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N. L RYCHAK[1], PhD (Geography),
Associate Professor at the Department of Ecology and Environmental Management
e-mail: rychak@karazin.ua ORCID ID: https://orcid.org/0000-0003-1620-3059

N. I. CHERKASHYNA[1],
Senior Lecturer at the Department of Foreign Languages for Professional Purposes
e-mail: n.i.cherkashyna@karazin.ua ORCID ID: https://orcid.org/0000-0002-4066-2530

D. S. MAKEIEVA[1],
Bachelor,
e-mail: makieieva2021.9685818@student.karazin.ua ORCID ID: https://orcid.org/0009-0006-6561-2608

[1] *V.N. Karazin Kharkiv National University*,
4, Svobody, Sq., Kharkiv, 61022, Ukraine

HYDROCHEMICAL COMPOSITION FEATURES OF SURFACE WATERS OF THE RIGHT-BANK PART OF THE SIVERSKIY DONETS BASIN (KHARKIV REGION)

Purpose. To determine seasonal variations in the hydrochemical composition of surface waters and assess the ecological status of water bodies on the right bank of the Siverskyi Donets River within Kharkiv region.

Methods. Field studies, analytical, system analysis, methodology for determining the water pollution index, systematic approach to generalized results.

Results. There are the results of the ecological assessment of the water quality of the right-bank tributaries of the Siverskyi Donets River flowing through Kharkiv region during the spring-summer flood and autumn low water period of 2024 in the Velyka Babka River and the Molodova Pond at six representative sites, reflecting different economic uses. Organoleptic, physical- chemical indicators, and heavy metal content were determined in the waters. The results show that all hygienic indicators except hardness complied with the standards. The ecological quality of the rivers on the right bank of the Siverskyi Donets basin was assessed using the water pollution index based on our own field studies and information from open sources. The research has identified, among the existing sources of pollution, urban municipal wastewater, operating enterprises, the effects of agriculture, as well as military operations (the Velyka Babka River), and the diffuse impact of neighboring tributaries.

Conclusions. According to the surface water pollution index, all rivers on the right bank of the Siverskyi Donets belong to pollution class III, moderately polluted, with only the Bereka River classified as class II. Although the overall condition of the water remains satisfactory, we should take measures to improve water quality, especially for rivers such as the Udy, Mozh, and Tetlega, which are affected by industrial enterprises and agriculture. The Chepil, Gomilsh, Bereka, and Byshkin rivers require detailed field hydrochemical studies to determine the pollution level.

KEY WORDS: *surface water, hydrochemical indicators, water pollution index, the Siversky Donets basin*

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Introduction

According to Article 21 of the Water Code of Ukraine, state water monitoring is carried out in order to ensure collection, processing, storage and analysis of information on the state of waters, forecasting changes and developing scientifically based recommendations.

for making management decisions on use, protection and reproduction of water resources. Its components are observations of biological, hydromorphological, chemical and physical-chemical indicators [1]. According to the EU Water Frame work Directive, the main measures are application of monitoring programs and creation of a set of measures to prevent deterioration of waters conditions. In the context of European integration, Ukraine is harmonizing its Water Legislation, which provides for transition to integrated water resources management based on the basin principle and introduction of unified environmental standards for assessing water quality [2]. Goal 6 "Clean Water and Sanitation" takes a key place among the 17 Sustainable Development Goals, since access to high-quality water and appropriate sanitary and hygienic conditions is a basic prerequisite for environmental protection, sustainable functioning of ecosystems, ensuring health, and food security. The implementation of Goal 6 has a significant cross-sectoral effect (Goals 1, 2, 3, 11, 15), being one of the fundamental factors for the integrated achievement of all other Sustainable Development Goals [3].

In the last decade, a significant increase in anthropogenic activity in the form of business activities and military operations have become increasingly serious factors affecting the quality of surface waters. One of the most obvious consequences of these problems is a change in the conditions of water bodies. This is indicated by changes in the class of water quality as well as in quantitative hydrochemical indicators. Kharkiv region of Ukraine is one of the regions that have problems with water supply not only due to a relative shortage of water resources, but also due to a sharp deterioration in the state of water bodies. Studying the dynamics of water conditions in the region is relevant, since 70-80% of the region's water supply depends on the Siversky Donets River basin [4]. Assessing changes in the general ecological state of the region can be useful in determining the existing risks to the ecological state of water bodies and the possibilities of their further solution. The essence of the research problem is to determine the current ecological state of water bodies on the right bank of the Siversky Donets River in Kharkiv region and analyze their state under conditions of increased influence of anthropogenic activity. The article focuses on the impact of various factors on water quality, provides its ecological assessment, and identifies seasonal variability of the hydrochemical composition of small rivers on the right bank of the Siversky Donets River.

Analysis of previous studies. Today, in addition to rapid anthropogenic activity, the Siversky Donets is also affected by the hostilities nearby, which is the cause of additional environmental load on its basin. Thus, it is important to find out whether there have been significant changes in the state of its rivers, hydrochemical indicators. Consequently, the main attention is paid to the right bank of the river and its tributaries that flow within Kharkiv region. These are the rivers: the Bereka, Chepil, Byshkin, Gomilsha, Mozh, Udy, Tetleha and Velyka Babka.

According to the Water Code of Ukraine [1], all of the above-listed rivers of the right bank of the Siversky Donets are small rivers, except for the Udy River, which is a medium-sized one.

The general location of the rivers is in the following areas: the Udy, Velyka Babka, Tetleha, Gomilsha and Mozh - East European Plain, East Ukrainian Region; the Bereka, Chepil - Oryol-Samara Lowland Region, Left-Bank the Dnieper-Azov Region; the Byshkin - East Poltava Upland Region, Left-Bank Dnieper Region. According to zoogeographic zoning, the rivers are located in the area of the East European deciduous forest and forest-steppe, namely the left-bank Dnieper subdivision, and in the western steppe (Azov) section [5]. Aquatic and coastal plants play an important role in the formation of hydrological indicators in water bodies. Aquatic plants change the gas and chemical composition of water bodies. Due to plant life, organic matter, necessary for the life of animal organism, enriches water bodies. In addition, chemical energy accumulates, creaing conditions for the course of many chemical reactions [6]. The results of the reseach indicate the neccessity to take a closer look at the quality of wetlands located along the riverbedin detail, to maintain the lands in proper conditions.The species composition of plants, their richness in functional groups of birds, as well as the diversity of benthic macroinvertebrates are promising indicators for a standardized biodiversity method in the restoration of coastal wetlands, which could signal biodiversity crediting in the study areas [7]. The results of modern studies have shown that shallow lakes are sources of CH_4 and CO_2 emissions into the atmosphere. The peak of CH_4 emissions falls on the peak of the growing season in July, while the peak of CO_2 emissions falls on the end of the growing season in October (for the example of Lake Ulansuhai, China). In plant environments, the content of CH_4 was nine times higher than in non-plant environments. The results of the study demonstrate that aquatic plants influence carbon emissions in multi-environmental aquatic systems. With the expected rapid expansion of shallow marsh lakes due to climate change, their contribution to the regional carbon budget is expected to increase significantly [8].

In the process of interaction of the lake-river-aquifer system, formed under the complex influence of anthropogenic loads and climatic conditions, the determining factor is hydrological changes, whose influence significantly prevails over the influence of climatic factors [9]. According to the hydrological zoning, the rivers studied are located in the Siversk-Donetsk-Dnipro region with insufficient water stock, are in a moderately continental climate type, on a small-relief area with characteristic signs of forest-steppe transformations. However, in the steppe zone, a drier climate with less precipitation prevails. In the spring, the right tributaries of the Siversky Donets provide 50-60% of the annual runoff, and the floodplain begins a month earlier, that is, it lasts from February to April. As a result, the summer period is extended by a month and covers May-August, while winter is reduced to two months - December and January. Due to periodic melting of snow in spring, a relatively low floodplain is formed both in terms of maximum water flow and total runoff volume, and the average layer of spring floodplain runoff of rivers is 70-80 mm in the upper Donets [10]. River water content is an extremely important characteristic in the study of hydrological and hydrochemical indicators and water quality. The module of the average annual water flow within the right-bank part of the Siversky Donets basin is from 1,5 to 2 $l/sxkm^2$. The module of the average annual water flow within Ukraine, $l/sxkm^2$ [9,11]. Monitoring of river runoff can help determine the optimal levels of its use for sustainable water resources management in conditions of climate change,and water content of the rivers under study [12]. In the right-bank part of the basin in the Donetsk Ridge area, the chemical composition of river waters forms under the influence of saline rocks. Significant fragmentation of the terrain contributes to the drainage of highly mineralized waters by aquifers. River waters here are characterized by increased mineralization and predominantly sulfate-chloride composition [6].

In recent years, the groundwater level has decreased in most rivers. For instance, in the 1980s, the Velyka Babka was more full-flowing due to groundwater recharge, and became shallower with decreasing water level. This has also led to the appearance of a larger number of drying streams, as the sources of recharge decreased [4,13]. With increasing precipitation, freshwater recharge can be enhanced, thereby diluting ion concentrations and changing hydrogeochemical conditions. The hydrochemical characteristics of interconnected groundwater and surface water systems are largely regulated by precipitation, which acts coordinated with other hydrological processes, such as evaporation and mixing. The temporal and spatial distribution of electrical conductivity, ion concentrations, stable isotope ratios, and dissolved organic carbon concentrations empirically confirm the significant influence of precipitation and the interaction of these hydrological processes [14].

Considering complex relationship between hydrochemical characteristics and water quality, the authors carried out in-situ measurements for pH, conductivity, total dissolved solids and laboratory analyses for major ions, hardness [15]. The studies establish the factors determining chemical composition of water, reflecting different sources of pollution and anthropogenic influences. For rivers, such studies have established significant spatial heterogeneity in water quality, which emphasizes the need for specific management approaches that integrate geological conditions, land use patterns and socio-cultural priorities. The results of the studies emphasize the importance of understanding the dynamics of water quality and chemical characteristics in the context of global climate change, providing valuable information for decision-making in the sustainable management of environmentally sensitive river basins [15].

According to published materials and open sources of information on the ecological state of the Udy River in 2018, it was found that the most critical situation was in the waters near the village of Khoroshevo and the city of Eskhar. The ecological index I*E* in those areas corresponded to the fifth category (unsatisfactory water quality) and the third class (satisfactory condition) [16]. Analysing the risk to health of the population associated with recreational water use, it became clear that the most unfavorable conditions were found in the river near the city of Eskhar. Since the Udy River flows within the borders of two countries, pollution acquires a transboundary character. In addition, the river flows through a significant territory of Kharkiv region, which also negatively affects its water quality. The forecast of the ecological state of the Uda River within the city of Eskhar indicates that in 2030 the maximum value of the ecological index for this river section will correspond to 7*th* category and V class, characterized as a very poor state. Similar situation will develop with hydrochemical indicators of surface water quality, it will be impossible to use it for fishery needs [16].

According to the research in 2020, in the waters of the Uda River (Okop village, an approved state quality monitoring point on the border with the Russian Federation), the indicators of BOD_5, ammonium nitrogen, nitrite nitrogen and sulfates did not meet the TLV standards for fishery reservoirs. The river experienced the largest discharge of organic substances among the studied reservoirs according to the results of 2020 [13].

Hydroecological and hydrochemical studies of the Uda River showed a tendency towards a negative impact of the city of Kharkiv on the hydroecological situation in its system based on calculations of the water pollution index (WPI), modified WPI and the pollution coefficient χ for many years [17]. The indicators do not demonstrate pronounced time trends. According to the pollution coefficient, water quality is improving along the river network, with the exception of a section on the Uda River near the village of Khorosheve, where the pollution level is classified as “catastrophic”. Further, in the area of the city of Eskhar, water quality improvesdue to natural processes of the river's self-purification. In 2022, excess concentrations of manganese, cadmium, lithium, cypermethrin, and polyaromatic hydrocarbons were recorded in two of the studied sections of the river [17, 18].

The ecological state of the Tetlega River in 2020, determined according to the “Methodology for the ecological assessment of surface water quality by relevant categories”, coresponded to quality class III of category 4 (satisfactory, slightly polluted) [17]. The main pollutants were sulfates, chlorides, oil products and dry residue. Exceedance of the TLV at the river mouth for BOD_5, oil products, cadmium (twice) and manganese (three times) was recorded in the area[17].

In 2023, the waters of the Chepil River had excess of lithium (2 cases), manganese (3 cases) and simazine (2 cases) [18]. Data on other potential pollutants such as heavy metals, pesticides, surfactants are limited, thus,the river requires additional hydrochemical studies. In addition, in 2018 the hydrological reserve “Vitrivsky” with an area of 349 hectares was created in the river basin. Therefore, the Chepil River is of ecological value and requires special attention [19].

There is practically no information about the state and potential pollutants of the Gomilsha River, but we can assume that if the Siverskyi Donets River is polluted almost along the entire length of the watercourse, the Gomilsha River may also be polluted. Moreover, there is pollution from agricultural activities. That is, the problem is in the lack of clear hydrochemical indicators regarding the water quality of this river. The Chepil River and Gomilsha Rivers are located within the National Nature Park “Gomilshanski Lisy” [20].

Information on the ecological state of the Bereka River is limited and requires additional research. According to the results of the study, during 2021–2022, the water quality remained stable without significant changes [21]. The actual hydrochemical indicators of the Bereka River are not published separately, therefore the available data relate only to the general characteristics of the river waters.

In the Mozh River, environmental standards for several chemical substances and compounds were exceeded: barium, benzo(a)pyrene, cadmium, lithium, manganese (10 cases of exceedance), simazine and trichloromethane [22]. Within the city of Zmiiv, sewage wastewater was discharged into the river (public utility company “Zmiiv-service”). Over time, a characteristic gray sediment formed in the floodplain and along the riverbank [22]. This sediment is the cause of a strong odor, toxic compounds can provoke the death of local aquatic organisms, leaving only the most tolerant species to toxicants. There is a significant threat of increased eutrophication of the reservoir.

The ecological state of the Velyka Babka River in open sources is assessed within the Siverskyi Donets River basin without separate monitoring points. According to research results [23], the reservoir has been polluted as a result of military operations, improper handling of household waste (in 2022, in the villages of Fedorivka, Shestakovo, Velyka Babka).

We have limited information that requires additional research on the ecological conditions of the Byshkin River.

Considering the peculiarities of water management use of the studied water bodies, we presume that water is taken from the Bereka River for the Bereka Reservoir, for the ponds of the enterprise limited liability company (LLC) “Rybgosp”, which is about 3.581 mln. m^3 of water [24]. Water from the river is usually used by the population, mainly for irrigation, fish farming and recreation.

The waters of the Uda River are one of the main sources of water supply for Kharkiv region. Water is withdrawn from the river by Thermal power plant-2 (TPP-2), namely the branch of "Teploelektrotsentral" and the joint-stock company "Naftogazovydobuvna Company " and PJSC "Kharkiv TPP-5". The withdrawal reaches 82.32 mln. m^3 of water [24].

The water use of the Chepil River is insignificant: no large facilities have been created, no water is taken. In nearby villages, the main source of drinking water is groundwater (wells); for technical needs, water from the centralized water supply is used.

The waters of the Mozh River are used for irrigation. The following enterprises Agricultural Limited Liability Company (ALLC) "Mozh", State-owned Enterprise (SE) "Artemivskyi spirtlazavod", Closed Joint-Stock Company (CJSC), "Novoselskyi Mmining and Processing Plant (MPP)" withdraw waterfrom it [24].

The waters of the Gomilsha River are mostly used for recreational purposes, since it is located on the territory of the National Nature Reserve "Gomilsha Forests". There is no information about a significant use of its waters.

A bridge was built across the Tetleha River on the route T-21-11 "Chuguyiv – Pechenihy– Velykyi Burluk" in Kharkiv region, connecting the city of Kharkiv with the Velykyi Burluk and Pechenihy communities. According to 2023 data, it was established that the municipal enterprise (ME) "Kharkivvodokanal" discharged return waters and pollutants into the river [18]. It is planned to create coastal protective strips for the reservoir in order to prevent pollution and clogging of surface water bodies and to preserve its water regime. No industrial and land reclamation facilities have been created in the riverbed, there are no significant industrial water intakes or hydroelectric facilities [25].

The waters of the Byshkin River are not used as the main water supply source,they are used for irrigation and recreational purposes.

The waters of the Velyka Babka River are used for recreational purposes, they are not used for irrigation or fish farming. The floodplain of the river serves as a good pasture for livestock and a place for harvesting hay.

We also studied an unnamed pond in the village of Molodova, Chuguyiv district, located 3 km from the Siverskyi Donets River. The pond was created at the beginning of the 20*th* century by damming the Velykyi Log River, which has dried up in our time [26]. The reservoir is of interest to the population as a recreational and aesthetic object, it is a place for fish farming and an ecosystem for the existence of certain species of biota, for example, beavers, waterfowl. The pond is home to common rudd, common crucian carp, common carp, as well as amphibians and reptiles. The pond is a popular recreation area for the local population of the village of Molodova and the surrounding community. The reservoir is used in extreme conditions during the fire season, which arise from arson, drought or hostilities nearby.

The right-bank part of the Siverskyi Donets basin is an agricultural area. Therefore, studies related to nitrate pollution are important. As a rule, studies focus on the level and load of pollution, source tracking, migration and transformation, impact factors, potential risks and forecasting, removal and restoration [27]. In most parts of the territory, the minimum mineralization of river waters at the highest river flows ranges from 120.0–300.0, while during low floods it reaches 370.0 mg/dm^3. In the right-bank part of the Siverskyi Donets River basin, in the catchments south of the Berek River, waters of sulfate-hydrocarbonate, sulfate-chloride and chloride-sulfate composition are formed in the low season. The mineralization level reaches 2000.0–5000.0 mg/dm^3, total hardness – 20.0–29.0 mmol/dm^3 [6].

The purpose of the article is to assess comprehensively the ecological state of water bodies on the right bank of the Siverskyi Donets, identify the main factors affecting their quality, and determine the hydrochemical features of small rivers on the right bank of the Siverskyi Donets.

The scientific novelty lies in using a comprehensive approach for a systematic analysis of the impact of various activities on the water resources of the region and determining the hydrochemical features of small rivers on the right bank of the Siverskyi Donets. The results obtained complement and clarify understanding of the current state of water bodies and have become a scientific basis for proposing effective measures for protection and rational use of these water bodies.

The applied value lies in using the results of the study to form a water resources management strategy and plan environmental protection measures.

Objects and materials. Research methodology

The object of the study is the water bodies of the right bank of the Siverskyi Donets within the river basins and within Kharkiv region, the content of which is focused on the ecological state of these water bodies in conditions of increased human activity and military operations. To ecologically assess and determine the features of the seasonal behavior of hydrochemical indicators in the surface waters of the right-bank part of the Siverskyi Donets basin, field studies were conducted for the Velyka Babka River (Fig. 1) and the Molodova Pond (Fig. 2).

a) b)

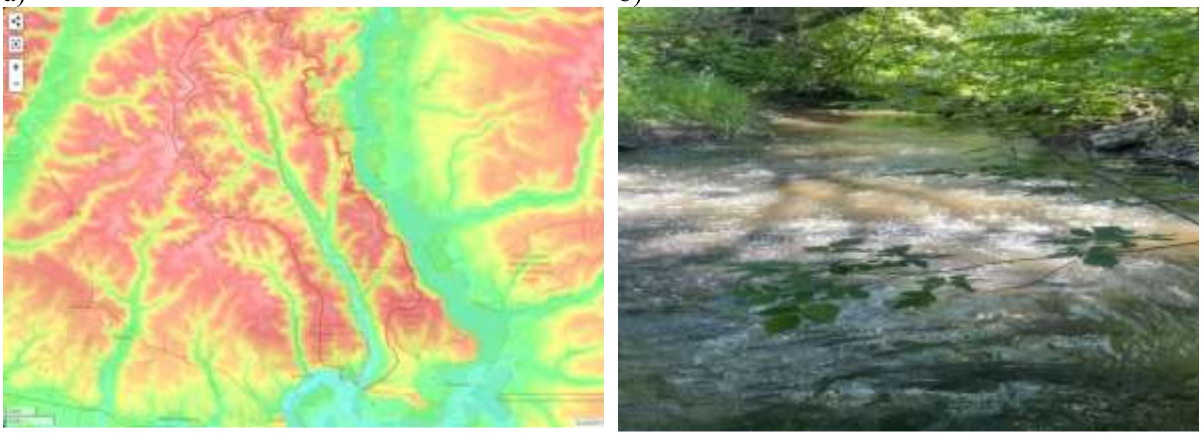

Fig. 1 – The Velyka Babka River: a) river basin; b) control water sampling site

a) b)

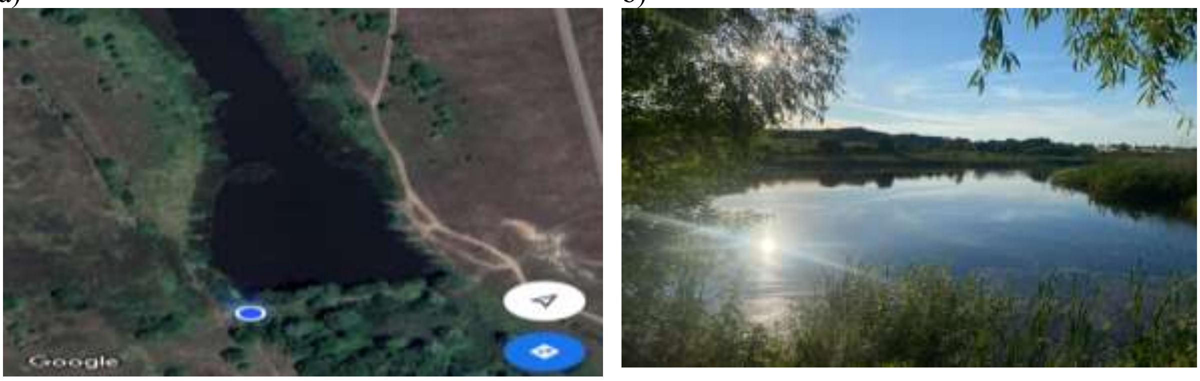

Fig. 2 – The Molodova Pond: a) location of the Molodova Pond;
b) one of the water sampling control points

Using Google Earth tools, we have determined that the area of the pond's surface is 11,784.64 m^2, the length reaches 287 m, and the maximum width is 83 m. The length of the coastline along the zero isobath is 715.2 m. The degree of indentation of the coastline is 0.42.

In surface water bodies, water samples were taken [28, 29, 30] at six representative sections that reflected different economic uses (Table 1). Samples were taken in the spring-summer flood and autumn low water. A wide range of parameters (pH, transparency, odor, hardness, alkalinity), chemical compounds (ammonia, nitrites/nitrates, chlorides), and the content of heavy metals (HM) (iron, zinc, copper, manganese, cadmium, chromium) were studied and analyzed. The criteria for the analysis of the obtained results for ammonia content, organoleptic indicators, alkalinity and hardness were applied hygienic requirements for drinking water intended for human consumption [31]. The criteria for the analysis of the content of HM were Hygienic Standards, 2022 [32].

Table 1

Environmental justification for choosing the location of sampling points

Hydrological object	Water sampling coordinates	Environmental justification
The Velyka Babka river	49.9876097 N, 36.7526857E	Determination of the pollution level in a section of the river due to the impact of motor vehicles, which can be a source of heavy metal emissions (cadmium, zinc, copper); a section of the road near the shore; a section with a weak current
The Velyka Babka river	49.9831781 N, 36.7513067 E	Impact of fish farming activities on water quality in the river, determination ofnutrients (nitrogen), concentrations, organic matter residues, silt; bay-shaped area; area with weak current
The Velyka Babka river	49.9775219 N, 36.7506050 E	The territory with widened channel, determination of hydraulic works impact, changes in physical and chemical indicators, changes in mineralization, heavy metals, and biogenic elements; straight-flow channel
The Molodova Pond	50.0435368 N, 36.7693580E	determined the level of the pond pollution due to the impact of motor vehicles, which can be a source of heavy metal emissions (cadmium, zinc, copper); a section of the road near the shore; a bay
The Molodova Pond	50.0442484 N, 36.7702344 E	impact of fish farming activities on water quality in the pond, determination of nutrients (nitrogen),concentrations, organic matter residues, silt; bay-shaped area
The Molodova Pond	50.0448827 N, 36.7696758 E	The impact of recreational activity (swimming, boating, picnics) on the quality of water in the pond, determination of the content of nutrients and organic compounds; site along the shore

Determination of indicators and measurement of the content of heavy metals (HM) was carried out in two periods: 06/19/2024 and 10/29/2024 at the educational and research laboratory of analytical ecological research, V.N. Karazin Kharkiv National University (Protocols No. 2000-2024 research of surface water bodies). The content of chlorides, hardness and alkalinity was establishedby titration. The content of nitrites was determined using a KFK-2 photocolorimeter, while the content of nitrates - by a portable nitrometer. The content of HM was determinedby the method of modulation polarization spectrophotometry using a spectrophotometer MTA 915 MD, manufacturer with a hollow lamp for the corresponding metals. All measuring equipment is approved for use by calibration certificates. For quantitative ecological assessment of water bodies conditions , the water pollution index (WPI) was used [33, 34].

Results and discussion

The obtained results of studies on the activity of hydrogen ions showed that the highest acidity indicators were recorded at three sections of the pond during the spring-summer flood period: (8.0; 7.9; 7.8) (Table 2).

In the autumn low season, a slight change in the pH indicator was observed in the river - an increase of 0.4 – 0.5, (Fig. 3, a, b) in the pond an increase of 0.2 is observed (Fig. 4, a, b). In general, during the study period, there were

Table 2

Indicators of the state and chemical composition of water during the spring-summer flood period

Substance	Sample 1*	Sample 2*	Sample 3*	Sample 4**	Sample 5**	Sample 6**	Units of measurement
pH	7,525	7,367	7,085	8,002	7,891	7,825	-
Ammonia	0,04	0,04	0,04	0,04	0,04	0,04	mg/dm^3
Odor	0	0	0	0	0	0	-
Transparency	16	18	17	20	19	17	centimeter
Nitrites	0,002	0,002	0,002	0,001	0,001	0,001	mg/dm^3
Nitrates	20	15	31	0	0	0	mg/dm^3
Chlorides	240	240	248	232	224	224	mg/dm^3
Alkalinity	6,6	7,1	7,0	9,0	9,0	9,3	$mmol/dm^3$
Hardness	7,4	7,0	7,2	8,0	8,4	7,8	$mmol/dm^3$
Iron	0,0912	0,0814	0,0812	0,08	0,0555	0,0544	mg/dm^3
Zinc	0,122	0,114	0,0984	0,0915	0,0985	0,0985	mg/dm^3
Copper	0,008	0,007	0,00915	0,0012	0,00815	0,0095	mg/dm^3
Manganese	0	0	0,0001	0	0,0001	0	mg/dm^3
Cadmium	0	0,0001	0	0,0001	0,0001	0	mg/dm^3
Chromium	0,0002	0,0002	0	0,0001	0,0001	0,0001	mg/dm^3

Note: * - water samples of the Velyka Babka River; ** - water samples of the the Molodova Pond

Table 3

Indicators of the state and chemical composition of water during the autumn low water period

Substance	Sample 1*	Sample 2*	Sample 3*	Sample 4**	Sample 5**	Sample 6**	Units of measurement
pH	7,526	7,759	7,573	7,888	7,945	8,027	-
Ammonia	2,0	2,0	2,0	0,04	0,04	0,04	mg/dm^3
Odor	0	0	0	0	0	0	-
Transparency	12	18	20	22	24	27	centimeter
Nitrites	0,04	0,002	0,001	0,001	0,001	0,001	mg/dm^3
Nitrates	16	0	15	0	0	0	mg/dm^3
Chlorides	264	256	264	280	272	280	mg/dm^3
Alkalinity	7,5	7,4	7,4	7,3	7,1	7,1	$mmol/dm^3$
Hardness	7,4	7,8	5,4	8,6	8,6	8,0	$mmol/dm^3$
Iron	0,0812	0,0503	0,0543	0,0982	0,0804	0,0814	mg/dm^3
Zinc	0,0915	0,098	0,099	0,124	0,116	0,0973	mg/dm^3
Copper	0,0012	0,00815	0,0090	0,00715	0,00655	0,00983	mg/dm^3
Manganese	0	0,0001	0,0001	0	0	0,0001	mg/dm^3
Cadmium	0,001	0,0001	0	0	0,0001	0	mg/dm^3
Chromium	0,0001	0,0001	0,0001	0,0002	0,0002	0	mg/dm^3

Note: * - water samples from the Velyka Babka River; ** - water samples from the Molodova Pond

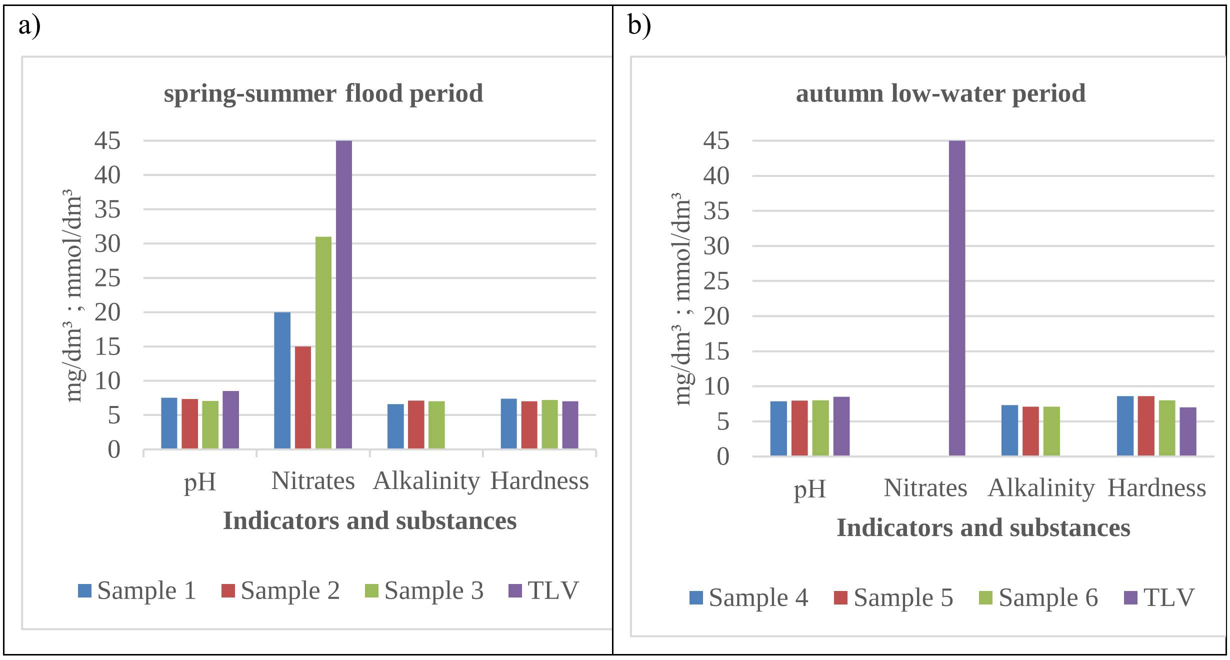

Fig. 3 – Individual hydrochemical indicators of water quality in the Velyka Balka River:
a) during the spring-summer flood period; b) during the autumn low water period

conditions of neutral and acid-base balance of the environment. (Fig. 3, 4).

In the spring-summer floodplain and in the autumn low tide at all the study sites, there is no odor in water bodies with different speeds and self-purification capabilities. A slight presence of ammonia was recorded during the autumn low tide at all sites in the waters of the Velyka Babka River. This hydrochemical situation is explained by the deficiency of dissolved oxygen, inhibiting the nitrification process, which leads to the accumulation of ammonia in the water. Regarding transparency, high variability was observed with an amplitude of up to 3 cm typical for the river and from 2 cm to 10 cm in the pond. The highest amplitude in the river and in the pond is characteristic of sites that were laid in places of intensive recreational load, which explains the decrease in transparency. The transparency indicator plays an important role in the formation and functioning of ecological zones (layers), especially in pond conditions. The decrease in transparency during the low season limits the functioning of the pond ecosystems.

Particular attention is paid to the content of nitrites and nitrates in the conditions of agricultural use of the river basin and pond. The results of the research [35] showthat temporal heterogeneity, type of land use, population density and type of vegetation cover affect the sources of nitrates entering surface waters. Nitrates and nitrites are within the environmental standards according to [32]. Regarding nitrites, their content in the river waters increased during the low season (from 0.002 mg/dm^3 to 0.04 mg/dm^3) under the influence of agricultural lands, in the pond the content did not change and approached 0.001 mg/dm^3. The content of nitrates has certain features. We observe changing behavior of nitrates in the river waters during the spring-summer flood period from 15 mg/dm^3 to 31 mg/dm^3 and during the autumn low water period from 0 to 16 mg/dm^3 and their absence in the pond waters (Fig. 3,4).

This peculiarity of nitrate behavior is formed by several factors. First, these are seasonal hydrological conditions. In spring, rivers have a higher water exchange due to floods, which raise dissolved compounds, including nitrates, from the soil and groundwater. In addition, in spring, a significant dose of nitrogen fertilizers is applied during agricultural work, some of which is not immediately absorbed and is washed out into surface and groundwater; in spring, young vegetation is poorly developed and is not able to fully absorb nitrogen. However, the issue of the absence of nitrates in pond waters remains unresolved. This requires additional monitoring studies. According to the results of the studies, the con-

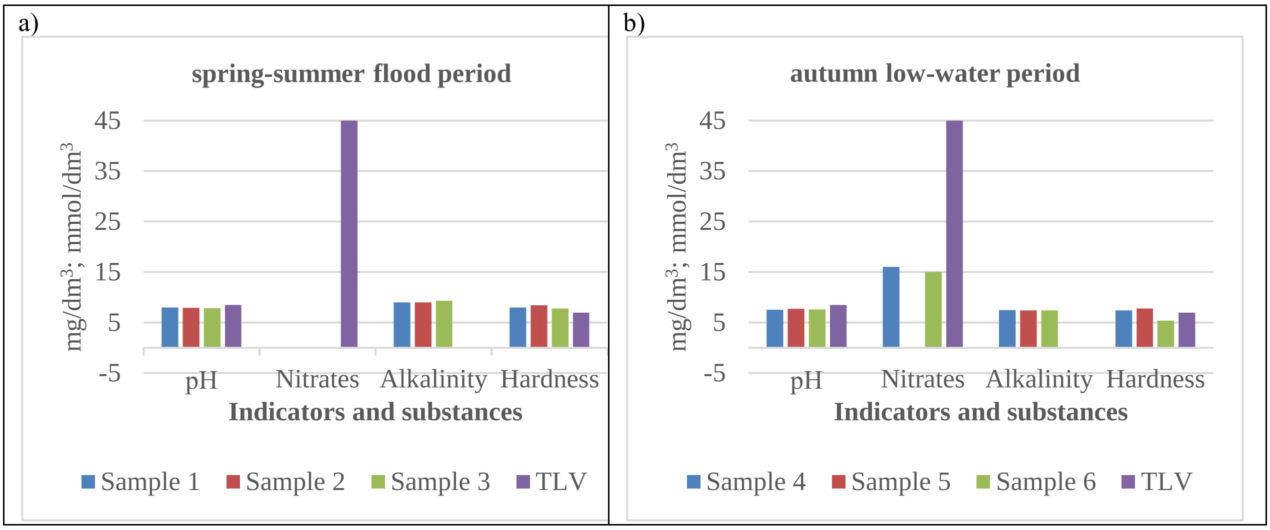

Fig. 4 – Individual hydrochemical indicators of water quality in the village of Molodova: a) during the spring-summer flood period; b) during the autumn low water period

tent of chlorides did not exceed the recommended hygienic standards [32]. During the spring-summer flood period, a slightly lower content of compounds in the pond (by 8 - 24 mg/dm^3) was observed compared to their content in the river. During the autumn low water period, the chloride content in the pond was 16 mg/dm^3 higher than in the river waters. Thus,we revealed a peculiarity of chloride behavior in fresh waters: during the autumn low water period, the amount of chlorites increases compared to the spring-summer water level in both hydrological objects and a higher concentration of chlorides was recorded in the pond compared to the river for two periods of observation (Fig. 3, 4). Such peculiarities of hydrochemical behavior are primarily explained by the increase in the chloride content in autumn by hydrological conditions: in autumn, rivers and ponds have a smaller inflow of fresh water, so the concentration of substances increases [36]. With a decrease in temperature in the air and in the upper layers of reservoirs and watercourses, the biological activity of plants and algae decreases, they do not absorb a significant amount of substances. Given that the pond is a closed system with slow water exchange, chlorides are concentrated in greater quantities.

Analysis of alkalinity indicators shows an increased buffering capacity of surface waters against acidification, high mineralization and water hardness. [36]. During the spring-summer flood period, alkalinity in river waters ranged from 6.6 mmol/dm^3 to 7.1 mmol/dm^3, in pond waters from 9 mmol/dm^3 to 9.3 mmol/dm^3 (Table 2, 3). During the autumn low water period, alkalinity in pond waters decreased, on average, by 1.9 mmol/dm^3. The hydrochemical feature is explained by a slightly increased acidity of pond waters during this period (Table 3) and the decomposition of organic matter, which led to a decrease in acidity. With a decrease in buffering, the ecosystem becomes more vulnerable to acidification. Geological monitoring is necessary so that the decrease in alkalinity does not exceed the permissible natural limits. For river waters, during the autumn low water period, there was an increase in alkalinity, on average, by 0.5 mg/dm^3. Higher alkalinity in the waters means a significant amount of dissolved salts (calcium, magnesium, sodium bicarbonates). This indicates a natural feature of the river basin (washing out of carbonate and gypsum rocks) and anthropogenic activity (liming of soils). Higher alkalinity is stressful for the ecosystem, leading to a decrease in species diversity; more salt-tolerant species will be characteristic of the ecosystem [36, 37, 38].

The results of water hardness studies confirmed the results of alkalinity and the features of its changes (Tables 2, 3). Water hardness increases. From 7.3 mmol/dm^3 in the river and 8.1 mmol/dm^3 in the pond (in average) during the spring-summer flood period to 6.8 mmol/dm^3 in the river and 8.4 mmol/dm^3 in the pond (in average) during the autumn low water. This hardness makes the water more mineralized, with an increased content of Ca^{2+} and Mg^{2+} [36, 37]. In general, the results show that the hardness index in pond waters is higher than in river waters; when comparing hardness at different periods, we found thatduring the autumn low water period hardness was higherin pond waters. From a hydrological and hydrochemical point of view, the increase in hardness indices during the autumn low water period is natural, because there is a decrease in the inflow of water volumes (rain-free period, evaporation), which leads to an increase in salt concentrations [39]. Under such conditions, crustaceans and mollusks function well in ecosystems, while plankton and algae suffer from a lack of phosphates [36].

Analysis of heavy metals amount showed a low content in surface waters with changes in hydrological periods caused by various factors. Exceedance of ecological and recommended hygienic standards [32] was not recorded. Heavy metals have a tendency to decrease their content in water. The highest concentrations were recorded for zinc, iron and copper, and the lowest for chromium, manganese and cadmium [6]. Analysis of iron content indicates an increased amount in pond waters during the autumn low water period of 0.086 mg/dm^3 compared to the content in the river of 0.06 mg/dm^3 (Table 2, 3). The primary causes of such hydrochemical behavior are weak water exchange and the presence of stagnant water in the pond, which leads to a decrease in oxygen, so iron is not oxidized to poorly soluble forms [36]. However, we should take into consideration rather low iron values in water. The lower limit of iron content in rivers is 0.05 mg/dm^3, in ponds 0.1 mg/dm^3. The water meets physiological indicators, which does not create a stressful situation for the inhabitants of the ecosystem and its functioning. Zinc content during the autumn low water period in the pond is 0.11 mg/dm^3 (Table 3), which is higher than in the river (Tables 2, 3). The hydrological reasons for this may be convective mixing of water layers as a result of temperature changes and runoff from the fields where fertilizers were applied. The copper content shows a low amount of compounds in the river and in the pond in different periods. The physiological lower limit is met. There are certain features of the compounds content. An increase in copper compounds was found in waters of the pond site under the influence of motor vehicles during the autumn low water period, and a decrease in copper compounds in the river waters also for the first site (motor vehicle impact). On other sites, the indicators of copper compounds were practically unchanged. Thus, we observe the impact of anthropogenic activity on the formation of water quality and self-purification processes that improve water quality in the river. The manganese content was determined only at the sampling sites that were under recreational load for two periods and at the second site (fish farming impact) in the autumn low water period for the river. As for the pond, the content of manganese compounds was determined in the autumn low water period at the recreational load site. In general, as a result of anthropogenic impact,the hydrochemical behavior of manganese compounds in these conditions is formed. The content of cadmium compounds was recorded in the waters of the pond during the spring-summer flood period and in the waters of the river during the autumn low water period. A feature is thatcadmium compounds are constantly present at the second research site, fish farming being the main load on it, in the waters of both water bodies during both hydrological periods of the study. Analysis of chromium compounds behavior shows that the compounds are present in the waters of the river in two periods, during the spring-summer flood period the content is higher. In the pond waters, the content of chromium compounds is higher during the autumn low water period. Thus, significant factors influencing the hydrochemical behavior of heavy metal compounds are the processes of self-purification of water bodies and the intensity of anthropogenic load.

The WPI indicators were calculated for all the studied rivers, using our own research results and information from open sources [40, 41, 42]. The Uda River, according to the criteria for assessing water quality in 2015, belonged to the fifth class of water quality, i.e. “dirty”, the WPI value was 4.47. According to the results of the research in 2024, the river belonged to the third class of water quality with the following WPI values: the headwaters near the city of Eskhar had an WPI of 2.04, near the village of Zolochiv – WPI of 1.07, beyond the city of Kharkiv had an WPI of 1.70. This is the third class of water quality, “moderately polluted”. It is clear that closer to the river mouth the water quality of the Uda River deteriorates. Such an assessment of water quality is characteristic of the waters of many rivers that are under the load of industry and agriculture, as proven by the results of the research [43]. Compared to 2015, water quality indicators in the Udy River in

2024 indicate a significant improvement in the situation, but moderate pollution can still be foundalong the course.

For the Mozh River, beyond the town of Merefa, the WPI value is 1.03, at the mouth near the town of Zmiiv, the WPI is 1.05. This is the third class of water quality, "moderately polluted" (Fig. 5). For the Tetlega River, the WPI value is 1.39 – the third class of water quality, "moderately polluted water".

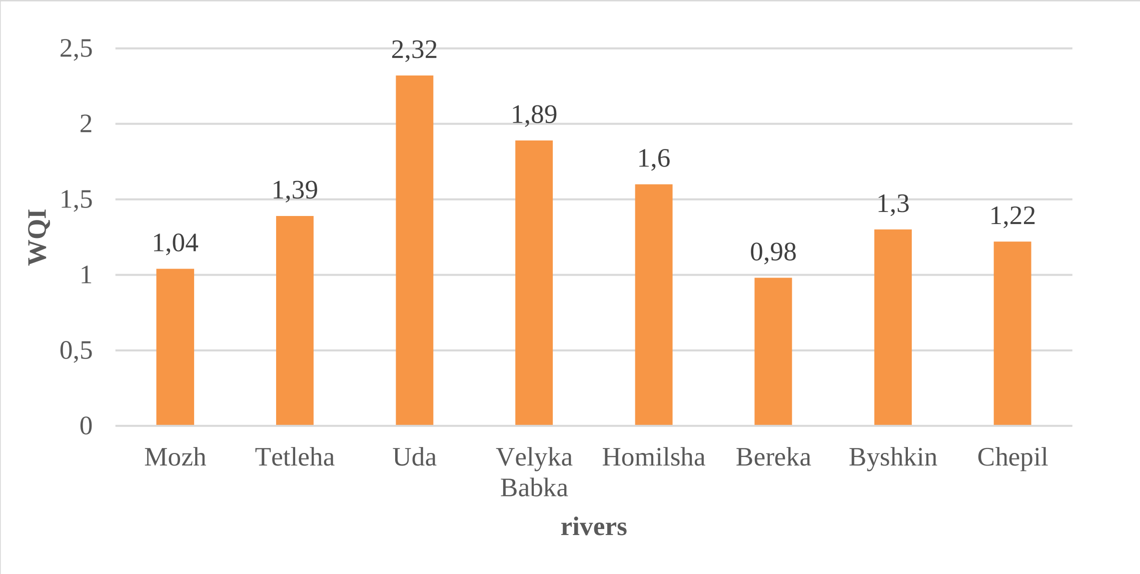

Fig. 5 - Water pollution indicators of rivers of the right-bank part of the Siverskyi Donets basin (Kharkiv region)

A potential factor for quality degradation is pollution in the form of sewage effluents. The WPI for the Velyka Babka River is 1.89, this is the third class of water quality– "moderately polluted". The waters of the Gomilsha River belong to the third class of water quality (WPI – 1.6). Based on the average values of six mandatory indicators and focusing on the indicators of the Uda River, which flows nearby, an approximate WPI for the Bereka River was calculated, which is 0.98 (the second class of water quality is "clean water") (Fig. 5). As for the Chepil River, we can assume thatbecause of absence of industrial and urban effluents in its basin, the average concentrations of substances will be approximately 25% of the indicators for the Siverskyi Donets, the WPI will be 1.22, the third class of water quality is "moderately polluted", but the calculations require clarification. There are no direct hydrochemical observations for the Byshkin River in open sources. Therefore, for the most reliable assessment of water quality, the authors used monitoring results of a nearby tributary, the Rohan River [24], when calculating the WPI. The WPI was 1.3 (the third class of water quality - water "moderately polluted") (Fig. 5).

Conclusions

The study of surface water bodies on the right bank of the Siversky Donets River within Kharkiv region has shown that all the determined water quality indicators (pH, nitrites and nitrates, chlorides, alkalinity, heavy metals) corresponded to the maximum permissible concentrations, with the exception of hardness, which in most samples exceeded the standard, the maximum concentration was 8.6 mmol/dm³.

Calculation of the WPI for the studied rivers gave a value in the range of 1.03–2.04, which according to the classification refers water bodies to class III, moderately polluted. Only the Bereka River was classified as class II.

Although general condition of the water remains satisfactory, there is a need for measures to improve water quality, especially for such rivers as Udy, Mozh and Tetlega, the state of which is under the influence of enterprises and agricultural management.

The Chepil, Gomilsha, Bereka, Byshkin Rivers require detailed field hydrochemical studies in order to clarify the level of pollution.

Conflict of Interest

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

Authors Contribution: all authors have contributed equally to this work.

The work does not use artificial intelligence resources.

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Н. Л. РИЧАК[1], канд. географ. наук, доц.,
доцент кафедри екології та менеджменту довкілля
e-mail: rychak@karazin.ua ORCID ID: https://orcid.org/0000-0003-1620-3059

Н. І. ЧЕРКАШИНА,[1]
старший викладач кафедри іноземних мов професійного спрямування,
e-mail: n.i.cherkashyna@karazin.ua ORCID ID: https://orcid.org/0000-0002-4066-2530

Д. С. МАКЄЄВА[1],
бакалавр,
e-mail: makieieva2021.9685818@student.karazin.ua ORCID ID: https://orcid.org/0009-0006-6561-2608

[1] *Харківський національний університет імені В. Н. Каразіна*
майдан Свободи, 4, м. Харків, 61022, Україна

ОСОБЛИВОСТІ ГІДРОХІМІЧНОГО СКЛАДУ ПОВЕРХНЕВИХ ВОД ПРАВОБЕРЕЖНОЇ ЧАСТИНИ БАСЕЙНУ СІВЕРСЬКОГО ДІНЦЯ (ХАРКІВСЬКА ОБЛАСТЬ)

Мета. Визначити сезонні мінливості гідрохімічного складу поверхневих вод та оцінити екологічний стан водних об'єктів правобережжя Сіверського Донця в межах Харківської області.

Методи. Польові дослідження, аналітичні, системний аналіз, методологія визначення індексу забруднення води (WQI) ґрунтується на використанні методів агрегації.

Результати. Надано аналіз результатів екологічного оцінювання якості вод правобережних приток Сіверського Дінця, що протікають Харківською областю під час весняно-літнього водопілля та осінньої межені 2024 р. у річці Велика Бабка та ставку Молодова на шести репрезентативних створах, що відображають різне господарське використання. Визначено органоліптичні, фізико-хімічні показники та вміст важких металів. За результатами можна зазначити, що усі гігієнічні показники окрім жорсткості відповідали нормам. Оцінювання екологічної якості річок правобережної частини басейну Сіверського Донця здійснювалась на основі визначення індексу забруднення води на підставі власних польових досліджень та інформації з відкритих джерел. Серед наявних джерел забруднення виявлено міські комунальні стоки, працюючі підприємства, наслідки ведення сільського господарства, наслідки військових дій (р. Велика Бабка), дифузний вплив від сусідніх приток.

Висновки: За індексом забруднення поверхневих вод всі річки правобережжя Сіверського Дінця належать до III класу забруднення, помірно забруднені, лише р. Берека віднесена до II класу. Хоча загальний стан води залишається задовільним, є необхідність в заходах покращення якості води, особливо для таких річок як Уди, Мжа та Тетлега, на стан яких впливають підприємства та ведення сільського господарства. Річки Чепіль, Гомільша, Берека, Бишкін потребують проведення детальних польових гідрохімічних досліджень з метою уточнення рівня забруднення

КЛЮЧОВІ СЛОВА: *поверхневі води, гідрохімічні показники, індекс забруднення води, басейн Сіверського Дінця*

Конфлікт інтересів

Автори заявляють про відсутність конфлікту інтересів щодо публікації цього рукопису. Крім того, автори повністю дотримувалися етичних норм, включаючи уникнення плагіату, фальсифікації даних та дублювання публікацій.

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В роботі не використано ресурс штучного інтелекту.

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