EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2023, 24(1), 233–246
https://doi.org/10.12912/27197050/155193
ISSN 2719-7050, License CC-BY 4.0

Received: 2022.09.20
Accepted: 2022.10.19
Published: 2022.11.01

Factors of Environmental Safety Reduction on Styr River in the City of Lutsk (Ukraine)

Viktor Kopylov[1], Vasyl Popovych[1*], Igor Shukel[2], Mykhailo Fitak[2], Igor Koliadzhyn[3]

[1] Institute of Civil Protection, Lviv State University of Life Safety, Kleparivska Str. 35, Lviv, 79007, Ukraine
[2] Ukrainian National Forestry University, G. Chyprynky Str., 103, Lviv, 79057, Ukraine
[3] Vasyl Stefanyk Precarpathian National University, Shevchenko Str. 57, Ivano-Frankivsk, 76018, Ukraine
* Corresponding author's e-mail: popovich2007@ukr.net

ABSTRACT
Water ecosystems comprise above two thirds of our planet and play an important role in stabilization of global climate, and also provide a wide range of services to the rapidly increasing society. A number of scientific works are devoted to the study of environmental safety. Water is a basis of life on our planet, and the issue of rivers protection should be of top priority. Unfortunately, a considerable number of surface water reservoirs undergo anthropological influence. The analysis of the research allows us to note that surface water reservoirs, lakes, rivers and their floodplain suffer from human-made pollution. At the time of total use of plastics in all spheres of life, its presence in rivers is detected at the micro-level. The aim of our study is the analysis of landscape-forming factors of ecological safety of the river Styr within the city of Lutsk (Ukraine). The volume of discharge of untreated return water into the river Styr within the city of Lutsk during the last years tends to decrease: in 2018 – 427 000 m^3; 2019 – 424.9 000 m^3; 2020 – 423 000 m^3. It is established that the quality of water of the river Styr in the range line above the city are affected by the pollution from the river Ikva housing-communal enterprise "Mlynivske" and state communal enterprise "Dubnivske", and also waste waters transferred from Lviv region – communal enterprise "Radekhiv water sewage enterprise" (through the river Ostrivka) and communal enterprise "Brodyvodokanal" (through the river Bovdurka). The quality of water in the range line below the city undergoes the influence of the waste waters from communal enterprise "Lutskvodokanal". In order to assess transformation of ecological conditions within urban floodplain, it is proposed to run biomonitoring on the basis of fluctuating asymmetry (FA) of a leaf of a plant, which is informative in case of description of the peculiarities of formation of vegetation.

Keywords: river, pollution, hazardous substances, aquatic vegetation, environmental safety.

INTRODUCTION

Scientists define five sources of anthropological pollution, which affect sea and fresh-water ecosystems: waste waters, nutrients, terrigenous substances, crude oil, heavy metals and plastics (Häder et al., 2020). Developing countries are characterized by presence of numerous cases of waste water discharge into rivers and other surface water reservoirs. Such situation is obviously unacceptable. There are not rare cases of uncontrolled discharge of return mine waters into the rivers (Popovych et al., 2019a; Popovych et al., 2019b). Industrial regions, including mining areas, are noted for increased level of radionuclides in the rivers (Bosak et al., 2020). Substantial technogenic influence on the quality of surface water reservoirs, including rivers, is caused by accidental oil spills (Karabyn et al., 2019). Accurate knowledge of sources and ways of transportation of different influences in water catchment areas is especially important for any administrative activity. Online high temporary resolution measurements are appropriate for the aim of such kind, especially in small and medium water catchment basins (Meyer et al., 2019).

Let us overview some research on river pollution in different countries. Thus, the concentration of microplastics in the rivers of Japan to a great extent correlates with urbanization and population density, which indicates that the concentration of microplatics in the river depends on human activity in the river basin. In addition, a substantial relation is observed between abundant and mass concentration and biochemical oxygen demand, which is an ecological indicator of river pollution. This result demonstrates that microplastics pollution in the river progresses more in the polluted rivers with the low quality water rather than in the rivers with good quality water, which gives grounds to conclude that sources and processes of microplastics occurrence in rivers is similar to other pollutants (Kataoka et al., 2019). During the research of microplastics content, its characteristics, and temporal variation along the river Gang (India), 140 microparticles of microplastics were identified, while the higher concentrations were observed prior to monsoon (71.6%), than in the samples after the monsoon (61.6%). Most microplastics are present in fibers (91%), the other were fragments (9%). In New Zeeland, the research on gradient of urbanization of amount and form of plastics in minor streams show that all streams include microplastics in the concentrations similar to those found in the huge systems (up to 303 particles m^{-3} in water and 80 particles kg^{-1} in sediments). Fragments and small particles are the most common (63–500 mkm). Chemical types of plastics vary in size, form and color. The difference in the amount of plastics in various streams was considerable. However, the relation of human population density or rainwater runoff, and the amount of plastics was not defined. Residential soil cover is connected with a substantial amount of microplastics, however the relation is low. In the process of measurement of microplastics pollution of minor streams local factors could be more essential than process of water catchment basins (Dikareva et al., 2019).

The results of the research of microplastics pollution of the river Tamsui and its tributaries demonstrate positive correlation between precipitation amount and amount of microplastics particles found in the rivers. Mount of microplastics varies in the rivers and fluctuates around from 2.5 ± 1.8 particles per m^{-3} in the river Sindian up to 83.7 ± 70.8 particles per m^{-3} in the river Dahan. Moreover, special and temporal variations of microplastics amount among the left, middle and right parts of the flow are observed (Wong et al., 2020). The analysis of bottom sediments alongside the river Brisbane (Australia) defined relatively high concentrations of microplastics in the sediments with the content from 0.18 up to 129.20 mg mg^{-1}, or from 10 to 520 units per kg^{-1}. Lower and higher concentartions of microplastics were found respectively in dry and wet seasons. Considerable temporal variations of microplastics concentration was detected in residential and commercial areas of Queensland. Polyethylen (PA), polyamide (PA) and polypropylene (PP) are the main types of polymers in the sediments of the river Brisbane. Besides, other types of polymers, especially polyethylene terephthalate (PET) were found. The size of the most microplastics particles was not less than 3 mm (He et al., 2020).

The study of the surface sediments sampled from the typical trans-Himalayan river Koshi (India) demonstrated that Cr, Co, Ni and Zn are mainly from the parent rock, and Cu, Cd and Pb occurred due to both natural and anthropogenic sources. Heavy metals concentration in the river sediments, despite the contrast conditions of the environment and human activity alongside the flow, demonstrate coherence with the natural background and inconsiderable pollution (Li et al., 2020). The results of the research of heavy metals accumulation, risk, distribution and sources in 62 lakes alongside the river Yangtze (China) were shown and relation between the river and the lake, economic structure, the number of population and metals diffusion were studied. Average concentration of Cr, Cu, Hg, Zn, Cd, Pb and As in the sediments of the lakes was 90.8, 60.1, 0.06, 102, 0.89, 42.7 and 6.01 mg/kg. Most lake sediments (99%) are contaminated with Cd. The lakes in the medium stream and on the southern bank of the river Yangtze were characterized with the higher ecological risk. Cr is generated naturally, while Zn, Cu, Pb, Cd and As occur as a result of human activity. The lakes which are separated from the river Yangtze have higher concentration of Cu, Zn, Pb and As and the lakes connected with the river have higher concentration of Cd and Cr. During the analysis, the characteristics of heavy metals pollution were defined, the reasons of non-spot pollution on the plain by the river Yangtze were described and it was demonstrated that soil erosion is an important factor in case of metal water diffusion (Luo et al., 2021).

The quality of freshwater water resources, especially those located in vicinity of agricultural and urban areas, suffer from pollution caused by anthropogenic activity. Population increase with the combination of water scarcity determine protection of fresh water resources. In order to protect them, it is vital to define initial sources of pollution along the river. Water quality components, including water temperature, pH, total hardness, content of chlorides, phosphates, nitrates, arsenic, cadmium, trivalent chromium, hexavalent chromium, copper, molybdenum, nickel and zinc were evaluated at twenty nine stations alongside the river Kor (Iran) throughout the period of two years. Water quality is affected by local industrial enterprises to such an extent that central and medium parts of the river are marked as severely polluted. The results show that higher concentration of Cd, Cl−, Cr(III), Cu, Mo, PO_4^{3-}, As and Ni on the territories by the factories. Most likely, it is related to the emission of pollutants from industry, including oil and chemical, meat and leather factories (Mokarram et al., 2020). Heavy metals (Cr, Ni, Cu, Zn, Cd, Pb, As and Hg) were found in the soil samples in Heigangkou-Liuyuankou irrigation areas of Kaifeng (China). Among them, Cd is the most concentrated than the other. The main sources of heavy metal pollution of soil are transport, village settlements and water basins, where transport is the most crucial factor (Zhang et al., 2018).

Heavy metals (Cu, Pb, Zn, Fe, Mn, Cd, Cr, Ba and As) content in the tissues of crayfish and sediments of processed and unprocessed water basins of the middle stream of the river Yangtze (China) in order to evaluate the health risks for crayfish population. Average concentrations of heavy metals were in the crayfish positively correlated with the concentration of sediments in unprocessed lakes. However, the correlation between the sediment concentration and heavy metals concentration in the crayfish was not observed in the processed lakes. The sources identification showed heavy metals in sediments are caused by transport and agriculture. The crayfish consumption does not pose a considerable risk for human health (Xiong et al., 2020).

Heavy metals (HM) distribution in the sediments of the river Songan (the city of Shenzhen, China) demonstrated a wide range of variations within urban functional zones. Industrial and residential areas had higher HM content in the order Cu > Zn > Ni > Cr > Pb. In addition, vertical characteristics (5–300 cm) of HM content showed the tendency of reduction in depth, with clear layer of around 120–180 cm. There is a huge correlation between urban functional zones, HM content and amount of microorganisms in urban river sediments (Wang et al., 2021).

HM concentration in soils, rise and wheat corn was higher alongside the border by the territory near the point of confluence of the polluted waste water and the river to the border, and the local spoils in the river Sutlej in Indian Panjabi. The possibility of cancer development in a human being due to the metals consumption from water is in the order: Cd > Ni > Cr > As, and the risk is higher in the areas along the border. These results are useful to formulate a plan of action to improve quality of water in the river basin of Sutlej, including water-soil-plants continuum (Setia et al., 2020). HM phytoavailability in wheat and rise grown at the floodplain of the river Sutlej (India) and their influence on human health were estimated. It was defined that Pb, Cd and Co concentration in wheat, as well as Cr, Co, Pb and Cd in the rice corn exceed safe limits. Bioaccumulation coefficient for extracted metals, pollution load index for such metals and health risks are higher along trans-border stream of the river (Setia et al., 2021).

HM water pollution is a major problem for humanity. The main pollutant is a As. Moreover, Cr, Ni, As and Cd have high values, which are considered as a high risk of cancer development through nutrition rather than skin. To reduce risks for people, it is important to include such methods of re-cultivation as introduction of phytoremediational water plants and adsorbents into the land management plans (Kumar et al., 2019; Ma et al., 2019). Remediation potential of *Phragmites australis* and *Brachia mutica* during inoculation by five different rhyzosphere and endophyte bacteria in the wetlands of the river Ravi, which obtains wastes of untreated domestic and industrial waste waters in the city of Lahore (Pakistan) was studied. It was found that the productivity of *P. australis* is better than *B. mutica.* Vegetation and bacterial synergism for *P. australis* reduced COD, BOD5, and TOC respectively to 85,9%, 83,3% and 86,6% during 96 hours. Total content of nitrogen was reduced from 37.5 to 2.07 mg/l, nitrates – from 33.3 to 1.23 mg/l, phosphorus – from 2.63 to 0.53 mg/l. The traces of the metals were reduced to 79.5% for iron, 91.4% for nickel, 91.8% for manganese, 36.14% for lead and 85.19% for chromium. Floating wetlands with bacteria support could be a relevant choice for reclamation of severely polluted water in river (Shalid et al., 2019).

The analysis of the research allows us to note that surface water reservoirs, lakes, rivers and their floodplain suffer from human-made pollution. At the time of total use of plastics in all spheres of life, its presence in rivers is detected at the micro-level. Similar situation comes with heavy metals which occur in water basins usually due to human cause. Thus, the research of ecological safety of rivers, especially those running through cities, is a crucial aspect of urban ecological system complex pollution study.

MATERIALS AND METHODS, GEOGRAPHICAL CHARACTERISTICS

The aim of our study is the analysis of landscape-forming factors of ecological safety of the river Styr within the city of Lutsk (Ukraine). Waste waters of the cities of Lutsk, Rozhyshche, Varash, Zarichne and other are drained into the river Styr (Fig. 1). The river Styr originates from a numerous sources which come to the surface at severely swampy streambed located near the village of Vydry in Brody district in Lviv oblast, at 257 m above the sea level. The length of the river is 494 km (Regional report…, 2021). Styr plays an important role in the water mode of Rivne nuclear electrical station (Khrinnytske reservoir), receives waste waters from three sugar factories. Ecological niche of water environment is provided by well-developed meadow and swamp floodplains and phytomass of water vegetation (Hanushchak, 2012).

The main task of the research are to conduct the analysis of scientific and literary sources related to the characteristics of the quality of water in the river Styr; to analyze interactive map "Clean water" in regards to the dynamics of pollution of the river Styr; to study the main factors of influence on the quality of water in the river Styr; to propose measures on preservation of the main values of the quality of water within the maximum permissible concentrations.

RESULTS AND DISCUSSION

As it was noted, the river Styr runs through the regional center of Volyn oblast in Ukraine, the city of Lutsk. The volume of discharge of untreated return water into the river Styr within the city of Lutsk during the last years tends to decrease: in 2018 – 427 000 m^3; 2019 – 424.9 000 m^3; 2020 – 423 000 m^3. The reduction of pollutants discharge into the river Styr within the city of Lutsk is observed: in 2018 – 264.1 tons; 2019 – 263.4 tons, 2020 – 263.9 tons (Fig. 2).

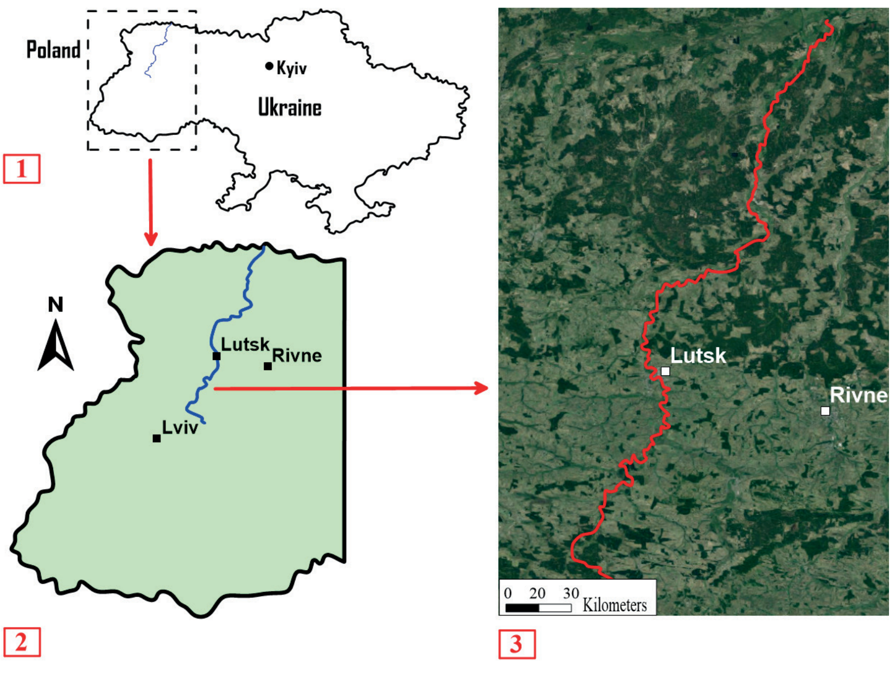

Figure 1. The scheme of the flow of the river Styr through the territory of Ukraine: 1 – geographical position on the map of Ukraine; 2 – marking of regional centers in the vicinity of the river; 3 – map of the river from Google maps

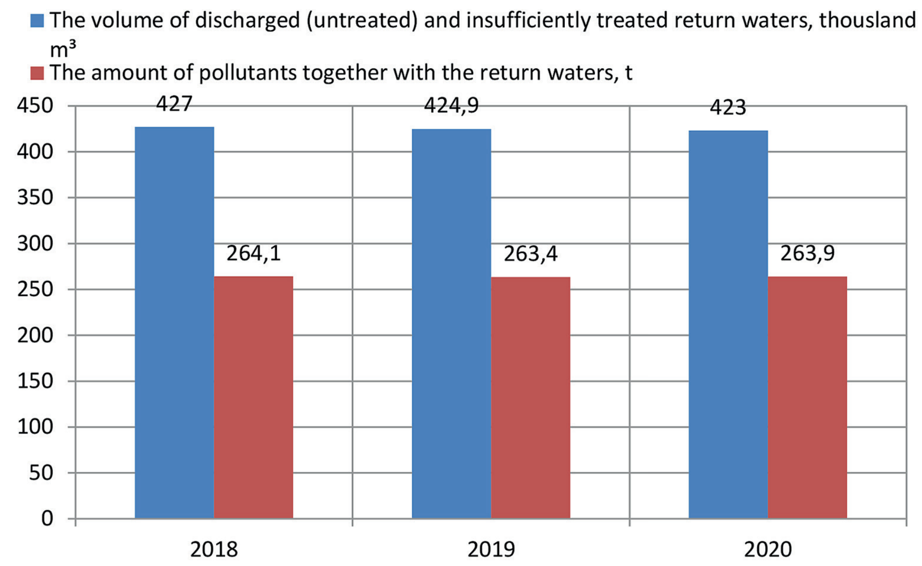

Figure 2. The discharge of return waters and pollutants by the main water users, contaminators of the surface water objects in the river Styr, 2020 (according to Regional report…, 2021)

However, such figures stay at the high level and are the factors of the river pollution by hazardous substances and compounds, which as a result reduce the quality of water and its ecological safety. Average mineralization of water in the river makes up: spring flood – 373 mg/dm^3; summer-autumn baseflow – 414 mg/dm^3; winter baseflow – 542 mg/dm^3. The water is colorless, tranquil, suitable for domestic and household supply, sometimes is characterized by sour taste; in the vicinity of the city of Lutsk it is polluted with waste waters from industrial factories (Hanushchak, 2012). Average annual concentrations of pollutants (mg/dm^3) in the river of Styr within the city of Lutsk are demonstrated on the Figure 3. The quality of water of the river Styr in the range line above the city are affected by the pollution from the river Ikva housing-communal enterprise "Mlynivske" and state communal enterprise "Dubnivske", and also waste waters transferred from Lviv region – communal enterprise "Radekhiv water sewage enterprise" (through the river Ostrivka) and communal enterprise "Brodyvodokanal" (through the river Bovdurka). The quality of water in the range line below the city undergoes the influence of the waste waters from communal enterprise "Lutskvodokanal". Oxygen mode of the river is satisfactory and comparing to the previous year no crucial changes took place. In this observation point in 2017, 4 cases of severe water pollution

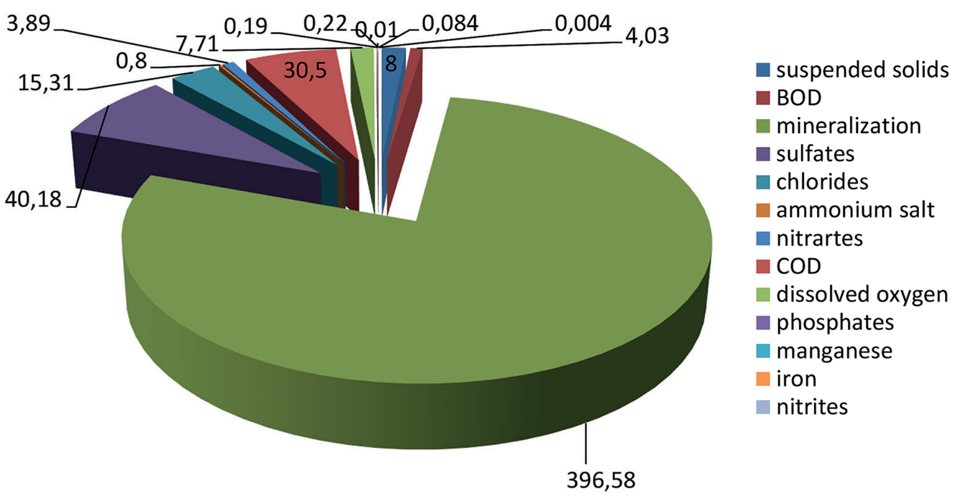

Figure 3. Average annual concentrations of pollutants (mg/dm^3) in the river Styr within the city of Lutsk in 2020 (according to Ecological passport, 2020)

were noted: in the range line above the city by ammoniac nitrogen (14.3 MPC) in October and manganese ions (12.6 MPC) in April; in the range line below the city by ammoniac nitrogen (13.8 MPC) in February and manganese ions (15 MPC) in April (Didok et al., 2014).

The dynamics of pollutants accumulation in the water of the river Styr was detected by us and it was defined that the major discharge of return waters in the city of Lutsk is produced by communal enterprise "Lutskvodokanal" (0.428 mln m^3) (Clean water, 2021). Waste water treatment plants of communal enterprise "Lutskvodokana" are located at the north west from the boarder of the city near the village of Lypnyany and comprises the square of 40.1 ha. Sewage system in the city of Lutsk functions according to partial distribution scheme. Disposal and treatment of domestic and industrial waste waters is performed through city centralized sewage system. Productive capacity of sewage system is defined as 160.0 thousand m^3/day. Treatment (mechanical and biological with additional cleaning in biological water basins (8.64 ha) with further discharge of the treated waste waters in the river Styr.

The access of pollutants MPC in the water of the river Styr is observed in dynamics for nitrites, phosphates, ammonium. Biological and chemical oxygen demand is also detected in the water (Fig. 4). A major factor of damaging ecological safety of the river Styr and the quality of its water is flood. Congestion (accumulation of ice in the riverbed which prevents river flow, which results in water rise and its spill) on the river Styr in vicinity of the post Kolky has not been observed since 1985. Ice jams (accumulation of loose ice in the riverbed) were formed as a result of ice creation or ice destruction, affected the level mode insignificantly. Maximum duration of ice drift during the period of observation lasted not more than 2 days in 1991, 1992, 1994, 1996. Maximum height of ice drift was 315 in 1999. Maximum ice thickness reached 45 cm in March 1996. Total characteristics of congestions and ice jams on the river Styr during 1985–2022 is described in the Table 1.

Considering the above-mentioned facts, we can state that due to the climate warming during the last years, long-term spring ice drift on the river Styr near the urban-type settlement Kolky to the north of the city of Lutsk is practically not observed. Emergency situations related to ice drifts as of 1985 has not occurred on the river. Special environment for plants is created in cities, when vegetation is considered from the point of view of city for human being in ecological and esthetic regard. With the population growth in cities and strengthening of anthropogenic load, extension or global transformation of natural types of vegetation, included into the composition of the territory of the city or its suburbs, and occurrence of new, earlier non-existing types of habitats with new vegetative groups take place. The study of flora and vegetation in the cities has been an object of study for a long-term period, since it is a basis of sustainable use of vegetative resources and organization of protection of rare and endangered species of plants.

Lutsk is one of the regional centers of Ukraine with a high anthropogenic load. Strengthening of ecological problems in the city is observed also due to increased transport load. The quality of water in the rivers is deteriorating; toxic pollutants accumulate in soils and occur in ground waters etc. Floodplains in Lutsk are characterized by substantial transformations of natural landscapes. The growth of vegetation groups in the floodplains of the city of Lutsk is determined by the influence of urbo-ecological systems (urban, suburban and country floodplains), by the size of river which form a floodplain (major and minor rivers) and orographic conditions of floodplain (riverine, central and upper floodplain).

Assessment of the environmental state should be performed by all available methods, including biomonitoring. Besides, phytoindication is a perspective method, since plants are less movable, have a considerable assimilating surface and are susceptible to a complex of unfavorable environmental condition. One of biomonitoring methods is assessment of population developmental stability according to fluctuating asymmetry (FA), which is an incidental minor deviation from symmetric state of bilateral morphological structures. Especially, the state of natural populations of bilateral symmetrical organisms could be assessed through the analysis of FA parameter, which characterizes minor undirected violation of developmental stability and are an integral response of the organism to the environmental state (Didok et al., 2014). As objects of the research of FA parameters, we used leaves of the most typical plants in the floodplains in Lutsk, *Urtica dioica* L. and *Plantago major* L. The research is performed in the floodplains of the major river Styr and minor rivers (Sapalayivka, Chornohuzka, Omelyanyk,

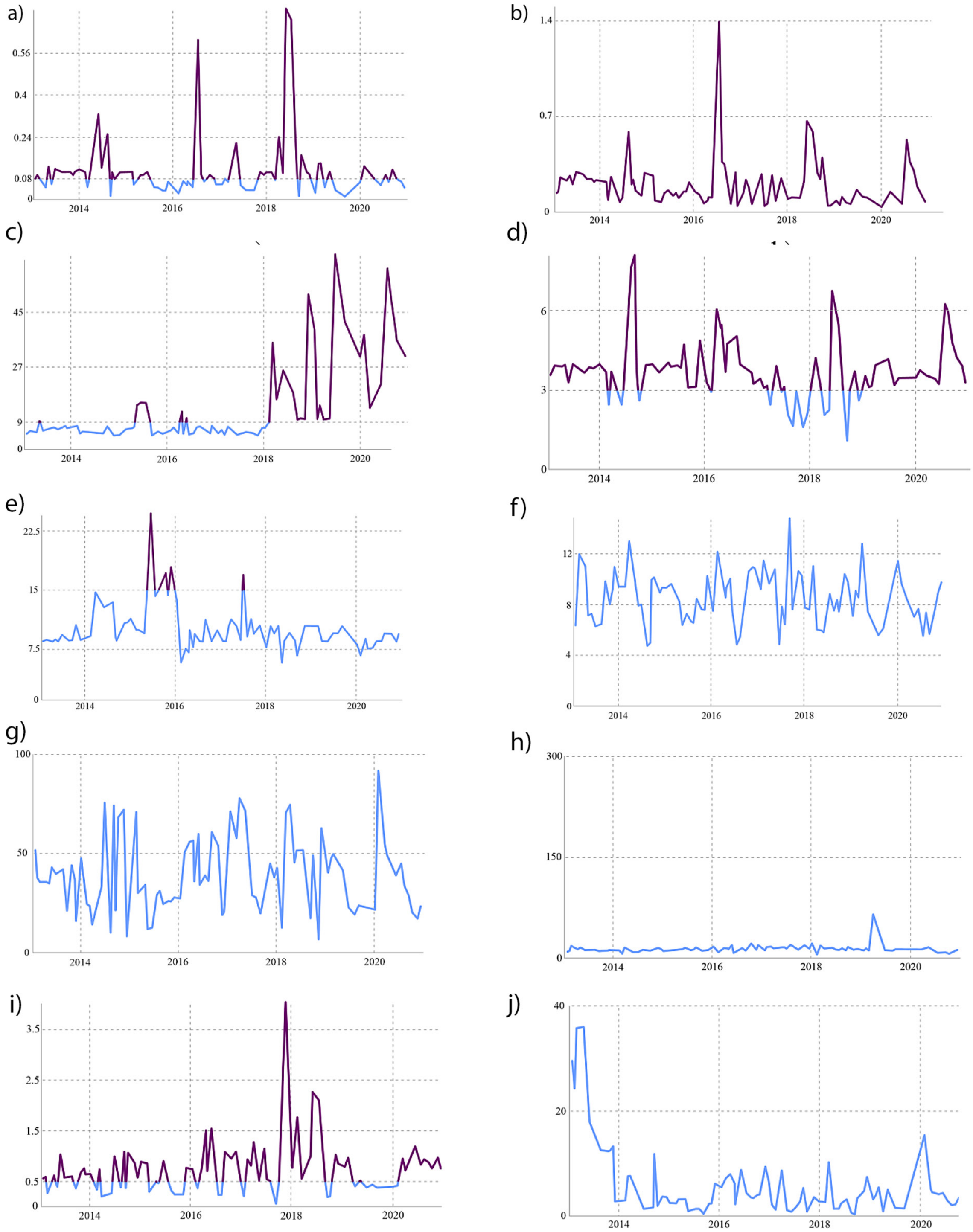

Figure 4. The dynamics of water pollution in the river Styr within the city of Lutsk during the 5 years of observation (Clean water, 2021), (a) nitrite-ions, mg/dm^3, (b) phosphate-ions, mg/dm^3, (c) chemical oxygen demand, mg O_2/dm^3, (d) biological oxygen demand, mg O_2/dm^3, (e) suspended solids, mg/dm^3, (f) dissolved oxygen, mg/dm^3, (g) sulphate-ions, mg/dm^3, (h) chloride-ions, mg/dm^3, (i) ammonium-ions, mg/dm^3, (j) nitrate-ions, mg/dm^3

Zhyduvka, Zmiyinets) in Lutsk in 25 phytocenoses of meadow and swamp floodplains of riverine, central and upper floodplains. It was found that five morphometric parameters of a leaf blade of the studies species are characterized by a substantial level of divergence between the right and left parts (Table 2). It was established that the studies species are susceptible to bioindentificators of natural and urbogenic and transformed floodplains, and ecological conditions

Table 1. Characteristics of congestions and ice jams on the river Styr at the water point in urban-type settlement Kolky in the Volyn region

Year	Characteristics of congestion and ice jam during the ice melting	Level rise from congestion and ice jams, cm per period	Duration of spring- ice drift, days during the period	Level, cm		Maximum ice thickness, cm date	Duration of the period with ice phenomena
				Ice drift max/min	Ice jams max/min		
1985	Without negative effect	38 22-23.11.1984	1 27.03	276 –	269 78	32 10.02	11.11.1984- 27.03.1985
1986	Without negative effect	78 24-26.11.1985	1 23.03	268 –	274 132	30 28.02	20.11.1985- 23.03.1986
1987	–	–	1 30.03	256 –	238 56	28 15.01	09.12.1986- 30.03.1987
1988	–	–	1 06.03	185 –	208 124	22 05.03	09.12.1987- 06.03.1988
1989	–	–	–	–	–	–	11.11.1988- 13.01.1989
1990	–	–	–	–	204 157	8 10.01	26.11.1989- 18.01.1990
1991	–	–	2 10, 11.03	161 145	201 79	26 20.02	22.12.1990- 11.03.1991
1992	–	–	2 16, 17.02	200 198	177 67	12 05.02	08.12.1991- 25.02.1992
1993	–	–	–	–	244 183	–	23.12.1992- 16.03.1993
1994	Without negative effect	48 16-21.02	2 03, 04.03	237 230	260 175	–	13.11.1993- 04.03.1994
1995	–	–	1 08.02	187 –	205 138	–	21.12.1994- 08.02.1995
1996	–	–	2 03, 04.04	231 225	208 70	45 15.03	04.12.1995- 04.04.1996
1997	Without negative effect	21-23.12.1996*	1 26.02	191 –	183 84	26 31.01	17.12.1996- 26.02.1997
1998	–	–	–	–	286 220	–	15.12.1997- 14.02.1998
1999	–	–	–	–	315 254	–	16.11.1998- 06.03.1999
2000	–	–	–	–	280 224	–	22.12.1999- 24.02.2000
2001	–	–	–	–	–	–	23.12.2000- 06.03.2001
2002	–	–	–	–	295 261	–	04.12.2001- 02.02.2002
2003	–	–	–	–	272 118	33 15.02	06.12.2002- 17.03.2003
2004	–	–	–	–	197 101	12 31.01	24.12.2003- 11.03.2004
2005	–	–	–	–	290 158	21 15.02	23.12.2004- 25.03.2005
2006	–	–	–	–	237 161	36 15.02	21.12.2005- 28.03.2006

2007	–	–	–	–	–	–	28.01- 02.03.2007
2008	–	–	–	–	–	–	24.12.2007- 25.01.2008
2009	–	–	–	–	–	–	29.12.2008- 31.01.2009
2010	–	–	–	–	283 194	28 15.02	16.12.2009- 17.03.2010
2011	–	–	–	–	307 299	15 10.03	02.12.2010 16.03.2011
2012	–	–	–	–	268 142	21 15.02	18.01- 13.03.2012
2013	–	–	–	–	299 213	18 31.01	09.12.2012- 31.03.2013
2014	–	–	–	–	255 191	23 05.02	20.01- 22.02.2014
2015	–	–	–	–	172 101	–	01.12.2014- 17.01.2015
2016	–	–	–	–	178 65	15 20-25.01	02.01- 03.02.2016
2017	–	–	–	–	228 117	20 05-10.02	04.12.2016- 28.02.2017
2018	Without negative effect	27.02-02.03*	–	–	267 192	–	16.01- 12.03.2018
2019	–	–	1 09.02	155 –	214 144	–	30.11.2018- 12.02.2019
2020	–	–	–	–	–	–	–
2021	–	–	–	–	256 110	–	16.01- 04.03.2021
2022	–	–	–	–	219 123	–	22.12.2021- 03.02.2022

of vegetation growth in the floodplains of Lutsk differ drastically in regards to location in the conditions of urban, suburban and country floodplains, both on major and minor rivers. Assessment of FA of *Urtica dioica* L. leaves in riverine floodplains varies from 1 point (quality of the environment is notional - normal) in the conditions of country floodplain – up to 5 points in the conditions of urban floodplain (the quality of environment is assessed as critical). The developmental stability of *Plantago major* L. leaves in regards to FA parameter in the condition of urban floodplain is assessed at 3 points (the quality of the environment – as a medium level of the norm deviation). However, the influence of urbogenic environment is identified on the boarder of the city, where the quality of growing conditions is identified from nominal-normal, (1 point in *Urtica dioica* L. leaves in riverine and upper floodplains on the major river, and in *Plantago major* L. on the minor river), with minor deviations from the norm (2 point in *Urtica dioica* L. leaves in the central floodplain on the major river, and in *Plantago major* L. in riverine floodplain on the major river, and in *Urtica dioica* L. leaves in the floodplain on a minor river), with a medium level of the norm deviation (3 point in *Plantago major* L. in the central floodplain of the major river) and critical condition (5 point in *Plantago major* L. in the upper floodplain of the major river).

The results of the conducted research allow referring species *Urtica dioica* L. and *Plantago major* L. as susceptible bio-indicator of natural and urbogenic transformed territories as they are characterized by unequal level of sensitivity in

Table 2. Index of developmental stability of leaves

Parts of floodplain	Country floodplain		Suburban floodplain		Urban floodplain	
	FA value	FA assessment, point	FA value	FA assessment, point	FA value	FA assessment, point
Major river						
Urtica dioica L.						
Riverine	0.055	1	0.046	1	0.088	5
Central	0.056	2	0.069	2	0.105	5
Upper	0.054	1	0.044	1	0.094	5
Plantago major L.						
Riverine	0.059	2	0.057	2	0.077	5
Central	0.042	1	0.064	3	0.075	5
Upper	0.041	1	0.083	5	0.071	5
Minor river						
Urtica dioica L.						
Riverine	0.027	1	0.064	2	0.102	5
Central and upper	0.022	1	0.059	2	0.145	5
Plantago major L.						
Riverine	0.027	1	0.260	1	0.062	3
Central	0.031	1	0.226	1	0.080	5

relation to urban environment. Ecological conditions of plant growth in floodplains in Lutsk are determined by the size of complex urbogenic gradient of the environment and differ considerably in comparison to the control and defined by the critical condition. According to the results of the research of ecological and cenotic structure of floodplain vegetative groups within the city of Lutsk, the main groups of ecotypes formed in the conditions of urban, suburban and country floodplains are distinguished and divided based on river size and orographic conditions of floodplain. Table 3 showed the results of calculation of gradation of ecological factors according to D. M. Tsyhanov's cenoflora of the floodplains in Lutsk (Buzuk et al., 2009).

Table 3. Ecological parameters of the environment of the floodplain in Lutsk

Type of cenoflora	Ecological parameters of the environment									
	TM	KN	OM	CR	HD	TR	NT	RC	LC	FH
Urban cenoflora	Regression									
	TM	KN	OM	CR	HD	TR	NT	RC	LC	FH
	9.6	11.3	7.7	10.0	12.7	6.3	11.0	9.4	0.9	5.9
	Average (max + min)/2 according to the factors of the environment									
	8.9	9.1	7.6	8.0	12.7	8.0	7.1	7.4	3.2	6.5
Suburban cenoflora	Regression									
	TM	KN	OM	CR	HD	TR	NT	RC	LC	FH
	9.8	9.9	8.0	10.0	14.1	6.1	10.2	9.3	0.7	6.1
	Average (max + min)/2 according to the factors of the environment									
	8.8	8.9	7.7	8.1	13.2	8.2	6.9	7.5	3.4	6.4
Country cenoflora	Regression									
	TM	KN	OM	CR	HD	TR	NT	RC	LC	FH
	8.7	9.5	8.1	9.4	15.8	5.0	8.4	9.1	0.9	6.9
	Average (max + min)/2 according to the factors of the environment									
	8.6	8.7	7.7	8.2	13.6	7.8	6.2	7.6	3.1	6.1

It was established that the vegetation groups in urban floodplains are characterized with the following ecological conditions:

- thermo-climate mode of the studied ecotopes is estimated as boreal- nemoral – eunemoral and it makes up from 8.7 to 9.6 points (the analysis is conducted according to parameters at their regression). The range of index change within the floodplains remains within the range of parameters, however the influence of "urban island of warm" is observed in urban floodplains;
- continentality of the climate changes from subcontinental type (11.3 points) within urban floodplain to continental in suburban and country floodplains (9.9. and 9.5 points). This fact support the thesis on "warmer" conditions within the city;
- an indicator of aridity / humidity of climate is defined as subarid/ subhumid with the relation of amount of annual precipitation to annual evaporation P-E = 0–400 mm/year. Its value shows that the floodplains in Lutsk are located on the border of forest-steppe and forest zone;
- crio-climate indicator in the city and suburbs defined the territory as of less warm winters, and in the country – as a territory of mild winters;
- soil moisture in urban ecotypes of the floodplains of dry-forest-meadow/ wet-forest-meadow type and it is defined as the driest type. Maximum moisture is typical for country a floodplain as a less dry type (wet-forest-meadow). Its conditions of soil moisture are defined as wet-forest-meadow/ wet-forest-meadow;
- trophic level of soil in urban and suburbal floodplains could be regarded as conditions of poor/rich soils. Minimum content of mineral salts, 5.0 points (conditions of poor soils), is typical for country conditions;
- soil nitrogen supply is a minimum value of nitrogen is noticed in country conditions (soils sufficiently supplied with nitrogen/ nitrogen rich soils). Soils, the most rich in nitrogen (soils excessively rich in nitrogen), are typical for urban floodplains which is determined by the influence of landscape gardening;
- soil acidity is characterized by neutral soil conditions;
- illumination-shading was assessed for the floodplains as of open spaces;
- variability of soil moisture for urban floodplain is estimated as weakly periodically moisturized, and for suburban and county – moisture increases to weakly variable moisture / mildly variable moisture.

In addition, it was established that the parameters of ecological conditions at the floodplains of the major river does not substantially differ from general characteristics of vegetation in the floodplains in Lutsk. The differences which do not exceed 1 point are observed in country cenoflora almost at all parameters.

Besides, cenoflora of the floodplains of the minor rivers differs at all parameters both from cenoflora of major rivers and whole cenoflora of the floodplains in the city of Lutsk. However, the difference in indicators of ecological factors of urban cenoflora of minor and major rivers and total cenoflora of floodplains is essessed within the value of point. It should be noted that variability of soil moisture at minor rivers in urban conditions is estimated as of mildly variable moisture. Thermo-climate mode in suburban cenoflora of major rivers is referred as sub-Mediterranean (50–60 kkal./cm^2/year) / Mediterranean (60–70 kkal./cm^2/year). The continentality of climate in floodplains of minor rivers in comparison to the floodplains at major rivers and the total cenoflora increase the richness of soils with nitrogen – excessively nitrogen-rich soils.

According to orographic conditions, the groups of ecotypes of riverine, central and upper floodplains with their types of vegetation cover were distinguished within the river floodplains in Lutsk. The parameters of thermo-climaticity, continentality, aridity / humidity, crioclimaticity of the river floodplains have a small range of diversity and are characterized by typical for transitional type between forest and forest –meadow conditions of "urban island of warm". Nitrogen supply and soil enrichment indicates high degree of smoothability and their range is close to optimal for mesophyte vegetation. Humidity, soil acidity and variability of soil moisture demonstrate wide diversity of edatopes types. They are related to the soils structure and content which influence the diversity of types of vegetation which affects floristic composition.

The differences of cenoflora in the floodplains in Lutsk are determined by urbogenic, hydrographic and orographic influence. Flora composition of the floodplains in Lutsk comprises 301 species of vascular plants, 6 classes, 45 orders, 65 genera and 180 families. The studied flora represents exceptionally a part of the flora of

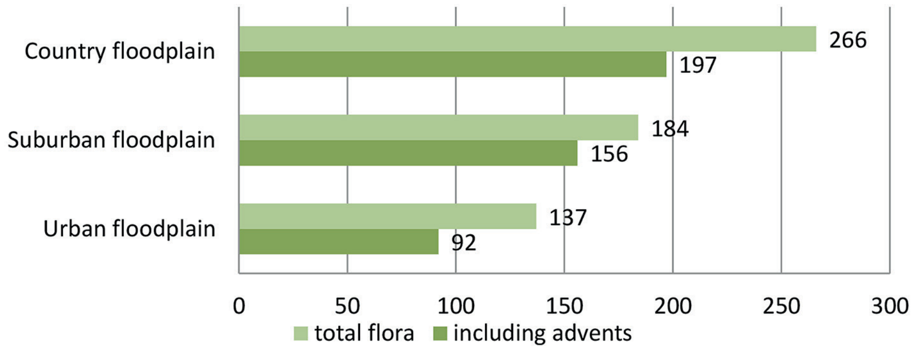

Figure 5. Number of higher plants at the floodplains in Lutsk

Volhynian-Podilian upland (1893 species) (Fig. 5). Specific features of flora in urban floodplains in comparison to country floodplains are:

- domination of mesophyte and hydrophyte hydromorphes. The increase of humidity of urban floodplains is reflected in the number of hyhrophytes;
- the presence of plantations of *Picea abies* (L.) Karst. and *Pinus sylvestris* L. in the park named after Lesia Ukrainka in the urban floodplains and absence of species of *Charophyta* class at urban floodplains;
- major cenoflora families of *Asteraceae, Rosaceae, Apiaceae, Fabaceae, Lamiaceae*, *Polygonaceae* in the floodplains make up 51.79%;
- among angiosperms, a part of dicotyledons considerably exceedes monocotyledons. The ratio of monocotyledons and dicotyledons in the summary flora makes 1:3.39, in urban flora – 1:3.72, suburban 1:3.55 and country 1:1.11. It is determined by the prevailing role of the species of *Poaceae* family in formation of grasslands of suburban floodplains;
- a great part of species *Ateraceae, Rosaceae, Apiaceae, Fabaceae, Lamiaceae* – 104 species, 46.43% of flora;
- a considerable number of monotypical families in cenoflora of the floodplains – 27 families, including angiosperms – 15 families;
- dominant families in the grasslands of urban floodplain in Lutsk are the following: *Asteraceae* (12,12% defined species), *Apiaceae* (5,68%), *Fabaceae* (5,30%), *Lamiaceae* (5,30%) i *Rosaceae* – 14 species (5,30%). Dominant families in the grasslands of suburban floodplain in Lutsk are *Asteraceae* - 17 species (12,41%), *Rosaceae* (8,76%), *Lamiaceae* (5,84 %), *Polygonaceae* (4,38%) та *Apiaceae* – 5 species. Dominant families in the grasslands of country floodplains: *Asteraceae* 19 species (14,18%), *Apiaceae* (6,72%), *Lamiaceae* (6,72%), *Fabaceae* (4,48%) та P*olygonaceae* (4,48%).

CONCLUSIONS

The analysis of ecological and cenotic structure of floodplain vegetation groups within the city of Lutsk allows to distinguish main groups of ecotypes, which are formed in the conditions of urban, suburban and country floodplains. They are defined by the size of river and orographic conditions of floodplain. In order to assess transformation of ecological conditions within urban floodplain, it is proposed to run biomonitoring on the basis of FA of a leaf, which is informative in case of description of the peculiarities of formation of vegetation.

The assessment of the parameters of ecological conditions (thermo-climaticity, continentality of the climate, aridity/humidity of the climate, crioclimaticity) of the floodplains have an insignificant range of divergences and reflect the conditions which are typical for transitional for forest to forest-steppe territories and demonstrate the result of the influence of “urban island warm” on the floodplain. Nitrogen supply and salt enrichment have a high degree of smoothability, and their range is close to optimal for mesophyte vegetation. Soil moisture, soil acidity and variability of soil moisture also show a wide diversity of types of edotopes in the floodplains. These parameters are related to urbogenic influence and depend on the size of river and type of orographic conditions.

Antropogenic influence in Lutsk leads to occurrence of non-typical, prior non-existing types of habitats and formation of vegetation groups with domination of synantropic species of plants, therefore a floodplain within the city is determined by the increase of the diversity of edaphotopes and vegetation.

Acknowledgements

The authors express gratitude to the leading specialist at the Department of Civil Defense of the Head Office of State Emergency Service of Ukraine in the Volyn region, Oleksandr Buhaychuk for his assistance in material selection for the scientific article.

REFERENCES

1. Bosak P., Popovych V., Stepova K., Dudyn R. 2020. Environmental impact and toxicological properties of mine dumps of the Lviv-Volyn coal basin. News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical, 2(440), 48–54. https://doi.org/10.32014/2020.2518-170X.30
2. Buzuk G.N., Sozynov O.V. 2009. Regression analysis in phytoindication (on the example of D. N. Tsyganov's ecological scales). Botany, 37, 356–362. [in Russian]
3. Clean water. [Electronic resource]. Access mode: https://texty.org.ua/water/ [in Ukrainian]
4. Didok O.I., Karpin N.I., Shukel I.V. 2014. Growth and development of species of the genus *Tilia* L. in garden and park complexes of the city of Lviv. Actual problems of the forest complex, 39, 114–118. [in Russian]
5. Dikareva N., Simon K.S. 2019. Microplastic pollution in streams spanning an urbanisation gradient. Environment pollution, 250, 292–299. https://doi.org/10.1016/j.envpol.2019.03.105
6. Ecological passport of the Volyn region. 2020. Lutsk, 133. [Electronic resource]. Access mode: https://voladm.gov.ua/category/ekologichni-pasporti/1/ [in Ukrainian]
7. Environmental passport of the city of Lutsk. [Electronic resource]. Access mode: https://voladm.gov.ua/article/ekologichniy-pasport-mlucka/ [in Ukrainian]
8. Häder D.P., Banaszak A.T., Villafañe V.E., Narcarte M.A., González R.A., Helbling E.W. 2020. Anthropogenic pollution of aquatic ecosystems: Emerging problems with global implications. Science of the Total Environment, 713, 136586. https://doi.org/10.1016/j.scitotenv.2020.136586
9. Hanushchak M.M. 2012. Hydrochemical features of the Styr River runoff formation. Scientific bulletin of Lesya Ukrainka Volyn National University. Physical and constructive geography, 9(234), 3–10. [in Ukrainian]
10. He B., Goonetilleke A., Ayoko G. A., Rintoul L. 2020. Abundance, distribution patterns, and identification of microplastics in Brisbane River sediments, Australia. Science of the Total Environment, 700, 1334467. https://doi.org/10.1016/j.scitotenv.2019.134467
11. Karabyn V., Popovych V., Shainoha I., Lazaruk Y. 2019. Long-term monitoring of oil contamination of profile-differen-tiated soils on the site of influence of oil-and-gas wells in the central part of the Boryslav-Pokuttya oil-and-gas bearing area. Petroleum and Coal, 61(1), 81–89.
12. Kataoka T., Nihei Y., Kudou K., Hinata H. 2019. Assessment of the sources and inflow processes of microplastics in the river environments of Japan. Environment pollution, 244, 958–965. https://doi.org/10.1016/j.envpol.2018.10.111
13. Kumar V., Parihar R.D., Sharma A., Bakshi P., Sidhu G.P.S., Bali A.S., Karaouzas I., Bhardwaj R., Thukral A.K., Gyasi-Agyei Y., Rodrigo-Comino J. 2019. Global evaluation of heavy metal content in surface water bodies: A meta-analysis using heavy metal pollution indices and multivariate statistical analyses. Chemosphere, 236, 124364. https://doi.org/10.1016/j.chemosphere.2019.124364
14. Li M., Zhang Q., Sun X., Karki K., Zeng C., Pandey A., Rawat B., Zhang F. 2020. Heavy metals in surface sediments in the trans-Himalayan Koshi River catchment: Distribution, source identification and pollution assessment. Chemosphere, 244, 125410. https://doi.org/10.1016/j.chemosphere.2019.125410
15. Luo M., Yu H., Liu Q., Lan W., Ye Q., Niu Y., Niu Y. 2021. Effect of river-lake connectivity on heavy metal diffusion and source identification of heavy metals in the middle and lower reaches of the Yangtze River. Journal of Hazardous Materials, 416, 125828. https://doi.org/10.1016/j.jhazmat.2021.125818
16. Ma T., Sheng Y., Meng Y., Sun J. 2019. Multistage remediation of heavy metal contaminated river sediments in a mining region based on particle size. Chemosphere, 225, 83-92. https://doi.org/10.1016/j.chemosphere.2019.03.018
17. Meyer A.M., Klein C., Fünfrocken E., Kautenburger R., Beck H.P. 2019. Real-time monitoring of water quality to identify pollution pathways in small and middle scale rivers. Science of the Total Environment, 651, 2323-2333. https://doi.org/10.1016/j.scitotenv.2018.10.069
18. Mokarram M., Saber A., Sheykhi V. 2020. Effects of heavy metal contamination on river water quality due to release of industrial effluents. Journal of Cleaner Production, 277, 123380. https://doi.org/10.1016/j.jclepro.2020.123380
19. Napper I.E., Baroth A., Barrett A.C., Bhola S., Chowdhury G.W., Davies B.F.R., Duncan E. M.,

Kumar S., Nelms S.E., Niloy N.H., Nishat B., Maddalene T., Thompson R.C., Koldewey H. 2021. The abundance and characteristics of microplastics in surface water in the transboundary Ganges River. Environmental Pollution, 274, 116348. https://doi.org/10.1016/j.envpol.2020.116348

20. Popovych V., Stepova K., Voloshchyshyn A., Bosak P. 2019a. Physico-chemical properties of soils in Lviv Volyn coal basin area. E3S Web of Conferences 105, 02002. https://doi.org/10.1051/e3sconf/201910502002
21. Popovych V., Voloshchyshyn A. 2019b. Features of temperature and humidity conditions of extinguishing waste heaps of coal mines in spring. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 4(436), 230-237. https://doi.org/10.32014/2019.2518-170X.118
22. Regional report on the state of the natural environment in the Lviv region in 2020. 2021. Lviv, 323. [Electronic resource]. Access mode: https://mepr.gov.ua/files/docs/EkoMonitoring/2021/regional/.pdf [in Ukrainian]
23. Setia R., Dhaliwal S. S., Kumar V., Singh R., Kukal S.S., Pateriya B. 2020. Impact assessment of metal contamination in surface water of Sutlej River (India) on human health risks. Environmental Pollution, 265, 114907. https://doi.org/10.1016/j.envpol.2020.114907
24. Setia R., Dhaliwal S.S., Singh R., Kumar V., Taneja S., Kukal S.S., Pateriya B. 2021. Phytoavailability and human risk assessment of heavy metals in soils and food crops around Sutlej river, India. Chemosphere, 263, 128321. https://doi.org/10.1016/j.chemosphere.2020.128321
25. Shalid M.J., Arslan M., Siddique M., Ali S., Tahseen R., Afzal M. 2019. Potentialities of floating wetlands for the treatment of polluted water of river Ravi, Pakistan. Ecological Engineering, 133, 167-176. https://doi.org/10.1016/j.ecoleng.2019.04.022
26. Wang F., Dong W., Zhao Z., Wang H., Li W., Chen G., Wang F., Zhao Y., Huang J., Zhou T. 2021. Heavy metal pollution in urban river sediment of different urban functional areas and its influence on microbial community structure. Science of the Total Environment, 778, 146383. https://doi.org/10.1016/j.scitotenv.2021.146383
27. Wong G., Lowemark L., Kunz A. 2020. Microplastic pollution of the Tamsui River and its tributaries in northern Taiwan: Spatial heterogeneity and correlation with precipitation. Environmental Pollution, 260, 113935. https://doi.org/10.1016/j.envpol.2020.113935
28. Xiong B., Xu T., Li R., Johnson D., Ren D., Liu H., Xi Y., Huang Y. 2020. Heavy metal accumulation and health risk assessment of crayfish collected from cultivated and uncultivated ponds in the Middle Reach of Yangtze River. Science of the Total Environment, 739, 139963. https://doi.org/10.1016/j.scitotenv.2020.139963
29. Zhang P., Qin C., Hong X., Kang G., Qin M., Yang D., Pang B., Li Y., He J., Dick R.P. 2018. Risk assessment and source analysis of soil heavy metal pollution from lower reaches of Yellow River irrigation in China. Science of the Total Environment, 633, 1136-1147. https://doi.org/10.1016/j.scitotenv.2018.03.228