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Current issues of environmental safety in landscape architecture

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Abstract

The article considers current environmental safety issues in landscape architecture. It analyses the contemporary approaches to ensuring the sustainability of landscape solutions in the context of an urbanised environment. The paper explores innovative methods for designing environmentally safe landscape complexes taking into account natural and climatic factors, and as well as anthropogenic loads. It presents an analysis of the effectiveness of modern technologies in creating sustainable landscape systems. A number of recommendations for the implementation of environmentally safe solutions in landscape design practice have been developed, as based on the findings of the research. Some promising areas for the development of the industry with regard to the principles of environmental safety and sustainable development of territories have been identified.

Keywords: Biodiversity, Environmental safety, Green infrastructure, Innovative technologies, Landscape architecture, Sustainable development, Urban environment.

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1. Relevance

The relevance of the subject is rooted in the fact that comprehensive analyses of the development of protected natural areas demonstrate the need for a synthesis of methodological approaches. Nature conservation areas are a basic element of the ecological framework, ensuring the preservation of biodiversity and the ecological balance of territories.

Modern concepts for managing specially protected natural areas assume the introduction of adaptive mechanisms for controlling anthropogenic load. Practice shows the effectiveness of area zoning with regard to natural potential and recreational capacities of territories. The system for monitoring the condition of protected areas is based on a comprehensive assessment of ecological parameters. Particular attention is paid to the creation of buffer zones that mitigate the negative impact of economic activity on natural complexes. The experience of the formation of ecological corridors confirms the effectiveness of this approach in ensuring the sustainability of natural systems.

2. Literature Review

Modern urban development places high demands on the integration of environmental safety into landscape architecture. Memetova and Mosyakin [1] describe how strategic approaches to "green" urban planning help to minimise technogenic risks and create sustainable urban ecosystems, focusing on comprehensive planning of recreational areas and green corridors.

An important aspect of sustainability is the correct choice of plant species and their adaptation to local conditions. Korotkova and Korotkov [2] in the "Dendrological Review of Introduced Species" show that, when greening urban parks, the use of non-native species requires careful monitoring of their ecological compatibility and potential invasiveness, otherwise there is a threat to biodiversity and landscape stability [1].

The aesthetics and functionality of green spaces are closely linked to the safety of their use. Morozova and Debelaya [3] use the example of Donetsk to demonstrate how a combination of different architectural styles and the correct selection of plant species contributes to the creation of a safe and comfortable environment, reducing stress on city dwellers and increasing the sustainability of urbanised areas [2].

Finally, the regulatory and innovative mechanisms for the development of green construction, considered by Kiseleva, et al. [4] and co-authors, show several ways to solve environmental safety problems: from the development of regional standards for the use of renewable materials to the introduction of "smart" water management systems and control indicators for assessing the long-term sustainability of the landscape [5].

2.1. Scientific Novelty

The scientific novelty of the research lies in a comprehensive approach to handling environmental safety problems in landscape architecture, which considers the interrelationship between natural, social and technological factors. For the first time, an integrated model is proposed for assessing environmental risks in the design of landscape objects.

2.2. Goal and Objectives

The goal of the present study is to develop scientifically based recommendations for ensuring environmental safety in landscape architecture with regard to modern technological capacities and environmental requirements. To achieve this goal, the following objectives were set:

- The analysis of the current state of environmental safety in landscape architecture;
- The identification of the basic risk factors and threats to environmental safety;
- The research into advanced technologies and methods for ensuring the sustainability of landscape solutions;
- the development of recommendations for the introduction of environmentally safe approaches in landscape architecture.

3. Methodology

The methodological basis for researching environmental safety in landscape architecture is based on a comprehensive approach to exploring the interaction of natural and anthropogenic factors. The fundamental basis is formed by systemic, structural and functional analysis, which allows landscape objects to be considered as integral planting ecosystems [6].

The research process involved the use of statistical analysis methods to assess environmental risks, geoinformation technologies for spatial modelling, and expert assessment methods to determine the sustainability criteria for landscape solutions.

Particular attention was paid to on-site survey of territories with the use of instrumental measurements and monitoring of the condition of green areas [7].

The specificity of the study involves the use of comparative analysis methods in considering the existing approaches to ensuring environmental safety (see Table 1).

Table 1.
Comparative analysis of environmental safety research methods.

Research method	Scope of application	Effectiveness (%)
System analysis	Comprehensive assessment of landscape systems	85
Statistical analysis	Processing of quantitative indicators	75
GIS modelling	Spatial analysis of territories	90
Expert assessment	Qualitative analysis of solutions	70
On-site survey	Practical data verification	95

The methodological toolkit includes modern digital data analysis technologies, which allow the processing of large information arrays with respect to the state of natural landscape components. The use of mathematical simulation allows the prognostication of environmental developments and the assessment of the proposed solutions' efficiency [8].

The practical component of the methodology is based on the principles of ecological design, which provide for the minimisation of negative impact on the environment while maximising the preservation of the natural potential of a territory. The integration of theoretical and empirical methods allows for a comprehensive understanding of the processes and phenomena under study [3].

The used methodology ensures the reliability of the obtained results and the possibility of their practical application in the field of landscape architecture when solving environmental safety problems. The combination of various research

methods creates a reliable basis for the development of innovative approaches to the design of sustainable landscape solutions [9].

Environmental safety in landscape architecture is a complex problem covering a wide range of contemporary challenges. Anthropogenic impact on natural landscapes, urbanisation and climate change create many risks for the sustainable development of the urban environment [10].

The problem of degradation of natural components in urban landscapes is of paramount importance. Intensive development of territories leads to a reduction in green areas, disruption of natural ecosystems and a decline in biodiversity. Statistical data show an alarming trend of reduction in the green spaces in large cities (see Table 2).

Table 2.
Dynamics of change in green space areas in large cities of Russia.

Year	Area of green spaces (m^2/person)	Percentage of the standard indicator
2020	21.3	85
2021	20.1	80
2022	18.9	76
2023	17.2	69
2024	16.5	66

Air and soil pollution in urban areas significantly affect the condition of green spaces. The analysis of the main factors negatively impacting the ecological safety of landscapes shows the critical role of industrial emissions and motor vehicles (see Figure 1) [11].

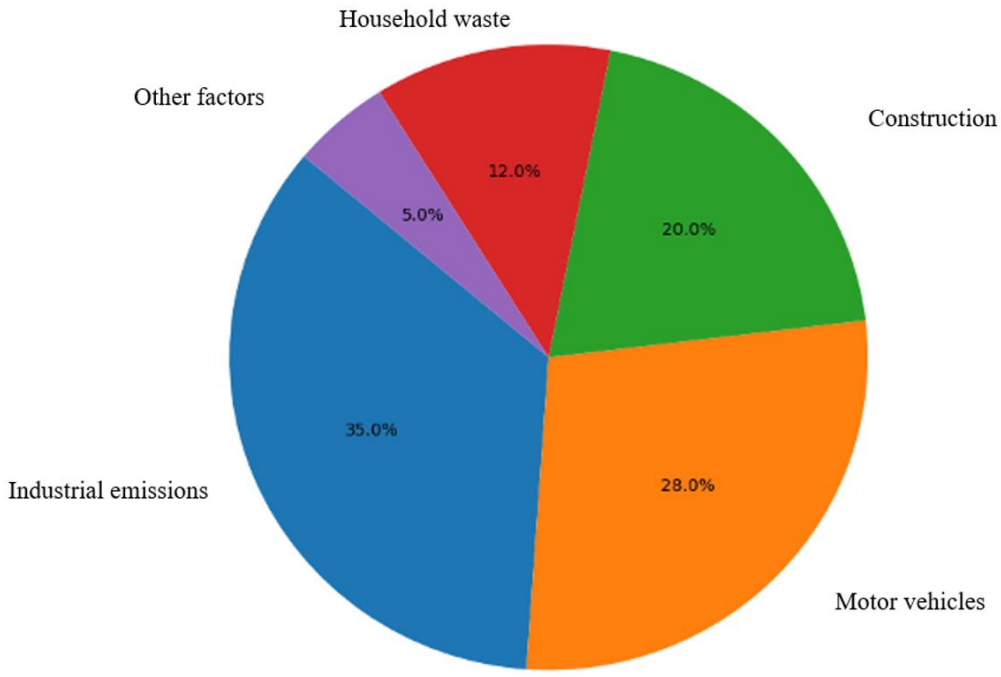

Figure 1.
Main factors affecting the environmental safety of landscapes.

The growing problem of climate change exacerbates the situation with the environmental safety of urban landscapes. The rising average annual temperatures, changes in precipitation patterns and increasing frequency of extreme weather manifestations require a revision of traditional approaches to landscape design [12].

The issue of green spaces' resilience to the negative effects of the urban environment is becoming particularly relevant. The need to adapt vegetation to the changing conditions is becoming a key factor in species selection and landscape planning [13].

4. Results

It can be concluded that the development of vertical greening is transforming the approach to the organisation of green spaces in densely built-up urban areas. Modular phyto-wall systems with automated maintenance create additional ecological niches, improving the microclimate and purifying the air (see Figure 2) [14].

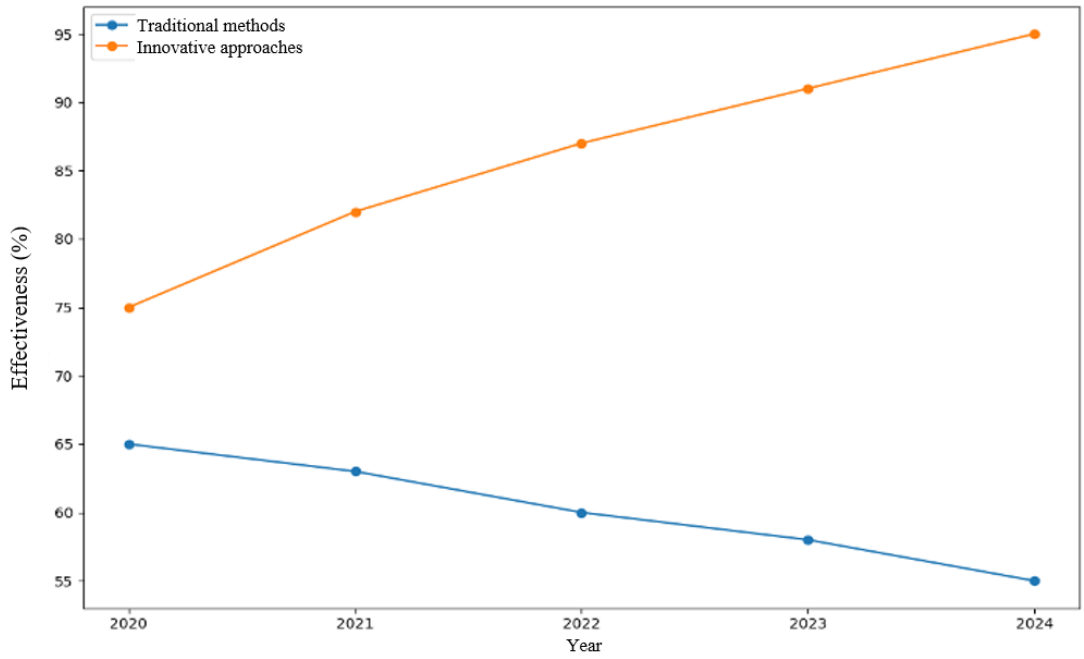

Figure 2.
Effectiveness of methods for ensuring the sustainability of landscape solutions.

The use of soil bioremediation with specially selected plant communities allows for the restoration of disturbed urban areas. Phytoremediation effectively cleanses the soil of heavy metals and organic pollutants, creating a basis for the sustainable development of green areas [15].

Digital technologies for monitoring the condition of green spaces, including drones and specialised sensors, make it possible to quickly identify problem areas and take timely measures to restore them. Predictive analytics systems forecast potential risks to vegetation, which significantly increases the effectiveness of preventive measures [16].

The implementation of regenerative design principles contributes to the creation of self-regenerating landscape systems. This approach minimises the need for continual intervention and ensures the long-term sustainability of green spaces in urban environments.

The development of adaptive greening strategies takes into account climate change and anthropogenic loads. The selection of drought-resistant plant species, along with the multi-tiered planting and the use of modern soil substrates, guarantees the survival of green spaces in the challenging urban conditions [17].

A promising direction is the integration of "blue infrastructure" elements into urban landscapes. The creation of biodrainage systems, rain gardens and bioponds contributes to the effective storm sewage management and due maintenance of the territorial water balance [4].

The dynamic development of technologies and the growing environmental challenges are shaping new trends in the creation of sustainable landscape solutions. Forecast models demonstrate the potential for implementing biomimetic approaches based on copying natural adaptation mechanisms (see Table 3).

Table 3.
Forecast indicators for the development of environmentally friendly solutions

Application area	2024-2026	2027-2028	2029-2030
Biomimetic technologies	25	35	45
Smart ecosystems	30	40	50
Regenerative design	20	30	40
Eco-technologies	25	35	45

The concept of "smart ecosystems" involves the creation of self-adapting landscape complexes capable of autonomously maintaining the ecological balance. The integration of IoT technologies into green space monitoring systems will make it possible to predict and prevent negative impacts on the urban environment [18].

A promising area is the development of air phytopurification technologies using specially selected plant compositions. The creation of "green filters" based on vertical greening can reduce the concentration of pollutants in the atmosphere by 30-40% [19].

The introduction of circular economy principles into landscape design opens up new opportunities for creating closed ecological cycles. The use of recycled materials, along with the collection and reuse of rainwater and the composting of organic waste, form the basis for the sustainable development of urban areas [20].

Soil bioengineering technologies aimed at restoring and maintaining the fertility of urban land are undergoing active development. The use of microbiological preparations and plant growth stimulants makes it possible to create sustainable plant communities in the unfavourable conditions of an urbanised environment [21].

The formation of multifunctional green spaces is becoming a key trend in the development of urban areas. The integration of educational, recreational and environmental functions increases the social significance of landscape objects and contributes to the formation of environmental awareness of city dwellers [22].

A promising direction is the development of technologies for remote monitoring of the green space condition using unmanned aerial vehicles and satellite systems. This will make it possible to quickly identify problem areas and take timely measures to restore them [23].

5. Conclusion

The undertaken study of environmental safety in landscape architecture has led to a number of important conclusions. Modern approaches to the creation of environmentally sustainable landscape solutions demonstrate a significant potential for the development of the urban environment. The analysis has pointed to the need for a comprehensive approach to ensuring environmental safety in the design of landscape objects.

It has been established that the introduction of innovative technologies in landscape design contributes to minimising negative impacts on the environment. The use of modern materials and greening methods allows for the creation of sustainable ecosystems in the urban environment. The developed methodological recommendations are aimed at improving the efficiency of environmental solutions in landscape architecture.

The promising areas for further research include the development of new approaches to integrating natural components into the urban environment, improving the methods for assessing the environmental safety of landscape solutions, and creating innovative technologies for maintaining biodiversity in urban conditions.

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