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«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

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Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

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COMPREHENSIVE ASSESSMENT OF HEAVY METAL POLLUTION OF A RIVER WITHIN A LARGE CITY

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Abstract. This study examines the features of chemical pollution of water and soil in the riparian zone of the Styr River (Ukraine), considering distance from pollution sources and landscape type. The results show significant variability in chemical pollution levels. The main pollutants in water include elevated concentrations of Cu, Zn, Pb, and Mn, while soils are primarily affected by Cu, Cd, and Ni. The analysis reveals four distinct element groups: I – Cd, Cu in soils and Cu, Mn, Zn in water; II - Zn in soils and Pb, Sr in water; III - Pb, Co, Cr, Ni in soils; IV - Cd, Co, Cr, Ni in water. Three site groups were identified by heavy metal pollution levels: Group I (sites near Boratyn, Rovantsi, and central Lutsk); Group II (sites near Lyplyany and Kniahynynok); Group III (Hnidavske bog and Teremnivski ponds in Lutsk). Multidimensional analysis of geochemical gradients reflects pollution distribution in water and soil compared to control areas. The practical significance of these results lies in their potential to predict ecosystem dynamics, enabling more effective protection and restoration of ecosystem components. Understanding these geochemical conditions helps forecast stability and changes in ecosystem due to environmental pollution.

The practical significance of the results obtained is that forecasting dynamic trends, protection and restoration of ecosystem components are impossible without taking into account their relationships with environmental conditions, in particular, with the level of chemical pollution of the environment. Knowing the geochemical conditions of ecotopes in a certain period of time, it is possible to determine their position in the ecological space on the complex gradients of the environment of the Styr River and its tributaries, to predict the stability and possible changes in vegetation, fauna and microflora due to environmental pollution. The results of the research can be used in regional monitoring systems for geochemical pollution of hydrographic networks of rivers of large cities.

Keywords: river, heavy metals, environmental safety, mathematical modeling, city

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ҮЛКЕН ҚАЛАДАҒЫ ӨЗЕННІҢ АУЫР МЕТАЛМЕН ЛАСТАНУЫН КЕШЕНДІ БАҒАЛАУ

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Аннотация. Мақалада ластану көздеріне дейінгі қашықтықты және ландшафт түрін ескере отырып, Штырь өзенінің (Украина) жағалау аймағындағы су мен топырақтың химиялық ластану сипаттамаларын зерттеу нәтижелері ұсынылған. Нәтижелер химиялық ластану деңгейінің айтарлықтай өзгергіштігін көрсетеді. Негізгі су ластаушыларына Cu, Zn, Pb және Mn жоғары концентрациясы жатады, ал топыраққа негізінен Cu, Cd және Ni әсер етеді. Талдау элементтердің төрт түрлі тобын анықтайды: I – Cd, Cu топырақта және судағы Cu, Mn, Zn; II – Zn топырақта және судағы Pb, Sr; III – Pb, Co, Cr, Ni топырақта; IV – Cd, Co, Cr, Ni суда. Ауыр металдардың ластану деңгейіне байланысты үш топ учаскелер бөлінді: I топ (Боратынь, Рованцы және орталық Луцк маңындағы учаскелер); II топ (Липляны және Княгиньок маңындағы учаскелер); III топ (Луцктегі Гнидавское батпақты және Теремновски тоғандары). Геохимиялық градиенттердің көп айнымалы талдауы су мен топырақтағы ластанудың бақылау учаскелерімен салыстырғанда таралуын көрсетеді. Бұл нәтижелердің практикалық маңыздылығы экожүйенің динамикасын болжау әлеуетінде жатыр, бұл экожүйе компоненттерін тиімдірек қорғауға және қалпына келтіруге мүмкіндік береді. Бұл геохимиялық жағдайларды түсіну экожүйенің тұрақтылығын және қоршаған ортаның ластануынан туындаған өзгерістерді болжауға көмектеседі.

Алынған нәтижелердің практикалық маңыздылығы - динамикалық үрдістерді болжау, экожүйе компоненттерін қорғау және қалпына келтіру олардың қоршаған орта жағдайларымен, атап айтқанда, қоршаған ортаның химиялық ластану деңгейімен байланысын ескермей мүмкін емес. Белгілі бір уақыт кезеңіндегі экотоптардың геохимиялық жағдайларын біле отырып, олардың Штир өзені мен оның салаларының қоршаған ортасының күрделі градиенттері бойынша экологиялық кеңістіктегі орнын анықтауға, қоршаған ортаның ластануына байланысты өсімдіктердің, фаунаның және микрофлораның тұрақтылығы мен мүмкін болатын өзгерістерін болжауға болады. Зерттеу нәтижелерін ірі қалалардың өзендерінің гидрографиялық желілерінің геохимиялық ластануын аймақтық мониторинг жүйелерінде пайдалануға болады.

Түйін сөздер: өзен, ауыр металдар, экологиялық қауіпсіздік, математикалық модельдеу, қала

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КОМПЛЕКСНАЯ ОЦЕНКА ЗАГРЯЗНЕНИЯ РЕКИ ТЯЖЕЛЫМИ МЕТАЛЛАМИ В КРУПНОМ ГОРОДЕ

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Аннотация. Представлены результаты исследований особенностей химического загрязнения воды и почвы в прибрежной зоне реки Стыр (Украина) с учетом расстояния до источников загрязнения и типа ландшафта. Результаты показывают значительную изменчивость уровней химического загрязнения. К основным загрязнителям воды относятся повышенные концентрации Cu, Zn, Pb и Mn, в то время как почвы в основном подвержены воздействию Cu, Cd и Ni. Анализ выявляет четыре различные группы элементов: I – Cd, Cu в почвах и Cu, Mn, Zn в воде; II – Zn в почвах и Pb, Sr в воде; III – Pb, Co, Cr, Ni в почвах; IV – Cd, Co, Cr, Ni в воде. По уровням загрязнения тяжелыми металлами были выделены три группы участков: группа I (участки вблизи Боратына, Рованцы и центрального Луцка); группа II (участки вблизи Липлян и Княгинынока); группа III (Гнидавское болото и Теремнивские пруды в Луцке). Многомерный анализ геохимических градиентов отражает распределение загрязнения в воде и почве по сравнению с контрольными участками. Практическое значение этих результатов заключается в их потенциале для прогнозирования динамики экосистемы, что позволяет более эффективно защищать и восстанавливать компоненты экосистемы. Понимание этих геохимических условий помогает прогнозировать стабильность и изменения в экосистеме, вызванные загрязнением окружающей среды.

Практическое значение полученных результатов состоит в том, что прогнозирование динамических тенденций, охрана и восстановление компонентов экосистемы невозможны без учета их взаимосвязей с экологическими условиями, в том числе и с уровнем химического загрязнения среды. Зная геохимические условия экотопов в определенный период времени, можно определить их положение в экологическом пространстве на комплексных градиентах среды Стир и ее приток, прогнозировать устойчивость и возможные изменения растительности, животного мира и микрофлоры вследствие загрязнения окружающей среды. Результаты исследований можно использовать в системах регионального мониторинга геохимического загрязнения гидрографических сетей рек крупных городов.

Ключевые слова: река, тяжелые металлы, экологическая безопасность, математическое моделирование, город

Introduction. According to the "Water Strategy of Ukraine until 2050", the quality of surface waters, which are a source of drinking water for 80% of the population of Ukraine, is unsatisfactory and is characterized by an increased content of organic and biogenic substances, while groundwater is characterized by increased hardness and mineralization, as well as an above-normal content of iron and manganese compounds. Heavy metals enter the soil mainly with emissions from industrial enterprises and transport, wastewater, industrial and municipal waste, mineral fertilizers, and pesticides (Sternik, 2017). About 90% of heavy metals released into the environment are accumulated in soils. Therefore, soil condition should be considered as an integral indicator of the long-term process of environmental pollution. Meanwhile, soil contamination is a source of secondary pollution of the ground air layer, surface and groundwater. In this regard, the problem of the dependence of the levels of soil pollution in the coastal zone and the water of the Styr River and its tributaries arose. Researchers of the migration of heavy metals emphasize that soils are not only a medium for growing plants and a reservoir for waste disposal, but also a powerful source of many pollutants to surface and groundwater, the atmosphere, and human food. It is known that the pH also directly affects the mobility of chemical elements. Due to this feature, it is possible to predict the most dangerous areas of migration of potential toxicants to water sources within the urban area. Heavy metals are found in water bodies in the form of free (hydrated) ions, complex compounds of various natures, and as part of suspended solids (Chirane et al., 2024).

Water pollution with heavy metals is most often referred to as Cd, Pb, Zn, Cr, Ni, Co, Hg, etc. The main sources of water pollution with heavy metals are electroplating facilities, mining, ferrous and non-ferrous metallurgy enterprises, machine-building plants, etc. (Allia et al., 2024). Heavy metals in a water body cause a range of negative effects: entering the food chain and disrupting the elemental composition of biological tissues, they have a direct or indirect toxic effect on aquatic organisms (Bui et al., 2024). Heavy metals enter the human body through the food chain. Once in the human body, heavy metals cause serious health consequences (Nersesyan et al., 2021; Serhiyenko et al., 2022), as they can provoke the emergence of dangerous diseases and exacerbation of acquired chronic diseases among people of all ages. In some cases, the diseases are accompanied by oncological effects and other serious diseases of the human body (Serhiyenko and Serhiyenko, 2022; Skrobala et al., 2022).

Heavy metals are among the most dangerous chemical pollutants for the environment. Heavy metals are characterized by low migration activity in soils, are well deposited, and accumulate in the surface layer. Soil self-purification is almost non-existent or very slow. Toxic substances accumulate in the soil, which leads to gradual changes in the chemical content of the soil (Popovych et al., 2021). This means that the areas will remain contaminated for decades. A significant proportion of heavy metals that pollute the environment gets into the soil, which serves as a powerful accumulator and is practically not lost over time. Considerable attention is paid to the release of heavy metals into surface and underground water bodies during mining activities, which are developed in Ukraine (Pukish et al., 2024). The technogenic load is also increasing in flood-prone areas, especially in industrial regions (Adamenko et al., 2017).

Currently, there are different approaches to assessing the level of soil and water pollution (Rahman et al., 2024; Fredj et al., 2024), as well as erosion processes (Mohanty and Tare, 2024) and hydromorphological changes. The main criterion for the hygienic assessment of the hazard of pollution by harmful substances is the maximum permissible concentration (MPC) of chemicals (Sternik, 2017). The content of chemicals in soil and water should not exceed the maximum permissible concentration (MPC). The sanitary and hygienic MPC of a chemical (Andrusyshina et al., 2020) in water is the maximum concentration that does not directly or indirectly affect the health of the current and future generations of humans when exposed to the body and does not worsen the sanitary conditions of water use (Serhiyenko and Serhiyenko, 2021).

Materials and methods. These indicators include: concentration coefficient *Kc*, total pollution index *Zc*, soil or water pollution index *PI*. (Andrusyshina et al., 2020; Sternik, 2017).

The concentration coefficient *Kc* is defined as the ratio of the actual content of the chemical *C* (in mg/kg for soil or mg/dm3 for water) to its maximum permissible concentration C_{MPK}:

$$Kc_i = C_i / C_{MPKi} \tag{1}$$

Where: i – is the serial number of the chemical substance.

The total pollution index *Zc* is equal to the sum of the concentration coefficients of chemical elements *Kc*. In a modified form, it is represented by the formula:

$$Zc = \sum_{1}^{n} Kc_i \tag{2}$$

Where: n – is the quantity of chemical pollutants.

The soil or water pollution index *PI* (pollution index) is defined as the arithmetic mean of the concentration coefficient *Kc*:

$$PI = \sum_{1}^{n} Kc_i / n = Zc / n \tag{3}$$

Standardized values of heavy metal concentrations were calculated by the formula:

$$z_i = (x_i - M) / \sigma \tag{4}$$

Where: z_i – is the standardized value of the concentration of a chemical element in soil or water;

x_i is the actual concentration of the chemical element; M is the arithmetic mean;

σ is the standard deviation.

Taking this into account, 8 research sites were selected (Fig. 1).

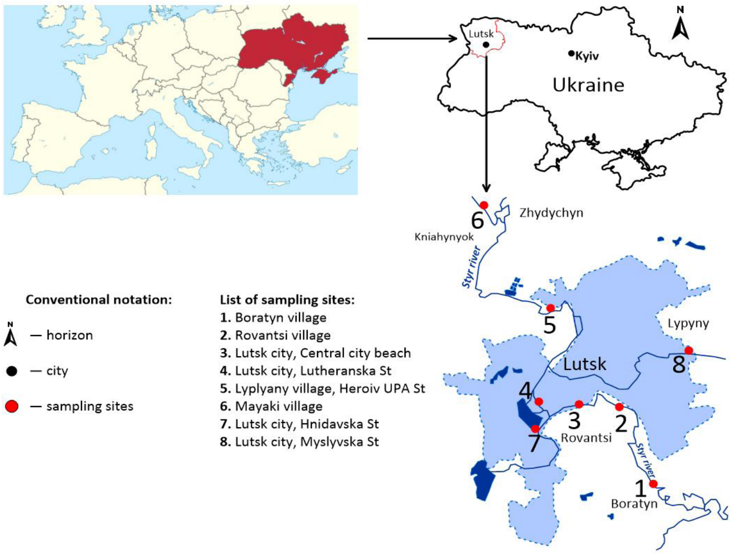


Figure 1 - Schematic representation of the investigated areas of heavy metal content in the water of the Styr River

The hydrological network of Lutsk is directly formed by the Styr River. Its water quality is influenced by tributaries - the Sapalaivka, Omelyanyk, Zhyduvka, and Chornoguzka rivers.

The Chornoguzka river is the largest right-bank tributary of the Styr River, flowing into it at a distance of 320 km from the mouth. Although the Chornoguzka River does not flow through the city, the deterioration of the river's condition is due to the influence of urbanization. The river is most polluted by industrial enterprises, in particular, "Hnidavsky Sugar Plant". The river's headwaters are located near the village of Lyniv, Lokachynsky community. The river carries its waters from west to east. The floodplain is 0.7 km wide. The channel is meandering. Its width is from 2 to 5 m. The slopes of the valley in the upper and lower parts of the river, where it flows onto the low terraces of the Styr river, are steep, in the middle part – steep (Zabokrytska and Khilchevskyi, 2016).

The Sapalaivka river is a right-bank tributary of the Styr, flows into it at a distance of 302 km from the mouth. The source is in the village of Garazdzha. To the city of Lutsk it carries its waters through the Teremnivskyi micro district. On this section are located Teremnivskyi ponds. The length of the river is 12.4 km, within Lutsk - 8.3 km. The catchment area is 39.2 km^2. The width of the floodplain is 1 km. The width of the channel is 2 m. The Sapalivka valley is swampy in places. In Lutsk, the Sapalaivka channel is cleared and canalized. Parks and gardens within the basin are not a significant factor in the formation of the hydrological regime. Due to the discharge of untreated surface runoff from the city territory, the river makes a depressing impression. However, in the past, the Sapalaivka was a fairly full-flowing river. The Omelyanyk River is a right-bank tributary of the Styr River. The Omelyanyk River basin is located within the village. Velyky Omelyanyk and Volodymyrska, Kovelska, Chernyshevsky, Zarichna streets. It flows into the Styr river from the side of Shevchenko street. The length of the main riverbed is 12.5 km, within Lutsk - 3.5 km. The basin area is 40 km^2. The river's tributary flow is regulated by ponds. The river is used for recreation (Zabokrytska and Khilchevskyi, 2016).

The Zhyduvka river is a left-bank tributary of the Styr river. It has a length of 4 km, the basin area is 9.5 km^2. The Zhyduvka river originates west of Lvivska street, flows next to "Bearing Plant", crossing Potebni street, merges into the Styr river (Zabokrytska and Khilchevskyi, 2016).

The sampling process was influenced by physicochemical and climatic factors: overgrowth of the coastal zone, silting of the river, the presence of fast currents in some places, high air temperature (hot summer), swampy banks, bank landslides, lack of exits and access to the coastal zone, high water mineralization, the presence of an unpleasant odor from the water, the concentration of wastewater and water stagnation in floodplains.

Results. After analyzing the content of heavy metals in water at 8 studied sites at different times of the year, it became necessary to study the patterns of accumulation of heavy metals in the water of a river flowing within the boundaries of a large city.

For assessing the level of abnormality of chemical elements, we determined the concentration factor (K_c) (Table 1), which characterizes the excess of the actual content of a chemical substance compared to its maximum permissible concentration.

Table 1 - Heavy metal concentrations in the ecotopes of the Styr River and its tributaries

	Concentration coefficients of chemical elements *Kc* at the research sites[1]							
	1	2	3	4	5	6	7	8
Exceedance of the maximum permissible concentration in soil, times								
Cu	0.19	0.26	0.24	0.25	0.21	0.17	1.21	0.15
Cd	0.30	0.31	0.25	0.23	0.08	0.27	1.03	1.14
Zn	0.10	0.19	0.19	0.23	0.26	0.25	0.22	0.25

Pb	0.26	0.30	0.27	0.30	0.30	0.29	0.14	0.23
Cr	0.25	0.27	0.26	0.26	0.27	0.17	0.11	0.06
Co	0.65	0.70	0.64	0.62	0.56	0.52	0.04	0.03
Mn	0.09	0.16	0.17	0.18	0.14	0.10	0.12	0.14
Ni	2.52	2.51	2.61	2.96	1.70	1.49	1.67	0.85
Total soil pollution index *Zc*	4.35	4.71	4.63	5.02	3.51	3.25	4.54	2.87
Soil pollution index *PI*	0.54	0.59	0.58	0.63	0.44	0.41	0.57	0.36
Exceedance of the maximum permissible concentration in water, times								
Cu*	0.002	0.002	0.002	0.002	0.003	0.003	0.012	0.007
Cd*	3.00	2.00	2.00	2.00	1.60	3.00	2.70	2.50
Zn*	0.006	0.006	0.004	0.007	0.015	0.009	0.019	0.006
Pb*	0.83	0.97	0.90	0.87	1.10	1.07	1.07	1.07
Cr*	0.08	0.10	0.04	0.08	0.02	0.06	0.06	0.04
Co*	0.10	0.10	0.09	0.08	0.12	0.12	0.08	0.08
Mn*	0.36	2.19	0.50	0.46	0.97	0.22	3.19	3.08
Ni*	0.36	0.32	0.31	0.20	0.31	0.31	0.27	0.26
Sr*	0.03	0.03	0.02	0.05	0.03	0.03	0.03	0.04
Total soil pollution index *Zc*	4.77	5.72	3.86	3.74	4.17	4.82	7.43	7.08
Soil pollution index *PI*	0.53	0.64	0.43	0.42	0.46	0.54	0.83	0.79
Conventions. [1]Numerical numbering of plots: 1 - Boratyn village; 2 – Rovantsi village; 3 - central city beach, Lutsk; 4 - Luteranska street area, Lutsk; 5 – Lyplyany village; 6 - Knyahynynok village; 7 - Hnidavske marsh, Lutsk; 8 - Teremnivski ponds, Lutsk. * - data relate to the aquatic environment.								

Soil pollution by heavy metals is mainly controlled by 3 elements of the first toxicity class (lead, cadmium, zinc) and 4 metals of the second toxicity class (nickel, chromium, cobalt, copper). The soils of the coastal zone of the Styr River and its tributaries exceed the MPCs for nickel, copper and cadmium (Popovych et al., 2021). Nickel is a hazard class II element, characterized by high biochemical activity, carcinogenicity and moderate toxicity. In almost all areas, except for Teremnivski ponds (site No. 8), its content exceeds the MPC (Table 1).

Copper (Cu) is a relatively common, vital, and moderately toxic base metal. Copper can migrate through the soil and accumulate at considerable depths. High copper content in soils is observed at Site 7 (Hnidavske bog).

Cadmium is highly mobile in soil and has the ability to accumulate in living organisms. Large amounts of cadmium are found in fuel oil, diesel fuel, paints, varnishes, and industrial wastewater. Even at low doses in the environment, it can accumulate throughout a person's life. Cadmium has a low rate of elimination from living organisms, causes metabolic disorders, and reduces the body's ability to resist diseases. Part of the lead and cadmium from the soil is transferred to plants (fodder crops) through the roots. The cadmium content in the soil exceeds the maximum permissible concentration at sites No. 7 (Hnidavske bog) and No. 8 (Teremnivski ponds).

For most heavy metals (Cu, Zn, Cr, Co, Ni, Sr), the content in the water of the Styr River and its tributaries does not exceed the maximum permissible concentrations (Table 1). The exceptions are lead, cadmium and manganese.

According to the total pollution index Zc (Table 1), which is equal to the sum of the concentration coefficients of chemical elements *Kc*, the ecotopes of the Styr River and its tributaries are characterized by an acceptable level of pollution (*Zc*<16). At all sites, the soil and water pollution index *PI* is less than one. At the same time, the results of the calculations presented in Table 1 make it possible to see the shortcomings of these indicators. For example, for site No. 7 (Hnidavske bog, Lutsk), where the maximum permissible concentration of three chemical elements (Cu, Cd, Ni) was exceeded, and sites No. 1-3 (Boratyn village, Rovantsi village, and central city beach, Lutsk), where only Ni exceeds the MPC, the values of the total pollution index *Zc* are almost the same. Site No. 8 (Teremnivski Ponds, Lutsk) has the lowest total soil pollution (*Zc=2.87* mg/dm^3) and at the same time one of the highest total water pollution values (*Zc=7.08* mg/dm^3). Water and soil pollution indicators do not take into account the hazard class of chemical elements.

For an integrated assessment of heavy metal pollution in the ecotopes of the Styr River and its tributaries, it is first of all necessary to take into account the relationships between the concentrations of chemical elements (Table 2). Despite the fact that the quality of water and soils in the coastal zone is largely formed under the influence of surface runoff from agricultural or urbanized areas, there is a weak relationship between the concentration of the same chemical element in soils and water. Only Cu has a correlation coefficient of r=0.84. The results of the studies also revealed that heavy metals are characterized by certain features of presence in soil and water. (Table 2). There is a high positive correlation between the pairs of chemical elements Pb-Cr, Pb-Co, Cr-Co, Cr-Ni, Co-Ni in soils, Cu-Mn in water.

Table 2 - Relationship between heavy metal concentrations in the ecotopes of the Styr River and its tributaries

Binary system	Correlation coefficient, r	Binary system	Correlation coefficient, r	Binary system	Correlation coefficient, r
Cu-Cu*	0.84	Cu-Zn*	0.76	Pb-Cu*	-0.94
Cd-Cd*	0.39	Cd-Pb	-0.83	Cr-Co	0.94
Zn-Zn*	0.35	Cd-Cr	-0.91	Cr-Ni	0.83
Pb-Pb*	-0.28	Cd-Co	-0.94	Cr-Cu*	-0.80
Cr-Cr*	0.26	Cd-Cu*	0.86	Co-Ni	0.77
Co-Co*	0.48	Cd-Mn*	0.86	Co-Cu*	-0.92
Mn-Mn*	0.05	Zn-Pb*	0.77	Mn-Cd*	-0.80
Ni-Ni*	0.01	Pb-Cr	0.71	Ni-Pb*	-0.85
Cu-Pb	-0.85	Pb-Co	0.82	Cu*-Mn*	0.80
Conventions: * – data refer to the aquatic environment.					

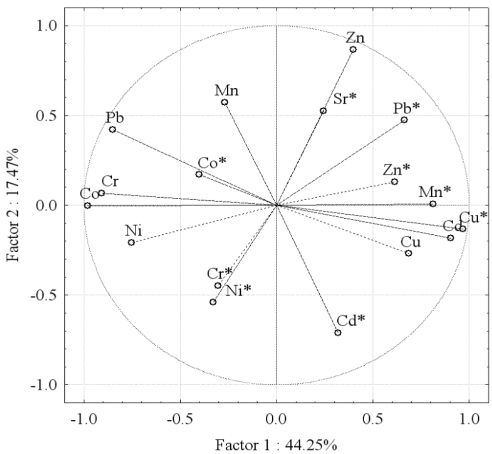
The idea of our further calculations was to perform mathematical modeling of the location structure of the ecotopes of the Styr River and its tributaries in the hyperspace of signs of heavy metal concentration in soils and water. Since it is impossible to visually recognize the structure in a multidimensional space, the main attention was paid to the methods of multidimensional ordination (Skrobala et al., 2020, 2022).

The statistical parameters of heavy metal content in the ecotopes of the Styr River for further calculations of z_i are given in Table 3.

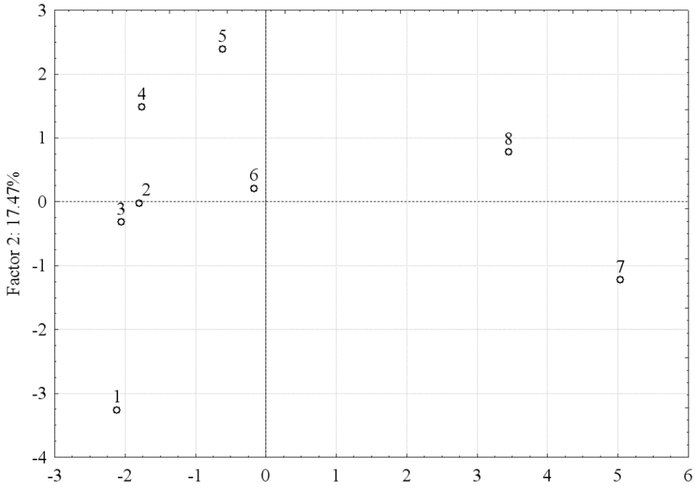
Table 3 - Statistical parameters of heavy metal content in the ecotopes of the Styr River

Chemical element	Arithmetic mean, mg/kg	Standard deviation, mg/kg	Chemical element	Arithmetic mean, mg/kg	Standard deviation, mg/kg
Cu	1.00	1.07	Cu*	0.0041	0.0036
Cd	1.35	1.20	Cd*	0.0024	0.0005
Zn	4.86	1.25	Zn*	0.0090	0.0052
Pb	8.39	1.70	Pb*	0.0295	0.0032
Cr	1.24	0.50	Cr*	0.0030	0.0013
Co	2.35	1.37	Co*	0.0096	0.0017
Mn	206.19	48.61	Mn*	0.1371	0.1253
Ni	8.16	2.86	Ni*	0.0292	0.0048
-	-	-	Sr*	0.2270	0.0615
Conventions: * – data refer to the aquatic environment.					

The main regularity of the formation of the quality of ecotopes of the Styr River and its tributaries (the first principal component of $Factor_1$) is the following structure of relationships between chemical elements (Fig. 2): as the concentration of Cu* (correlation coefficient r=0.97), Mn* (r=0.81), Pb* (r=0.66) and Zn* (r=0.90) in water increases, the concentrations of Cd (r=0.90), Cu (r=0.68) in soil increase, and the concentrations of Co (r=-0.98), Cr (r=-0.91), Pb (r=-0.85) and Ni (r=-0.75) in soil decrease.



a)

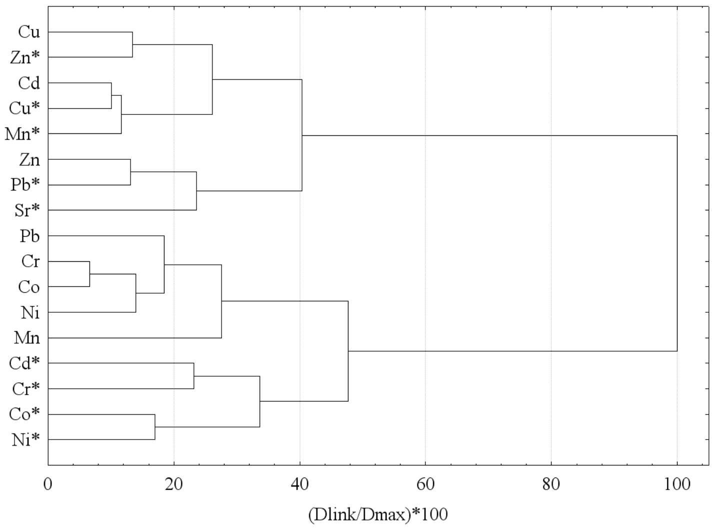


b)

Figure 2 - Results of the Principle Component Analysis of the main components of heavy metal content in water and soils of the coastal zone of the Styr River and its tributaries

Conventions: $Factor_{1\text{-}2}$ - main components, complex environmental gradients; numerical numbering of the plots is given in Table 1; * - data refer to the aquatic environment

Discussion. Thus, low values of the first principal component $Factor_1$ are characterized by sites No. 1 (Boratyn village) and No. 3 (Fig. 3), which are distinguished by low average values of the concentration coefficients *Kc* of heavy metals Cu*, Mn*, Pb* in water, Cu in soil, and relatively high levels of Ni and Co concentration (Table 1). The maximum values of the first principal component are distinguished by sites No. 7 and No. 8, where high values of the *Kc* concentration coefficients for Cd*, Pb* in water, and Cd and Cu in soil were reported.



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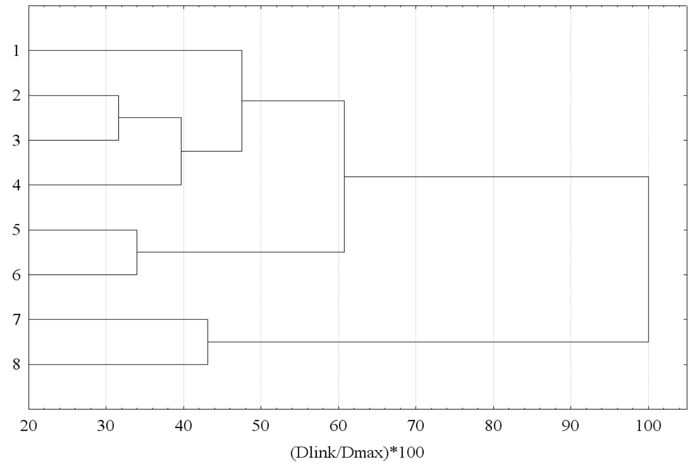

b)

Figure 3 - Dendrogram of similarity of chemical elements (a) and sites (b) based on the distribution of pollutants in the water and soil of the coastal zone of the Styr River and its tributaries. Conventions: the numbering of the sites is given in Table 1; * - data refer to the aquatic environment.

The second axis of maximum variation, Factor2, additionally explains 17.5 % of the total variance of the data. The value of the Factor2 function mainly depends on the content of Zn (r=0.87), Mn (r=0.57) in soil, Cd* (r=-0.71) and Ni* (r=-0.54) in water. The minimum values of the Factor2 function are characterized by site No. 1 (Boratyn village), which is characterized by the lowest concentrations of Zn and Mn in the soil and higher concentrations of Cd* and Ni* in water compared to other sites. The maximum value of the second principal component is observed at site No. 5 (Lyplyany village), which is characterized by the opposite trend in the content of these chemical elements. The third axis of maximum variation of Factor3, which additionally explains 16.4 % of the total variance of the data, mainly depends on the content of Co* (r=0.86), Ni* (r=0.65), Pb* (r=0.52) in water, Mn (r=-0.67) and Ni (r=-0.52) in soil. The maximum values of the Factor3 function are characterized by sites No. 6 (Knyahynynok village) and No. 5 (Lyplyany village), and the minimum values are characterized by site No. 4 (Lutheranska street, Lutsk).

We assessed the similarity of sites and chemical elements by their location in the coordinate system of complex environmental gradients (Fig. 2, a, b) based on cluster analysis. We used the Ward's method, in which the minimum variance is optimized within the clusters, and as a result, clusters of approximately the same size are created. The Euclidean distances were used as a measure of differences. The main result of the hierarchical cluster analysis is a dendrogram (Fig. 3, a, b).

Statistical processing of data on the content of heavy metals in environmental components, in particular in reservoirs, was carried out by a number of scientists. Among such scientific studies, one should note the scientific work (Loska and Wiechuła, 2003), where principal component analysis (PCA) was used to assess the sources of water pollution. PCA allows you to reduce the data and description of a given multivariate system using a small number of new variables. Also, in the work (Sojka et al., 2019), cluster analysis (CA) was used to determine similarities and differences between sampling sites in terms of TM concentration. Note that the scientist Varol, 2013 applied cluster analysis, which grouped ten sampling sites into three clusters. Clusters 1 and 2, as well as cluster 3, corresponded to regions with relatively low and moderate pollution, respectively. According to García-Ordiales et al., 2016, PCA revealed that the silty fraction is the main carrier of metals (oides) in the sediments. Among the potentially harmful elements is a group (Al, Cr, Cu, Fe, Mn, Ni, and Zn) that cannot be strictly related to mining activities, since their concentrations depend on the lithological and edaphological characteristics of the materials.

Based on the correlation of heavy metal content and complex environmental gradients (Fig. 1, a), the following associations (groups) of chemical elements can be distinguished (Fig. 3, a):

I - Cu, Cd in soils, Cu*, Zn*, Mn* in water;

II - Zn in soils, Pb* and Sr* in water;

III - Pb, Cr, Co, Ni in soils;

IV - Cd*, Cr*, Co*, Ni* in water.

The closest in terms of location in the hyperspace of complex environmental gradients are Cr and Co (Euclidean distance 0.34), Cd and Cu* (Euclidean distance 0.52), Cd and Mn* (Euclidean distance 0.53) (Fig. 3, a).

According to the location of the sections of the Styr River and its tributaries on the axes of complex environmental gradients (Fig. 1, b), the following groups can be distinguished (Fig. 3, b):

I - Boratyn, Rovantsi, central city beach (Lutsk), Lutheranska street (Lutsk);

II - Lyplyany, Knyahynynok;

III - Hnidavske bog (Lutsk), Teremnivski ponds (Lutsk).

The results of gradient analysis and clustering of settlements on the axes of complex environmental gradients are consistent with the results of our previous studies based only on water pollution indicators (Popovych et al., 2025).

The most distant in the hyperspace of complex environmental gradients by the content of heavy metals (Fig. 3, b) are sites No. 4 and No. 7 (Euclidean distance 7.91), sites No. 1 and No. 7 (Euclidean distance 7.86), and sites No. 3 and No. 7 (Euclidean distance 7.72). Site No. 7 is the most distant from the center of coordinates, while site No. 6 is the least distant (Fig. 3, b). According to the set of chemical parameters of the environment, site 7 is the most unique. It has the highest content of Cu and Cd in the soil, Pb* and Mn* in the water.

The results of studies of the content of heavy metals in the hydrographic network of the river within the boundaries of the large city showed that their highest concentration is observed in reservoirs with stagnant water. This situation is associated with low water productivity in the reservoir, silting of the banks, overgrowth of coastal aquatic vegetation, falling leaves into the water, and a low level of natural self-purification.

Conclusions. The growing anthropogenic load significantly affects the surface waters of the Volyn region. There have been changes in the salt composition and quality of river waters of the region. Acidification of surface waters has increased, as a result, atmospheric air pollution from localized sources, urbanized areas (poorly treated and stormwater, the specific weight of which is approximately 60% of the total mass of pollution), a third of pollution comes from agricultural landscapes (biocides, biogenic compounds, organic matter). The most dangerous sporadic cases of accidental pollution of the river network are observed in the autumn-winter period by wastewater from sugar factories. As a result of the entry of saponin glycoside (contained in sugar production waste) into the aquatic environment, a glycolytic effect is exerted on the erythrocytes of fish blood at a dilution of 1:1000000. As a result, the fish die and do not reproduce. In the future, it is necessary to prevent uncontrolled discharges of wastewater from sugar factories and other industrial enterprises. Water pollution of the Styr River causes not only the death of biota, but also negatively affects the aesthetics of the environment.

Having conducted a study of the content of heavy metals in the river of a large city and its tributaries, we came to the conclusion that stationary sources are not the main water pollutants. Non-stationary sources and discharge of untreated water are a significant factor in the entry of heavy metals into water. In our work, we have established the patterns of distribution of heavy metals by groups. The statistical distribution of heavy metals, which are most common in the hydrographic network of the river and its tributaries within the city of Lutsk, has been determined.

References

Adamenko Y.S., Arkhypova L.M., Mandryk O.M. (2017). Territorial Normative of Quality of Hydroecosystems of Protected Territories. Hydrobiological Journal, 53 (2). – P. 50-58. DOI: 10.1615/HydrobJ.v53.i2.50 (in Eng.).

Allia Z., Lalaoui M., Chebbah M. (2024). Spatial and seasonal assessment of surface water quality for domestic use in a semi-arid area of the Upper Kebir Sub-basin, NE Algeria. Water Supply. 24 (8). – P. 2946-2962. DOI:10.2166/ws.2024.182 (in Eng.).

Andrusyshina I.M., Holub I.O., Demchenko V.F., Lampeka O.G. (2020). Comparative assessment of the content of heavy metals in the soils of different urban agglomerations: methodological approaches to environmental monitoring. Environment & Health. 4. DOI: 10.32402/dovkil2020.04.071 (in Eng.).

Bui L.T., L.T.H. Tran D., Nguyen D.P. (2024). Prediction of the river water environment carrying capacity using LSTM networks. Water Supply (2024) 24 (7). – P. 2518-2533. DOI: 10.2166/ws.2024.138 (in Eng.).

Chirane M.S., Belmeskine H., Boudjellaba S., Megatelli S. (2024). Assessment of chemical and bacteriological status of treated wastewater of the Baraki WWTP (Algeria) for agricultural purposes. Water Supply. 24 (7). – P. 2383-2394. DOI: 10.2166/ws.2024.134 (in Eng.).

Fredj A., Ghernaout R., Dahmani S., Remini B. (2024). Assessing soil erosion through the implementation of the RUSLE model and geospatial technology in the Isser watershed, northern Algeria. Water Supply (2024) 24 (7). – P. 2487-2505. DOI: 10.2166/ws.2024.154 (in Eng.).

García-Ordiales, E., Esbrí, J.M., Covelli, S. et al. (2016). Heavy metal contamination in sediments of an artificial reservoir impacted by long-term mining activity in the Almadén mercury district (Spain). Environ Sci Pollut Res 23. – P. 6024-6038. DOI: 10.1007/s11356-015-4770-6 (in Eng.).

Kantardzic M. (2020). Data Mining. Concepts, Models, Methods, and Algorithms. 3rd ed. Wiley: IEEE press. 639. (in Eng.).

Loska K., & Wiechuła D. (2003). Application of principal component analysis for the estimation of source of heavy metal contamination in surface sediments from the Rybnik Reservoir. Chemosphere, 51(8). – P. 723-733. DOI: 10.1016/S0045-6535(03)00187-5 (in Eng.).

Mohanty M., Tare V. (2024). Hydromorphological shifts in the Yamuna River: Post-barrage impacts and water management implications. Water Supply. 24 (6). – P. 2143-2157. DOI: 10.2166/ws.2024.136 (in Eng.).

Nersesyan A., Mišík M., Cherkas A., Serhiyenko V., Staudinger M., Holota S., Yatskevych O., Melnyk S., Holzmann K., & Knasmüller S. (2021). Use of micronucleus experiments for the detection of human cancer risks: a brief overview. Proceeding of the Shevchenko Scientific Society. Medical Sciences, 65(2). DOI: 10.25040/ntsh2021.02.05 (in Eng.).

Popovych V., Bosak P., Petlovanyi M., Telak O., Karabyn V., Pinder V. (2021). Environmental safety of phytogenic fields formation on coal mines tailings. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 2 (446). – P. 129-136. DOI: 10.32014/2021.2518-170X.44 (in Eng.).

Pukish A., Mandryk O., Arkhypova L., Syrovets S., Hryniuk D. (2024). Mathematical modeling of pollution of underground aquifers due to mining of minerals. Mining of Mineral Deposits, 18 (3). – P. 94-103. DOI: 10.33271/mining18.03.094 (in Eng.).

Rahman A., Negahban-Azar M., Shirmohammadi A., Karki R. (2024). Evaluating the potential of recycled water use for irrigation in southern Maryland: impact on groundwater conservation and crop yield. Water Supply. 24 (7). – P. 2451-2472. DOI: 10.2166/ws.2024.137 (in Eng.).

Serhiyenko V., & Serhiyenko O. (2021). Diabetes mellitus and arterial hypertension. International Journal Of Endocrinology (Ukraine), 17(2). – P. 175-188. DOI: 10.22141/2224-0721.17.2.2021.230573 (in Eng.).

Serhiyenko V., Holzmann K., Holota S., Derkach Z., Nersesyan A., Melnyk S., Chernysh O., Yatskevych O., Mišík M., Bubalo V., Strilbytska O., Vatseba B., Lushchak O., Knasmüller S., & Cherkas A. (2022). An exploratory study of physiological and biochemical parameters to identify simple, robust and relevant biomarkers for therapeutic interventions for PTSD: study rationale, key elements of design and a context of war in Ukraine. Proceeding of the Shevchenko Scientific Society. Medical Sciences, 69(2). DOI: 10.25040/ntsh2022.02.14 (in Eng.).

Serhiyenko V.A., Serhiyenko A.A. (2022). Ezetimibe and diabetes mellitus: a new strategy for lowering cholesterol. Miznarodnij Endokrinologicnij Zurnal, 18, (5). – P. 302-314. DOI: 10.22141/2224-0721.18.5.2022.1190 (in Eng.).

Skrobala V., Popovych V., & Pinder V. (2020). Ecological patterns for vegetation cover formation in the mining waste dumps of the Lviv-Volyn coal basin. Mining of Mineral Deposits, 14(2). – P. 119-127. DOI: 10.33271/mining14.02.119 (in Eng.).

Skrobala V., Popovych V., Tyndyk O., Voloshchyshyn A. (2022). Chemical pollution peculiarities of the Nadiya mine rock dumps in the Chervonohrad Mining District, Ukraine. Mining of Mineral Deposits, 16 (4). – P. 71-79. DOI: 10.33271/mining16.04.071 (in Eng.).

Sojka M., Jaskuła J., Siepak M. 2019. Heavy Metals in Bottom Sediments of Reservoirs in the Lowland Area of Western Poland: Concentrations, Distribution, Sources and Ecological Risk. Water. 11(1):56. DOI: 10.3390/w11010056 (in Eng.).

Sternik V.M. (2017). Biotychna aktyvnist urboedafotopiv mista Rivne [Biotic activity of urban eco-photopes of the city of Rivne]. Specialty 03.00.16 - ecology. Dissertation for the degree of Candidate of Biological Sciences. Rivne: 2017. – P. 179. (in Ukr.).

Varol M. (2013). Dissolved heavy metal concentrations of the Kralkızı, Dicle and Batman dam reservoirs in the Tigris River basin, Turkey. Chemosphere, 93(6). – P. 954-962. DOI: 10.1016/j.chemosphere.2013.05.061 (in Eng.).

Zabokrytska M.R., Khilchevskyi V.K. (2016). Vodni obiekty Lutska: Hidrohrafiia, lokalnyi monitorynh, vodopostachannia ta vodovidvedennia [Water bodies of Lutsk: Hydrography, local monitoring, water supply and sewerage]. Hidrolohiya, hidrokhimiya i hidroekolohiya. 3. 42. – P: 64-76. (in Ukr.).

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