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ORIGINAL ARTICLE

Ecological monitoring of water bodies in Central Polissya (Ukraine)

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Extensive and long-term use of Ukraine's rivers in various spheres of human activity has caused them to undergo significant changes. In many cases, their condition is approaching a crisis or has already acquired it. The flow of various pollutants into rivers results in significant changes in hydrochemical characteristics. The state environmental monitoring of water bodies uses a comprehensive approach, but not all water bodies are covered by state monitoring. We have conducted a comprehensive analysis of the ecological status of water bodies in Central Polissya, using current and retrospective data of hydrochemical, hydrobiological analysis for rivers described in this article. The article presents the results of the ecological assessment of surface water quality of rivers Uzh and Irsha, taking into account hydrochemical parameters that indicate the polluted state (class III) during 2018-2020 with a significant contribution and in the formation of the quality class of salt composition, trophosaprobiological block, and block of other toxic substances. Flushing from urban areas contributes a significant share to the pollution of Polissya's surface springs. An essential component of bioresources is fish stocks, which have been declining in recent years. The main factors hindering the development of fisheries and negatively affecting the reproduction of fish stocks are pollution of water bodies, violation of the hydrological regime, weakening of state control over the catch and sale of aquatic living resources. Analysis of the age composition of the ichthyofauna of the studied rivers by catching nets and tools for catching young fish makes it possible to determine perch (Perca fluviatilis) and silver carp (Carassius gibelio) dominate in the reservoirs. Currently, fish stocks in the rivers of the Dnieper basin are under intense pressure from poaching, which is one of the most negative anthropogenic factors.
Keywords: surface waters, ecological assessment, surface water quality, pollution, ichthyofauna, species composition.

Introduction

The current ecological situation in Ukraine can be described as a crisis when the ability of aquatic ecosystems to self-renew compared to the growth of anthropogenic pressure is ten times behind. Adverse climate change, increasing transboundary impact, irrational use of water resources, intensive growth of artificial discharges, the use of outdated technologies have led to significant problems within the water sector. Combining these and other harmful factors causes large-scale socio-environmental problems, especially in large industrial centers, where most rivers and lakes are sources of water supply and sewage receivers (Astrelin et al., 2015; Rud'ko, 2015; Feshchenko, 2016).

Under these conditions, it is most relevant and appropriate to study the current state of water bodies, substantiate scientific methods and means of ensuring the sustainable functioning of the water complex in river basins. It is also essential to examine the natural processes to preserve the biosphere, especially the most vulnerable part of it - surface freshwater. However, the preservation of the latter is possible only when water quality is considered, first of all, as a condition for the existence of aquatic ecosystems. Therefore, water protection activities should be aimed at meeting the requirements of certain sectors of economic activity and preserving natural waters as a habitat. Thus, the ecological understanding of water quality is related to its properties as a habitat for biota and a significant component of aquatic ecosystems (Honcharuk, 2009; Vasenko, 2010).

Currently, most tributaries of the Dnieper receive a significant load of pollution, which are classified as heavy and dirty. Given this, this study aims to assess the transformation of hydro ecosystems of Polissya under the influence of natural and anthropogenic factors. The monitoring allows to evaluate the ecological capacity and vulnerability of biohydrocenoses and establish the limits of their allowable loads and create a database for forecasting and developing a set of measures to protect

water bodies, their recovery from anthropogenic digression of biocenoses. An important task aimed at protecting surface waters is identifying "foci" of pollution and assessing their impact on the quality of river waters. The current standard methodology of estimating the degree of pollution is limited and does not define all spectrum of influence of the growing quantity of pollutants contained in water streams. Therefore, several methods are necessary for sufficient research (Dubyna, 2006; Klymenko, 2010).

Materials and Methods

The research is carried upon the example of waters of the Uzh and Irsha rivers that belong to the Dnieper river basin and are used for the needs of various spheres of the national economy. In order to obtain comprehensive and objective information on the current ecological status of the river basin and anthropogenic activities, we used data collection and analysis, chemical-analytical, laboratory, and mathematical (calculation of the integrated water quality index) methods.

The assessment of river water quality in the Uzh and Irsha basins was carried out on eight sites in Korosten district of Zhytomyr region and Ivankiv district of Kyiv region during 2018-2020, using the most common method of ecological assessment of water quality at the level of synthesis and analysis of long-term time dynamics according to the relevant categories of hydrochemical parameters (Romanenko et al., 1998). This technique assesses water quality by three blocks of indicators: salt composition (I1), tropho-saprobiological composition (I2), and specific toxic substances (I3). Based on standard environmental criteria, it is possible to compare water quality in water bodies in different regions and to calculate the integrated water quality index (IE), the value of which is equal to the arithmetic mean of the block indices:

$$I_e = \frac{(I_1 + I_2 + I_3)}{3}$$

where: I_1– index of pollution by components of salt composition; I_2– index of tropho-saprobiological (ecological-sanitary) indicators; I_3– index of specific indicators of toxic and radiation action.

Results and Discussion

The studied water resources belong to the right-bank Dnieper hydrological zone, a moderately developed river network and small river slopes (0.5–2 m/km). Also, the rivers of Polissya have weak valleys and vast floodplains, which are often flooded during the growing season. A significant part of rivers flow within the Zhytomyr and Kyiv regions is swampy (1-10%). The riverbeds are marked by meandering, their beds are often composed of sand and silt, but the water is the least turbid (up to 50 g/m^3).

The Irsha River is the largest and longest left tributary of the Teterev (total length - 132 km, catchment area - 3070 km^2), snow, and rain supply. The Uzh River is a right tributary of the Pripyat River (total length - 256 km, catchment area - 8080 km^2). River water is used for industrial and domestic water supply and irrigation (Dubyna, 2006; Klymenko, 2010).

Since there is no single indicator that would characterize the whole set of water characteristics, water quality is assessed based on a system of indicators. According to the Water Code of Ukraine (Vodnyy Kodeks..., 2011), water quality assessment is carried out based on ecological standards of water quality used for municipal and fishery purposes. The latter includes water bodies as habitats for fish and other aquatic organisms that require more stringent maximum permissible concentrations (MPCs) of water quality (Hranychno dopustymi znachennya..., 1990).

The quality of water, to some extent, depends on its ionic composition. The composition of solutes surface waters is very diverse, as they interact with different geological rocks. However, it is possible to identify critical hydrochemical indicators that assess water quality for different types of water use. For most natural waters, the total salt content is determined by cations Ca^{2+}, Mg^{2+}, K^+, Na^+ and anions HCO_3^-, SO_4^{2-}, Cl^-. Other ions are present in relatively small quantities, but in addition, they can significantly affect the properties and quality of water (Khilchevsky et al., 2012).

The analysis of the studied rivers of Polissya showed that the indicators of salt composition are within the MPC (100 mg/dm^3). The ion composition of the primary chemical pollutants in the Uzh and Irsha rivers is relatively stable, among them calcium (29–75 mg/dm^3) and hydrocarbonate ions (140–268 mg/dm^3) dominate.

Due to SO_4^{2-} and Cl^- ions, which enter the aquatic ecosystems naturally, and due to anthropogenic intervention, a significant share of mineralization is formed. Sulfate ions also enter natural waters due to the dissolution of sulfur-containing minerals (gypsum) and by oxidation of sulfur and sulfides.

In general, one of the leading natural factors that determine the mineralization of water is the volume of water runoff. During the last decade of the XXI century, excessive rainfall caused a significant washing of soils and rocks. The subject rivers fell into the range of natural waters with medium mineralization (200–500 mg/dm^3), according to the classification of O.O. Alekina (Khilchevsky et al., 2012). It is also well known that elements with high migration capacity (such as chlorine, sodium) are leached from excessive moisture areas, particularly Kyiv and Zhytomyr.

According to river monitoring, in Central Polissya's territory, almost all indicators of the *tropho-saprobiological* group exceed the MPC, as shown in Fig. 1.

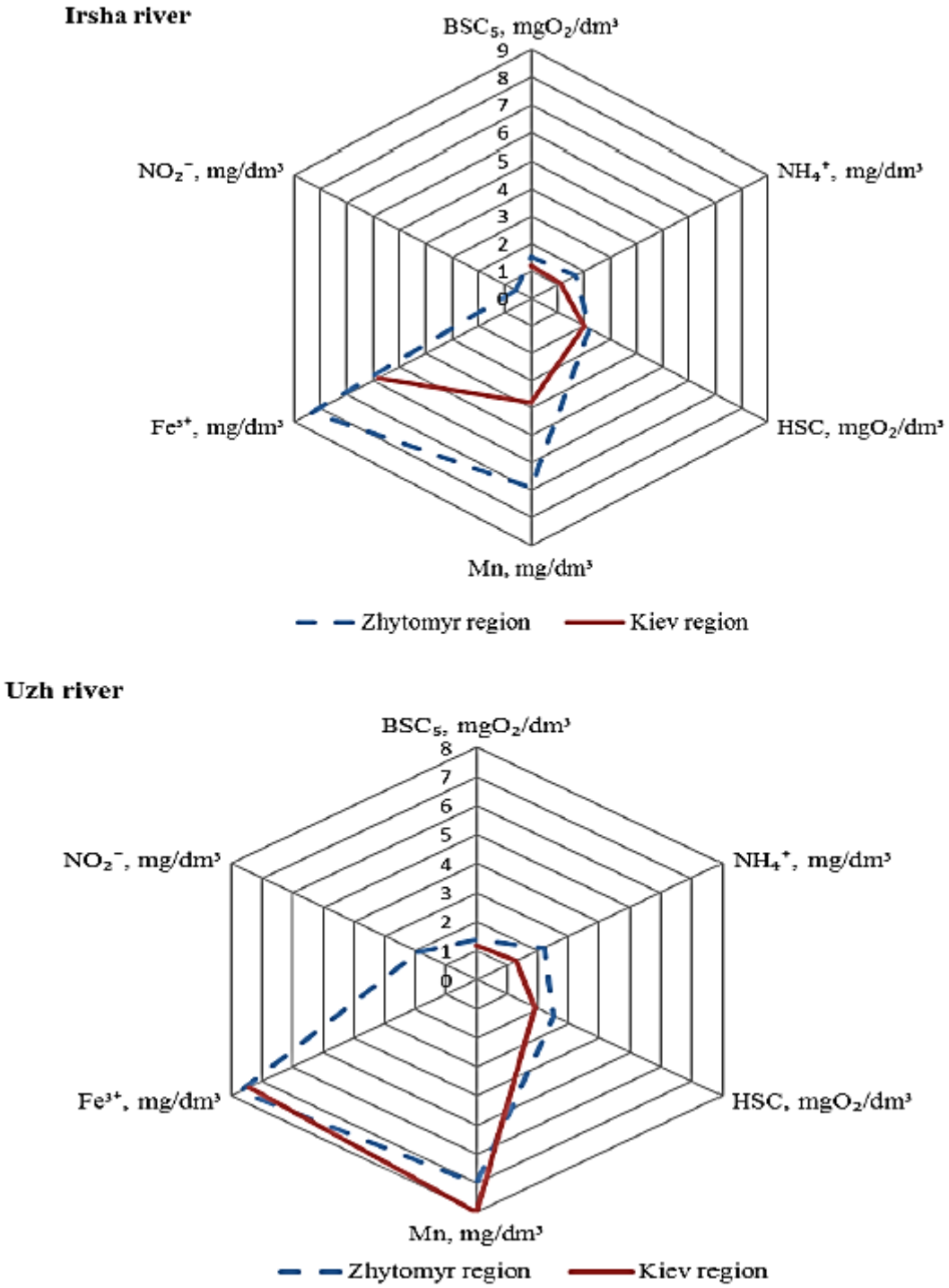


Fig. 1. Exceeding the MPC of tropho-saprobiological and toxic groups in the water of the Irsha and Uzh basins

Nutrients' content in natural waters is controlled by dissolved mineral ionic forms of compounds of nitrogen (NO_2^-, NO_3^-, NH_4^+) and phosphorus (PO_4^{3-}) are essential for ecosystems of water bodies. An increase in the concentration of NH_4^+ is often observed in water objects in places of dumping of sewage. The highest content of this pollutant was recorded in the river Uzh in the Zhytomyr region, reaching 0.85 mg/dm^3. One of the reasons for this is the inflow of wastewater from Korosten VUVKG and complete physical wear-out of technological equipment at the old treatment facilities. The smallest - in the river Irsha, which flows in the Kyiv region. (0.43 mg/dm^3) (see Fig. 1).

An important indicator of natural water pollution by organic matter is the biochemical oxygen demand for five days. In surface waters, BSC_5 usually varies in the range of 0.5–4 mg O_2 /dm^3 and is subject to seasonal and diurnal fluctuations, which depend mainly on temperature changes and the initial concentration of dissolved oxygen. Quite significant changes in the values of BSC_5 depend on the degree of water pollution. The analysis of BSC_5 values indicates insignificant exceedances of the MPC throughout the study period. This trend is most pronounced for targets that are located in areas affected by wastewater. Thus, the latter comes to the Irsha River in the Zhytomyr Region from the Irshansky DKP, the Irshansky GOK, as well as the Malynsky Paper Mill and the Malynsky Banknote Factory.

During the monitoring, the water quality of the studied rivers in the Zhytomyr and Kyiv regions gradually changed in the direction of deterioration with increasing organic pollution. Analysis of the hydrochemical state of rivers shows that the highest pollution is in the Uzh River in Korosten, where high rates of organic water pollution reach 37.9 mg O_2/dm^3. In the future, downstream pollution decreases, and the open field of surveillance has a minimum value - 29.1 mg O_2 /dm^3 (Ivaniv district of Kyiv region).

Indicators of NO_2^- content exceed the maximum concentration limits only in the Zhytomyr region, which indicates the intensive decomposition of organic matter and delayed oxidation of NO_2^- to NO_3^-, as well as water pollution (see Fig. 1, 2). As for the nitrate ion content, their high concentrations are not typical for the aquatic ecosystems of Polissya. According to research results, their concentrations did not exceed the maximum concentration limit for fishery reservoirs. Thus, the maximum concentration in the Irsha River (Zhytomyr Region) reaches 2.63 mg/dm^3, which is much lower than the MPC. In addition, the stable state of the studied aquatic ecosystems confirms the average pH value, which varies slightly. The development of aquatic plants and the nature of production processes depend on this indicator.

After analyzing the diagram (see Fig. 1), we can conclude that in the group of specific toxic substances, there is also an excess of the maximum concentration limit, in particular total iron and manganese, the content of which is 5.8–8.3 times and 3.8– 6.9 times respectively. Regarding the total iron content, a significant amount comes from groundwater, wastewater from metallurgical, metalworking, textile industries, and agricultural effluents. In addition, along with the factor of anthropogenic impact, the main form of Fe (III) entry into surface waters is played by physical and geographical features of the territories. The high level of groundwater, weak surface-slope runoff contribute to waterlogging, and the low forest cover of the territory causes an increase in its concentrations in the studied rivers. In addition to the anthropogenic component, the distribution of manganese ions is influenced by a natural factor, as Mn_2^+ is formed due to the extinction and decomposition of aquatic organisms, including blue-green (*Cyanobacteria*) and diatoms (*Bacillariophyta*), and higher aquatic plants. In general, the group of prokaryotic organisms that currently play an essential role in the life of aquatic ecosystems is one of the leading producers of organic matter (Dubyna, 2006).

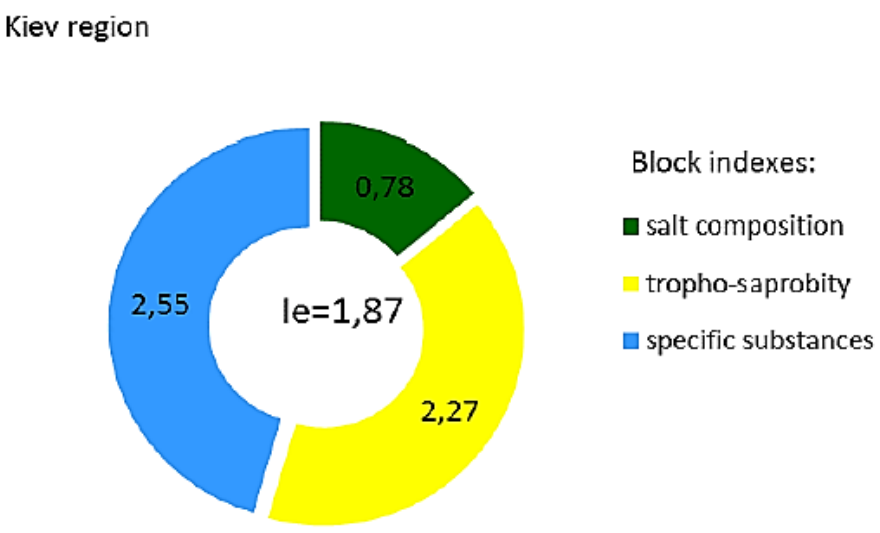
Heavy metals also occupy a predominantly important place in some toxic compounds, as once in, they practically do not get removed from natural ecosystems. Over time, they only change their form of existence, redistribute, and gradually accumulate in various abiotic and biotic aquatic ecosystem components. The responsibility for the entry of heavy metals into the water lies upon the enterprises, whose activities are related to the use of heavy metals in the production cycle and which do not have local treatment plants that provide high-quality treatment (Serpokrylov, 2009).

The waters of the studied rivers contain low concentrations of Cu, Zn, as they flow within the Ukrainian crystalline shield, where they come to the surface or lie close to the day surface and are covered by poor sedimentary rocks of water-glacial origin of sandy and sandy granulometric composition (granite, gabbro, labra) with relatively small reserves of trace elements. Thus, the highest rates in the Irsha River (Zhytomyr Region) were recorded for copper and reached 0.018 mg/dm^3, and the lowest - in the Uzh River (Kyiv Region) for zinc (0.003 mg/dm^3).

The data obtained from studying the hydrochemical composition of water samples is used to calculate the complex ecological index (I_e) of water quality according to the values of 5 classes and seven categories according to the degree of their purity.

According to the calculated comprehensive ecological index, which allowed to reflect in more detail the trend of water quality in the rivers of Central Polissya (Figs. 2, 3), it was recorded that the water quality of most rivers of Polissya in controlled areas corresponds to class III category 4 (polluted water). According to the average levels of indicators, the worst water quality is marked by the block of indicators of specific substances. Only the water of the Irsha River (Kyiv region), according to the results, can be classified as class II category 3.

a



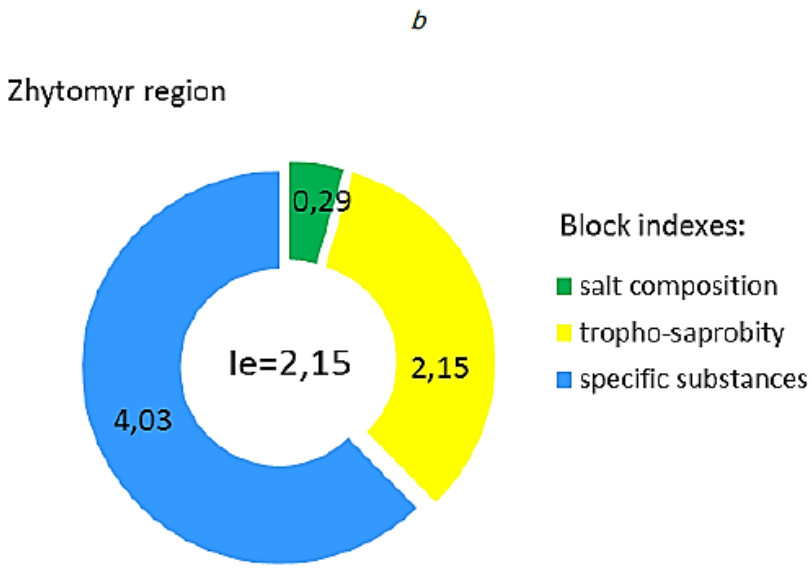


Fig. 2. Ecological assessment of water quality of the Irsha river basin in Kyiv (*a*) and Zhytomyr (*b*) regions

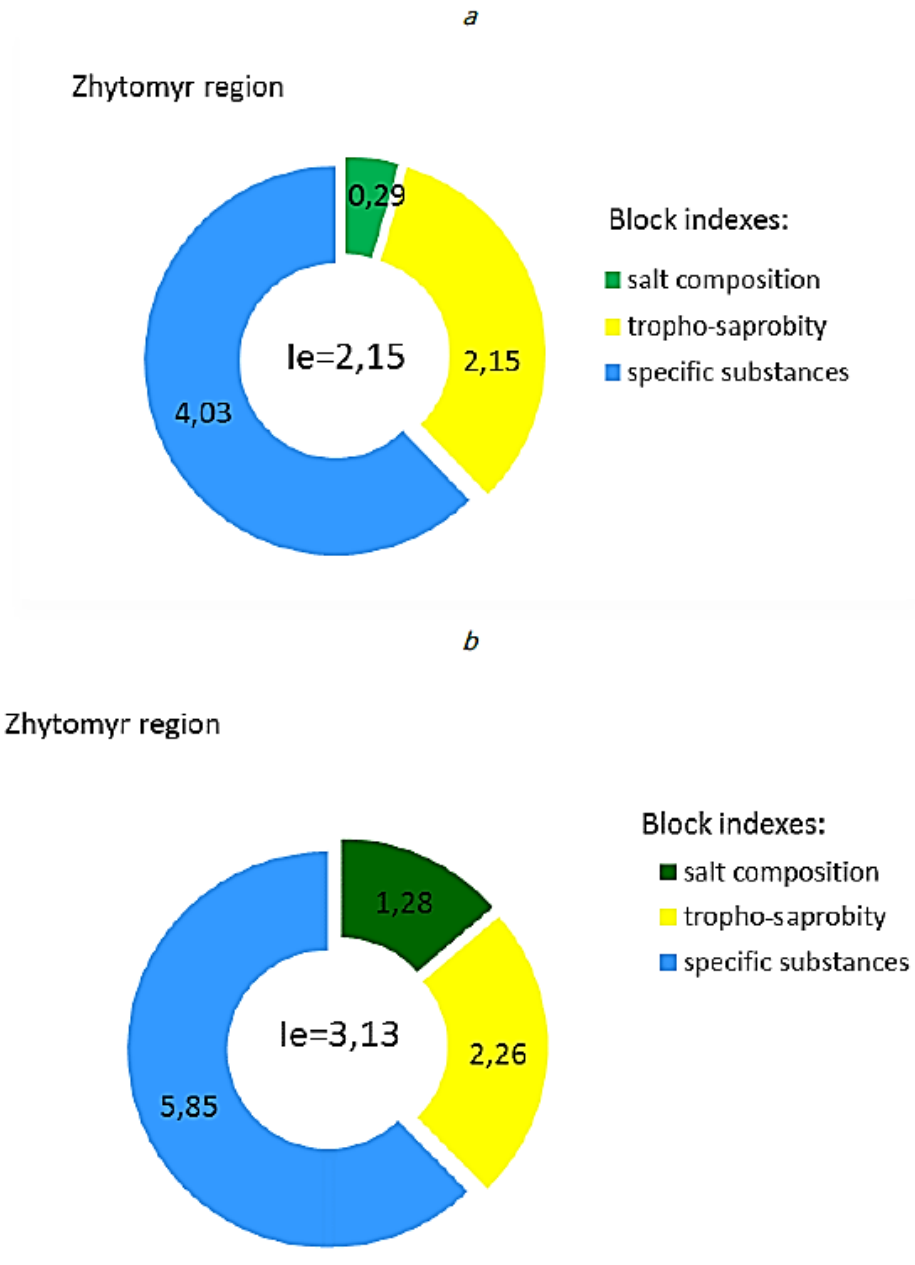


Fig. 3. Ecological assessment of water quality of the Uzh river basin in Kyiv (*a*) and Zhytomyr (*b*) regions

There are several possible explanations for these results. First of all, there is a seasonal deterioration of the ecological condition of the studied water bodies, which is caused by harmful factors of man-caused and natural nature. Thus, there has been a shortage of water in river basins in recent years due to their natural low water content. Also, the ecological condition of water bodies is negatively affected by significant plowed lands, low forest cover, over-regulation of rivers by reservoirs, chaotic construction of floodplain river lands, discharge of polluted wastewater into rivers due to insufficient treatment facilities, use of outdated treatment technologies or no treatment and the consequences of the Chernobyl disaster. Also, the deterioration of natural water quality is due to the violation of their self-cleaning ability. Everyone knows that river ecosystems can self-clean, but now there is a threat of transition to a crisis in the most polluted areas. This means that considerable increases in the pollutant concentration may not cause catastrophic consequences, but a little later, even a slight addition causes a catastrophe. First of all, it is the discharge of insufficiently treated domestic and wastewater (e.g., KP "Zhytomyrvodokanal", KP "Ivankivvodokanal", Volodarsk-Volynske ZhKP, PJSC "Ushytsya plant of building materials", OJSC "Ivankivsky butter factory", Oran starch plant), the number of which is growing, as well as inflated standards and environmentally hazardous methods of chemical fertilizers, and plant protection products. Because of this, it is recommended to carry out wastewater treatment via biological means with the subsequent use of these waters in irrigation fields. Drainage reclamation and violation of river feeding regime, straightening of their channels and hydraulic engineering construction, and violation of water protection regime in coastal territories contribute to the decrease of self-cleaning capacity of Polissya rivers.

A significant environmental problem is eutrophication, which is associated with reduced flow, expanding the area of shallow areas, and caused by the construction of a cascade of reservoirs. The main reasons for this process are the leaching of mineral fertilizers from agricultural fields, water pollution from livestock complexes, and the accumulation over time of livestock and crop residues. Since then, the water gradually becomes turbid, silt and detritus accumulate at the bottom, and reservoirs become eutrophicated for tens and hundreds of years, which is manifested in "aging". Also, non-compliance with environmental requirements in the implementation of agricultural activities and unauthorized plowing of lands almost to the water's edge leads to the washing away of humus and increase the area of eroded lands.

Besides, the issue of protection of water bodies from "blooming" remains unresolved. The latter is the presence of shallow water, where the development of cyanobacteria, the intensity of which increases every year.

Flushing from urban areas contributes a significant share to the pollution of Polissya's surface springs. Due to insufficient funding, construction and reconstruction of water supply and sewerage facilities are virtually non-existent. Destruction of hydraulic structures can lead to shallowing of rivers, intensification of erosion processes, deterioration of sanitary and epidemiological conditions in settlements and river basins, lack of recreation areas. In most settlements, particularly the town of Ivankiv, Irshansk has an unsatisfactory condition, or there are no sewerage networks and treatment facilities, contributing to the quality of surface water bodies in general in control areas in particular.

It is known that the waste of agro-industrial enterprises leads to a negative impact on the ichthyofauna, in particular on the development of eggs, hatching larvae, their growth, development, and preservation, as well as disrupt several physiological functions in adults. Fish representing the upper step of the trophic pyramid is the most sensitive link to the state of the environment in general and water quality in particular. As there is currently a significant degradation of water bodies, there are significant changes in the ichthyofauna, as evidenced by the gradual decrease in species composition and fish population and reduction of fishing (Bulakhov et al., 2008; Kurbatova & Tsedyk, 2012).

Given the work of previous researchers (Kessler; Belinh; Lyashenko; Sattarov; Kunytskyy), we can say that the water resources of Central Polissya have a heterogeneous species composition of ichthyofauna. In the Teterevo basin, the fish population is represented by pike (*Esoxlucius*), which occurs both among coastal shrubs and in deeper places, horse mackerel (*Alburnus alburnus*), found in slow-flowing rivers, as well as whiting (*Rutilus rutilus*), pikeperch (*Gut*) gobio), perch (*Perca fluviatilis*), which avoid strong currents. The species composition of fish in the Pripyat basin includes nine species, most of which belonged to carp (*Cyprinidae*). An invasive species, *Perccottus glenii* (Protasov, 2002; Movchan, 2012), occurs singly.

Assessing the current state and observing trends in the composition of the ichthyofauna of the studied reservoirs, it becomes clear that the tense environmental situations that have developed in water bodies in recent decades have significantly affected biodiversity. After analyzing the current state of waterways in Polissya, it was found that the ichthyofauna of rivers is significantly impoverished. During the research period, 9 and 4 species of fish and their young belonging to 2 families were registered in Uzh and Irsha, respectively. Analyzing the composition of the ichthyofauna of the studied rivers made it possible to determine that the perch (*Perca fluviatilis*) and the silver crucian (*Carassius gibelio*) dominate in the reservoirs. Less common are carp (*Cyprinus carpio*), white (*Hypophthalmichthys molitrix*) and variegated (*Hypophthalmichthys nobilis*) silver carp, and other species of fish of larger and smaller sizes.

It should be noted that the growth and development of germ cells of fish are negatively affected by changes in environmental factors. Thus, reducing river runoff and falling water levels, reducing oxygen in the winter significantly change the direction of metabolic processes in fish. Also, in reservoirs subject to anthropogenic impact, the indicators of individual absolute fertility of fish increase, and during the summer period, asynchrony of oocyte development is observed. All this affects the physiological state of fish, affects biochemical and histological parameters, and affects the size, age, and sex structure of populations.

In general, a brief analysis of the general composition of ichthyofauna about the rarity or possibility of the modern existence of many fish in reservoirs indicates the need for continuous monitoring of this group of animals. Of particular concern is that today, among the modern aboriginal inhabitants of the studied rivers, most fish have become rare, and some have disappeared altogether, which threatens the decline of ichthyofauna shortly. Therefore, the reservoirs of Central Polissya now require a set of works to improve the conditions of reproduction, including acclimatization. The main industrial reservoirs should have their

separate rehabilitation programs, which will prescribe specific measures to improve the ecological status of reservoirs and the state of their aquatic living resources.

The state and the whole nation can only achieve the solution to all these problems. Improving the ecological condition of the Dnieper basin is possible through a targeted state environmental policy. Resolution of issues related to the water factor, May 24, 2012, the Verkhovna Rada of Ukraine considered in second reading the draft law "On approval of the National Target Program for Water Management and Environmental Rehabilitation of the Dnieper River Basin until 2021" and adopted in general as the Law (Protasov, 2002). The implementation of all planned activities with the participation of all stakeholders and the public will restore the ecological condition of the country's rivers.

Conclusions

Monitoring of water quality of the Uzh and Irsha rivers shows that despite the significant decline in industrial production in recent years and the reduction, therefore, of wastewater discharges, the Kyiv and Zhytomyr regions tend to deteriorate. Thus, water quality in the studied rivers deteriorated due to discharges of insufficiently treated wastewater. As a result, water has high levels of total iron, ammonium nitrogen, manganese. Besides, the concentration of nutrients that enter the water during the decomposition of animal and plant organisms is insignificant, but these elements determine the level of productivity of water bodies and, thus, determine their water quality. The Irsha and Uzh rivers have high ammonium content, which indicates anaerobic conditions for forming the chemical composition of water and its unsatisfactory quality. Furthermore, the concentration of nitrates is insignificant due to their consumption by aquatic organisms.

Currently, almost all reservoirs in terms of pollution have approached the third class due to wastewater from industrial enterprises, domestic sewage, unsatisfactory operation of equipment at treatment plants. With the diversification and strengthening of the impact on both reservoirs - the habitat of fish, and directly on them in the development of their reserves, the state of the diversity of ichthyofauna of reservoirs deteriorates in both qualitative and quantitative indicators.

So far, not many "healthy" rivers remain, as most suffer from reckless interference, but there are also those that have not lost the ability to recover. Therefore, it is necessary to know well and learn to understand the river, which we are cruelly exploiting, draining swamps, polluting the water with industrial waste, destroying the natural environment. In the future, only knowledge of the processes occurring in aquatic ecosystems can become a reliable basis for conservation and rescue.

References

Alekseyev, L.S. (2009). Kontrol kachestva vody. Moscow: INFRA-M (in Russian).

Astrelin, I., Herasymov, E., Hirol, A. et al. (2015). Fizyko-khimichni metody ochyshchennya vody. Upravlinnya vodnymy resursamy. Kyiv: Water Harmony (in Ukrainian).

Bulakhov, V.L., Novitskyy, R.O., Pakhomov, O. E. & Khrystov, O.O. (2008). Biolohichne riznomanittya Ukrayiny. Dnipropetrovs'ka oblast. Kruhloroti (*Cyclostomata*). Ryby (*Pisces*). Dnipropetrovsk: Dnipropetrovsk National University (in Ukrainian).

Dubyna, D.V. (2006). Vyshcha vodna roslynnist. *Lemnetea*, *Potametea*, *Ruppietea*, *Zosteretea*, *Isoeto-Littorelletea (Eleocharition acicularis, Isoetes lacustris, Potamion graminei, Sphagno Utricularion), Phragmito-Magnocaricetea (Glycerio-Sparganion, Oenanthion aquaticae, Phragmition communis, Scirpion maritimi*). Kyiv: Fitosotsiotsentr (in Ukrainian).

Feshchenko, V.P. (2016). Ratsionalne vykorystannya ta vidnovlennya vodnykh resursiv. Zhytomyr: Zhytomyr State University named after I. Franko (in Ukrainian).

Honcharuk, V.V. (2009). Khimiya vody i problemy pytnoho vodopostachannya. Nauka i Tekhnolohiyi, 4, 18-27 (in Ukrainian).

Hranychnodopustymi znachennya pokaznykiv yakosti vody dlya rybohospodarskykh vodoym. Zahalnyy perelik HDK i OBRV shkidlyvykh rechovyn dlya vody rybohospodarskykh vodoym (1990). No 12-04-11, 09-08-1990. Kyiv: Ministerstvo rybnoho hospodarstva SSSR (in Ukrainian).

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