the justified use of didactic resources in the geography lesson in the context of the teacher's design thinking is proposed.

RESULTS & DISCUSSION

What is the place of didactic resources/media in the teaching and learning process?

Along with the selected learning content and methods, didactic resources/media are objects and sources of information needed to construct the teaching and learning process (Fig. 1). "Therefore, the question of whether the use of multimedia improves learning is ill-posed. Crucial to the success of teaching and learning is the learning content and organization of teaching, including the form used to present the information' [12]. Among the scientific studies, the meta-analysis of Hattie [2], [3] and Kerres [4] stands out, according to which the increase in learning effectiveness depends primarily on didactic methods (eg problem solving and Concept Mapping) and less on the chosen media technology (eg computer-assisted learning and web-based learning). This means that the impact of computer-assisted learning and web-based learning is not so much due to the media used, but primarily to the possibility that the user of the program receives direct individual feedback on his decisions. In this sense, the selection and use of media must correspond to the objectives of the lesson and be the result of didactic reasoning (reasoning) [6]. One more thing, the representation of reality is a big challenge: the selection of media vigans is the result of a specific, subjective idea of reality: Which exact space to present? What is the perspective taken? What part of reality is emerging? In this sense, there are opportunities for manipulation. (ibid)

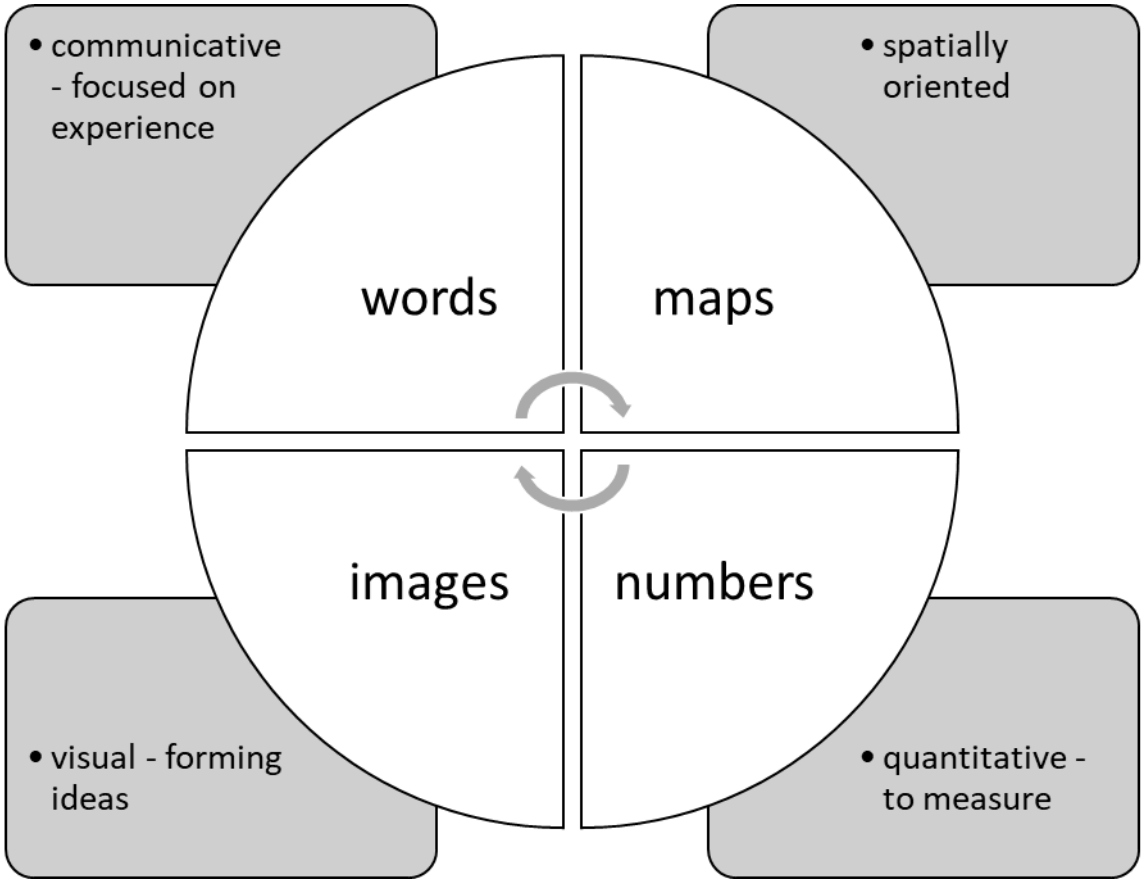


Fig 1. Classification of media according to their character for recreating educational content in the teaching and learning process (according to [1], [5])

What functions do didactic resources/media perform in the teaching and learning process?

In the process of lesson planning, the media play a critical role in fulfilling certain functions, such as supporting visibility, structuring problematic situations, accentuating key points, stimulating memory, and providing indirect experience where actual experience is not possible. Other functions of media include stimulating conversational communication during the lesson, arousing interest, activating motivation, and provoking critical thinking. In addition, media can be used to create a flexible, needs-based teaching arrangement that can vary based on observation, structure the learning process, differentiate according to student levels, and be used in group settings. Media can also be used to reinforce learning through exercises and control through problem-solving tasks. Finally, media can be used to develop ideas and attitudes by presenting opposing viewpoints on a topic and creating opportunities for students to apply what they have learned (supplement according to [10], [14]).

What criteria justify the selection of didactic resources/media in the lesson?

A selection of didactic resources, oriented towards the goals, learning content and methods of each lesson, is a prerequisite for efficiency in the use of didactic resources. Regarding the selection of media in the lesson, a decision-making framework is constructed (Fig. 2).

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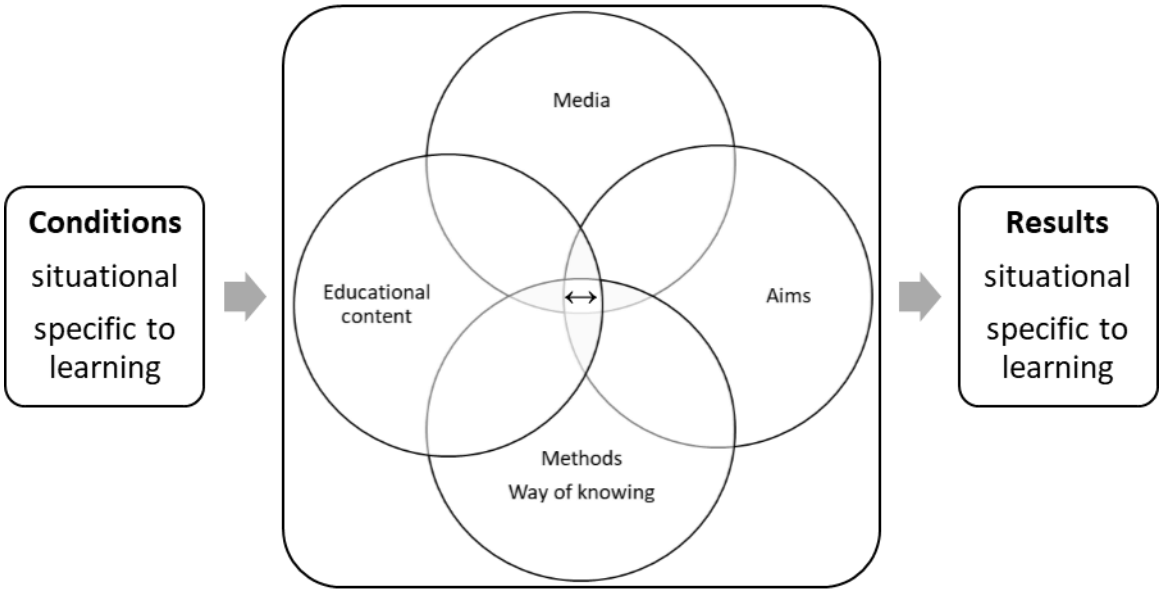


Fig. 2. A Framework for Decision Making in Lesson Planning (after [10])

In accordance with the above framework and in the context of design thinking, the criteria of Rinschede [8], [9]:

Targeting (Why?): The media should contribute to the achievement of the lesson objectives. This is about geographical knowledge and spatial orientation about the location, issues and problems covered in the learning content. In the field of competences "acquisition of knowledge/methods", the media competence of the students is placed in the foreground as a goal.

Socialization (Why?): In addition to cognitive competences (geographical knowledge, spatial orientation) and methodological competences (acquisition of knowledge/methods), media also contribute to the achievement of social goals (communication, evaluation, attitude). Does the media raise questions and frame arguments? Does it offer an opportunity for discussion and communication?

Visibility and the possibility of self-activity with the media (For what?)

Content Orientation (What?): The learning content presented should match the lesson objectives. Timeliness, scientific correctness and comprehensibility are other sub-aspects in the evaluation of learning content.

Media Adequacy and Structure (What?): Is the media appropriate for framing the issue? The structure of the geographical teaching content significantly affects the selection of media in the lesson: photographs, drawings, maps and aerial photographs allow the coverage of external features and physiognomic aspects (eg landforms, urban environments). Thematic maps, cartograms and causal profiles clarify structural relationships (annual rainfall, share of grassland). Processes and dynamic developments, the course of which must be represented at a different point in time can be presented with diagrams, graphs, animations, movies and thematic maps. For acoustic phenomena (noise, natural sounds) audio media is needed, and for visual phenomena – photos and

films (volcanic eruption, earthquakes). Opinions of different groups allow to be presented with text (eg interview) and cartoons.

Perspectives (Who? What?): Both the views of the media's creators and the perspective on the selection and presentation of learning content (eg, image detail) mark the subjectivity and manipulability of the media.

Adequacy to the addressee (Who?): The media must be suitable for the cognitive and instrumental level of the students (without demands below and above their capabilities), be up-to-date and oriented around the interests of the students. Another criterion is the comprehensible construction or the possibility of transfer to other spaces and examples.

Didactic place (When?): Introduction/Motivation, setting a problem situation (task: arousing interest), locating, formulating a hypothesis and solution strategy, phase developing the new learning content (task: lots of information), consolidation phase (task : key findings), application phase, control phase (task: feedback).

Organizational problems and other (technical) conditions (Where? How efficiently? Keeping appliances or spaces, getting to know the technique).

How to justify the selection of didactic resource/media in the context of design thinking?

Undoubtedly, the choice of media must be justified. Therefore, the functions of the media in the teaching-learning process must be taken into account, as well as the possible criteria for selecting the media in the specific case and according to their importance, including in the context of design thinking. The goals to be achieved with the help of the media must be formulated in advance. In this sense, certain didactic and methodological questions must be answered when making a decision. At the end of the analysis are the answers to the following questions: Is the media suitable for achieving the lesson's objectives? Which media are selected?

Table 1. Media selection questions in the context of design thinking (after [7])

Focus	Focus Sample questions for consideration
Why?	Does media use motivate students?
	Does the media point to a problematic situation?
	Does media cause cognitive conflict?
	Does the media reflect the learning content?
	Can they learn and practice different ways of working through the media?
	Which competences can be formed through the media?
	Is the media suitable for reinforcing the results of the lesson, for practice or deepening?
What?	What learning content should be taught?
	Is the content adequately represented in the media?
	From what perspective is the media created?

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How?	Is the media appropriate for the intended social form?
Who studies?	Is the media appropriate for the age of the students? What available knowledge do students have about the learning content? What available skills do students have regarding the use of the media type (media competence)?
Who teaches?	What competences does the teacher need regarding the use of the media (technical skills, professional training/experience)?
When?	Is the time of day, day of the week, time of year selected appropriately? In which phase of the lesson should the media be used?
How much time?	How much media handling time is required?
Where?	Where should the media be used (in the classroom, in another space, in the field, outside the school)?
How effective?	Does it justify the expected effect, the effort to use the media?

CONCLUSION

In conclusion, a teacher's media competence in lesson planning can be characterized as an illustration of their design thinking. The teacher has the responsibility of incorporating the didactic resource or media in a meaningful manner in the lesson, which is related to the development of their abilities to skillfully, i.e. critically, responsibly, and consciously handle the media within and outside the school. Specifically, what is associated with a teacher's media competence? Referring to the concept of media competence defined by Tulodziecki et al. [13], we propose the following:

• *Knowledge and ability of the teacher to analyze and select media:* The teacher must explore the range of media (both cross-curricular and specific to geography), their manifestations (such as different types of diagrams), and their specific applicability (selection of appropriate media for the objectives and content of the lesson).

Media design: The teacher must understand media as a form of presentation (photograph, graphic, text, film, animation), as a creation technique (camera recording, film excerpt, tone combination), and as a form of creation (message, commentary, report).

• *Creating and distributing media*: The teacher must know how to create and distribute media (for example, at the end of a project, fieldwork, field trip), including tracking and evaluating economic, legal, political, or other conditions for creating and distributing media, and must understand their potential effects.

• *Use of media: The teacher must know how to present media or use media.*

• *Impacts of the media and influence:* The teacher develops an attitude towards the media, in the context of its impact on the emotions, representations of reality, behavior and value orientation of the students. "Today, geography takes on the important role of a particularly intensive media subject. Frequent work with various didactic resources/media is connected, on the one hand, with the possibility to present a problem situation in a different way and to achieve different goals. On the other hand, however, media selection can lead to distortion and manipulation' [11].

• *Developing a critical attitude towards the media:* The educator is capable of critically examining the content, representation, and purpose of the media; they are able to form a clear opinion about various media forms. According to the educational standard and the geography curricula for the secondary school, the media competence of the teacher can be summarized in three areas:

- *Orientation in space*: The teacher is able to work adequately with maps (in research, making simple maps, cartography).
- *Acquisition of knowledge/methods*: The teacher is able to extract geographic scientific information from real space or media.
- *Evaluation:* The teacher is able to evaluate selected scientific geographical information from the media according to criteria.

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THE TRANSFORMATION OF EDUCATIONAL MODELS AS THE KEY FACTOR OF ECO-INNOVATIONS

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ABSTRACT

Eco-innovation is a crucial factor in the drive towards sustainable development, albeit a knowledge-intensive process that requires a fundamental transformation of the education system. The focus should be on sustainable education, characterized by holistic approaches, strategic planning and transformative change. Key elements are learning experience systems that include cognitive understanding, practical skills, social cohesion and emotional intelligence. As UNESCO points out, eight key competences - systemic thinking, forecasting, regulatory and strategic approaches, cooperation, critical thinking, confidence and integrated problem solving - are essential for achieving the SDGs. The aim of this study is to examine the impact of learning methods on students' involvement in the creation and implementation of eco-innovations. The study involved first year students who were split into two groups. The first group was a traditional learning group that took a course of study using traditional lectures and a test of theoretical knowledge. The second group was the active learning group, where students were involved in the study process and active learning methods were used. The next year of study, the active learning group showed better results on an environmental technology study course, as well as taking part in hackathons where eco-innovations were created.

Keywords: educational models, eco-innovations, educational system transformation

INTRODUCTION

Education is one of the critical factors in promoting sustainable development as it is a key element in creating eco-innovations. Eco-innovations encompass a wide range of products, processes, systems, and services that improve the quality of life in society while significantly reducing environmental impact. Integrating eco-innovation into study programs enhances students' ability to create innovative solutions to environmental problems, thus promoting sustainability. Eco-innovations play a crucial role in improving the performance and competitiveness of companies and moving towards sustainability [1]. A higher potential for eco-innovations fosters the implementation of sustainability-based innovations in small and medium-sized enterprises [2]. Moreover, eco-innovations are crucial for reducing environmental impact, improving resource efficiency, and promoting an environmentally friendly economy [3].

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The implementation of eco-innovation practices in organizations promotes the development of sustainable products and processes, reduces adverse impacts, and saves costs, thereby fostering sustainable development [4]. Furthermore, eco-innovation is recognized as a key element to support sustainable intellectual capital in companies, promoting innovation processes that address critical environmental issues such as greenhouse gas emissions, toxic impacts on ecosystems, and loss of biodiversity [5]. Additionally, eco-innovations are considered a strategy that provides value to companies and customers, promotes sustainable development, and encourages environmentally friendly practices [4]. By utilizing eco-innovations, companies can strengthen their competitive advantages, improve sustainable operational results, and help achieve the overall goal of sustainability [1]. Therefore, education plays a crucial role in promoting the potential for eco-innovations among individuals and organizations, ultimately fostering sustainable development and environmental management.

Comprehensive approaches, strategic planning, and transformative changes are essential elements to drive eco-innovations towards sustainable development. Organizations can develop and support eco-innovation programs that cover environmental, social, and economic aspects to effectively address environmental problems [6]. Strategic planning is essential to drive eco-innovations towards sustainable outcomes. Xavier research group [7] emphasize the importance of strategic systems, such as the Eco-Innovation Readiness Model, to promote the integration of eco-innovation in companies. Strategic planning helps align eco-innovation initiatives with long-term sustainability goals, ensuring positive environmental outcomes. Transformative changes are the main driving force for pushing eco-innovations towards sustainability. Flores-Rivera research team [8] highlight the mediating role of eco-innovation strategies in transforming motivation into environmental sustainability outcomes. These changes include shifts in organizational practices, processes, and thinking towards sustainable approaches, thereby creating tangible environmental benefits.

The creation and implementation of eco-innovations is a complex process influenced by a range of factors affecting their implementation and the global economy's move towards sustainability. The main factors can be grouped into several categories: **Organizational barriers** related to insufficient resources for research and development. The complexity of managing the eco-innovation implementation process and the lack of organizational capacity are often cited [7]. **Insufficient financial resources** for acquiring cleaner technologies and investments in eco-innovations. Financial constraints particularly affect small and medium-sized enterprises [9]. **The lack of regulatory frameworks** and inadequate national and municipal policies, as well as unclear regulations, are often key hindering factors for eco-innovation implementation [10]. **The lack of information and knowledge**, as well as scepticism and stereotypes, often hinder eco-innovation implementation. Companies lack essential information, knowledge, and understanding of the significance of eco-innovation for sustainability, limiting their ability to implement even low-cost eco-technologies. **Knowledge and technology directions** that do not directly align with the company's core activities limit access to alternative knowledge. Market imbalances and unfair competition can create problems in implementing eco-innovations. Companies fail to effectively integrate external knowledge into their innovation processes [11]. **The increasing shortage of qualified and knowledgeable human resources**, especially scientists and inventors,

hampers the development and implementation of eco-innovations and sustainable technologies [12]. **Human natural resistance to change** and the complexity of implementing eco-innovations hinder their adoption. Innovations are often perceived as too complex and even disruptive [13]. Education and knowledge transfer are the main driving forces for eco-innovations. The supportive educational environment and continuity in the education process play a significant role in the creation of eco-innovations, increasing the intensity of their implementation.

The aim of this study is to examine the impact of learning methods on students' involvement in the creation and implementation of eco-innovations.

MATERIALS AND METHODS

The experiment aimed to evaluate the efficiency of the active learning approach [14], [15] by dividing students into two groups. Eighteen students were enrolled in the study and randomly assigned to either the traditional learning group or the active learning group. The traditional learning group, consisting of nine students, was taught using the traditional lecture-based method. In contrast, the active learning group, also comprising nine students, was taught using the active learning approach, which followed a structured six-step method (See Figure 1).

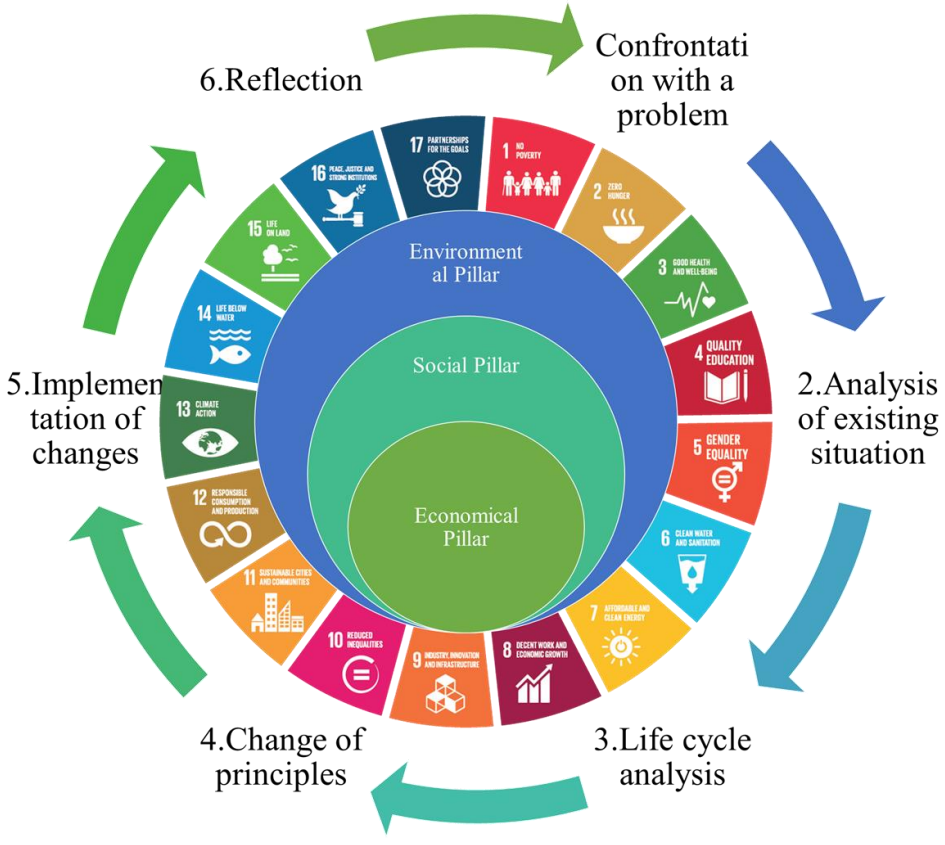


Figure 1. The six-step active learning approach.

The content of the study focused on sustainable development, a topic chosen for its relevance and complexity. Both groups received the same teaching material, ensuring consistency in content delivery. The stages of six-step active learning approach: **Problem Confrontation**: The first step involves presenting students with an

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investigational problem. This problem is enriched with visual materials, statistical data, research results, and other relevant sources of knowledge. This ensures a comprehensive understanding and multifaceted approach to the problem. **Situation Analysis**: In the second step, students analyse a current situation, which is based on real events. This encourages them to connect theoretical knowledge with practical, real-world applications. **Cause Investigation**: The third step requires students to delve into the causation of the specific problem. They analyse the problem within its context to understand the underlying factors and reasons. **Creating Changes**: In the fourth step, students are tasked with creating changes or new conditions to address the problem. This involves problem-solving and innovative thinking to devise effective solutions. **Local Integration**: The fifth step focuses on integrating the developed conditions at the local level. This step ensures that solutions are practical and tailored to specific community needs, fostering a sense of responsibility and community engagement. **Personal Reflection**: The sixth step involves personal reflection by each student. They reflect on their learning and the application of their solutions, considering the impact on the local community.

The training took place over February and March 2023. Each group had 2 hours of training per week. The total training duration was 14 hours per group. In the final week, students in exam answered 24 questions. Each question required a written and justified response. Faculty members rated the responses without knowing the group to which the author belonged. Scores were given on a 10-point scale per question. In the next semester from September to December 2023 were monitored students' performance in study course Environmental Technologies and students activity according to innovation activities. All study year from September 2023 till June 2024 students involved in experiment get information about activities related to eco-innovation development.

The Shapiro-Wilk test was used to check for normality in the data. The Kruskal-Wallis test was used for comparing multiple groups, likely due to the non-parametric nature of the data.

RESULTS

The results of the descriptive statistics for exam performance and the Environmental Technologies course are presented in Table 1. **Exam Performance.** The descriptive statistics compare Traditional and Active learning methods, emphasizing the differences in student performance and score variability. Both methods encompass 216 observations with no missing values. The Active learning method yields a higher mean score 7.5 and median score 8.0 compared to the Traditional learning method, which has a mean score of 5.8 and a median score of 6.0. This indicates a superior overall performance in the Active learning group. The Traditional learning method exhibits greater variability with a range of 9.0 and a standard deviation of 2.8. Conversely, the Active learning method shows a narrower range of 5.0 and a lower standard deviation of 1.7, suggesting more consistent performance among students. Overall, the Active learning method results in higher and more consistent student scores compared to the Traditional learning method. The higher mean and median values, coupled with lower variability, indicate that students benefit more from Active learning, achieving better and more uniform outcomes. This suggests that Active learning could be a more effective approach for enhancing student performance and reducing score disparities. **Study Course Environmental Technologies.** The Traditional learning group consisted of 9

observations with no missing values. The assessment scores ranged from a minimum of 4.0 to a maximum of 8.0, resulting in a range of 4.0. The mean score for this group was 6.4, with a standard deviation of 1.5, indicating moderate variability around the mean. The Active learning group also comprised 9 observations with no missing values. The scores for this group ranged from a minimum of 7.0 to a maximum of 10.0, yielding a narrower range of 3.0. The mean score for the Active learning group was 9.0, with a standard deviation of 1.2, indicating a relatively lower spread of scores around the mean compared to the Traditional learning group. The Active learning group exhibited higher overall scores compared to the Traditional learning group, as evidenced by the higher mean 9.0 and 6.4 and higher medians 10.0 and 6.0. The range of scores was slightly narrower in the Active learning group 3.0 than in the Traditional learning group 4.0, suggesting less variability in the former. Quartile values further indicated that the majority of scores in the Active learning group were at the upper end of the scale, whereas the Traditional learning group showed a more evenly spread distribution. The standard deviation was lower in the Active learning group 1.2 compared to the Traditional learning group 1.5, reflecting a tighter clustering of scores around the mean in the Active learning group. The Active learning approach resulted in higher and more consistent assessment scores compared to the Traditional learning method.

Table 1. The results of descriptive statistics for exam performance and the Environmental Technologies course.

Statistic	Results of exam (Spring 2023)		Results of Environmental Technologies (Autumn 2023)	
	Traditional learning	Active learning	Traditional learning	Active learning
Nr. of observations	216	216	9	9
Nr. of missing values	0	0	0	0
Minimum	1.0	5.0	4.0	7.0
Maximum	10.0	10.0	8.0	10.0
Range	9.0	5.0	4.0	3.0
1st Quartile	3.0	6.0	5.0	8.0
Median	6.0	8.0	6.0	10.0
3rd Quartile	8.0	9.0	8.0	10.0
Mean	5.8	7.5	6.4	9.0
Standard deviation (n)	2.8	1.7	1.5	1.2

Given that the datasets from the exam and study course Environmental Technologies student assessments do not follow a normal distribution, as determined by the Shapiro-Wilk test ($\alpha = 0.05$; p-values < 0.0001 and 0.006), the Kruskal-Wallis test was employed to compare the two groups. The results showed p-values of 0.0001 for the exam and 0.005 for the study course, both below the significance threshold ($\alpha = 0.05$), leading to the rejection of the null hypothesis and indicating a statistically significant difference in ratings between the traditional and active learning groups in both cases.
Students from the active learning group participated in seven eco-innovation events. In one event, they received financial support for the future development of their proposed idea of textile waste management.

DISCUSSION

The findings from this study underscore the critical role of educational models in fostering eco-innovation and sustainable development. The comparative analysis of

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traditional and active learning methods reveals significant insights into how pedagogical approaches can influence student engagement, comprehension, and performance in the context of eco-innovations.

The data indicates that students in the active learning group consistently outperformed their peers in the traditional learning group. This is evident from the higher mean and median scores in both the initial exam and the Environmental Technologies course. The active learning group's mean score of 7.5 in the exam and 9.0 in the Environmental Technologies course, compared to 5.8 and 6.4 respectively for the traditional learning group, suggests that active learning strategies significantly enhance student performance.

This improvement can be attributed to the structured six-step active learning approach, which fosters critical thinking, problem-solving, and collaborative learning. These methods engage students more deeply with the material, encouraging them to apply theoretical knowledge to practical problems, thereby enhancing their understanding and retention. This aligns with existing literature, which suggests that active learning environments promote better academic outcomes and deeper learning experiences [15].

The study also highlights the consistency of student performance in the active learning group. The lower standard deviation in scores for this group suggests that active learning methods not only improve overall performance but also reduce variability in student outcomes. This consistency is crucial for educational equity, ensuring that all students benefit from the learning process, not just those who might excel in traditional, lecture-based settings.

The superior performance of students in the active learning group has significant implications for the field of eco-innovation. As the study demonstrates, students exposed to active learning methods are better equipped to engage with complex environmental issues and develop innovative solutions. This is particularly important in the context of sustainable development, where creative problem-solving and interdisciplinary approaches are essential. Active learning methods that emphasize real-world applications, collaborative projects, and reflective thinking prepare students to tackle the multifaceted challenges of eco-innovation. By integrating these methods into educational curricula, institutions can cultivate a generation of innovators who are not only knowledgeable but also capable of implementing sustainable solutions in diverse contexts.

The study also sheds light on the barriers to effective eco-innovation education. Traditional learning models often fail to engage students actively, limiting their ability to internalize and apply knowledge. This is compounded by organizational and resource constraints, particularly in small and medium-sized enterprises [9]. Active learning, by contrast, addresses these barriers by creating a more interactive and engaging learning environment. This approach can mitigate issues related to passive learning and lack of engagement, fostering a more conducive atmosphere for the development of eco-innovations.

The research supports the notion that strategic and transformative changes in educational practices are essential for promoting eco-innovations. Strategic planning [7], ensures that educational initiatives are aligned with long-term sustainability goals. Transformative changes, such as those implemented through active learning methods,

can shift educational paradigms towards more holistic and integrated approaches, ultimately supporting sustainable development.

CONCLUSION

This study highlights the impact of educational methods on student engagement and performance in eco-innovation. The analysis shows that active learning significantly improves student outcomes compared to traditional lecture-based learning. Active learning enhances academic performance, consistency, critical thinking, problem-solving, and collaboration, essential for developing innovative solutions to environmental issues. The findings emphasize the importance of integrating real-world applications, collaborative projects, and reflective thinking into curricula to prepare students for eco-innovation challenges. Institutions that adopt these methods can cultivate innovators equipped to implement sustainable solutions. Moreover, the research calls for strategic changes in educational practices to promote eco-innovation and align with sustainability goals. Active learning methods are more effective than traditional approaches in enhancing student engagement and performance in eco-innovation education, advocating for a transformation in educational models to support sustainable development goals. Future research should explore the long-term impacts of these methods on professional capabilities in eco-innovation.

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GEOINFORMATION TECHNOLOGIES AS A MEANS OF DEVELOPING

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ABSTRACT

Modern information educational technologies open up a wide range of opportunities for teachers of general education institutions to develop students' key competences in geography and ecology lessons. According to the federal state standard for geography, the requirements for subject outcomes of the geography course at the profile level should reflect the ability to work with geographic information systems. The existing level of information technology development allows geographic information systems to be adapted for use in the educational process at secondary school to develop students' spatial thinking skills and create a more complete picture of the world around them. The speed and simplicity of geospatial data processing by means of geoinformation technologies make it possible to significantly individualise the training process for students

In methodological recommendations on geography, much attention is paid to improving the skills of independent activity, including the use of geographic information systems resources. The results of mastering the basic educational programme should reflect the knowledge of geoinformation technologies as a tool for collecting and processing research materials and as a source of geographical information.

The article considers the possibility of introducing modern pedagogical technologies in the educational process, on the example of geoinformation technologies. The activity approach is the main one in modern education in accordance with modern requirements. The article describes the experience of organising the study of ecological and geographical features of the native land by creating an interactive web map of the region. Such an interactive map serves as a means of combining data and visualising them in a clear and easily accessible form. The results obtained can be used in the educational process at school and university.

Keywords: education, field research, GIS, Web maps, project activities

INTRODUCTION

The contemporary era of societal development is referred to as the informatization stage, which currently involves the extensive integration of information and communication technologies into the educational process. The integration of GIS

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technologies into the educational process is a crucial step towards modern education. It enhances the quality of learning, develops students' competencies, and prepares them for professional activities in the digital era [1].

The use of geoinformation technologies in education allows students to delve deeper into geographical and environmental concepts and develop analytical and problem-solving skills. GIS represents a new stage in the development of cartographic methods for studying geography and ecology, utilizing modern software packages and tools. Students can use GIS tools to conduct research, analyze data, model and present their findings. GIS technology enables students to analyze, organize and visualize information, promoting the development of teamwork skills.

Traditional methods of studying geography and ecology do not meet federal state educational standards, making it necessary to introduce geoinformation technologies. Web mapping is one such tool for solving these problems [2,3].

Web mapping is the process of creating interactive maps that are accessible via the internet. It enables users to interact with geographical data, analyze and visualize information directly in the browser.

It is worth noting that web maps are a powerful tool for implementing modern pedagogical technologies in the field of ecological and geographical education. GIS technology allows for the combination of geographical object information, environmental aspects, and spatial data, making the learning process more interactive, visual, and engaging.

The introduction of GIS into the school education system can be achieved through various methods and forms of work with these technologies. For instance, lessons can be conducted using special software and interactive maps that enable students to create and analyze geographical maps independently. It is possible to organize project work in which students conduct research and create their own maps based on data from various sources. This will allow them to apply what they have learned in practice and develop their GIS skills.

This article provides an example of studying the ecological and geographical features of the native land through project activities. Project activity is becoming increasingly relevant in modern teaching as it is through proper independent work on project creation that schoolchildren's information competence and culture of mental labor are best formed [4,5].

The secondary general education sample program in geography places significant emphasis on enhancing independent activity skills, including the utilization of geographic information system resources. The subject outcomes of mastering the basic educational program should demonstrate proficiency in geoinformation technologies as a tool for collecting and processing research materials, as well as a source of geographical information. [6].

MATERIALS AND METHODS

The potential for integrating web technologies into student project activities is exemplified by the creation of an interactive map showcasing the Republic of Tatarstan. The map serves to consolidate dispersed data and present it in a clear and accessible

manner through pop-up windows, which provide detailed information about the mapped objects. The primary objective of creating an interactive web map was to organize a vast amount of information and present it visually in a way that is accessible to a broad range of users.

To achieve this, NextGis software was used, including the desktop geographic information program NextGis QGIS and the web GIS on the cloud service nextgis.com (NextGIS Web).

The research methods employed included web GIS technologies, geoinformational, and cartographic techniques.

RESEARCH RESULTS AND THEIR DISCUSSION

The practical introduction of geoinformation technologies into the educational process aims to increase students' motivation to study the ecological and geographical features of their native land. This is achieved through project activities that involve creating an interactive map of the Republic of Tatarstan. By engaging in this project, students can develop their skills and interest in studying their region.

This work was organized in several stages, where each stage is aimed at logically sequential mastering the skills of working with geoinformation technologies. During project activities, students develop various competences, such as computer skills (using software packages), research skills (studying and analyzing data), creative skills (presenting information in an engaging and understandable format), and communication skills (working in a team).

The first step involves defining the project's objective and the type of interactive map. Students must determine precisely what they wish to display on their map, such as local historical and natural landmarks, geographical or ecological characteristics of the area (district), specially protected natural areas, or other relevant features. After determining the purpose of the map, students should select an appropriate format, including the layers to be included and their appearance.

The second step is to conduct research on their home region, gathering information on its history, characteristics, and notable locations, depending on the map's purpose. They collect photos, texts, videos, and other materials to illustrate the information on their map.

The third stage is crucial and involves creating a geo-information project in the form of a set of geodata. Creating geodata is the primary task of mapping, and it is at this stage that GIS skills are developed.

During the NextGis mapping process, trainees were taught how to add base maps. The QGIS series offers a wide range of modules that include various base maps (map liners), such as Google Maps, Bing Maps, OpenStreetMap, and others. To add a base map to a project, the necessary module must first be installed, followed by the selection of the required map. Finally, the selected map is loaded into the program's working field. Afterwards, the geoinformation project is initiated, and a vector base is created, which is essentially a map of the territory. To accomplish this, the most appropriate map substrate (base map) is selected, which can be a cartogram, satellite image, top base, etc. [6].

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It is also essential to have knowledge of the digitization process, which involves creating vector layers, such as a shapefile. By adding a new layer to the project and editing it, students create individual objects, such as points, lines, or polygons.

This allows for the creation of a personal spatial database, consisting of a set of required vector layers with spatial referencing and their corresponding characteristics. When creating individual polygons on a layer, the program automatically determines certain characteristics, such as area and perimeter.

Once the students have digitized and obtained the vector base of the territory, they proceed to populate it with attributive information. This step acquaints students with the attribute table and involves filling it with fundamental data about the object. Each row in the attribute table represents a separate object created on the layer. The columns in the attribute table are referred to as fields and can be added or deleted as required. Each field is responsible for a specific type of information. For example, one field contains coordinate data, while the second field contains the name.

The fourth and final step involves integrating the created geodata into the Web GIS, which introduces students to web mapping. Web GIS is a system that stores and manages spatial data through a web interface.

To create an interactive map using the NextGIS platform, students must follow a sequence of several steps.

To begin, learners should import their spatial data in a format supported by NextGIS, such as Shapefile, GeoJSON, or KML, using NextGIS built-in tools. Then, they should upload the data to the NextGIS cloud server. Once all the data has been uploaded, a new project will be created on the server, which functions as a container for the data and style settings of the map being created. This is also where the symbols and visualization of the data layers are configured. NextGIS provides a wide range of tools and settings for creating beautiful and informative maps.

The primary task at this stage is to develop interactive elements on the map. NextGIS enables the addition of interaction, such as mouse clicks or hovering over map objects, customization of pop-up information associated with objects, and the ability to switch between data layers. Trainees utilize the information gathered in Step 2 to create these elements.

Consequently, a comprehensive interactive map of the Republic of Tatarstan is produced, containing a vast amount of heterogeneous information. Once all students have uploaded their geodata, customized its style, and added interactive elements, the resulting map is published.

The map can be accessed through any internet browser. All data is stored and maintained on the NextGIS server. NextGIS Web provides an efficient way for multiple users to work with one interactive map, allowing for convenient access to updated information on the map. Each user has their own account that stores information about their map access rights. In the future, users can add new objects to the map, modify their attributes, move and delete them. All changes will be recorded and displayed for each user working with this map.

In addition to organizing project activities, the interactive map can also be used in the educational process. It is an excellent tool for learning about the local region, and its use in lessons can diversify the learning process and maintain student interest.

The interactive elements create engagement and interest in students. On the Web Map, information about an object can be accessed by clicking on it. A pop-up window will appear with relevant information. This allows for the extraction of a large amount of text and graphic information from the map. The pop-up window can display different types of data, including attributive information in text format and multimedia data such as schemes and illustrations.

CONCLUSION

Web maps are a powerful tool for introducing modern pedagogical technologies into the educational process. They enable teachers and students to efficiently organize information, visualize knowledge, and learn new concepts easily. Web maps also allow students to independently research a topic and work on projects, developing their critical thinking and independence.

Geoinformation technologies also provide individualization of the educational process. Tasks of varying difficulty or content can be created for each learner, allowing them to learn according to their individual needs and abilities. Additionally, web maps provide opportunities for collaborative work, enabling students to work together on a single map, share ideas, comment, and make changes. This approach promotes communication and collaborative skills among them.

Therefore, the use of web maps in education allows modern educators to implement innovative teaching methods. The approach results in students actively participating in the educational process, developing their cognitive and creative abilities, and improving overall learning effectiveness.

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SECTION ENVIRONMENTAL LEGISLATION, MULTILATERAL RELATIONS AND FUNDING OPPORTUNITIES

ANALYSIS OF THE EUROPEAN GREEN DEAL BASED ON ESG ASPECTS AND HOW COMPANIES IMPLEMENT THS EUROPEAN SUSTAINABILITY REPORTING STANDARDS (ESRS)

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ABSTRACT

The evolution of the view of the economic growth paradigm, the development of consumer awareness and the development of legal regulations affect the continuous formation of the conditions for sustainable development. The formation of the form, the definition of unambiguous standards and the continuous formation of the provisions of directives obliging an increasingly wide range of companies obliged to report sustainable development, in the short term, is a challenge for many companies operating in the Polish market. An important aspect of both in terms of EU policy, the formation of provisions of reporting standards and the undertaking of processes leading to sustainable action by the entities of the Polish economy are the provisions included in the Green Deal.

The purpose of this paper is to examine the standards and practices of sustainability reporting carried out by companies operating on the Polish market, with particular attention to the practices undertaken leading to the implementation of reporting standards included in the Corporate Sustainability Reporting Directive and the European Sustainability Reporting Standards specified therein.

Keywords: sustainable development, ESG, ESRS, Legislation

INTRODUCTION

Developments in public awareness, changing perceptions of economic growth or climate challenges have led to an increase in the importance of the concept of sustainable development, defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". [3]. The concept of sustainable development was first introduced at the Stockholm Conference in 1972, and since then it has become increasingly important and part of European policy. The European Union, with its goal to be carbon neutral by 2050 and to become the first carbon neutral continent, will face many challenges, the implementation of which will require the involvement of many sectors and the introduction of further legislation, including sustainability reporting, defined as the measurement, disclosure and management of

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accountability to external and internal stakeholders on these issues, their performance and results [4]. Reporting on sustainability issues is important in the context of the objectives of the European Green Deal. However, a number of factors have been identified in the ESG reporting process that lead to insufficient levels of information and reporting quality. These factors include different reporting standards and frameworks, as well as the cost and difficulty of aggregating the data needed for the process [1]. The legislator's response is to amend the introduction of a new EU Parliament and Council regulation on sustainability reporting in the form of Directive EU/2464/2022 of the European Parliament and of the Council of 14.12.2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive EU/34/2013 in the field of sustainability reporting. The Directive aims to increase the scope of companies covered by the reporting requirement, develop the level of comparability of the data disclosed in the report and achieve a higher level of detail, accessibility and reliability of the information disclosed. Entities will be required to report under the provisions of the Directive:

a) Large public interest entities with more than 500 employees and meeting one of the following criteria: a net turnover of more than €40 million or total assets of more than €20 million

b) Entities meeting two of the three requirements (as at the balance sheet date):

- Total assets of more than €20 million
- Net revenues of more than €40 million
- Number of employees over 250.

c) Small and medium-sized enterprises of the Member State which are not micro-entities.

d) Entities outside the European Union generating in the community more than 150 million net revenue expressed in euros. [2]

The Directive also introduces a uniform reporting standard in the form of ESRS (European Sustainability Reporting Standards) guidelines. The first group required to report on the basis of the CSRD guidelines are the entities subject to the NFRD, i.e. large public interest entities, which will be required to report from 2025, reporting on their activities for 2024.

The aim of the study is to verify whether the companies in the WIG ESG group are ready for changes in the sustainability reporting process based on the European Sustainability Reporting Standards introduced under the CSRD. The research group is the 28 companies comprising the WIG-ESG. The WIG-ESG index is published on the basis of a portfolio of shares of entities adhering to the principles of corporate social responsibility, including in the environmental, social and governance areas, covering companies listed in the WIG20 and mWIG40 indices. [5]

The research hypothesis adopted for the purposes of the study is that the companies included in the WIG-ESG are ready for a change in the reporting standard.

MATERIALS AND METHODS

The study decided to analyse the ESG reports for the 2023 reporting year published by the companies in the research group. The study was based on the analysis of selected

indicators and their assigned ESRS reporting disclosures, developed by the ESFG and published in November 2022. The set of indicators used in the analysis is presented in the table below (Table 1.).

Table 1. The summary of the ESRS indicators and disclosures used in the process of analysing ESG reports.

Indicator	Exposures
ESRS 2 - General, strategy, governance and materiality assessment disclosure requirements	• BP-1 - General basis for making sustainability statements • BP-2 - Disclosures of specific circumstances • GOV-1 - The role of the administrative, management and supervisory bodies • GOV-2 - Information provided to and sustainability matters addressed by the undertaking's administrative, management and supervisory bodies • GOV-3 - Integration of sustainability-related performance in incentive schemes • GOV-4 - Statement on sustainability due diligence • GOV-5 - Risk management and internal controls over sustainability reporting • SBM-1 - Market position, strategy, business model(s) and value chain • SBM-2 - Interests and views of stakeholders • SBM-3 - Material impacts, risks and opportunities and their interaction with strategy and business model(s) • IRO-1 - Description of the processes to identify and assess material impacts, risks and opportunities • IRO-2 - Disclosure Requirements in ESRS covered by the undertaking's sustainability statements
ESRS E1- Climate change	• E1-1 - Transition plan for climate change mitigation • E1-2 - Policies related to climate change mitigation and adaptation • E1-3 - Action plans and resources in relation to climate change policies and targets • E1-4 - Targets related to climate change mitigation and adaptation • E1-5 - Energy consumption and mix • E1-6 - Gross Scopes 1, 2, 3 and Total GHG emissions • E1-7 - GHG removals and GHG mitigation projects financed through carbon credits • E1-8 - Internal carbon pricing • E1-9 - Potential financial effects from material physical and transition risks and potential climate-related opportunities
ESRS E2 – Pollution	• E2-1 - Policies related to pollution • E2-2 - Pollution actions and resources • E2-3 - Targets related to pollution • E2-4 - Pollution of air, water and soil • E2-5 - Substances of concern and substances of very high concern • E2-6 - Potential financial effects from pollution-related impacts, risks and opportunities
ESRS E3 - Water and marine resources	• E3-1 - Policies related to water and marine resources • E3-2 - Actions and resources related to water and marine resources • E3-3 - Targets related to water and marine resources • E3-4 - Water consumption

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	• E3-5 - Potential financial effects from water and marine resources-related impacts, risks and opportunities
ESRS E4 – Biodiversity and ecosystems	• E4-1 - Transition plan on biodiversity and ecosystems • E4-2 - Policies related to biodiversity and ecosystems • E4-3 - – Actions and resources related to biodiversity and ecosystems • E4-4 - Targets related to biodiversity and ecosystems • E4-5 - Impact metrics related to biodiversity and ecosystems change • E4-6 - Potential financial effects from biodiversity and ecosystem-related impacts, risks and opportunities
ESRS E5 – Resource use and circular economy	• E5-1 - Policies related to resource use and circular economy • E5-2 - Actions and resources related to resource use and circular economy • E5-3 - Targets related to resource use and circular economy • E5-4 - Resource inflows • E5-5 - Resource outflows • E5-6 - Potential financial effects from resource use and circular economy-related impacts, risks and opportunities
ESRS S1 - Own workforce	• S1-1- Policies related to own workforce • S1-2 - Processes for engaging with own workers and workers' representatives about impacts • S1-3 - Processes to remediate negative impacts and channels for own workers to raise concerns • S1-4 - Taking action on material impacts on own workforce, and approaches to mitigating material risks and pursuing material opportunities related to own workforce, and effectiveness of those actions • S1-5 - Targets related to managing material negative impacts, advancing positive impacts, and managing material risks and opportunities • S1-6 - Characteristics of the undertaking's employees • S1-7 - Characteristics of non-employee workers in the undertaking's own workforce • S1-8 - Collective bargaining coverage and social dialogue • S1-9 - Diversity indicators • S1-10 - Adequate wages • S1-11 - Social protection • S1-12 - Persons with disabilities • S1-13 - Training and skills development indicators • S1-14 - Health and safety indicators • S1-15 - Work-life balance indicators • S1-16 - Compensation indicators (pay gap and total compensation) • S1-17 - Incidents, complaints and severe human rights impacts and incidents
ESRS S2 – Workers in the value chain	• S2-1 - Policies related to value chain workers • S2-2 - Processes for engaging with value chain workers about impacts • S2-3 - Processes to remediate negative impacts and channels for value chain workers to raise concerns • S2-4 - Taking action on material impacts on value chain workers, and approaches to mitigating material risks and pursuing material opportunities related to value chain workers, and effectiveness of those actions

	• S2-5 - Targets related to managing material negative impacts, advancing positive impacts, and managing material risks and opportunities
ESRS S3 – Affected communities	• S3-1 - Policies related to affected communities • S3-2 - Processes for engaging with affected communities about impacts • S3-3 - Processes to remediate negative impacts and channels for affected communities to raise concerns • S3-4 - Taking action on material impacts on affected communities, and approaches to mitigating material risks and pursuing material opportunities related to affected communities, and effectiveness of those actions • S3-5 - Targets related to managing material negative impacts, advancing positive impacts, and managing material risks and opportunities
ESRS S4 - Consumers and end-users	• S4-1 - Policies related to consumers and end-users • S4-2 - Processes for engaging with consumers and end-users about impacts • S4-3 - Processes to remediate negative impacts and channels for consumers and end-users to raise concerns • S4-4 - Taking action on material impacts on consumers and endusers, and approaches to mitigating material risks and pursuing material opportunities related to consumers and end-users, and effectiveness of those actions • S4-5 - Targets related to managing material negative impacts, advancing positive impacts, and managing material risks and opportunities
ESRS G1 - Business conduct	• G1-1 - Corporate culture and business conduct policies • G1-2 - Management of relationships with suppliers • G1-3 - Prevention and detection of corruption or bribery • G1-4 - Confirmed incidents of corruption or bribery • G1-5 - Political influence and lobbying activities

The selection of indicators included in the analysis of each individual company was based on a materiality analysis or double materiality analysis included in the report of the respective entity. Each of the required disclosures was assessed on a 3-grade scale, assigning a score of 0-2. 0 points were assigned if a given disclosure should have been included in the report, but the company did not disclose the information included in the disclosure or did not justify the lack of information on a given topic. 1 point was allocated if the company did not fully disclose the information making up the requirement of the disclosure in question. 2 points were assigned when the quality of the disclosure was high, i.e. the report contained the necessary information making up the over disclosure. The next step of the analysis was to assess the reports in terms of indicators. This assessment was done by calculating the percentage of points obtained by the entity in the previous step of the study, by adding up the points that were allocated to the company in the scope of disclosure, and then dividing the value obtained by the maximum value that could be obtained in the given scope. If a company was not obliged to disclose the information included in a given disclosure, the value it was assigned as the maximum value was 0 points.

In order to assess the level of preparedness of the entities in the study group, the percentage score obtained for each indicator and the percentage score for the report as a whole were calculated.

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RESULTS

The results of the analysis carried out are shown in Table 2.

Table 2. Percentages indicating the level of disclosure for individual indicators for selected companies included in the WIG-ESG.

	Implementation of the disclosures contained in the ESRS indicators [%]											
Companies	**2**	**E1**	**E2**	**E3**	**E4**	**E5**	**S1**	**S2**	**S3**	**S4**	**G1**	**Final evaluation value of the report [%]**
Alior Bank S.A.	67	22	0	20	-	-	59	30	40	70	42	**44**
Allegro S.A.	75	89	69	75	61	68	84	53	61	72	73	**75**
AmRest Holdings SE	29	52	55	50	-	45	65	32	26	30	34	**44**
Arctic Paper S.A.	92	34	42	50	33	56	54	43	4	33	25	**51**
Asseco Poland S.A.	67	76	42	50	-	18	26	30	34	13	63	**43**
Banco Santander S.A.	96	69	-	-	-	-	88	-	50	40	100	**80**
Bank Millennium S.A.	58	61	29	0	-	40	86	0	20	70	75	**55**
Benefit Systems S.A.	58	79	42	-	-	-	79	51	38	60	81	**65**
Budimex S.A.	75	68	58	88	83	65	79	55	38	41	87	**69**
CCC S.A.	96	94	67	90	75	100	100	90	100	88	92	**92**
CD Projekt S.A.	58	44	0	15	-	4	52	34	48	48	38	**39**
Comarch S.A.	67	78	75	60	-	8	68	40	80	70	75	**64**
Cyfrowy Polsat S.A.	79	82	50	63	100	65	73	38	45	69	65	**69**
Dom Development S.A.	71	100	84	50	100	67	76	85	82	84	93	**80**
ENEA S.A.	88	77	64	50	67	79	86	73	70	73	67	**79**
Eurocash S.A.	77	100	100	100	-	96	99	87	97	87	78	**91**
Grupa Kęty S.A.	61	78	75	88	50	70	80	41	79	47	80	**72**
ING Bank Śląski S.A.	92	75	0	-	-	25	79	39	51	47	61	**69**
Inter Cars S.A.	71	88	81	50	-	100	63	71	96	91	62	**74**
Kruk S.A.	58	41	-	-	-	-	72	76	76	39	34	**59**
LPP S.A.	75	75	-	75	50	89	84	81	50	74	74	**77**
Orlen S.A.	79	67	67	80	25	83	91	70	10	20	100	**69**
Pepco Group N.V.	83	72	-	-	-	50	62	92	98	75	83	**75**
Polimex Mostostal S.A.	71	69	60	100	-	81	80	61	40	41	91	**70**
Powszechny Zakład Ubezpieczeń S.A.	75	92	-	100	-	32	84	100	100	100	92	**84**
Tauron Polska Energia S.A.	21	83	75	-	-	58	73	49	38	92	50	**57**
Ten Square Games S.A.	71	28	-	-	-	-	29	-	-	20	42	**40**
XTB S.A.	67	79	40	83	100	44	76	71	50	65	67	**71**

The analysis carried out showed that the companies making up the research group achieved varying scores on the quality of the sustainability reporting process in relation to the criteria included in the ESRS standards. None of the entities achieved a score equal to 100%, which means. 5 of the surveyed entities achieved a score below 50%. The dominant part of the entities achieved a score in the 50-90% range.

DISCUSSION

The overwhelming majority of the sustainability reports analysed were developed on the basis of the GRI standard. In the analysis process, individual GRI indicators were assigned to the corresponding ESRS indicators. When analysing the results obtained, it should be borne in mind that the companies analysed, despite being aware of the legislative changes they will be subject to from 2025, are not yet required to report on the basis of the ESRS standard. This is due to the fact that the results obtained are an approximation, estimating to what extent the companies in the study group will be able to comply with the reporting obligation based on the provisions of the CSRD.

CONCLUSION

The companies in the research group noted, in the dominant majority of cases, awareness, the development of legal regulations in the field of sustainability reporting and, as a consequence, the entry into force of new reporting standards requiring them to take a more complex approach to the process of reporting sustainability information. Without being legally obliged to do so, companies have not chosen to undertake ESG reporting in 2024, based on the guidelines included in the European Sustainability Reporting Standard. A significant share of the entities in the study group reported in 2024 based on the GRI guidelines, introducing elements included in the new regulations like double materiality analysis. WIG-ESG companies, despite being classed as socially responsible entities, report varying levels of ESG reporting performance. During the analysis process, a wide variation in the quality, scope and level of disclosures was noted. Overwhelmingly, companies achieved a final report assessment value, which is the percentage rating of disclosures in an entity's ESG report, above 50%. This value can be interpreted as a satisfactory level given the fact that the sustainability reporting process has developed. Varying values were noted both in terms of companies and indicators, which should be interpreted as there is a large disparity in the ESG reporting process among the research group entities. It is also noted that there are companies that have achieved high scores in the areas of the indicators adopted. Based on the analysis conducted, the research hypothesis adopted cannot be unequivocally confirmed. Enterprises are characterised by a wide variety of results. At the same time, it is noted that there are problems, which the introduction of new legislation is intended to prevent, i.e. differences in the quality of reported information or a low level of data comparability resulting from differences in their presentation.

https://doi.org/10.5593/sgem2024/5.1/s23.94

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ENVIRONMENTAL IMPACT OF THE MODERNIZATION OF THE SOFIA - PLOVDIV RAILWAY LINE

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ABSTRACT

The Sofia-Plovdiv railway line is part of the Sofia-Plovdiv-Istanbul direction along the Orient/Eastern-Mediterranean corridor of the Trans-European network (TEN-T). The line is of important national and strategic importance. The project to modernize the line will lead to better conditions for transporting passengers and cargo and reaching European interoperability standards [1]. One of the predicted effects of modernization is an increase in the volume of freight transport at the expense of road transport. This will lead to easing the road network, improving traffic safety and reducing harmful gases released into the atmosphere. Reduced travel time and improved accessibility of the environment will lead to an increase in passenger traffic. With the higher speed of movement, it is necessary to straighten the route compared to the existing one and to implement numerous tunnels, bridges and overpasses. The approved route crosses the territory of two areas of the ecological network Nature 2000. These factors will lead to negative effects on the environment, cultural heritage and human health. The report examines measures to reduce noise, protect biological species, protect water and soil at the design stage. An analysis was made and the main risks facing the project were indicated. Currently, the project is at the construction stage with a completion date of 2027. After commissioning, it is planned to measure the measures included in the project to limit the harmful effects.

Keywords: environmental impact, railways, ecological network Nature 2000

INTRODUCTION

The railway line Sofia-Plovdiv has been declared an object of national importance. The line is part of the Sofia-Plovdiv–Istanbul (Burgas) direction along the Orient/Eastern-Mediterranean corridor of the Trans-European network (TEN-T). The line is also one of the most important railway connections in the country, connecting the major industrial centres in Southern Bulgaria. The investment project "Modernization of the railway line Sofia-Plovdiv in the section Elin Pelin-Septemvri" is part of this line. The implementation of the project will change the classification of the Elin Pelin-Septemvri section into a railway highway with speed 160 km/h. This will lead to:

- Increased throughput and reliability of line service;
- Increase in freight and passenger transport due to reduced travel time;
- Improving access for people with disabilities.

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For the modernization of the "Elin Pelin - Septemvri" railway section, four alternative options in terms of location and speed have been developed. Option A envisages improving the parameters of the existing trace, option B – speed 120 km/h with a length of 78.63 km, with the majority of its length running along a completely new trace; option C – speed 160 km/h, length 76.9 km, from Verinsko station to Septemvri station, the trace overlaps with option B.

In 2013, a revised version C was prepared for a speed of 160 km/h with a total length of 77.1 km. Thise variant was developed in order to optimize the alignment solution of the trace to avoid or limit the problem areas described in the opinion of the Ministry of Environment and Water MEW [2]. The Environmental Impact Assessment report EIA recommends approval of an improved version C of the investment proposal.

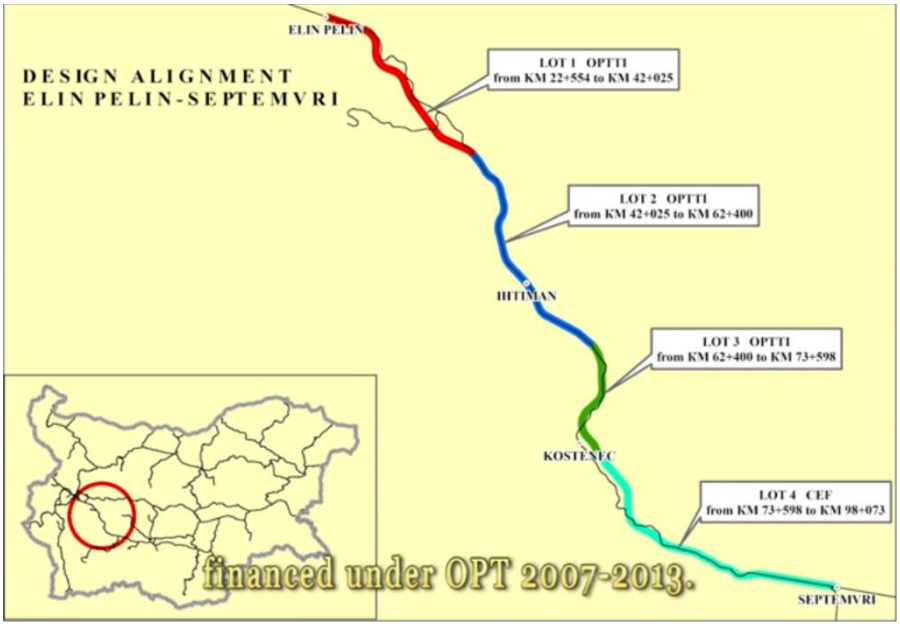


Fig. 1 Location of the object along the railway network of the Republic of Bulgaria

In the case of the improved version C, a running speed of 160 km/h for passengers and 120 km/h for freight trains is envisaged. Due to the increased speeds of movement, significant shifts in plan have been made compared to the existing railway line [3]. From the data shown in Table 1 for the section from km 22+500 (Elin Pelin railway station) to km 62+500 (about 1 km after the Stambolovo stop), it can be seen that 59% of the length of the section follows a new route.

Table 1 Position of the new line relative to the existing one

Section length	The trace coincides with the existing line		The trace doesn't coincide with the existing line	
40 км	Section from km to km	Length	Section from km to km	Length
	22+500÷27+000	4,5 km	27+000÷41+900	14,9 km
	41+900÷43+900	2,0 km	43+900÷45+800	1,9 km
	45+800÷47+100	1,3 km	47+100÷49+500	2,4 km
	49+500÷51+500	2,0 km	51+500÷52+500	1,0 km
	52+500÷54+700	2,2 km	54+700÷58+000	3,3 km
	58+000÷62+500	4,5 km	-	
	Total	16,5 km	Total	23,5

In addition, the railway line crosses two areas of the ecological network Nature 2000 (protected area BG0000304 "Golak" and protected area BG0000578 "Maritsa River").

The construction and subsequent operation of the line may lead to environmental problems.

MATERIALS AND METHODS

A study and analysis of the project documentation from the technical project phase was made for the possible harmful effects on the environment. They are grouped as: water pollution, noise impact, harmful effects on soils, harmful effects on plant and animal species. In order to reduce or prevent the listed adverse consequences of the modernization of the Sofia - Plovdiv line, measures related to the design and construction phases are foreseen. The measures are aimed at:

Water conservation

- Surface waters

The measures can be divided into two – separation and discharge of rainwater and waste water from the operation of the modernized railway line and guaranteeing the necessary conductivity of the drainage facilities. Regarding the discharge of water in the stations, a separation of waste water and rain water is provided. Rainwater is discharged into the adjacent grounds. The waste water from the railway stations is discharged into the city sewer. Oil catchers are provided for the water from the station platforms. Elin Pelin stations were examined fig. 2 and Ikhtiman.

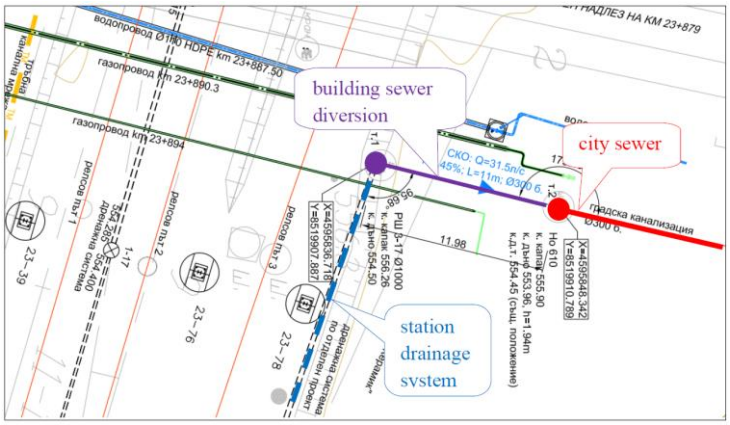


Fig. 2 Discharge of the drainage system Elin Pelin station

Elin Pelin railway station - during the rehabilitation, it is planned to remove the existing and build a new drainage system to be discharged into the city sewer fig. 2.

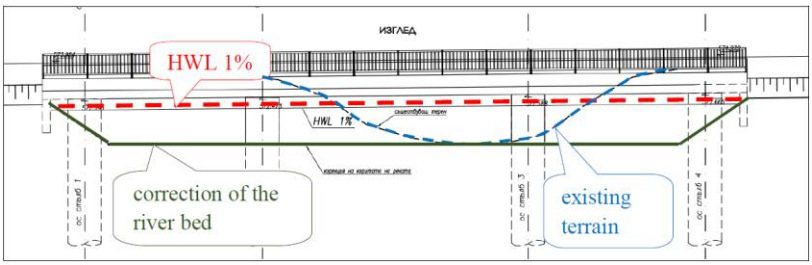


Fig. 3 Correction of the river bed at the bridge at km 25+987

Regarding the conductivity of the facilities, the conductivity of the bridges with a height of less than 10 m was checked. In the master plans of these facilities, a High Water Level

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with a 1% guarantee was noted fig. 3. To prevent the danger of flooding, a project was made to correct the river at a bridge at km 25+987.

- Groundwater

During the modernization of the railway line, the trace was designed so that it does not cross the first sanitary protection zone (SPZ) of the water sources for drinking and domestic water supply. The railway line runs partially within the scope of the second SPZ of Shakhtov Kladenets "Verinsko" from km 48+163 to km 48+283. To eliminate the possibility of contamination of the water source in this section, the line is in an embankment, and the ditches (position 1 and position 2) for the removal of surface water outside the area are lined fig.4.

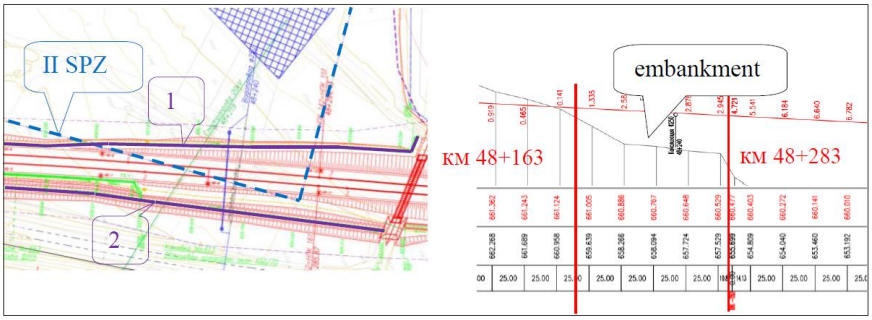


Fig. 4 Crossing of the II SPZ

In the case of tunnels, it is intended that the underground water around the tunnel pipes is taken away and discharged into the ditches on the open road or in the adjacent terrains. To remove the water contaminated during operation, a separate system of collectors is built, which are discharged into a special tank, where they are stored and then transported to the nearest place for disposal and purification.

Tunnel 2 falls within the boundaries of two bodies of water. According to the studies carried out, a minor impact on the amount of groundwater is expected to be insignificant. For the purpose of watertightness, injection works are carried out in the areas with concentrated water inflow and a high filtration coefficient. The primary tunnel lining is made of concrete with watertightness class Cw0.8.

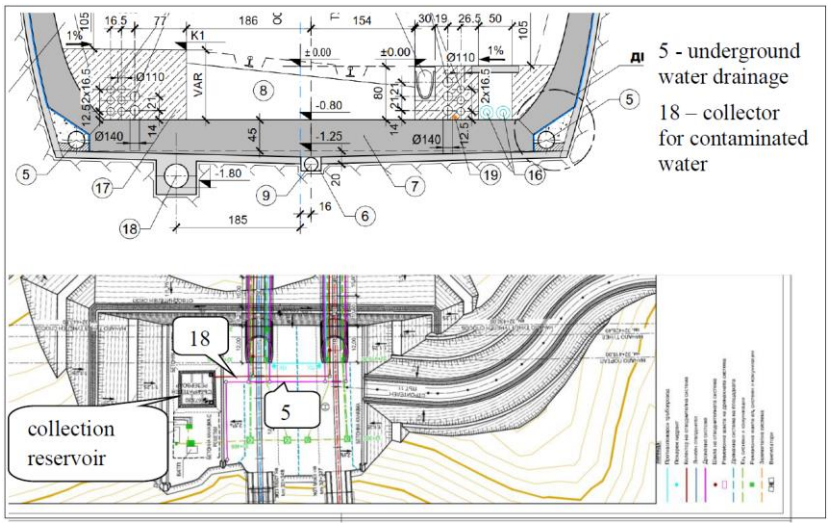


Fig. 5 Separate tunnel drainage

Impact of noise

The project documentation includes a part "Sound-absorbing fences - acoustics". It provides an assessment of the acoustic environment and the noise load in the territory and in the premises of the buildings. Based on the compiled noise map, the locations and characteristics of the transport noise protection screens were selected. In fig. 6 is the map of the noise when passing through the Lily of the valley with transport noise shields applied on both sides of the line.

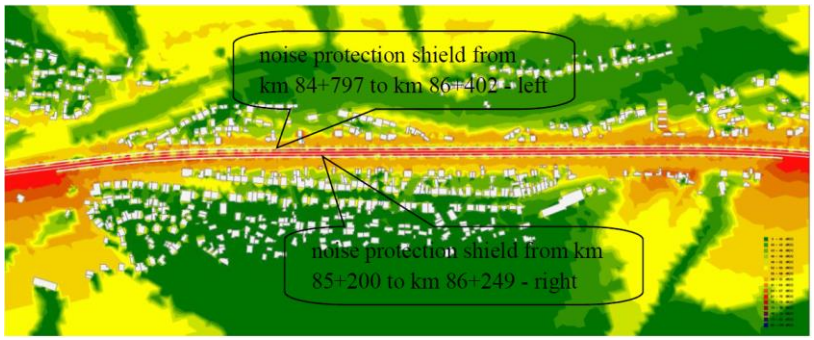


Fig. 6 Noise map from km 84+100 to km 86+200

Soil protection

Soil protection measures can be divided into two groups – reclamation of abandoned parts of the line and minimization of adverse impacts during construction.

In the "Ikhtiman - Septemvri" section, a project has been developed for the technical and biological reclamation of the sections of the line that will be decommissioned. The total length of these abandoned routes is 22.5 km. The design solution foresees the following activities - dismantling of the rail-travers grid, removal of ballast and alignment, laying of 20 cm of humus, weeding with grass species resistant to the climatic conditions in the area and undemanding to the soil conditions. The proposed reclamation technology fig. 7 implies a minimum intervention in the environment and the microhabitats created over the years around the route of the existing railway line are preserved to the maximum extent.

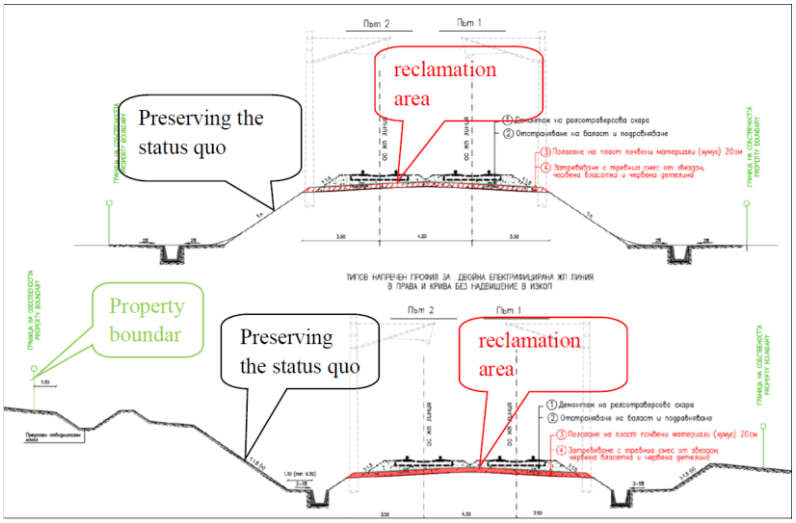


Fig. 7 Reclamation of abandoned parts of the railway

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To limit the harmful impacts during construction, part of the temporary roads are planned to follow existing agricultural roads, improving their condition.

Conservation of biological diversity

The trace of the modernized railway line passes through two areas of the ecological network Nature 2000 - protected area BG0000304 "Golak" and protected area BG0000578 "Maritsa River". A fence with a fine mesh is planned for the route when it passes through these areas. According to the technical project, the route crosses the Maritsa River area in a very small peripheral section with a length of 35 m, and the affected part falls within the scope of the existing railway line. No special measures are foreseen in this section. For the "Golak" protected area, measures related to the restoration of the areas disturbed during construction, measures for the protection of plants and measures for the protection of animals are foreseen. In implementation of the listed measures, a dendrological project is foreseen. Plant species are adapted to the type of territory and its status.

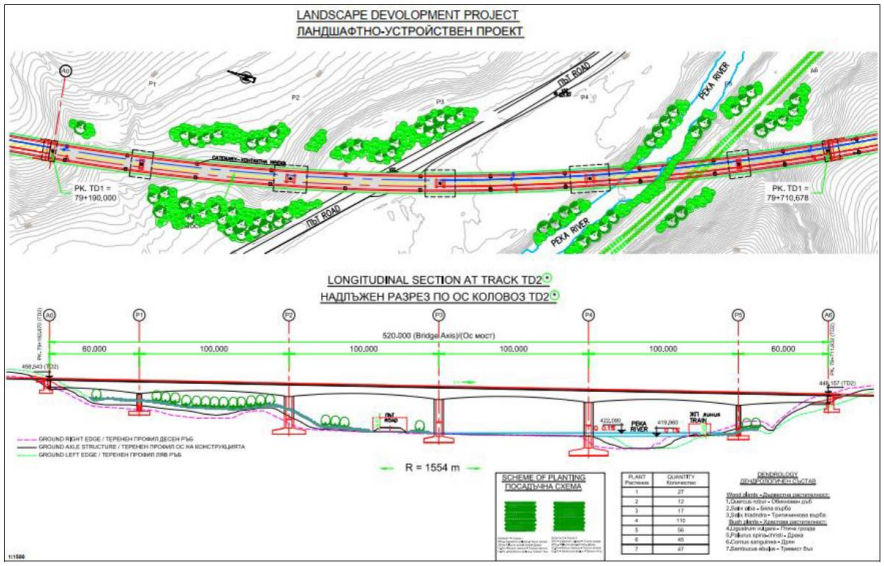


Fig. 8 Dendrological project - situation

n the sections crossing the "Golak" zone, the route of the railway line passes through very rugged terrain and the construction of a large number of tunnels, bridges and culverts is planned, which will allow the unhindered crossing of the route by small and large animals, including species subject to conservation in the area. The distances between the facilities are less than 400 m. An exception is allowed for the section from km 84+196.16 to km 84+665.79, the route is in a deep trench and it is not possible to build an additional facility. To protect the animal species, the secondary lining of all tunnels is smooth and prevents bats from using the tunnels for shelter. Ultrasonic electronic devices are planned to be installed at all tunnel entrances. Ultrasound waves cannot be heard by humans.

Waste generation

A Construction Waste Management Plan has been prepared. The sites for the storage of construction waste do not fall within the protected areas under Nature 2000. Moreover, they are not close to sanitary areas of water sources and there is no danger of being inundated with water. Part of the earth masses excavated during the execution of the tunnels will be used to make embankments.

RESULTS

The report reflects only a stage of the scientific research, namely environmental protection measures provided for in the project for the modernization of the line Sofia - Plovdiv. The cost/benefit analysis is conducted in order of impacts.

Table 2 Impact on the environment - cost/benefit analysis

Action	Advantages	Disadvantages
Carry out reclamation of disturbed terrain during construction - removal and utilization of the humus layer	Restoring the natural state of the grounds.	The natural environment is changing.
The generated waste should be collected separately and stored in accordance with the regulations on waste management.	Waste management plan - temporary and permanent landfills for waste storage.	Prerequisite for contamination of surface and groundwater in the area.
Noise protection facilities to be completed before commissioning of the Elin Pelin railway section - September.	Noise levels below the limit for the territory of the nearby settlements are reached.	Obstacles to construction work are created, a prerequisite for accidents and malfunctions.
Effective management of activities with hazardous chemical substances and mixtures. Implementation of measures for deactivation, raking and removal from the site.	Protection of the surrounding terrains, natural environment and impact on the population.	Danger of contamination and risk of release into the environment: water, air, etc.
Construction of a fence with a fine mesh on the route in the area crossing the two protected areas 1 km before and after the bridge.	Preservation of fauna from harmful effects.	Risk of small animals and insects passing through the railway line area.
To build passages and culverts with dry paths to ensure the migration of small mammals.	Conservation of the territory of habitation.	Penetration of dangerous predators and transmission of diseases characteristic of domestic animals.

DISCUSSION

The results of the measures will be checked after the line is put into operation. The main risks to the measures are changes in the climate as a result of human activity, incorrect and untimely implementation of environmental protection activities, untimely initiation, implementation and completion of individual stages of construction due to delays in financing, etc.

Guidelines for future projects to avoid harmful environmental impacts:

- Not to cross 1 belt of watersheds;
- to fill in all available information regarding intersections with water pipes, pipelines, NEC facilities, concessions during the development of the project
- as far as possible, temporary roads follow existing agricultural roads

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CONCLUSION

The design of railway objects of national importance is a long and complex process, passing through all design phases (from preliminary studies to the working design). The normal term for the implementation of the project is 5 to 7 years. An obligatory part of such projects is the environmental impact assessment report EIA. Design decisions must be related to ensuring the safe and reliable operation of the line and minimizing harmful impacts on the environment, people, and cultural heritage. In the current development, some of the good practices in this direction were considered:

- Railway lines are long artificial barriers created by human activity, preventing the natural circulation of water, for which drainage is necessary.
- They interfere with the natural movement of wild animals in the areas they pass through.
- In the project for the modernization of the Sofia-Plovdiv line, a part "Noise dampening fences - acoustics" is included.
- All available information regarding intersections with water mains, pipelines, NEC facilities, concessions was also used.
- Corresponding measures have been taken to bypass the watersheds and concessions near the line.

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EVOLUTION OF THE COMMON AGRICULTURAL POLICY OF THE EU

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ANNOTATION

The agricultural sector is an important strategic branch of any economy. Food security and food independence of the state are the key to ensuring the national security of the state. This fact became especially evident during Russia's aggression against Ukraine, which, among other things, affected the global food market. The Common Agricultural Policy (CAP) is one of the oldest policies of the European Community, as it was launched in 1957 by the Treaty of Rome, signed by six countries (Germany, France, Italy, the Netherlands, Belgium and Luxembourg), which were about the creation of the European Union. The goal of CAP has always been a strong and competitive policy in the field of agriculture and ensuring a sufficient amount of food for the population. At the same time, it should be noted that CAP has evolved significantly from the beginning of European integration to the present stage, in addition to the above-mentioned initial goals, new goals have appeared in it. The purpose of this article is to show the evolution of CAP with special emphasis on environmental protection and the role of CAP in climate change. The Common Agricultural Policy for 2023-2027 and its strategic priorities were analyzed. New priorities included in CAP were revealed. General theoretical methods of study were used. Analysis and synthesis, system-functional method, theoretical generalization made it possible to generalize tendencies of the development of the CAP.

Keywords: food security, food safety, agricultural policy, environmental risks, ecological safety, environmental security, environmental protection, environmental and legal culture.

INTRODUCTION

The common agricultural policy of the EU (CAP) from the very beginning of its existence was based on three principles: the unity of food markets within the entire EU; support of producers of agricultural products from member countries and financial solidarity of all subjects. At the same time, the CAP underwent constant changes in order to adapt the agricultural sector to the new challenges of globalization and climate change and to strengthen the role of joint institutions in ensuring food security. Simultaniosly, monitoring of the implementation of standards "from field to table" strengthened the protection of consumers. CAP has turned out to be very effective, so it

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is worth studying in order to identify and implement its positive experience in other countries. Despite military actions certain steps are being taken in Ukraine to support producers of agricultural products. The aid paid to agricultural producers does not compensate for all the losses, but taking into account all the circumstances, every possible support of producers of agricultural products should be made. This experience can be useful for the states which find themselves in the similar circumstances taking into account the fact that different armed conflicts become more and more often.
The purpose of the study: to study and analyze the development of the Common Agricultural Policy.
Objectives of the study: 1) to determine the trends of development of the Common Agricultural Policy; 2) to identify the features of the modern Common Agricultural Policy; 2) to analyze legal regulation of the support for agricultural producers in Ukraine and the possibility of applying the provisions of the CAP in it.

MATERIALS AND METHODS

During the writing of this scholarly work, both general scientific and special scientific research methods were used. Using the system-functional method allowed to identify the the necessary preconditions for receiving of direct payments by the producers of agricultural products, which are used due to the implementation of the CAP in the EU member states. The dialectical method was used to find out the current regulatory and legal status of state support for food producers in the European Union as well as in the Ukraine. Historical method allowed to identify the features of the CAP in different periods of its development. With the use of this method the flexibility of the CAP, which allows to respond in the best way to new challenges and circumstances (combating climate change and reaching the goals of the European Green Deal, as well as goals of sustainable development) was determined. The method of hermeneutics was used to analyze the current CAP 2023-2027 aimed at supporting agricultural producers in the EU member states and at the same time strengthening environmental protection, biodiversity and effectiveness in the struggle with climate change, as well as to identify the shortcomings of the CAP. Comparative method allowed to compare the support of producers of agricultural products in the EU according to the CAP with the legal regulation of support of agricultural producers in Ukraine according to the Decree of the Cabinet of Ministers of Ukraine of August 4, 2023 No. 807 "On the approval of the Procedure for the provision of one-time monetary assistance to the affected population as a result of the Russian Federation blowing up the dam of the Kakhovka hydroelectric power station for the lost harvest" and the Decree of the Cabinet of Ministers of Ukraine providing financial state support to business entities of January 24, 2020, No. 28 (as amended of March 14).

RESULTS

The study focuses on the development of the Common Agricultural Policy of the EU, its main aims and features. Attention is also paid to the legal regulation of the support of producers of agricultural products during armed conflict in Ukraine.

1.Evolution of the CAP

Special importance was attached to the agricultural sector already at the first stages of economic integration [6]. In a general sense, the CAP can be characterized as a system of certain government incentives in various forms, including subsidies paid to EU

farms, as well as establishing a common market and giving preference to EU agricultural products. CAP has an impact on the size of agricultural production in member states and employment in agricultural sector. The EU, after its expansion in 2004, became one of the largest producers, exporters and importers of agricultural products.

Initiated in 1962 the agricultural policy of the EU was aimed at ensuring a sufficient amount of food products for Europe, which, as a result of the war, felt a shortage of them. The CAP was based on production subsidies, price subsidies and the purchase of surplus products. These means of supporting the production of agricultural products are no longer applied in the EU. After the CAP's reforms in 2003 and 2013 EU policy started to focus on ensuring that food producers can produce sufficient quantities of high quality food for European consumers; to fully promote diversified economic development in rural areas; comply with strict regulations in the field of environmental protection and ensure satisfactory living conditions for animals. The emphasis has changed from the quantity of food produced to its quality, and in order to receive direct subsidies producers of agricultural products had to fulfill new requirements. It has become necessary to fulfill environmental requirements and ensure animal welfare.

CAP 2014-2020 distinguished the following goals: viable food production, sustainable use of natural resources and mitigating the consequences of climate change; balanced territorial development. That is, once again the environmental requirements and the goal of achieving sustainable development were strengthened. The following features of the modern European model of agriculture can be noted: diversity of agriculture, which is competitive and at the same time does not harm the surrounding natural environment; agricultural activity is carried out mainly on family-type farms; the development of agriculture simultaneously with the development of rural areas; production of quality food products, improvement of quality and safety standards of food products, as well as methods of their production; inclusion of agriculture in the common competence of the EU and member states; the agricultural sector of all EU member states should be subject to a common policy; the unity of the agricultural market; solidarity manifested in the formation of guarantee and development funds for the regulation of the common agricultural market; environmentalization of agricultural production, which is manifested in the orientation of the CAP to the stimulation of ecologically safe farming and the implementation of environmental programs in the countryside. The development of rural areas, renewal of biological diversity, protection of soil and water are the main long-term goals of the EU in this field. The development of rural areas is gradually becoming the same priority of agricultural policy as the development of agricultural production. Paul F. also points out that the CAP also reduces the cost of producing agricultural products [7].

Let's dwell in more detail on the CAP 2023-2027. The new CAP's key goals are to insure sustainable agriculture and forestry as well as ensuring the implementation of the goals of the European Green Deal. There is a requirement that 3% of arable land should be used for non-productive purposes and increasing of biodiversity in order farmers can receive direct payments. Eco-schemes form 25% of budget for direct payments, which require environment-friendly and climate-friendly farming practices, including organic farming, the use of new, much more expensive biological preparations, genetically diverse systems and breeding methods. The CAP 2021-2027 provides that at least 40% of the total CAP budget and at least 30% of the Marine Fisheries Fund will be directed to climate measures. These innovations aim at the ecological transformation of the EU

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with the achievement of climate neutrality by 2050 [9; 10]. New requirements are aimed at making CAP more responsive to current and future challenges, including climate change and intergenerational responsibility, while supporting European farmers. We can see the flexibility of the CAP, which allows to respond in the best way to new challenges and circumstances. It should be noted that increased environmental requirements have resulted in constant protests by European farmers against CAP innovations.

At the same time it should be noted that the CAP has some shortcomings. Cuadros-Casanova I. points out on the missing appropriate planning measures [2]. National variations of the implementation of the CAP can lead to the increase in the complexity of the policy [1;8]. Guilliani A. and Baron H. draw attention to the unequal management of funds in favor of large companies [3].

2.Support for agricultural producers in Ukraine and the possibility of applying the provisions of the CAP

Certain steps are being taken in Ukraine to support producers of agricultural products. Despite the military actions, the state program "Affordable loans 5-7-9%" was continued [13]. A government grant program to support small and medium-sized businesses was developed, which began to operate on July 1, 2022. The list of agricultural crops for which it is possible to receive grants for the development of horticulture, berry growing and viticulture was increased. Almonds and rose hips were added to the list. The conditions for obtaining grants were simplified, in particular, changes were made regarding the number of employees required to receive a grant for the development of greenhouses - from now on, at least 4 permanent and 10 seasonal employees (previously, it was necessary to employ 14 permanent employees). At the same time, the period of employment of seasonal workers must be at least 8 months during the year. In 2023, 120 farms received state aid in the amount of UAH 492.2 million for the development of gardens and greenhouses [5]. These steps are definitely positive.

The Cabinet of Ministers of Ukraine approved Decree No. 807 "On the approval of the Procedure for the provision of one-time monetary assistance to the affected population as a result of the Russian Federation blowing up the dam of the Kakhovka hydroelectric power station for the lost harvest", which provides for the allocation of one-time monetary assistance to farmers who lost their crops due to the destruction of the Kakhovskaya HPP by the Russian invaders [12]. Assistance was provided to farmers of the Kherson and Mykolaiv regions who own a plot of land for personal farming or building a house. The amount of assistance was set at UAH 3,318 per hectare of land on which the farmer lost his/her vegetable crop. Assistance is provided for an area of up to 20 acres for the Mykolayiv region and up to 30 acres for the Kherson region. In order to receive monetary assistance, the victim had to confirm ownership of the land through an extract from the State Register of Real Property Rights. To provide assistance to citizens, a commission was created, which was tasked with surveying the plots of land on which the vegetable crop was destroyed [5]. Russian aggression caused huge losses to producers of agricultural products [4]. Of course, the aid paid to agricultural producers does not compensate for all the losses. But taking into account all the circumstances, such steps were absolutely necessary.

The blockade of sea ports led to a significant reduction in exports. This led to a drop in domestic prices of agricultural products sometimes below the prime cost. All this indicates the need for financial support for farmers.

Sarkisova T. points out that, in order to become a member of the CAP and enter the European legal field, it is necessary for Ukraine to harmonize the specified multiplicity of definitions of Ukrainian agribusiness entities with the concept of "farmer" used by European legislation [11]. In our opinion, using the example of the CAP, it is also necessary to make the amount of support for producers of agricultural products dependent on the greening of production, which is currently absent in Ukraine.

CONCLUSION

The CAP has a tendency to evolve in the direction of greening agricultural production and contributing to the mitigation of climate change. Support for producers of agricultural products and increased attention to the protection of the natural environment and prevention of climate change is worthy of implementation in other countries as well. This is especially relevant for Ukraine, because during the aggression of Russia, the rural areas and the production of agricultural products suffered huge destruction and the problems only intensify. Moreover, it is small and medium farms that need special support. Certain steps are being taken (support programs are being developed for producers of certain agricultural crops, loans are provided at a reduced discount rate), but they are not sufficient. Implementation of the CAP is currently not possible due to the war in Ukraine. However, it is possible to reduce taxation in the territories where hostilities are or have been conducted. There is a vital need to continue the duty-free regime with the EU and without quotas for several more years.

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LEGAL BASIS FOR ENSURING FIRE SAFETY IN FORESTS IN THE TERRITORY CONTAMINATED BY RADIOACTIVE EMISSIONS FROM THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

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ANNOTATION

In the context of martial law in Ukraine and significant climate change, the risks of forest fires are significantly increased. The forest areas of the Chornobyl Exclusion Zone are most exposed to such threats, which is additionally mediated by a number of factors: radioactive contamination and threats of migration of radioactive elements in case of forest fires, significant clutter of these areas, structure of the stand, lack of forest roads and communications, shortcomings of legal regulation and insufficient level of funding. The purpose of the article is to analyze the legal capacity of the State to ensure an adequate level of fire safety in the forests within the Chornobyl Exclusion Zone and to assess the relevant risks. The application of a system of both general scientific and special scientific research methods allowed for a comprehensive analysis of the problematic aspects of both the organizational and legal elements of the system of fire safety in the forests of Ukraine within the territory of the radioactive substances affected zone. The article describes the risks and threats of forest fires in the Exclusion Zone; identifies the peculiarities of forest management in the Chornobyl Exclusion Zone and the stricter requirements for fire safety in the respective forests due to these factors; and identifies additional threats associated with the military occupation of this territory in 2022, mine residues and risks of radioactive substances migration during forest fires in the Exclusion Zone. A number of shortcomings and conflicts of legal regulation in the area under study that affect the effectiveness of fire safety in the exclusion zone are identified and outlined, and a set of proposals for its optimization is proposed.

Keywords: legal regulation; forests; forest resources; fire safety in forests; environmental safety; Chornobyl Exclusion Zone; government authorities and local self-government.

INTRODUCTION

In recent years, Ukraine has seen a clear upward trend in the number of large-scale forest fires that spread rapidly and are difficult to extinguish. Currently, the worst level of fire safety in Ukraine's forests is observed in the Chornobyl Exclusion Zone and in

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the southeastern regions of our country. The reason for this is the full-scale aggression of the neighboring country. For the first month since the end of February 2022, the territory of the exclusion zone was under occupation.
The issue of forest fires on radioactively contaminated lands is extremely relevant among the environmental and social problems of Ukraine. Even small grassroots fires in radioactively contaminated areas have negative environmental consequences, in particular due to the accumulation of less than 40% of radionuclide residues in the forests of the exclusion zone in the burning litter [1].
In particular, the large-scale forest fires of 2015 and 2020 in the Chornobyl Exclusion Zone led to radionuclide contamination of large areas, which had a negative resonance in Europe. In fact, according to the modeling data of the Norwegian Institute of Atmospheric Research, these fires led to the spread of radionuclides in Belarus, Germany, Poland, Russia, Turkey, Ukraine, Scandinavia and the Balkan region. In fact, the 2020 fire resulted in human casualties, destruction of settlements, damage and death of forests on an area of more than 157 thousand hectares [2].

MATERIALS AND METHODS

To achieve this goal, the study used general scientific and special scientific methods of cognition. In particular, the use of the dialectical method allowed to analyze social relations in the field of Ukrainian forest protection in the exclusion zones in their unity and interconnection, to identify patterns and dynamics of their development and changes in legislation. The formal and logical method was used to analyze the current legislation governing fire safety requirements in the forests of the Ukrainian exclusion zone. The method of analysis and synthesis was used to determine the current features and prospects for ensuring fire safety in the forests in the study area. The application of the system-structural method made it possible to determine the components of the system of fire safety in forests affected by radioactive contamination in Ukraine. The formal legal method was used to analyze the relevance and consistency of legal regulation of social relations in the studied area. The application of the method of prognostic analysis made it possible to determine the prospects of the proposals for improving the organizational and legal framework for the protection of forests in radioactively contaminated areas from fires, depending on the legal regime of martial law and other circumstances. The materials for the study were based on the system of regulatory legal acts of Ukraine, which were subjected to a thorough analysis and comparative characterization.
A number of scientific works were also used, including: Zibtsev et al.- analysis of the Long-term dynamics of forest fires in Ukraine [2], Usenya et al. – analysis of the legislation of the Republic of Belarus and Ukraine regulating the protection of forests from fires in the exclusion zone [3], Golovko et al.– on the peculiarities of international legal regulation of environmental protection during armed conflict and the possibility of its application in Ukraine [4] та Legal Regulation of Taxation of Agricultural Activity in EU Member States [5], Oleksenko et al. – on the research of the place Ukraine in the Context of the World Organic Production of Agricultural Products. In Modern Development Paths of Agricultural Production [6], Voronkova et al. – about the study Environmental problems solving as a factor in the formation of a sustainable and balanced development paradigm [7], Dubchak et al. – about the study Legal regulation of ensuring nuclear safety and security in Ukraine on the way to European integration

[8], Gulac et al. – on the analysis Public Administration in the Field of Taxation of the Agricultural Sector of Ukraine [9].

RESULTS

The forests of the Chornobyl Exclusion Zone perform an important protective function as a conditional depot on the way of radioactive contamination spread. In fact, the degree of danger to the population and nearby territories depends on the reliability of the Exclusion Zone's barrier properties. After all, one of the main ways of radionuclides migration outside the Chornobyl Exclusion Zone is through the air - as a result of forest fires. As a result of the Chornobyl accident, 3.3 million hectares of forests were contaminated [10].

1.Principles of regulatory and legal support of fire safety in forests of Ukraine

Protection, defense, use and reproduction of forests on the Exclusion Zone land plots that have been radioactively contaminated are carried out in accordance with the procedure established by the Law of Ukraine "On the Legal Regime of the Territory Affected by Radioactive Contamination as a Result of the Chornobyl Disaster". This Law of Ukraine zoned the radiation-affected territory and identified: 1) the exclusion zone; 2) the zone of unconditional (mandatory) resettlement; 3) the zone of guaranteed voluntary resettlement [11].

The regulatory framework for ensuring fire safety in the forests of Ukraine is a system of legal acts, including:

1) adopted at the level of resolutions of the Cabinet of Ministers of Ukraine: No. 314 of 07.04.2023 "On Approval of the Procedure for the Establishment and Functioning of Fire and Rescue Units for Voluntary Fire Protection"; No. 612 of 20.05.2022 "On Approval of the Procedure for Organizing the Protection and Protection of Forests"; No. 976 of 16.09. 2009 "On Approval of the Regulation on State Forest Protection, Forest Protection of Other Forest Users and Forest Owners" (with the relevant changes in the title from 2022); No. 1127 of 14.07.2000 "On the State Protection Service of the Natural Reserve Fund of Ukraine";

2) adopted at the departmental level (a separate central executive body): Order of the Ministry of Environmental Protection and Natural Resources of Ukraine No. 382 of 23.12.2020 "On Approval of the Regulation on Departmental Fire Protection of the State Agency of Forest Resources of Ukraine"; Order of the State Committee of Forestry of Ukraine No. 526 of 28.12.2005 "On Approval of the Regulation on Forest Fire Stations"; Order of the State Committee of Forestry of Ukraine No. 278 of 27.12.2004 "On Approval of the Rules of Fire Safety in the Forests of Ukraine";

3) adopted at the interagency level: Joint Order of the Ministry of Ecology and Natural Resources of Ukraine and the Ministry of Internal Affairs of Ukraine No. 01/01 of January 10, 2018 "Instruction on the Organization of Fire Fighting by Units of the State Protection Service of the Nature Reserve Fund, the Civil Defense Rescue Service and Permanent Forest Users in the Natural Ecosystems of the Chornobyl Radiation and Ecological Biosphere Reserve", etc.

We have identified the shortcomings of the legal and regulatory framework for fire safety in the forests of Ukraine, namely:

1) the validity of legally and technologically outdated legal acts in the field of fire safety in the forests of Ukraine (Order of the State Committee of Forestry of Ukraine No. 526 of 28.12.2005 "On Approval of the Regulation on Forest Fire Stations"; Order of the

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State Committee of Forestry of Ukraine No. 278 of 27.12.2004 "On Approval of the Rules of Fire Safety in the Forests of Ukraine");
2) significant contradictions and discrepancies of a legal and substantive nature between the currently effective regulations in the area under study (the most significant of which are: between the Resolution of the Cabinet of Ministers of Ukraine No. 612 of 20.05.2022 "On Approval of the Procedure for Organizing the Protection and Protection of Forests" and Order of the State Committee of Forestry of Ukraine No. 278 of 27.12.2004 "On Approval of the Rules of Fire Safety in the Forests of Ukraine", which essentially regulate relations in the same area of public activity and set requirements for the protection of forests from fires).

2. Peculiarities of regulatory and legal support of fire safety in forests in the territory affected by radioactive contamination as a result of the Chernobyl accident

Fire safety rules in Ukrainian forests stipulate, among other things, that the fire hazard is set one class higher for plantations with a level of radiation contamination from 1 to 14 Ci/sq km, regardless of species composition and age [12]. According to official data, 66% of the Exclusion Zone territory is classified as the highest natural fire hazard class I, of which 38% is land with contamination of more than 555 kBq/m2, and 13% is classified as class II. The difficulty of extinguishing forest fires in the exclusion zone with high radiation levels, even in places where there are roads and water bodies, is also due to the impossibility of sending ground forces to fire centers, with only aviation being possible.
The Strategy for the Development of the Exclusion Zone and the Zone of Unconditional (Mandatory) Resettlement Affected by Radioactive Contamination as a Result of the Chornobyl Disaster for 2021-2030 has been developed and presented at the level of the Cabinet of Ministers of Ukraine, which includes a separate structural element within Section 5 "Directions for the Strategic Development of the Exclusion Zone and the Zone of Unconditional (Mandatory) Resettlement" - subsection 5.6.2 entitled "Development of a Fire Management Plan and Decision Support System for Prevention, Early Response and Radiation Safe Extinguishing of Forest Fires in the Exclusion Zone" [1].
Despite a significant number of forest fires, no special legislation on the specifics of fire safety and firefighting in areas contaminated with radionuclides has been developed and adopted for a long time. However, in 2018, a joint order of the Ministry of Internal Affairs and the Ministry of Environment was adopted to approve the "Instruction on the organization of fire extinguishing by units of the state protection service of the nature reserve fund, the operational and rescue service of civil protection and permanent forest users in the natural ecosystems of the Chornobyl Radiation and Ecological Biosphere Reserve" [13].
In addition, a number of regulatory acts were adopted that regulate certain aspects of this task, in particular, radiation safety. These include: the Order of the Ministry of Emergency Situations "Instruction on the Organization of Individual Dosimetric Monitoring in the Management Bodies and Subdivisions of the Ministry of Emergency Situations" [14]; the Order of the Ministry of Health of Ukraine and the State Emergency Service "Rules of Radiation Safety for Work in the Exclusion Zone and the Zone of Unconditional (Mandatory) Resettlement" [15]. The Orders of the State Agency of Ukraine on Exclusion Zone Management are also important in terms of the research

topic: “Emergency Response Plan for Technogenic and Natural Emergencies in the Exclusion Zone and the Zone of Unconditional Resettlement”; “On Establishment and Organization of the Emergency Response Headquarters in the Exclusion Zone”; “Mobilization Plan for Attracting Forces and Means to Extinguish Fires in Forests, Fallow Land and Peatlands of the State Enterprise ‘Northern Forest’ for 2016-2020” [4]. The protection of the exclusion zone territories, including forests, has specific protection statutes provided for by the national legislation. In particular, Part 1 of Article 14 of the Law of Ukraine “On the Legal Regime of the Territory Affected by Radioactive Contamination as a Result of the Chornobyl Disaster” states that a strict environmental protection regime is ensured in the exclusion zones. Part 2 of the same article regulates that public order protection is provided by the National Police units, and fire and industrial safety is provided by the central executive body that implements the state policy on supervision and control over compliance with the legislation on fire and industrial safety. Part 3 of Article 14, as amended by the Law of Ukraine No. 5459 of 16.10.2012, regulates that control over the implementation of these measures is carried out in the exclusion zone by the central executive body that implements the state policy in the field of management of the exclusion zone and the zone of unconditional (mandatory) resettlement [11].

CONCLUSION

Thus, today, fire safety in forests as an integral part of the national security system can be effectively ensured only in the case of integrated application of political, environmental, economic, legal, engineering and technical measures. Since the subject of the study, and therefore the search for optimization, concerns the regulation of the activities of a whole system of actors, including the civil protection system, bodies that formulate and implement forestry policy, local governments (executive authorities and local self-government), the conscious public and voluntary firefighting groups. Nevertheless, the algorithm of interaction and coordination of actions of bodies and organizations that regulate the relations of state bodies, public organizations, legal entities and individuals in this area, regardless of their type of activity and form of ownership, is crucial in the search, as the state is currently unable to fully fund all necessary measures.

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ON LEGISLATION AND SOME ASPECTS OF OCCUPATIONAL SAFETY IN GEORGIA

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ABSTRACT

The Constitution of Georgia provides the main principles of protection of employees and employers at job places, concerning healthy and safety conditions. The paper reviews the new Laws of Georgia pertinent to labor safety, elaborated and approved during the last years. These Laws regulate social-economical, technical, hygienic and other conditions of work of employees at job places. These are Laws, destination of which to secure the workers health and safety in the present, future and must not have a negative influence on the generation. It's indicated that at present technical supervision over the objects with increased technical danger in different branches of industry of Georgia is provided according to the Law of Georgia Code of Product Safety and Free Circulation by LLC Technical and Construction Supervision Agency. In paper are described the individual and collective protective means for employees' industrial traumas and occupational diseases prevention, as well as hardware components, used at different enterprises of Georgia. The data about occupational diseases at Georgian enterprises are given. The paper reviews the data about microclimate of the working zone – temperature, relative humidity, pressure, velocity of air stream, as well as about other important parameters of job places – dust, noise, vibration, radiation. The paper considers problems, dealing with electro safety, the reasons which provoke damages and the means of first aid in case of damages, provoked by electric current. The issues of influence of road tunnels fire safety and aerodynamic resistance with respect to air average velocity and consumption are considered as well.

Keywords: labor safety, protective means, microclimate of working zone, industrial trauma, occupational disease.

INTRODUCTION

The problems of Labor safety are very actual nowadays in every country, including Georgia. In compliance with International Labor Organization (ILO) data, every year more than 2 million persons die at job places because of violation of safety norms of exploitation. At the same time according to the data of World Health Organization (WHO) annually are registered about 150 million cases of different occupational diseases, from which about 30-40 % become as chronic diseases, and 10% - heavy disability. That's why for industrial traumas and occupational diseases prevention, it's very important conform requirement of labor laws. Various legislative normative acts, conventions, decrees for employees and employers labor safety at job places are provided by ILO and WHO.

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The Constitution of Georgia provides the main principles of protection of employees and employers at job places, concerning healthy and safety conditions, in particular, the item 30 of Constitution provides freedom of labor, right on labor including the right on healthy working conditions, as well as maintains the privileged work conditions for juvenile and women.

In Georgia, during the last years were elaborated and approved some Georgian Laws, pertinent to labor safety and health. These Laws are: Georgian Law Georgian Labor Code [1], Georgian Law About Labor safety [2], Georgian Law About Labor Inspection [3]. These Laws regulate social-economical, technical, hygienic conditions of work of employees at job places. So, these are Laws, destination of which to secure the workers' health in the present, future and must not have a negative influence on the generation. The aim of these Laws is to create comfortable area in the working zone.

Labour according to the Constitution of Georgia is free. Each of the workers can chose any business and profession, they have the right of safety and health conditions ensuring in the working zone, they mustn't get traumas, be poisoned and get occupational diseases. In the case of damage, they should get a full pay compensation. According to the agreement between employer and employee's administration gets an obligation to create good conditions for work and obliged to apply modern technical safety measures in order to avoid the traumas of the workers, create such sanitary-hygienic conditions, which don't cause occupational diseases. According to these Labor Laws the sides of working attitude may be employer or employer's association and employee or employee's association.

In Georgia Minimum age for begin working for physical person is 16 years, 14-16 years–in case of consent of person legal representative or organ of care and this person; agreement up to 14 years is possible only in field of sport, culture, art. Working attitude is registered in writing or orally, for definite or indefinite time. Duration of working time in a week: for adults – not more than 40 hours, for 16-18 years old persons–not more than 36 h and 6 h in a day; for 14-16 years old–not more than 24 h and 4h accordingly. Night works are prohibited for minor, woman who is expecting a child, if person has child up to 3 years without his consent. Duration of holiday is 24 days. If employee is occupied with heavy, injurious, danger conditions work, he can get in addition paid holiday–10 calendar days. In these Laws there are articles, devoted to collective agreement, interrupting and stoppage of the working attitude, as well as the strikes and lock-outs.

At present many Trade Unions are functioning in Georgia, but their activity in the field of labor safety is not effective and sufficient. As the most active Trade Union, according to its old traditions is Amalgamation of Georgian Trade Unions. This trade Unions studies the conditions of work of employees, analysis the situation and for decisions prepares items for discussion.

The Chief Department of emergency and civil defencee and the Chief Department of fire safety service of the Ministry of Internal Affairs of Georgia are responsible in the country during the period of disasters and emergencies.

Department of Labor Safety and Emergency Management of the Georgian Technical University prepares specialists of industrial safety–bachelors, masters and doctorates. Labor safety as discipline is learned at every faculty of this University.

ABOUT GEORGIAN LAW – CODE OF PRODUCT SAFETY AND FREE CIRCULATION

At present technical supervision over the objects with increased technical danger in different branches of industry of Georgia according to the Law of Georgia Code of

Product Safety and Free Circulation [4] is provided by Limited Liability Company Technical and Construction Supervision Agency and private Inspection Bodies. Agency has been elaborated and by Prime-Minister of Georgia was affirmed technical regulations for different objects with increased technical danger.

Agency provides: technical supervision, comprehensive safety management at objects with increased technical danger in compliance with legislation in order to avoid accidents, emergencies and injuries; cooperation in the frame of own competence with legal private inspection bodies, similar organizations abroad, other international organizations.

Functions of Agency are: inspection of enterprises in the frame of own competence; elaboration and registration of technical regulations and other normative documents on industrial safety; delivery permissions for using industrial explosive materials to juridical bodies and private persons and control whether the requirements of the permission are met. In the event of fail Agency shall act in compliance with the legislation; provision enterprises with methodological, informational and educational materials.

Technical and Construction Supervision Agency carries out the technical supervision of following objects: mining enterprises: quarries, mines, caves; lifts, escalators; rope ways, funiculars; hoisting equipment; vessels, operating under pressure; oil products storage facilities and terminals; ammonia refrigerating machines; side-shows; boilers; gas and oil main pipelines.

Technical and Construction Supervision Agency stops its activity in the field, when private inspection body appeared. This body must be accredited in accordance with the existed in this field legislation by the State Accreditation Centre. Private inspection body must transmit all the documents dealing with inspection to Agency during 5 days and Agency controls all the documents.

It should be noted that some important enterprises and objects of Georgia at present are without state supervision, such as: gas, chemical, metallurgical enterprises; automobile gas filling stations; cereal storage and processing objects.

PROTECTIVE MEANS FOR DAMAGES AND OCCUPATIONAL DISEASES PREVENTION

If the conditions of work–the main parameters of job places are not satisfactory (the level of dust, temperature, pressure, velocity of air stream, noise, vibration, lighting, radiation) workers are given individual and collective protective means.

According to the destination the following types of individual protective means are used at Georgian enterprises: a) insulating suits, for employee's protection in case, when is necessity of work in saturated with unhealthy substances atmosphere; b) special clothes: overalls, trousers, jackets, aprons, coats, half overalls. Special clothes are of common destination, for protection from humidity, radioactive emanation pollution; influence of acid and alkali, dust, toxic substances, temperature, electric current; c) special shoes: boots, semi-boots, high shoes. Special shoes are of common destination; humidity, acid, petroleum, thermo, vibro proof, for work in explosive and dusty environment; d) breathing apparatus and gas-masks for respiration organ; gas-mask is used as well for eyes, head and face skin protection from unhealthy substances; e) helmets for employees protection from mechanical trauma of head and electric current; f) eyes protective means: special glasses (goggles), shields and masks for eyes protection from thermal and radial influence, as well as from mechanical injury; g) hands protective means: gloves made from silk, leather, rubber, fur, polymer materials for hands protection from mechanical injury, thermal burn, acid, toxic substances, electric current influence. For vibro

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protection the gloves with special soft gaskets are used. For employee's hands protection the greases and pastes are used as well, especially if employee is in contact with glue and paint.

At some enterprises of Georgia are used different collective protective means against influence of: noise, dust, vibration, radiation, electric current, high or low temperature; mechanical, chemical and biological factors.

For industrial traumas and occupational diseases prevention majority of Georgian enterprises are provided with different hardware components as well, such as: a) stationary, demountable and transfer guard devices for insulation machines motive parts, electric current conductivity, radiation and other danger zones; b) protective devises for employee's prevention in emergency provoked by creation of danger condition or deviation of any parameter from operating condition. In this case protective device turns off the machine automatically; c) block system, for men's presence prevention in danger zone. Mechanical, electrical, hydraulic, pneumatic or combined devices are used; d) remote control system. Mechanical, pneumatic, hydraulic, electrical and combined systems are used. Most popular is electrical remote control owning to its simplicity and the process of switch on and off is quickly and it can realize at long distance; e) warning signals, established by standards.

From the analysis of investigated materials on accidents and occupational diseases at Georgian enterprises [5] is obvious, that most of the reasons are of organizing character. In particular, dissatisfactory organization of job places, low executive discipline, appointment to work without appropriate training and instruction on the infringement of labor discipline. It shows that sometimes employers don't realize their responsibility to provide health and safety labor conditions for their employees. The data about occupational diseases at different enterprises of Georgia in 1990-2015 years are presented on **fig. 1**.

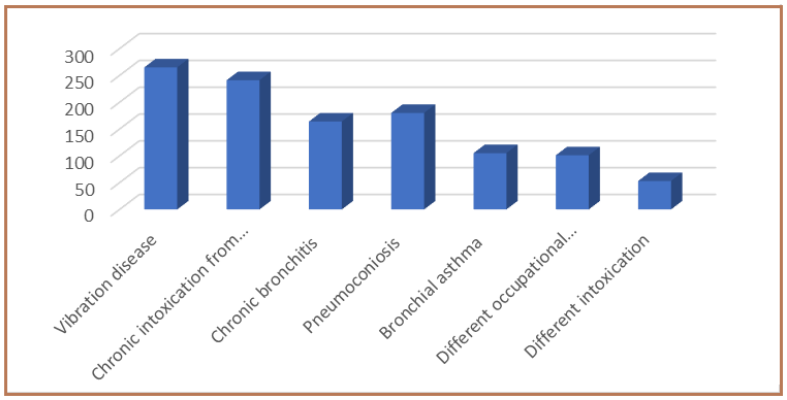


Fig. 1. Occupational diseases data in Georgia.

MICROCLIMATE OF WORKING ZONE

It is known that microclimate at the working zone is the climate inside the working place and its main parameters are temperature, humidity, pressure and velocity of air stream. All these factors have an influence upon the human body and as parameters are changed, it should always be accompanied by a physiological change in the human's body.

On the basis of analysis of scientific-research works at different enterprises of Georgia for the health of the body it is needed to keep the temperature about 36.6 ℃. For a normal state of organism if the temperature is definite, relative humidity is high and the velocity

of air is faster. If the humidity is definite, the velocity of air is fast and the temperature must be high. If the velocity of the air is constant and the humidity is high the temperature is low. The body recoils the heat by different means. When the temperature of the environment isn't more than 30 ℃ the body recoils the heat by evaporation. If the temperature is more than 30 ℃ the body loses the temperature by evaporation from the skin or the lungs. That's why the temperature is one of the most important factors, which shows the state of the body.

Humidity is also one of the important factors of the climate. As is known there are absolute, maximum and relative humidity. When the humidity is very high, person has a very bad sensation, which causes rheumatism and different troubles. When the humidity is low, the skin of the person is dry and his health decreases as well. All the considered parameters of working zone must be changed according to the sanitary norms, the numeral values of which are presented in table 1. For every enterprise for employees health and safety are very important as well the level of such parameters of job places as dust, noise, vibration, radiation, high level of which can provoke employees different occupational diseases. Clean air is very important for employees, as well as for equipment, measuring instruments, devices. In Georgia according to the International Sanitary Norms–list of Tolerant limit Concentrations (TLC), sometimes in the working zone of enterprises there are some damaging substances, especially in mining, chemical, biological, cement enterprises.

Table 1. Sanitary norms of parameters

Name of place	Category of work	Season	Optimum			Possible		
			Temperature of air t,℃	Relative humidity φ, %	Velocity of air v, m/s	t, ℃	φ, %	v, m/s
Industry with a low heating	Easy	Transient and cold	20-22	60-40	≤0.2	17-20	≤75	0,3
	Intermediate		17-19	60-40	≤0.3	15-17	≤75	
	Hard		16-18	60-40	≤0.3	13-15	≤75	
	Easy	Warmth	22-25	60-40	0.2-0.5	≤28	≤75	
	Interme-diate		20-23	60-40	0.3-0.5	≤28	≤75	
	Hard		18-21	60-40	0.3-0.7	≤28	≤75	

Dust negatively influent over the sight, skin, lungs, respiration system and can provoke pneumoconiosis, violation of respiratory organ function, nervous system damage, decreasing of blood circulation. In enterprises with high level of dust employees equipped with individual protective means for respiration organ. At the same time for such enterprises, it's necessary natural or artificial ventilation, which exhausts dirty air from the working zone and forces in fresh air.

Industry noise which is chaotic totality of sounds oscillation with different frequency negatively influent on the men's organism and in case of long influence provokes: damage of audibility function and loss of hearing temporarily or for ever; loss of sleep condition as well; increasing of irritability, violation of mental health. All these problems influent over the central nervous system and provoke headache, decreasing of memory and sight

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organs functions. To prevent these complications, at Georgian enterprises in such condition employees are used soft gaskets, ear-phones and special helmets.
Frequency of vibration from 16 up to 250 Hz is very harmful for a person and can provoke vibroillness. We distinguish following kinds of vibrations: common or general, which is passing to the body from the floor and local–from the limbs. Common vibration is more dangerous than the local one. Long term influence of vibration upon person's psychology provokes quick fatigue and rather often vibro occupational disease. As a result vibroillness destroyes nervous system, decreases the sensitivity of fingers, influent upon the joints and bones, functioning of the internal organs is deteriorated. In such conditions employees use individual protective means–gloves, rubber carpets, special antivibration springs.

Radiation is characterized by the radiance energy. At present there are a lot of different radiation sources. The employees even during the work with the computer are under the influence of different kind of electromagnetic waves such as laseric, ultraviolet, X-rays. Electromagnetic radiation is spreading with the high speed and is characterized by the correlation of the length of waves with the frequency. Electromagnetic waves have violent influence upon the health of the operator as a headache, fatigue and lowering the sharpness of the light.

LIFE – SAVING IN ROAD TUNNELS IN CASE OF FIRE

Life-saving in road tunnels is important international problem, for which extraordinary fire ventilation serves. For such ventilation designing, putting in operation and adjustment it's important to know its main technological parameters, such as backlayering length and critical velocity, which determine and stipulate the methods of evacuation and the means of fire – fighting.
In case of clean air descending ventilation is especially distinguished the opposite motion of smoke and other products of burn–reflow. The critical velocity in this case is minimum velocity of longitudinal ventilation, which excludes the creation of smoke reflow. Because of comparative simplicity the fire scenario in horizontal tunnel is better learned. Calculation of critical velocity numeral value in inclined tunnel is possible by critical velocity numeral value for horizontal tunnel by the formula [6]

$$u_c = K_g u_{c,0} \qquad (1)$$

here Kg is gradient – factor, which is used in case of fire for inclined tunnels.

Critical velocity may be calculated by the formula

$$u_c = k\left(\frac{g\dot{Q}_c H}{\rho_0 c_p T A}\right)^{1/3} \qquad (2)$$

where u_c is critical velocity, m/s; k -proportion constant; g - acceleration of gravity, m/s^2; $\dot{Q}_c$ - convection heat release rate, kW; H - height of tunnel, m; ρ_0 - outside air density, kg/m^3; c_p - specific heat capacity of air, kJ/(kg$K$); T- average temperature of smoke, ℃; A - tunnel transversal cross–section area, m^2.

Proportion constant is determined by the formula

$$k = \mathrm{Fr}_c^{-\frac{1}{3}} \qquad (3)$$

where k is Froud critical number, which is determined by formula

$$Fr_c = \frac{\Delta\rho g H}{\rho_0 u_c^2} \qquad (4)$$

where $\Delta\rho$ is difference of densities between the outside air and the smoke, kg/m^3.

The average temperature of smoke is calculated by the formula

$$T = T_0 + \frac{\dot{Q}_c}{\rho_0 c_p A u_c} \qquad (5)$$

where besides indicated values T_0 is the outside air temperature.
In the limits of mentioned legislation, by use of numeral simulation was determined the character of critical velocity variability for fires with different power, which is given on the **fig. 2** [7]

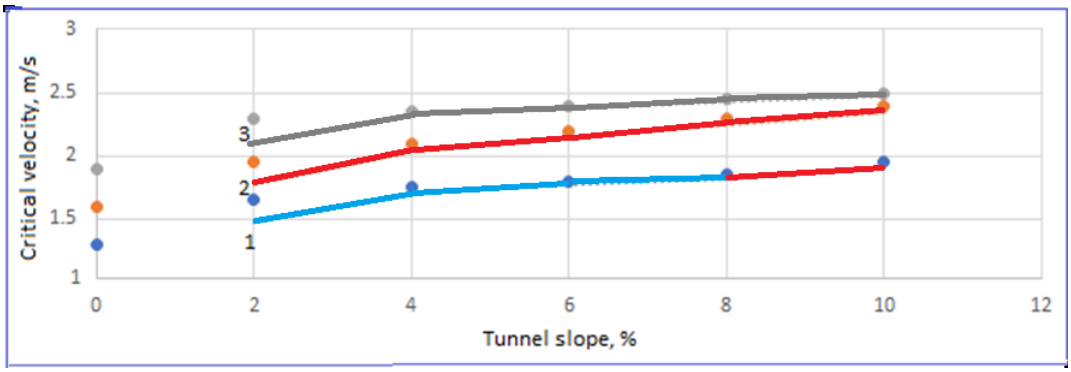


Fig. 2. Critical velocity variation depending on the tunnel slope in terms of fires of different strength: 1 - 5 MW; 2 - 10 MW; 3 - 15 MW.

As shown by fig 2, the variability of critical velocity is linear or is changed with approximate regularity in the range of fires with power of 5-15 MW.
By numerical simulation was determined as well the dynamics of air velocity in case of train motion in tunnel. We mean variability of air velocity before the train and variability of air stream in clearance between the perimeters of train and tunnel. We also consider here tunnel filling coefficient with train and train speed. The results are presented on the **fig. 3**.

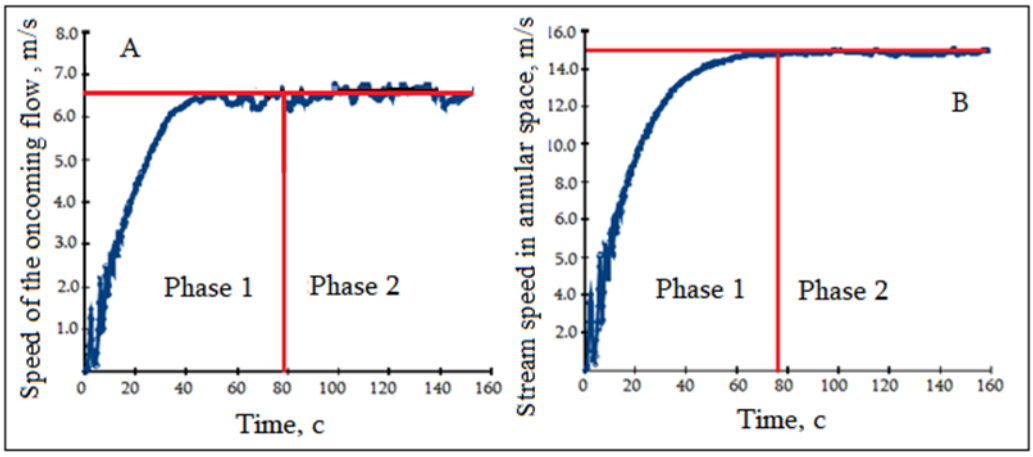


Fig. 3. Ventilation flow dynamics in front of the train (A) and between the train and the tunnel (B), when the train speed is 49.8 km/h and the tunnel fill coefficient is 0.6.

Thus, the train during the motion in tunnel creates the compression zone before the train and the vacuum is formed at the end, which capture the new air mass. As a result, air is pushed from the tunnel. The velocity of motive stream before the train is the same, as the velocity of the train in case, when the value of clearance is equal to zero. In real conditions the train velocity is reduced because of influence of aerodynamic resistance, which decreases the average consumption of air and velocity in tunnel.

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CONCLUSION

The Laws of Georgia dealing with labor safety elaborated and approved during the last years should improve the labor conditions of employees and increase the level of labor safety at Georgian enterprises. Should be established the system of statistical data in accordance with the requirement of International Standards. Should be activated the laboratories on labor safety that will implement many innovations on labor conditions at job places. Should be extended the sphere of technical supervision of some objects with increased technical danger, such as: metallurgical, chemical, gas enterprises and objects; cereal storage and processing enterprises; automobile gas filling stations. Should be created state special rescue service (for example in Department of Emergency and Civil Defense of Ministry of Internal Affairs of Georgia) for some important objects of Georgia – mines, metro, caves, hydroelectric power stations. All these measures will make possible to decrease the number of accidents and occupational diseases at Georgian enterprises. At the same time will improve the labor conditions and industrial surroundings, the grade of produced goods and service, the estimation of labor motivation, that will generally assist to strengthen the industry and the State.

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