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Influence of green infrastructure objects for quality of surface runoff (on the example of green roofs in Kharkiv)

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ABSTRACT

Relevance. Modern urbanization processes in Kharkiv are accompanied by an increase in anthropogenic pressure on the natural component, compaction of buildings and reduction of green areas. The concept of green infrastructure is used in many countries around the world; it is the best way to reorganize urban space into modern cities.

The purpose of the article is a determination of quality changes of water runoff after passing through of green roofs in Kharkiv, Ukraine.

Material and methods. A green roof is the roof of a build, partially or completely covered with vegetation and soil layer. Green roofs are divided into "intensive" and "extensive" types. In the research was studied the frequency of use of green roofs in construction and landscaping on the example of Kharkiv, was conducted an inventory of green roofs in Kharkiv. As the number of green roofs in Kharkiv is rather small, is optimal to choice the particular test sites for research. For chemical analysis, were taken samples of snow, surface runoff from the flat, and sloping green roofs and roof without greening for the content of pollutants. Chemical analysis of the samples was performed by the Laboratory of Analytical Ecological Research of V.N. Karazin Kharkiv National University. The laboratory has the attestation and certificate of ISO 10012:2005 № 01-0155/2019. The study determined the following indicators: pH, nitrites, nitrates, transparency, smell, turbidity, chlorides, general rigidity, total alkalinity, ammonia, zinc, copper, manganese, cadmium, total iron, chromium. Two types often represent green roofs in Kharkiv: parking roofs and cellars. Points of samples are located at Shevchenkivsky and Kholodnohirsky districts.

Results and discussion. Results of a study of snow and runoff sampling after a green roof and a roof without landscaping show that most water quality indicators improve after water passes through green areas. Thus, at points the pH, general rigidity, alkalinity, concentration of chlorides, chromium are decrease. The green roof of the first point (parking) also reduces the concentration of nitrites, ammonia, zinc and manganese. The concentration of iron also decreases in the second point. However, there is an increase in the concentration of heavy metals in the water due to their accumulation in the substrate of the green roof. The results of the study are can be used by the Post-Soviet countries, as previously the impact of surface runoff was considered only in terms of the flow of pollutants from storm sewers to water bodies.

Conclusion. The results of the study indicate that green roofs contribute to the treatment of runoff, natural replenishment of surface water bodies and groundwater and reduce the load on municipal wastewater treatment plant.

***Keywords**: green infrastructure, green roofs, stormwater regulation, urban water, surface runoff.*

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Introduction. Green urban space in Post-Soviet Union countries is a disparate network of linear and planar plantations. At the same time, the modern practice of construction, especially in large cities with a population of more than 1 million people, has a continuous using of "grey" solution. Urbanization is leading to more frequent floods in urban areas. Municipal stormwater collection and sewerage systems do not cope with the anomalous amount of precipitation and have an outdated material and technical fund. Researches of green infrastructure objects were conducted in different countries of Europe and Ukraine (Kuzyk, 2017; Kuzyk and Tsaryk, 2020). Ukrainian legislation on urban landscaping is based mainly on GBN B 1.1-14 (GBN 1.1-14, 2012). In previous studies, we also studied both the theoretical features of the organization of green infrastructure and landscape urban planning (Maksymenko, Burchenko, 2019; Klieshch et al., 2017; Bezliubchenko et al. 2011) and its particular objects (Maksymenko et al., 2021; Burchenko, 2021).

Green areas in cities provide a number of benefits: improving the quality of living space, atmospheric air, regulation of temperature and microclimate, regulation of surface runoff, adaptation to climate change, etc. The concept of green infrastructure is used in many countries around the world; it is the best way to reorganize urban space into modern cities. Using of green infrastructure in urban conditions contributes to the development of spatial processes, planning and management of which draws special attention to the impact of non-environmental solutions generated by the urban context (Shkaruba et al., 2021; H. Skryhan et al., 2020).

A green roof is the roof of a build, partially or completely covered with vegetation and soil layer. This green space created by the addition over traditional roofing system additional layer of fertile soil and plants. A green roof is also called an ecological and/or living roof.

Flat roofs are considered to have a slight slope, but not less than 2%, and sloping roofs can have a slope of 20% or more. The flat roof returns less than 1% of moisture to the atmosphere. A thin layer of vegetable soil 10 cm thick, covered with grass, holds up to 20% of precipitation. Green roofs can hold up to 80% of rainwater, which reduces the load on the city's sewage system, which often does not cope with rainwater volumes and cause flooding (Miniailo and Filonenko, 2015).

The existing types of architectural and planning solutions for green roofs can be reduced to several main types (Miniailo and Filonenko, 2015):

a) grass roofs in low-rise construction;

b) gardens on terraces;

c) gardens on the roofs of outbuildings (garages, shops);

d) gardens on the roofs of high-rise buildings.

According to the type of structure, green roofs are also divided into "intensive" and "extensive". Intensives are large enough facilities that typically require relatively complex engineering solutions (Fig. 1). Such roofs can accommodate even small ponds, swimming pools, trees and large recreation areas such as cafes or gyms.

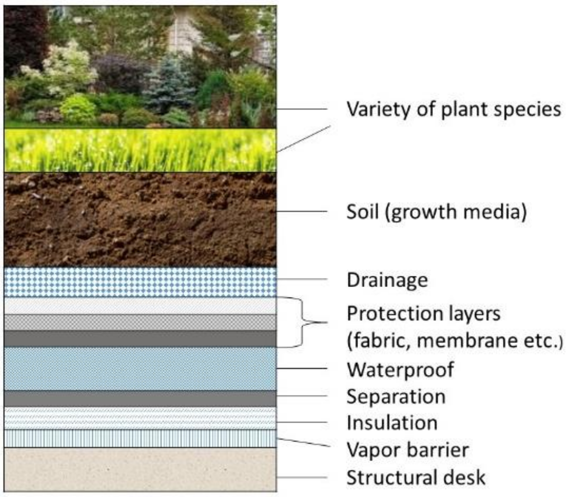

Fig. 1. Intensive type of green roof

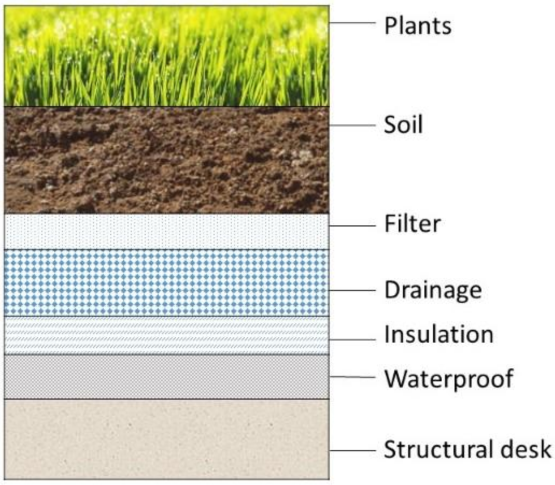

Fig. 2. Extensive type of green roofs

Extensive green roofs are roofs with a thin plant carpet of low grass, moss, lichens and other low and unpretentious plants. This type of green roof can be created independently on an existing house; as usual, the house does not require significant reconstruction (Fig. 2).

The intermediate type between extensive and intensive green roofs is quite popular. These are roofs where it is possible to grow garden crops, accessible for small group of visitors and as a recreation area. It is important that these areas do not interact directly with the earth's surface and may consist of different types of soil. They play an important role in the regulation of surface runoff, life and development of urban flora and fauna, provide protection against overheating of buildings, noise and cold and forming a comfortable microclimate (Bronz, 2017).

Green roofs are divided into sever and container types. However, the sever type of coating retains precipitation and provides wastewater treatment better than modular. And the calculation of the content of surface runoff can be carried out (Culligan et al., 2014) as ratio of the amount of runoff during the study period to the surface of the green roof.

In addition, it is necessary to pay attention to the need to fertilize the extensive green roof with fertilizers, which can come with runoff to nearby reservoirs (Gilmore et al., 2012).

For example, green roofs are actively used in Lviv, Ukraine on private builds, business centres, study and research institutions.

Retention of surface runoff by greenery, in particular green roofs, is confirmed in various studies (Talebi et al., 2019; Minova and Vranayova, 2020).

Drainage attenuation depends on local precipitation characteristics and individual roof design, but can reach up to 90% for intensive roofs. The peak flow is maintained for 15 minutes, which means relief for the sewer system. Because the green roof drain is filtered, the water can be used to feed groundwater or as tap water on the farm (NWRM project).

For example, green roofs in Geneva, Switzerland have been installed on the roof of a hospital (0.55 ha) to reduce flood risks in urban areas. Indeed, this green roof is designed to retain about 30.25 m^3 of water per day in the soil and plants and prevent it from running off (NWRM project).

A pilot research project on the benefits of green roofs was developed in Finland. Were studied the impact on the quality of wastewater, pollinating insects, the survival of Finnish endangered arid meadow species on various types of substrates, etc. Obviously, one green roof or several scattered roofs have little or no effect on stormwater regulation. However, simulations have shown that there are potential benefits for large-scale rooftop greening projects in urban areas (NWRM project).

The ability of plants to survive on green roofs depends on certain factors, such as plant species, solar radiation, rainfall, average annual temperatures. It was found (Lönnqvist et al., 2020) that spontaneous vegetation has a higher survival rate and performs ecosystem services than the vegetation chosen for the green roof.

The type of vegetation also affects the water retention efficiency of green roofs. The efficiency of water retention in almost does not depend on increasing the capacity of the substrate (Talebi et al., 2019).

However, the retention of water by the substrate and the filter layer affects the maintenance of temperature depending on the thickness of the layer (Tan et al., 2017).

On the negative side, it is determined (Raimondo et al., 2015) that green roofs are a very unfavourable environment for plant growth due to the small depth of the substrate, high temperatures and light, as well as the effects of wind. As a result, there is a need for a very precise selection of vegetation for a green roof. This in turn will reduce operating costs, ensure all the benefits of a green roof and extend its service life.

According to statistics, the total area of existing greenery in Kharkiv is about 15.4 thousand hectares, which is 44% of the total area of the city (which is 35.0 thousand hectares). However, almost half of all greenery has a significant age threshold. In other words, the level of landscaping in Kharkiv is not more than 25% - 30% with a regulatory value of 45%. In this research were studied, the frequency of use of green roofs in construction and landscaping, the quality of surface runoff after passing through the substrate of the green roof, on the example of Kharkiv.

Material and methods. In the course of the research was conducted an inventory of green roofs in Kharkiv by field survey and with the remote sensing and GIS (QGIS 3.16, SAS Planet). Samples were taken for chemical analysis of surface runoff samples from flat and sloping roofs, as well as analysis of snow samples for the content of pollutants. Was performed chemical analysis of surface runoff water from green roofs by the Educational Research Laboratory of Analytical Ecological Research of V.N. Karazin Kharkiv National University. The laboratory has the attestation and certificate of ISO 10012:2005 № 01-0155/2019.

Aqueous pH was determined using a pH meter. This method, in contrast to paper or special strips, allows to set the acidity and/or alkalinity of the liquid to the nearest hundredths.

The turbidity of the water is determined using a filter. First step is weighing the filter and second – weighing the filter after passing the sample of water through it, then dry the filter and weighing again. The difference in the mass of the filter will indicate the proportion of suspended solids in the water.

The transparency of the water is determined by the Snellen method, with the help of a glass cylinder with a flat bottom 30 cm high. The water must be mixed and poured into the cylinder to its full height. Under the bottom of the cylinder, it is necessary to put a paper with a standard font. Then, looking through the cylinder at the inscription, drain the water from it until the font becomes clear. The height of the water, expressed in centimetres, will indicate transparency.

To determine the smell at room temperature + 20°C, first shake the water well in a test tube, cover it with glass and then remove the glass and inhale the aroma through the nose.

Alkalinity was determined by acid-base titration within 24 hours after sampling. Previously, the acidity was measured using a pH meter. Next, water samples were titrated with HCl solution with methyl orange indicator. The methyl orange color change indicator indicates total alkalinity.

The general rigidity was determined by titration with a solution of disodium salt (Trilon B and complex III) in an alkaline medium using the indicator chromogen black.

Heavy metals, namely zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), cadmium (Cd), chromium (Cr) were determined by atomic absorption spectrometry and optical emission spectrometry.

Ammonia, or ammonium nitrogen, was determined using a photo-electro-colorimeter instrument ULAB 102UV under laboratory conditions. This device automatically determines the intensity of the image by comparing the selected water and standard solution with a known concentration of solution.

Nitrites were determined by the Gris method in the laboratory.

Nitrates were determined in the laboratory using a photo-electro-colorimeter.

The concentration of chlorides in water was determined in the laboratory by titrometric method.

Results and discussion. In the city of Kharkiv, the green infrastructure is represented mainly by parks, gardens, squares, linear plantings along roads and special purpose plantations (sanitary protection zones, green areas of enterprises and organizations). Green roofs are not very popular among architects and owners, so their number in the city is quite small. Green roofs in Kharkiv are often represented by two types: parking roofs (fig. 3) and cellars (fig. 4). The latter type is quite common, due to the traditions that have historically developed in the area. Cellars are used for storage of vegetables and canning and are located mainly near apartment buildings.

The first sampling point was parking at the Bakulina street near the residential complex (fig.3). The area is located in the yard of the private sector and plays the role of the roof of the parking. The area is 10 square meters (0.001 ha) with an angle of 25º, this position plays a role in the rate of water runoff from the surface. The lowest point of the roof is at a distance of 40 cm from the ground, the highest reaches about 4 meters. Vegetation is grown on the site artificially on a specially selected substrate (soil mixture), the ecosystem itself is up to 3 years old. The thickness of the surface layer is up to 10 cm of soil mixture. According to the Ukrainian legislation, for functional purposes, this area is for special use, i. e. access by unauthorized persons is prohibited.

The second sampling point for sampling was the area of the surface of the cellars at the Heroiv Pratsi street (fig.4). The plot is located near the garages in the courtyard of residential buildings. The green roof has an area of about 50 square meters (0.005 ha), with an angle of 0-3º. The height above the ground averages 1 meter. The roof is a typical soil of urban soil, which grows ruderal vegetation. The age of this ecosystem is about 20 years.

The third sampling point for comparison was the roof of a private house without landscaping at the Kholodnohirsky district of Kharkiv.

In the field, two samples were taken from each area. The first sample was water from the surface, namely melted snow, the second sample – water soaked through the surface of the green roof and taken from the drain. In the third sample, snow and melt water were taken from the drain. The study determined the following indicators: pH, nitrites, nitrates, transparency, smell, turbidity, chlorides, general rigidity, total alkalinity, ammonia, zinc, copper, manganese, cadmium, total iron, chromium. Comparison of samples of surface and drainage water from the first point at Bakulina street (table 1). All indicators do not exceed the norm of maximum permissible concentrations according to State Sanitary Norms And Rules 2.2.4-171.10 "Hygienic requirements for human water consumption", but the percentage of chemicals changes when passing through the soil mixture of the green roof. Therefore, the following changes can be observed:

- pH of surface water after impregnation decreased by 5.3%, nitrites by 50%, chlorides by 6.2%, general rigidity decreased by 39.5%, total alkalinity decreased by 21.30%, ammonia by 75%, zinc decreased by 13.6%, manganese by 69.3% and chromium by 100%.

These results tell us that the vegetation and substrate of the green roof do retain most of the chemical elements and clean the surface runoff. But instead there are indicators of the percentage of concentration which has increased:

- The smell of drainage water was 100% stronger than the surface and had a woody hue. The reason for this was the remains of leaves at the point of runoff.
- Heavy metals – cadmium and iron increased by 10 and 19 percent, respectively. The reason for this was the accumulation of chemical particles in the soil due to the constant inflow of surface water

In addition to variables, there are also those that remain at the initial concentration after water seepage through the surface of the green roof: copper (0.003 mg / dm^3), nitrates (0 mg / dm^3), turbidity (1.5) and transparency (25).

Summarizing the analysis of the first samples and their changes, it can be argued that the green roof on Bakulina Street plays an improving role as a surface runoff. Due to the fact that surface water concentrations of chemicals are initially within normal limits, even a small percentage increase in heavy metals is imperceptibly true for the quality of drainage water.

The study area at the Heroiv Pratsi street had the following results (Table 2):

- the concentration of impregnated water decreased compared to the surface at the following percentages: pH by 8.5%, chlorides ↘ 4.2%, general rigidity ↘ 87.8%, total alkalinity ↘ 81.5%, iron ↘ 1.6 %, chromium ↘ 100%;

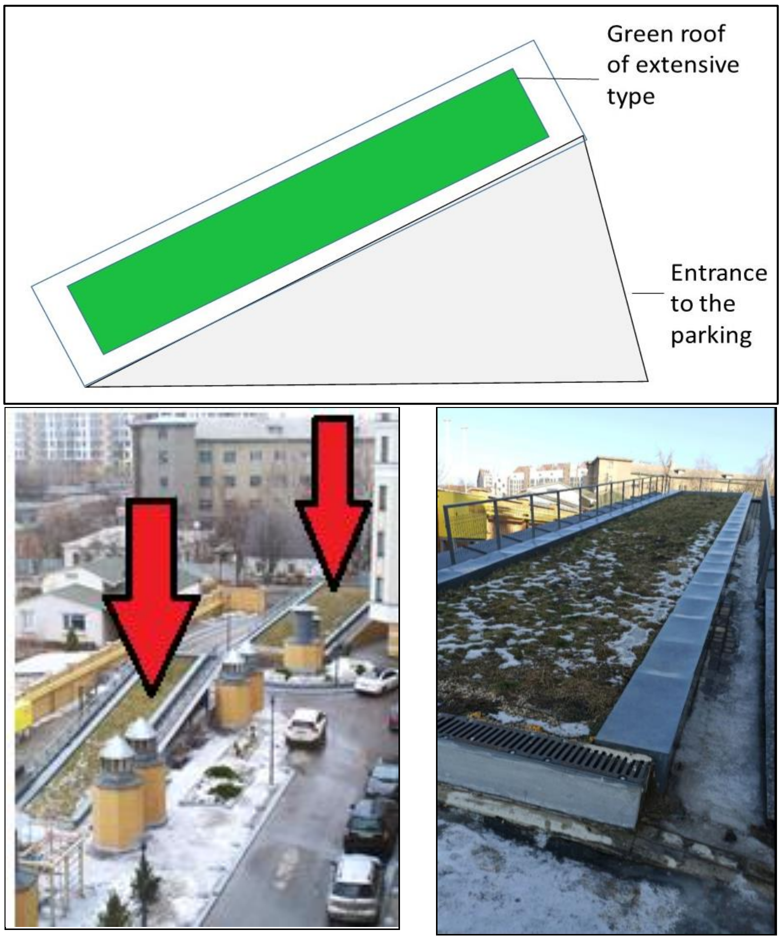

Fig.3. Green roofs on a parking

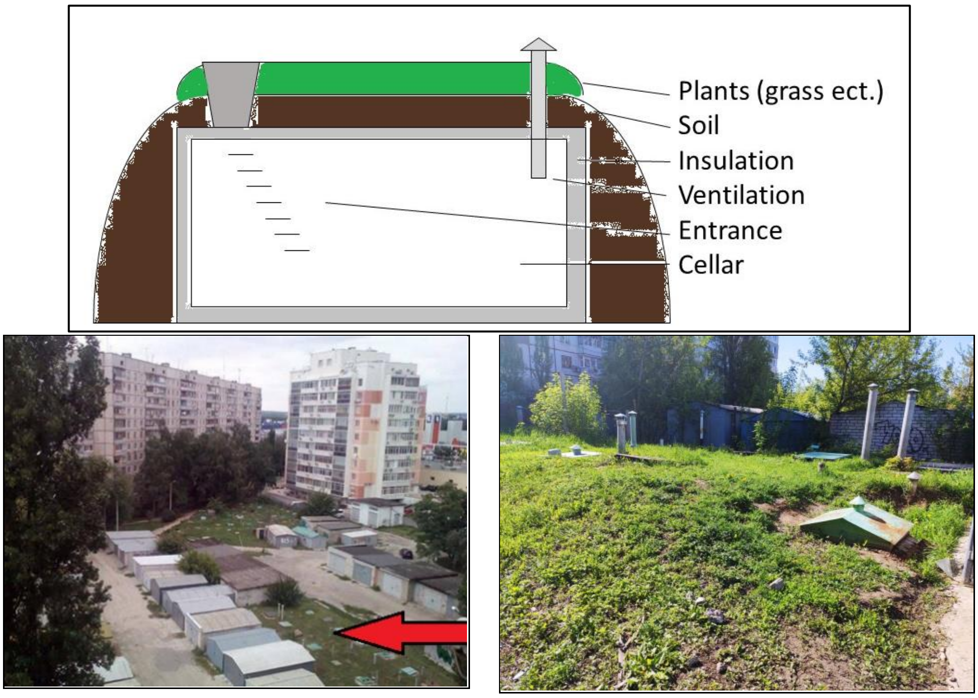

Fig. 4. Cellar

- the concentration increased after drainage through the green roof in the following indicators: smell by 100%, turbidity by 15%, in heavy metals – zinc (↗ 9%), copper (↗ 75%), manganese (↗ 77%), cadmium (↗ 50%).

The increase in the content of heavy metals after the infiltration of water through the surface, occurred due to their accumulation in urban soil. Especially that the ecosystem has existed for about 20 years and is constantly under anthropogenic interfe-

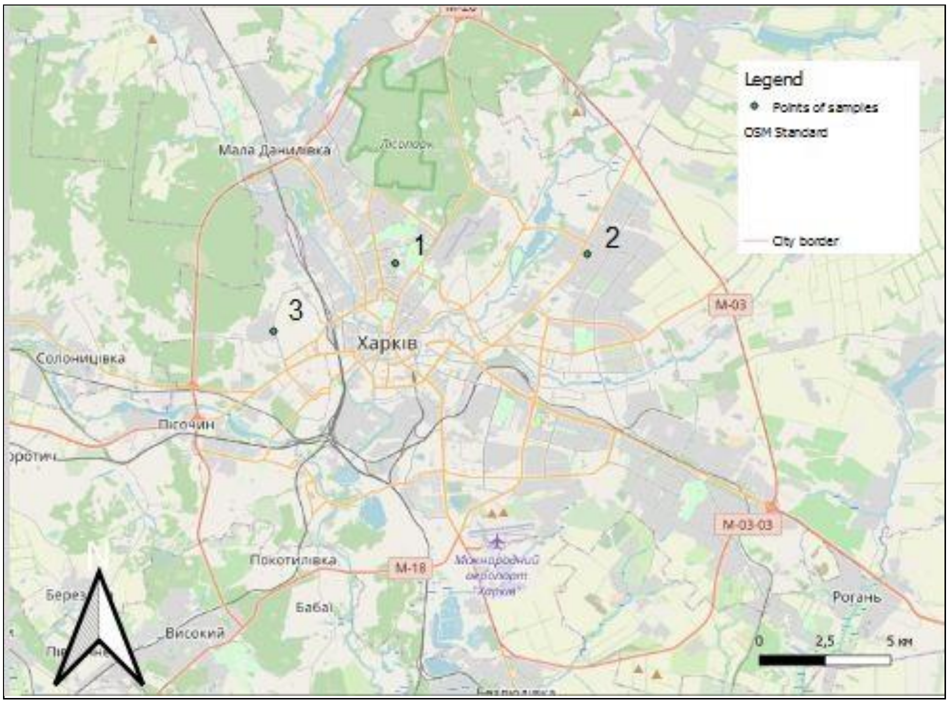

Fig. 5. Sampling points

Table 1

Comparison of samples of surface and drainage water from the first point at Bakulina street

Indicator	Units of measure-ment	Standard value	Sloping surface with grassy vegetation (green roof)	Drain after passing through the green roof	Changing in the concentration of the substance	The percentage change of the indicator
pH	-	6.5-8.5	8.266	7.83	↘	5.30 %
Nitrates (NO_3)	mg/dm^3	<50	0	0	–	0
Nitrites (NO_2)	mg/dm^3	<3.3	0.004	0.002	↘	50.0 %
Transparency	sm	>30	25	25		0
Smell	point	2	0	1	↗	100 %
Turbidity		<1	1.5	1.5	–	0
Chlorides (Cl)	mg/dm^3	<250	196	184	↘	6.2 %
General rigidity	mmol/dm^3	<7 (<10)	1.3	0.8	↘	39.5 %
Alkalinity general	mg/dm^3	0.5-6.5	1.65	1.3	↘	21.3 %
Ammonia (NH_3)	mg/dm^3	<2	0.08	0.2	↘	75.0 %
Zinc (Zn)	mg/dm^3	<1	0.0432	0.0373	↘	13.6 %
Copper (Cu)	mg/dm^3	<1	0.0003	0.0003	–	0
Manganese (Mg)	mg/dm^3	<0.05	0.00065	0.0002	↘	69.3 %
Cadmium (Cd)	mg/dm^3	<0.01	0.00045	0.0005	↗	10.0 %
Total iron (Fe)	mg/dm^3	<0.2	0.01935	0.0217	↗	19.0 %
Chrome (Cr)	mg/dm^3	<0.05	0.0003	0	↘	100 %

rence (for example, the roadway for vehicles or trampling). But if comparing the numerical values, even an increase in heavy metals corresponds to the norm State Sanitary Norms And Rules 2.2.4-171.10 “Hygienic requirements for human water consumption”. Only one indicator – turbidity, was initially not in the normal range and after drainage its value did not increase. This was due to the presence in the soil of various fine residues that remained in the water in a suspended state.

- The concentration remained unchanged after impregnation: nitrates (0 mg / dm^3), nitrites (0.001 mg / dm^3), transparency (25), ammonia (0.08 mg / dm^3).

Summing up the sample of surface and drainage water at the Heroiv Pratsi street, it can be argued that the green roof is more of a barrier to relatively light chemical elements. Due to the long life and irr-

Table 2

Comparison of samples of surface and drainage water from the second point at the Heroiv Pratsi street

Indicator	Units of measure-ment	Standard value	Sloping surface with grassy vegetation (green roof)	Drain after passing through the green roof	Changing in the concentration of the substance	The percentage change of the indicator
pH	-	6.5-8.5	7.292	7.252	↘	8.5 %
Nitrates (NO_3)	mg/dm^3	<50	0	0	–	0
Nitrites (NO_2)	mg/dm^3	<3.3	0.001	0.001	–	0
Transparency	sm	>30	25	25	–	0
Smell	point	2	0	2	↗	100 %
Turbidity		<1	1.5	2	↗	15 %
Chlorides (Cl)	mg/dm^3	<250	192	184	↘	4.2 %
General rigidity	mmol/dm^3	<7 (<10)	1.8	0.4	↘	87.80 %
Alkalinity general	mg/dm^3	0.5-6.5	2.8	0.8	↘	81.5 %
Ammonia (NH_3)	mg/dm^3	<2	0.08	0.08	–	0
Zinc (Zn)	mg/dm^3	<1	0.0417	0.0458	↗	9 %
Copper (Cu)	mg/dm^3	<1	0.0001	0.0004	↗	75 %
Manganese (Mg)	mg/dm^3	<0.05	0.0001	0.0003	↗	77 %
Cadmium (Cd)	mg/dm^3	<0.01	0.0002	0.0004	↗	50 %
Total iron (Fe)	mg/dm^3	<0.2	0.0066	0.0065	↘	1.6 %
Chrome (Cr)	mg/dm^3	<0.05	0.0001	0	↘	100 %

egular cleaning of the territory, the ecosystem cannot be quickly renewed.

Comparing the role of the green roof in two areas, common features and differences were found:

- Cadmium and smell in both samples increased in the water composition after drainage through the surface;
- Concentration of indicators: pH, Chlorides, total alkalinity, general rigidity, Chromium decreased after drainage in both samples;
- the values of Nitrates and transparency in both cases remained unchanged after passing through the soil layer;
- Iron, Manganese and Zinc were the opposite. If in 1 sample (Bakulina Street) the concentration of zinc and manganese decreased, in the second (Heroiv Pratsi Street) the opposite increased after drainage; Iron in the first sample increased and in the second decreased;
- Nitrites and Copper in the first sample decreased, in the second remained unchanged;
- Copper and turbidity in the second sample increased their concentration after drainage, in the first were static.

Table 3

Comparison of samples of surface and drainage water from the third point at Kholodnohirskyi district

Indicator	Units of measure-ment	Standard value	Sloping surface with grassy vegetation (green roof)	Drain after passing through the green roof	Changing in the concentration of the substance	The percentage change of the indicator
pH	-	6.5-8.5	6.185	7.685	↗	24.25 %
Nitrates (NO_3)	mg/dm^3	<50	0	0	–	0
Nitrites (NO_2)	mg/dm^3	<3.3	0.001	0.001	–	0
Transparency	sm	>30	30	30	–	0
Smell	point	2	0	0	–	0
Turbidity		<1	1.5	1.5	–	0
Chlorides (Cl)	mg/dm^3	<250	184	200	↗	8%
General rigidity	mmol/dm^3	<7 (<10)	1	2.0	↗	50%
Alkalinity is general	mg/dm^3	0.5-6.5	0.8	2.0	↗	60 %
Ammonia (NH_3)	mg/dm^3	<2	0.2	0.08	↘	60 %
Total iron (Fe)	mg/dm^3	<0.2	0.05	0.05	–	0

Research area without landscaping at Kholodnohirsky district had following results:

- increase pH, Chlorides, general rigidity and alkalinity
- reduction of ammonia after passing through the stormwater collection system
- indicators of nitrates, nitrites, iron, transparency, turbidity, smell remained unchanged.

Conclusion. The methods and forms of organization of green infrastructure are different in each city according to geographical, environmental, socio-economic conditions, the goals they pursue remain the same. Identification and expansion of green infrastructure is one of the most important strategies for implementing an ecosystem approach to spatial planning. One type of green infrastructure objects is a green roof.

Green roofs are the optimal urban green infrastructure due to their multifunctionality: they can be converted into existing buildings, they provide space for urban wildlife, and they can enrich public spaces for the city residents. In addition, green roofs make previously unfriendly places pleasant, as well as provide a new open space for office workers.

The main types of green roofs are extensive and intensive, sedum and container. They also differ from the typical vegetation and substrate. These factors will affect the maintenance of the green roof before the maintenance and treatment of stormwater runoff.

In the Post-Soviet countries, surface runoff was considered as a pollutant, which was sent to sewage treatment plants through the storm sewer system or to the water bodies directly. Our study shows positive aspect of green roofs on the qualitative characteristics of surface runoff.

In this study, were identified two types of green roofs – at the parking and typical for the Post-Soviet countries at the form of a cellar.

The results of a study of snow and runoff sampling after a green roof and a roof without landscaping show that most water quality indicators improve after water passes through green areas. Thus, at both points the pH, general rigidity, alkalinity, concentration of chlorides, chromium are decrease. The green roof of the first point (parking) also reduces the concentration of nitrites, ammonia, zinc and manganese. The concentration of iron also decreases in the second point. The increase in the content of individual elements (smell, turbidity, iron, zinc, copper, manganese, cadmium) is associated with the specific features of each area where the green roof is located and do not have regular repetition.

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Влияние зеленой инфраструктуры на качество поверхностного стока (на примере зеленых крыш в г. Харькове)

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Современные процессы урбанизации в Харькове сопровождаются усилением антропогенного давления на природную составляющую, уплотнением зданий и уменьшением зелёных зон. Концепция зеленой инфраструктуры используется во многих странах мира, это самый лучший способ реорганизовать городское пространство в современные устойчивые города. Целью исследования является определение качественных изменений химического состава поверхностного стока после прохождения через зеленые крыши в Харькове. Зеленая крыша – это крыша здания, частично или полностью покрыта растительностью и слоем грунта. Зеленые крыши делятся на два типа: экстенсивные и интенсивные. В исследовании изучалась частота использования и особенности зеленых крыш в зеленой инфраструктуре Харькова, проведена инвентаризация зеленых крыш в Харькове. Поскольку в Харькове достаточно небольшое количество зеленых крыш оптимальным является выбор отдельных тестовых полигонов для проведения исследований. Отобраны образцы для химического анализа поверхностного стока воды и снега от плоских и наклонных зеленых крыш и крыши без озеленения на содержание загрязняющих веществ. Химический анализ проб был проведен аттестованной лабораторией аналитических экологических исследований УНИ экологии Харьковского национального университета имени В.Н. Каразина, имеющая сертификат ISO 10012:2005 № 01-0155/2019. В ходе исследования определялись в воде следующие показатели: pH, нитриты, нитраты, прозрачность, запах, мутность, хлориды, общая жесткость, общая щелочность, аммиак, цинк, медь, марганец, кадмий, общее железо, хром. В Харькове зеленые крыши представлены преимущественно двумя типами: паркинг и погреба. Сравнение проб снега и стока после зеленой кровли и крыши без озеленения свидетельствует о том, что большинство показателей качества воды улучшаются после прохождения через зеленые насаждения крыш (снижаются показатели pH, общей жесткости, щелочности, концентрация хлоридов, хрома). Зеленая крыша первого участка (паркинг) уменьшает концентрацию нитритов, аммиака, цинка и марганца. На втором участке также уменьшается концентрация железа. Увеличение содержания отдельных элементов (запах, мутность, медь, марганец, кадмий) связано со специфическими особенностями каждого участка, где расположена зеленая крыша и не имеют регулярного повторения. Результаты исследования могут быть использованы постсоветскими странами, поскольку ранее влияние поверхностного стока рассматривалось только с точки зрения поступления загрязняющих веществ из ливневой канализации в водные объекты. и уменьшают нагрузку на городские очистные сооружения.

Ключевые слова: *зеленая инфраструктура, зеленые крыши, ливневое регулирование, городские воды, поверхностный сток.*

Вплив зеленої інфраструктури на якість поверхневого стоку (на прикладі зелених дахів у м. Харків)

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Сучасні процеси урбанізації в Харкові супроводжуються посиленням антропогенного тиску на природну складову, ущільненням будівель та зменшенням зелених насаджень. Концепція зеленої інфраструктури використовується в багатьох країнах світу, це найкращий спосіб реорганізувати міський простір у сучасні сталі міста. Метою дослідження є визначення якісних змін хімічного складу поверхневого стоку після проходження через зелені дахи у м. Харків. Зелений дах – це дах будівлі, частково або повністю вкритий рослинністю і шаром ґрунту. Зелені дахи поділяються на два типи: екстенсивні та інтенсивні. У дослідженні вивчалася частота використання та особливості зелених дахів у зеленій інфраструктурі м. Харкова, проведена інвентаризація зелених дахів у Харкові. Оскільки, у Харкові досить невелика кількість зелених дахів оптимальним є вибір окремих тестових полігонів для проведення досліджень. Відібрано зразки для хімічного аналізу поверхневого стоку води і снігу з плоских і похилих зелених дахів, та даху без озеленення на вміст забруднюючих речовин. Хімічний аналіз проб було проведено атестованою лабораторією аналітичних екологічних досліджень ННІ екології Харківського національного університету імені В.Н. Каразіна яка має сертифікат ISO 10012:2005 № 01-0155/2019. В ході дослідження визначались у воді такі показники: pH, нітрити, нітрати, прозорість, запах, каламутність, хлориди, загальна жорсткість, загальна лужність, аміак, цинк, мідь, марганець, кадмій, загальне залізо, хром. У Харкові зелені дахи представлено переважно двома типами: паркінг і погреби. Порівняння проб снігу та стоку після зеленого даху та даху без озеленення свідчать про те, що більшість показників якості води покращуються після проходження через зелені насадження дахів (знижуються показники pH, загальної жорсткості, лужності, концентрація хлоридів, хрому). Зелений дах першої ділянки (паркінг) зменшує також концентрацію нітритів, аміаку, цинку та марганцю. На другій ділянці також зменшується концентрація заліза. Збільшення вмісту окремих елементів (запах, каламутність, мідь, марганець, кадмій) пов’язане зі специфічними особливостями кожної ділянки, де розташовано зелений дах та не мають регулярного повторювання. Результати дослідження можуть бути використані пострадянськими країнами, оскільки раніше вплив поверхневого стоку розглядався лише з точки зору надходження забруднюючих речовин із зливової каналізації до водних об’єктів. Дослідженням доведено, що зелені дахи сприяють очищенню стоку, природному поповненню поверхневих водних об’єктів та ґрунтових вод та зменшують навантаження на міські очисні споруди.

Ключові слова: *зелена інфраструктура, зелені дахи, зливове регулювання, міські води, поверхневий стік.*

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