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GREEN INNOVATIONS IN URBAN LANDSCAPE: OPPORTUNITIES TO USE SLOVAKIA'S EXPERIENCE

Purpose. To analyze the results of an internship at the Slovak Agricultural University in Nitra, which was aimed at studying the possibility of introducing green industrial innovations into urban landscapes under the project of the International Visegrad Fund "Green Innovations in Urban Landscape Ecology".

Results. The experience of creating an interactive living laboratory of green innovations "ReImaGIne Living Lab" was studied and the possibilities of implementing this methodology in Kharkiv were analyzed. The scenarios of transformation of open space into a sustainable multifunctional city park are investigated. The project on the use of green and blue infrastructure elements in the construction of the Nivy bus station in Bratislava is analyzed and the availability of green infrastructure elements in Slovak cities is assessed.

Conclusion. In order to implement green innovations in Ukraine, which are widely represented in Slovakia, it is necessary to modernize the training of specialists through new teaching models, as well as the introduction of the principles of sustainable development in the educational process.

KEYWORDS: *green infrastructure, innovation, urban landscape, project, visegrad fund, sustainable development, educational process*

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Introduction

The scientific direction of studying the Concept of Green Infrastructure in Kharkiv began to be implemented after the implementation of the International Visegrad Fund project "GAP - Green and Blue Infrastructure in Post-Soviet Cities: Learning from the Legacy and Linking to the V4 Experience", in which the authors of this article participated. Karazin University has carried out a number of scien-

tific studies to develop the project, the results of which were presented at conferences and published. The works are mainly devoted to theoretical foundations of the green infrastructure concept [1 – 6], analyzing the current situation in the cities of Ukraine and Europe with the provision of green infrastructure to the population [6 – 12], as well as assessment of individual green infrastructure components and

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their environmental quality [13 – 25]. At the same time, there is a need to change the current state of affairs for the better.

The Faculty of Horticulture and Landscape Engineering at the Slovak Agricultural University in Nitra is a European leader in this field. The study of methodologies and experience in implementing new green infrastructure projects is the main prerequisite for developing a program for the post-war restoration of urban landscapes in Kharkiv (Ukraine). To do this, it is necessary to train specialists who are famil-

iar with the methods and techniques of forming green space in urban landscapes. That is why we have implemented an educational and scientific internship project. *The main purpose* of the article is to analyze the results of an internship at the Slovak Agricultural University in Nitra, which was aimed at studying the possibility of introducing green industrial innovations into urban landscapes under the project of the International Visegrad Fund "Green Innovations in Urban Landscape Ecology".

Results and discussion

The study of the experience of studying, modeling and practical implementation of the green infrastructure concept at the Slovak Agricultural University in Nitra can be divided into 3 components:

1. Acquaintance with the structure, specifics and best practices of the faculties, institute and university as a whole;
2. Learning - science – practice.

Let's take a closer look at each internship site and consider the possibilities of using their experience to develop green innovations in Ukraine.

1. Acquaintance with the structure, specifics and best practices of the faculties, institute and university as a whole

1.1. Institute of Landscape Architecture. At the Faculty of Horticulture and Landscape Engineering, the territories adjacent to the building are widely used to practice gardening and agricultural skills. I inspected the experimental sites that are actively used in research

on horticulture and landscape management (Fig. 1).

"ReImaGIne Living Lab". According to the internship program, I got acquainted with the experience of creating an interactive living laboratory of green innovations "ReImaGIne Living Lab" (Fig. 2). It was created and operates with the support of Norwegian grants to innovate the landscape and garden architecture curriculum through new learning models based on the principles of "project-based research," "co-design," and "evidence-based design."

1.2. Visit to the Envirocentrum. Education and awareness raising in the field of climate change and extreme weather events is the main mission of the new Envirocentrum, which was opened on April 19, 2024, at the Faculty of Horticulture and Landscape Engineering (FZKI) of the Slovak University of Agriculture.



Fig. 1 – Experimental plots around the building of the Institute of Landscape Architecture

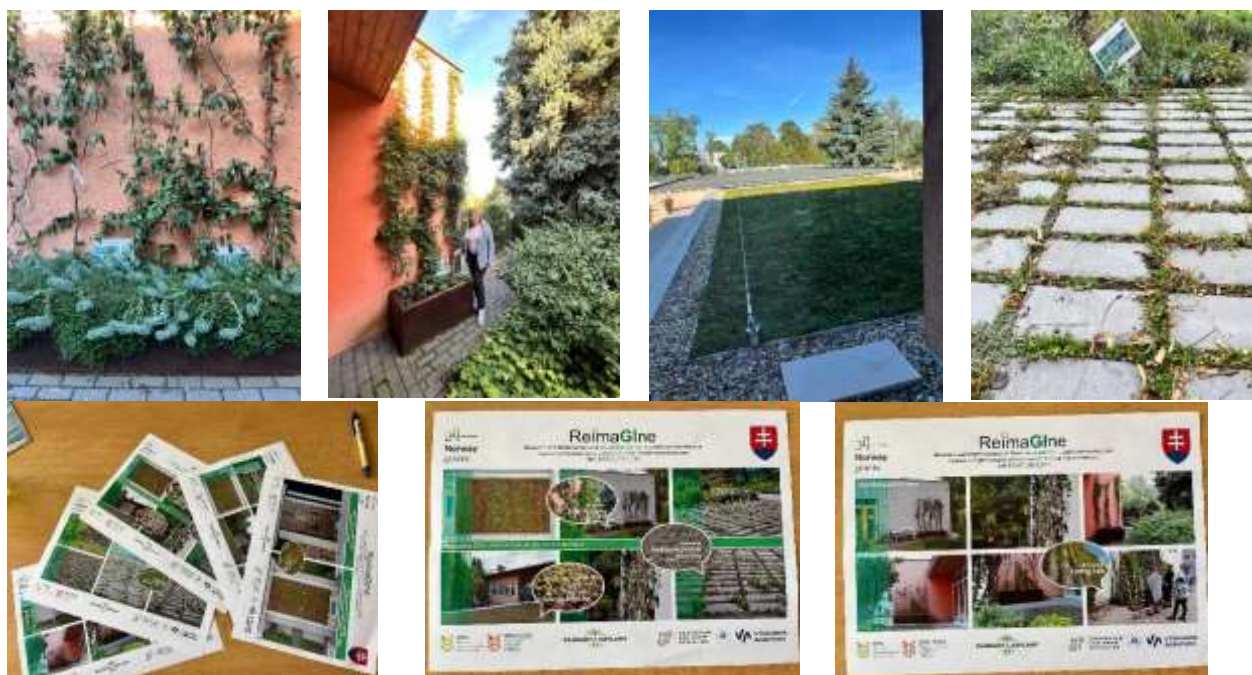


Fig. 2 – Interactive living laboratory of green innovations “ReimaGine Living Lab” by the ReImaGine project with the support of Norwegian grants

The main theme of the Envirocentrum is adaptation to climate change, which causes weather extremes such as droughts and floods. It serves not only students of the faculty and university, but also high school and elementary school students who conduct experimental excursions here. It is also open to the professional public. They can learn about the functions and impact of water on the environment through various models and demonstrations. For example, they will learn how a river channel changes over time or how a flood wave is formed. The Envirocentrum conducts meteorological observations and experiments on the rate of rainwater infiltration through different types of soil, with different vegetation cover, etc. (Fig. 3.).

The excursion to Envirocentrum inspired me to implement similar ecological models for the educational process in my country.

1.3. *Visiting to the AgroBioTech Research Center SUA in Nitra.* The AgroBioTech Research Center SUA in Nitra was established within the project “Creation of the research center AgroBioTech” ITMS 26220220180. This university research center was realized with the support of EU funds

from the Operational Program: Research and Development.

The AgroBioTech Research Centre (ABT RC) of the Slovak University of Agriculture in Nitra is a university-wide, specialized facility which performs concentrated innovative research in the relevant fields aimed at conducting new methods and procedures in research, especially within applied research, with the express goal of transferring its results into practice.

The ABT RC is equipped with state-of-the-art research infrastructure, thereby enabling the centre to conduct research at the highest level, applicable in practice, and consistent with the core needs of the priorities of agrobiological, the processing technology of agricultural products and the agri-food industry, biotechnology, genetic technologies, agroecology, bioenergetics, and bioeconomy.

Prof. Miroslava Kačániová introduced the work of the laboratories and showed me how they conduct the experiments (Fig. 4):

- Laboratory of Genetic Analysis
- Laboratory of Microscopic Analysis
- Laboratory of Spectroscopic Analysis
- Laboratory of Cell biology and cytogenetics.



Fig. 3 – Excursion to Envirocentrum



Fig. 4 – The AgroBioTech Research Center SUA in Nitra

1.4. *Botanical Garden.* Botanical Garden, which I regularly visited throughout my internship, is the place to study biological diversity, conduct research and educational work at the university. This gave me the opportunity to observe flora in different weather conditions and get acquainted with the work of pollinating insects, in particular *Macroglossum lapidoptera*.

The Botanical Garden of the Slovak Agricultural University in Nitra is a model of a natural space organization that combines educational, scientific and recreational func-

tions. The garden space is designed taking into account the principles of landscape architecture aimed at preserving biodiversity, supporting ecosystem services and ensuring comfort for visitors. Not only university students, but also all visitors have the opportunity to increase their knowledge about nature, since all areas have information stands (Fig. 5).

Key elements of space organization

Thematic sectors – The garden is divided into several thematic zones, each of which represents a separate group of plants or ecosystem.



Fig. 5 – Information support for visiting the Botanical Garden

For example, there are sectors with local flora, as well as with exotic plants, which introduce visitors to the richness of the plant world. Such a division not only facilitates navigation, but also creates conditions for educational activities (Fig. 6).

– *Water elements* – The garden has a small reservoir, which serves both to aesthetically improve the space and to maintain biodiversity. Water elements also create a favorable microclimate, humidifying the air and adding coolness on hot days (Fig. 7).

– *Path and navigation systems* – The paths are located in such a way that visitors can freely move between different sectors without disturbing the natural landscape. The navigation system includes information stands and signs that help navigate the garden and learn more about each plant zone.

– *Educational and research areas* – An educational trail with eighteen plant models. The nature trail presents innovative approaches to the design and care of herbaceous communities to the public, taking into account climate change. Information stands are placed for those who

do not come on the excursion, but wish to explore the nature trail without a guide. In some parts of the garden, there are well-equipped areas for conducting scientific research and practical classes for students. Experiments on plant acclimatization, research of soil and climatic conditions are carried out here, enabling students to gain practical experience (Fig. 8).

– *Recreational areas* – Cozy places with comfortable benches, gazebos and observation decks have been created for visitors to relax. These areas allow you to enjoy the views of the garden and create pleasant environment for relaxation. A logical extension of the recreational area of the Botanical Garden is an aviary for ungulates, which can be observed (Fig. 9).

The garden maintains an ecological balance through sustainable plant care methods. A rainwater harvesting system provides irrigation during dry periods, and organic fertilizers and compost contribute to the natural nutrition of the soil. In addition, the garden widely uses local plants, which minimizes the need for water and fertilizers.



Fig. 6 – Thematic sectors



Fig. 7 – Water elements



Fig. 8 – Educational and research zone



Fig. 9 – Recreation area

The university's Botanical Garden plays an important role in environmental education, offering students and researchers conditions for practical training. It is a platform for studying flora, ecological processes, as well as for raising public awareness of the importance of preserving biodiversity.

2. Education - Science - Practice

This internship area is dedicated to studying the experience of scientific research and practical work carried out by the institute, its employees, graduates and partners - landscape architects. In addition, during these activities, an information bank was formed on the forms, methods and means of organizing green infrastructure in the urban landscape.

2.1. *Visiting lecture to the resort of Sliach.* An excursion to the Sliach resort led by Prof. Ing. Viera Paganová, PhD, for master's and

postgraduate students allowed them to get acquainted with the natural conditions of the resort and methods of maintaining them.

The Sliach resort in Slovakia is a unique example of combining the natural environment with medical infrastructure, emphasizing the importance of preserving natural landscapes for maintaining human health. Located in a picturesque valley between the cities of Zvolen and Banská Bystrica, Sliach is known for its mineral springs and favorable climate.

Key natural features

- Mineral springs – The resort is famous for its healing springs, in particular, carbonic waters with temperatures of about 33°C. These springs contain a unique composition of minerals, which makes them especially useful in treatment of cardiovascular diseases. The landscape design around the springs preserves its natural

appearance and creates an atmosphere of tranquility (Fig. 10).

- Forest landscapes – The resort is surrounded by mixed forests rich in coniferous and deciduous tree species, which form a natural barrier, protecting the area from noise and pollution. These forests create optimal conditions for recreation, providing clean air and shade for walks even on hot days (Fig. 11).

- Garden and park infrastructure – The landscape design of the resort includes various walking routes, gazebos and recreation areas, which are inscribed in the natural relief.

Architectural and landscape solutions

- *Functional zones* – The resort is divided into zones for active recreation and quiet walks. Landscape architects have made the

most of the natural relief, creating routes with panoramic views. This contributes to health improvement both through physical activity and through aesthetic pleasure.

- *Greening and landscape art* – Landscape elements, such as flower arrangements, sculptures and water bodies, are located in such a way as to harmoniously complement the natural landscapes. At the same time, the principles of sustainable landscaping minimizing interference with the ecosystem and ensuring the durability of the landscape, are observed here.

- *Eco-educational routes* – The resort offers educational routes where visitors can get acquainted with the ecological features of local ecosystems and microclimate. This is an important aspect that increases the environmental



Fig. 10 – Mineral waters

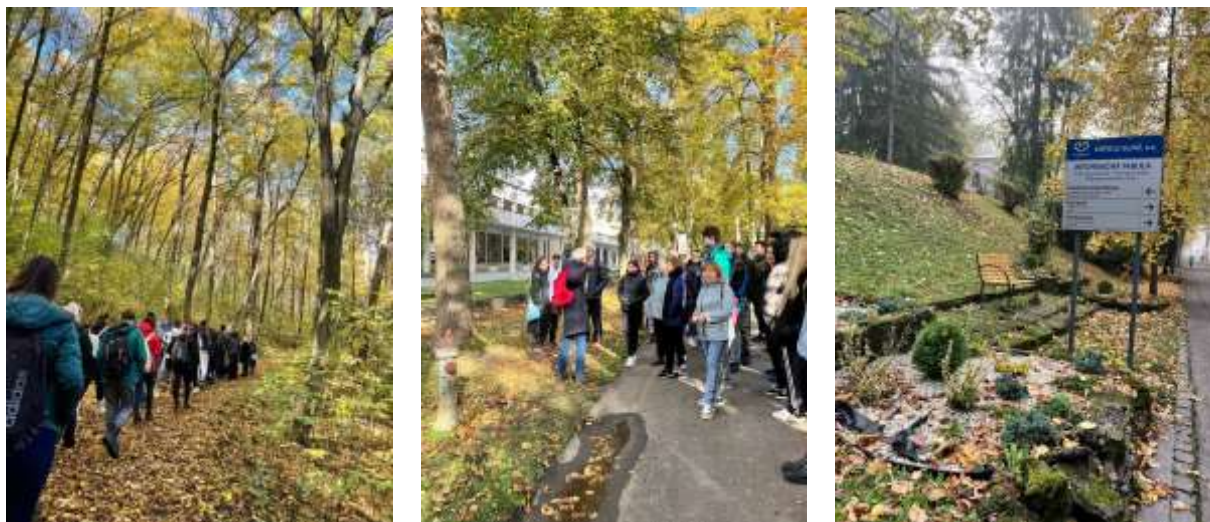


Fig. 11 – Forest and garden landscapes of the Sliač resort

awareness of vacationers and contributes to the preservation of nature.

Sliac is an example of preserving the natural environment in conditions of developed recreational infrastructure. The resort's landscape solutions reflect a modern approach to nature management, which contributes to environmental protection and also creates favorable conditions for recreation and treatment.

2.2. Seminar "*The Right Tree in the Right Place*". Participation in the seminar, held on October 17 by Ing. Marcel Raček, PhD. as

part of the activities of the public organization Association of Garden Design and Landscaping (www.szkt.sk) under the leadership of Ing. Mária Bihuňová, PhD, provided a lot of information regarding green infrastructure. The seminar discussed issues of urban green infrastructure, in particular projects aimed at improving the quality of life in cities through greening (Fig. 12). The seminar covered issues of landscape architecture, organization of horticultural exhibitions, quality control of trees, and consideration of potential risks when transporting plant material.



Fig. 12 – Seminar "Spravny strom na spravne miesto"

The second part of the seminar – practical – was held in the park area of Nitra. The park is an excellent example of modern green space that harmoniously combines the natural environment with cultural and social functions. Located near the historic center, it serves as an important place of recreation for residents and guests of the city, as well as a platform for cultural events and educational programs (Fig. 13).

Key characteristics of the park:

– *Diversity of plant associations* – the park has created several botanical zones, where local and foreign plant species are presented.

Thanks to this, the park contributes to the maintenance of local biodiversity, and provides visitors with the opportunity to get acquainted with the diversity of flora that enriches the ecosystem of the urban environment.

– *Water elements* – the park has natural and artificial reservoirs, which not only add aesthetics, but also provide the necessary microclimate, reducing the temperature in summer. These water bodies also serve as important ecosystems for waterfowl, insects and other species, which enriches the ecological environment.



Fig. 13 – Practical lesson in the park

– *Infrastructure for recreation and education* – there are walking paths, bicycle routes, playgrounds and recreation areas for different age groups.

– *Green architecture* – the park is equipped with elements of green architecture, such as environmentally friendly benches, solar lighting, as well as garbage cans for waste sorting. This contributes to the environmental education of visitors and is an example of a sustainable approach to the development of urban infrastructure.

Thus, the park in Nitra is an example of how a modern approach to landscape architecture and ecological planning can create sustainable urban spaces that contribute to an improved quality of life. Water features and green infrastructure make this park an exemplary place that supports biodiversity and promotes environmental awareness among the population.

2.3. Excursion to Bratislava

The educational excursion to Bratislava led by Ing. Mária Bihuňová, PhD and Doc. Ing arch Roberta Štěpánková, PhD for students and

postgraduates was aimed at demonstrating ecological solutions in the urban landscape, in particular the bowl park, the ecological roof of the "Nivy" bus station, the arrangement of green roofs in business districts and the "Smart City" concept.

The first location was a city park organized according to the principle of an inverted pyramid. It is located below the level of the surrounding urban space. It looks like a bowl, on the flat bottom of which there are green spaces, ponds, paths and places for sports training. The park is surrounded by green slopes and stairs along the perimeter, adapted for seating of vacationers. The park serves as a place for relaxation, walks with children and sports. In addition, it creates a comfortable microclimate in the urban environment (Fig. 14).

According to the previous internship program, we investigated the ecological roof of the bus station "Nivy" in Bratislava - an innovative example of using green roofs to integrate ecological infrastructure into the urban environment. Located in a new district of Bratislava, this roof combines recreational, ecological and energy-saving functions (Fig. 15).



Fig. 14 – Park Jama

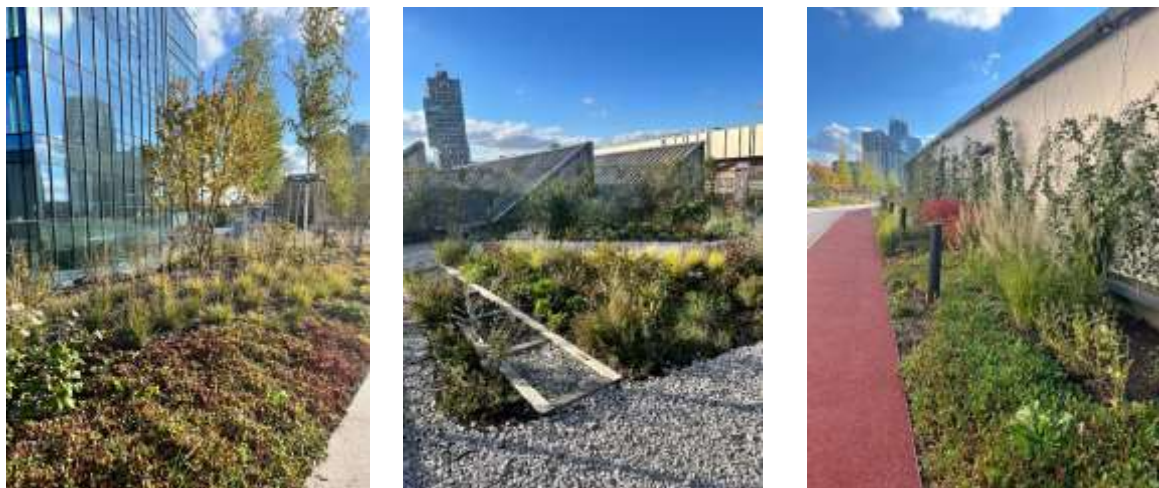


Fig. 15 – Ecological roof of the Nivy bus station in Bratislava
Key features of an ecological roof

– Biodiversity and greenery – the roof is covered with a variety of plants, including native species, which provide habitat for insects and birds. Thanks to this, the roof supports local biodiversity, even in urban conditions. Greening also creates a natural barrier that absorbs noise and dust, improving air quality.

– Water management – the roof is equipped with a rainwater collection system, which prevents excessive water from entering the city sewer system. The water is used to irrigate the green areas, and some of it evaporates, cooling the air and reducing the temperature on the roof. This helps reduce the urban heat island effect.

– Energy conservation – green areas on the roof help reduce the cost of air conditioning the building. Vegetation provides thermal insulation, which is an important factor in reducing energy consumption. It also increases the comfort of station visitors and helps reduce the carbon footprint.

– Recreational area for city residents – the roof is designed to be attractive to visitors: there are pedestrian paths, places to relax, as well as small corners with observation decks. This creates a unique space where residents can enjoy a green environment right in the city center, which contributes to improving the quality of life.

The ecological roof of the Nivy bus station is an excellent example of how green innovations can be effectively integrated into the transport infrastructure. It contributes to the maintenance of urban biodiversity, improves

air quality, and reduces the heat load on the city. In addition to the environmental benefits, this project increases the environmental awareness of the population and popularizes the idea of sustainable development, offering residents and visitors access to green space even in densely built-up areas.

During the excursion to Bratislava, we visited a new district of the city built according to the Smart City concept. The main ecological component of the district has become underground parking lots, the roofs of which are green zones of the inter-building space (Fig. 16).

From the engineering point of view, the arrangement of this territory requires significant efforts of architects and landscape architects, since:

- It is necessary to create a smart system for draining excess rainwater;
- To equip a smart system for drip irrigation of vegetation;
- To select plant material, namely the composition of the grass cover, which is able to withstand significant anthropogenic load, to be natural for this territory;
- To select and plant a tree stand with restrictions for the root system, due to the presence of underground parking;
- To equip a playground using environmentally friendly materials, taking into account drainage and avoiding the possibility of injury to children.

An expert Ing Jana Adámková, PhD spoke about all these design features



Fig. 16 – Smart city

2.4. *Presentations from Slovak and Czech landscape architects.* Meetings with professionals - practitioners, who presented their projects on urban greening in Slovakia and blue-green infrastructure in Vienna (Austria).

The presentation by the University of Nitra graduate **Ing. Júlia Straňáková**, who works at **RUDBECKIA**, describes key aspects of landscape architecture in urban spaces in Slovakia, including work with private, reserved and public areas (Fig. 17). It covers different types of locations: from private gar-

dens and corporate sites to public parks, squares, playgrounds and historical areas.

Key elements and stages of design:

– Community participation – the speaker emphasizes the importance of a participatory process in urban environment management, involving the community through surveys and public discussions. This makes it possible to collect feedback from residents, take into account their needs and wishes to create a comfortable urban environment.



Fig. 17 – At a meeting with Ing. Júlia Straňáková

– Design requirements – The projects encompass an integrated approach to urbanism, architecture and modular green infrastructure elements. In particular, it includes the provision of recreation areas, playgrounds and sports grounds, as well as prioritizing environmental elements such as mod-green infrastructure for water management.

– Preparatory work and surveys – Significant attention is paid to geodetic, hydrogeological and dendrological surveys to accurately analyze the soils, groundwater and tree conditions in the project area. Important steps include data collection, pollution assessment, and determining safe conditions for green infrastructure development.

– Detailing of zones and concepts – Projects include the development of graphic concepts for zones for various purposes: playgrounds, sports areas, recreation areas, and places for social events and meetings. These zones are designed for different age groups, including the needs of people with limited mobility.

– Reconstruction of historical sites – Special attention is paid to the restoration of historical sites while preserving cultural heritage. Each site is offered a different concept, such as creating symbolic alleys or installing architectural elements reminiscent of the city's history.

The work of the RUDBECKIA design bureau, which was represented by the speaker, demonstrates a systematic approach to creating an environmentally friendly and comfortable urban environment. The use of modern methods of assessment and community involvement creates the basis for the development of functional and environmentally oriented urban spaces that promote social connections and maintain biodiversity.

Presentation “The Blue-Green Transformation of Vienna” by Ing. Petr Forchtgott from the Czech Association of Landscape Architects, demonstrates an innovative approach to the development of the urban environment, in particular by integrating green and blue (water) components into the urban landscape (Fig. 18).



Fig. 18 – Lecture by Ing. Petr Forchtgott (Czech Association of Landscape Architects)

Key components of the transformation:

– Blue-Green Infrastructure – Vienna is actively implementing solutions that combine greenery with water management, creating adaptive spaces that help reduce the effects of climate change, such as rising temperatures and frequent flooding.

– Parks and green spaces system – The presentation highlights various parks (e.g. Helmut-Zilk-Park, Rudolf-Bednar-Park) that serve as recreational areas and function as ecological corridors. These areas support biodiversity and create conditions for efficient cooling of the city.

– Innovative architectural solutions – Particular attention is paid to facilities that combine business and sustainability, such as the IKEA City Store with a green roof that simultaneously serves to reduce energy consumption and improve air quality. Such projects contribute to the greening of urban areas and infrastructure.

– Restoration of water bodies – The project includes measures to preserve and clean up water bodies such as Donauinsel. This not only supports the recreational function of the water bodies, but also improves the state of local ecosystems.

– Sustainable urban spaces – Districts such as Seestadt Aspern are being developed as examples of “city-within-a-city” where the principle of ecological balance is paramount. Such projects take into account accessibility, sustainability, climate change adaptability, and the integration of public spaces for social interaction.

Vienna's Blue-Green Transformation project is an exemplary example of an integrated approach to creating a sustainable urban environment where technology and nature-based solutions contribute to a better quality of life. This presentation can serve as an inspiration for other cities seeking to combine environmental and social goals to shape a sustainable future.

Conclusions

The internship in Nitra was an extremely useful experience for deepening my knowledge in the field of environmental science and landscape architecture. The program was carefully designed and allowed me

to get acquainted with modern European approaches to environmental monitoring, organization of urban green infrastructure and the use of landscape architecture to improve the quality of life in urban areas.

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. Furthermore, the authors have fully adhered to ethical norms, including avoiding plagiarism, data falsification, and duplicate publication.

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ЗЕЛЕНІ ІННОВАЦІЇ В МІСЬКОМУ ЛАНДШАФТІ: МОЖЛИВОСТІ ВИКОРИСТАННЯ ДОСВІДУ СЛОВАЧЧИНИ

Мета. Аналіз результатів стажування в Словацькому аграрному університеті в Нітрі що спрямоване на вивчення можливості впровадження зелених індустриальних інновацій в урбандшафти за проектом Міжнародного Вишеградського фонду «Зелені інновації в екології міського ландшафту».

Результати. Вивчено досвід створення інтерактивної живої лабораторії зелених інновацій "ReImaGIne Living Lab" та проаналізовано можливості втілення цієї методики м. Харкові. Досліджено сценарії трансформації відкритого простору в сталий багатофункціональний місь-

кий парк. Проаналізовано проект з використання елементів зеленої та блакитної інфраструктури при спорудженні автовокзалу Nivu в Братиславі та зроблено оцінку доступності елементів зеленої інфраструктури в словацьких містах.

Висновки. Для втілення в Україні зелених інновацій, що широко представлені в Словаччині необхідно модернізувати підготовку фахівців через нові моделі викладання, а також впровадження принципів сталого розвитку в освітній процес.

КЛЮЧОВІ СЛОВА: *зелена інфраструктура, інновації, урболандшафт, проєкт, Вишеградський фонд, сталий розвиток, освітній процес*

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