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Dynamics of changes in surface water quality indicators of the Western Bug River basin within Ukraine using GIS technologies

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Abstract

The environmental assessment of the surface water quality of the Western Bug River has been made using the system of classification quality of land surface water of Ukraine in accordance with the approved methodology, which allows comparing water quality of separate areas of water objects of different regions. The calculation of the environmental assessment of water quality has been carried according to three blocks: block of salt composition, block of trophic and saprobic (ecological and sanitary) indicators and block of indicators of content of specific toxic substances. The results are presented in the form of a combined environmental assessment, based on the final conclusions of the three blocks and consists in calculating the integral ecological index. Comprehensive studies of changes in the water quality of the Western Bug River have been conducted within the territory of Ukraine for a long-term period. The water quality of the river on the final values of the integral indicators of the ecological condition corresponded mainly to 4nd category of the 3rd class – the water is “satisfactory” by condition and “little polluted” by degree of purity (except for points of observation that located within the Volyn region, where the water quality corresponded to 3rd category and the 2nd class. It is “good” by condition and “fairly clean” by the degree of purity). Visualization and part of the analysis are performed using GIS technologies in the software of the ArcGIS 10.3.

Key words: *ecological index, environmental assessment, environmental condition, GIS technologies, river, surface water, water quality*

INTRODUCTION

The deterioration of the ecological situation of river systems in Ukraine as a result of irrational use of water resources, significant technological influences is a very perceptible problem and constitutes a hidden danger for present and future generations. The main sources of pollution of river basins are industrial and municipal waste water, agricultural runoff, surface runoff and atmospheric precipitation. The issue of assessing the quality of surface water during the transboundary transfer of pollutants by rivers from the territory of one state to another, which can lead to negative changes in the river basin, creating potential threats to the environment and human security, is becoming particularly urgent [BIELSKI 2012; KLYMENKO *et al.* 2013; KLYMENKO, LIKHO 2009].

The study of water quality is a pressing issue, is of theoretical and practical importance since the Western Bug River is transboundary. The water resources of the Western Bug are used not only by Ukraine, but also by Poland and Belarus.

However, the existing significant anthropogenic load on the ecosystem of the river basin leads to a number of negative processes causing among other things the water quality deterioration. This issue is extremely important since it should be borne in mind that on the territory of Poland, the Western Bug River flows into the Zegrze Reservoir, which is the main source of drinking water for the city of Warsaw.

Monitoring of the environmental condition of surface water, especially transboundary rivers, is one of the main tasks of the state's environmental activities, the solution of which requires the joint efforts and means of neighbouring states aiming to preservation, rational use of surface waters, as well as mutual approximation of national and international laws, standards, implementation of active international environmental cooperation. Therefore, it is necessary to conduct timely observations of the qualitative condition of the surface water of the river basins and to analyze and summarize information about the condition of water bodies and predict its changes [KLYMENKO *et al.* 2013; KLYMENKO, VOZNYUK 2010; KRENGEL *et al.* 2018; ZABOKRYTSKA 2011].

The aim of the study is to analyze the changes in the quality indicators of the surface water of the Western Bug River basin (within Ukraine).

A lot of scientific studies is devoted assessing of the water quality from different positions. A lot of scientific studies is devoted of the ecological condition of the river were carried out after the creation of the transboundary association "Euroregion Bug".

A significant contribution to the methodology of complex and integrated assessment of the ecological condition of river basins were made by YATSYK *et al*. [2006] and KLYMENKO, VOZNYUK [2010]. The research of the assessment of the ecological condition of river basins were carried out by such scientists as: KLYMENKO, LIKHO [2009], ZABOKRYTSKA [2011], KOYNOVA *et al.* [2012], KOZYTSKA, MUZYCHENKO [2015], BURZYŃSKA [2016], VOZNYUK *et al.* [2017], and YATSYIK *et al.* [2017].

A large number of studies of Ukrainian, Polish and Byelorussian scientists are covered in the monographs published by the Warsaw School of Ecology and Management on the basis of international conferences on environmental problems of the Bug and Narva basins [BILYK, KOYNOVA 2009; KOYNOVA *et al.* 2012].

MATERIALS AND METHODS

The environmental assessment of the water quality in the Western Bug River was carried out using a system of classification of standards of the assessment of the quality of surface waters in Ukraine, given in the "Methodology..." [YATSYK *et al.* 2006]. On the basis of common environmental criteria, the method allows comparing the quality of water in separate areas of water objects in time and space, to determine the impact of anthropogenic loading on aquatic ecosystems, to assess changes in the condition of water resources. In our opinion, it fully meets the requirements of the EU Water Framework Directive 2000/60/EC [2000].

Characteristics of surface water quality includes a set of hydrophysical, hydrochemical, hydrobiological, specific and other indicators that reflect the features of the abiotic and biotic components of aquatic ecosystems [KLYMENKO, VOZNYUK 2010].

Environmental assessment of water quality involves the following steps: 1) collecting, grouping and statistical processing of source information; 2) definition of classes and categories of water quality according to individual indicators; 3) generalization of water quality assessments by separate indicators of each block with the definition of integral values of classes and water quality categories for each block; 4) determination of the joint assessment of water quality in a water object for a certain period of observation.

The calculation of the environmental assessment of water quality carried out within three blocks (Fig. 1): 1) block of indicators salt composition (I_1) which includes chlorides, sulphates, criterion of mineralization; 2) block of trophic and saprobiological (ecological and sanitary) indicators (I_2), including content: suspended matter, nitrates, nitrites, ammonium nitrogen, phosphates, dissolved oxygen, hydrogen index – pH, chemical oxygen consumption, biochemical oxygen consumption for 5 days; 3) block of indicators of content of specific toxic substances (I_3), which consists from one (general iron) to eight components (general iron, copper, zinc, manganese, total chromium, phenols, petroleum products, synthetic surface active substances). An integral (ecological) index (I_E) was calculated on a base of the values of block indices for to determine the class and water quality category. The procedure for determining the categories of water quality according to the ecological classification for each hydrochemical indicator by average values allowed the absolute quantitative values to be converted into unified, integral indicators of water quality (indices, categories, subcategories, classes), which reflect the essence of the process. This one the changes in the conditions for the formation of water quality under the influence of anthropogenic factors were fixed by the indices, and were defined boundaries of fluctuations of ecological indices of water objects which have important for the decision of issues of water management, implementation of environmental protection and restoration measures (Fig. 1).

Calculation values of integral ecological indices (I_E) is compared for according to the environmental classification with qualitative condition of water and the class and category of its quality is determined. In general, water quality is divided into five classes, which are accepted in many European countries. These classes have certain characteris-

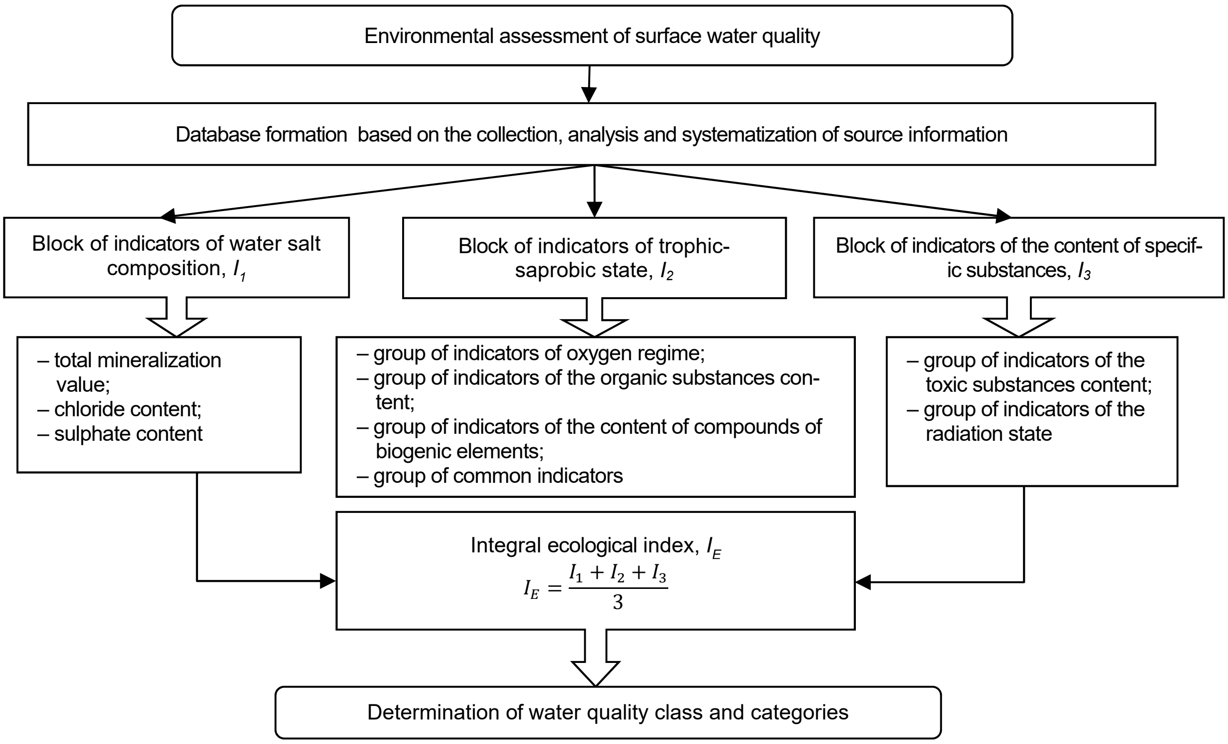

Fig. 1. Flowchart of the environmental assessment of the surface waters quality of the Western Bug River; source: own elaboration

Table 1. Classes and categories of surface water quality according to the ecological classification

Value of indicator I_E		1.0–1.50	1.51–2.50	2.51–3.50	3.51–4.50	4.51–5.50	5.51–6.50	6.51–7.00
Water quality classes and categories by their natural condition	class	I	II		III		IV	V
		excellent	good		satisfactory		bad	very bad
	category	1	2	3	4	5	6	7
		excellent	very good	good	satisfactory	mediocre	bad	very bad
Classes and categories of water quality by the degree of its cleanness (pollution)	class	I	II		III		IV	V
		very clean	clean		polluted		dirty	very dirty
	category	1	2	3	4	5	6	7
		very clean	clean	fairly clean	slightly polluted	moderately polluted	dirty	very dirty

Source: YATSYK *et al*. [2006].

tics and a corresponding colour of the designation, which allows to clearly illustrating the ecological condition of the reservoir (Tab. 1).

Certainly, with such a number of calculations to be carried out during the environmental assessment of the quality of surface water, it is necessary to use modern technologies of geographic information systems (GIS), both for carrying out calculations themselves and for visualizing their results. After all, they allow not only to visualize the quality of river water on the map, but also to reflect the dynamics of its changes, and automatically change the colour gamma according to the proposed method [YATSYK *et al*. 2006]. The use of geoinformation systems will allow in the future to track the causal relationships of changes in water quality indicators after the implementation of a complex of water protection measures implemented to improve them, or after the emergence of new additional sources of pollution.

The geodatabase, which contains layers of vector data, was created using ArcGIS. In addition to the standard set of layers (forests, roads, administrative boundaries, settlements, etc.), particular attention is paid to the organization of surface water data. In particular, the "Points of observation" layer was added, while the Western Bug River was divided into sections between these points. In the table of attributes columns on the water quality of the Western Bug River have been added. All this allows you not only to store information, but also to display the water quality of these areas in the colour range. In the future it is supposed to create a database in order to save information about the research results; connect modules for analysis of the dynamics of water quality change and predict the quality of the future; manage administration for multi-level access to information, and also publish the map with a piece of information on the Internet for all interested persons and organizations.

Figure 2 provides an example of the organization and visualization of GIS "Surface water quality assessment" in ArcGIS 10.3. By using the geodatabase as the basis, we can also carry out different types of analysis, and create thematic maps. For example, in Figure 3 there is a thematic map "Environmental assessment of the state of surface waters of the basin of the Western Bug".

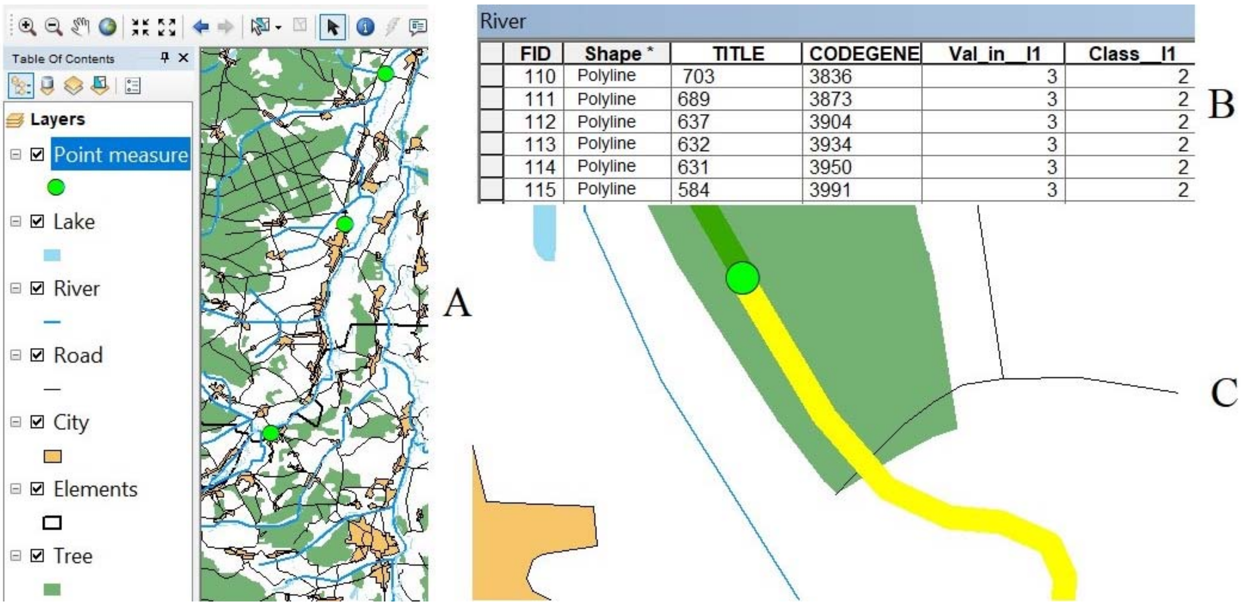

Fig. 2. Example of organization and visualization of GIS «Surface water quality assessment» in ArcGIS 10.3; A) an example of geodatabase organization; B) an example of adding attribute data to the geodatabase; C) an example of visualization of water quality of surface water according to the selected classification; source: own elaboration

RESULTS AND DISCUSSION

The Western Bug River is a transboundary river whose basin is located on the territory of three states: the Republic of Poland (49.2% of the area), Ukraine (27.4%), the Republic of Belarus (23.4%). The total area of the basin is 73,470 km^2. The length of the river is 772 km (within Ukraine – 404 km). The total river flow in the Western Bug basin in the average water year is 3,885 mln m^3, including in Ukraine – 1,317 mln m^3, in Belarus – 1,131 mln m^3, in Poland – 1,437 mln m^3 [KHILCHEVSKYI *et al.* 2016].

The Ukrainian part of the Western Bug River basin lies within the Volyn and Lviv regions of Ukraine, and borders in the South-West with the San River basin, in the South with the Dniester River basin, in the East with the Prypiat River basin, in the North with the Republic of Belarus, on West – with the Republic of Poland. The main tributaries of the Western Bug are the rivers Rata, Poltva, Luga, Gapa. Along the coastal strip there are 45 settlements. Surface water of the Western Bug for drinking water is not used [YATSYIK *et al.* 2017].

The condition of the surface water of the Western Bug River largely depends on the negative impacts that it undergoes in the process of water use and economic activities at the water intake. 444 water users are registered in the Ukrainian part of the basin of the Western Bug [Informatsiinyi… 2018], of which 43 are directly discharged, the rest carry out discharges into the general urban sewage systems. Among the point sources of pollution, 40% are enterprises of housing and communal services [KOYNOVA *et al.* 2012].

The main influence on the surface water quality of the basin is had by communal and industrial enterprises of the Lviv region (95% of all waste water). Influence of the enterprises of the Volyn region on the quality of river water is insignificant. As the volume of allotting in the surface water of the return water from the objects of the oblast is only 5% of the total drainage [KOYNOVA 2015].

The West Bug River also receives insufficiently treated industrial and agricultural drains, which results in an increase in the content of suspended matter and mineralization in the river waters, and the deterioration of the oxygen regime [KLYMENKO *et al.* 2003].

In recent years, the total use and drainage volume is more or less stable. The annual water intake from the rivers of the basin of the Western Bug ranges from 90–95 mln m^3. Of these, 75% are taken from underground aquifers, 25% from surface water.

In sectoral terms 54% of the needs of utilities are taken away, agriculture – 30%, industry – 15%, other objects – 1% [Informatsiinyi... 2018]. The dynamics of water use during the observation period shows that in the river basin there is a tendency to decrease the intake of water and its use that is primarily due to a drop in demand for production purposes.

The discharge return water in average is 180–190 mln m^3, 25% of which are classified as contaminated. The volumes of polluted (without cleaning) sewage slowly increase each year due to poor condition of municipal wastewater treatment facilities of cities. In 2017 about 64.0 mln m^3 of untreated wastewater was received in the surface water basins of the Western Bug River. Compared to the previous year, volumes increased by 24.3 mln m^3. It is worth noting that over the past few years there has been a tendency towards a reduction in the amount of pollutants that are thrown down in surface water objects by water users of the pool. In 2017, enterprises-water users of the basin had dropped of pollutants by 47.76 thous. t less, compared with 2016 [Informatsiinyi... 2018].

The main sources of water pollution in the West Bank region are the municipal economy, whose enter-

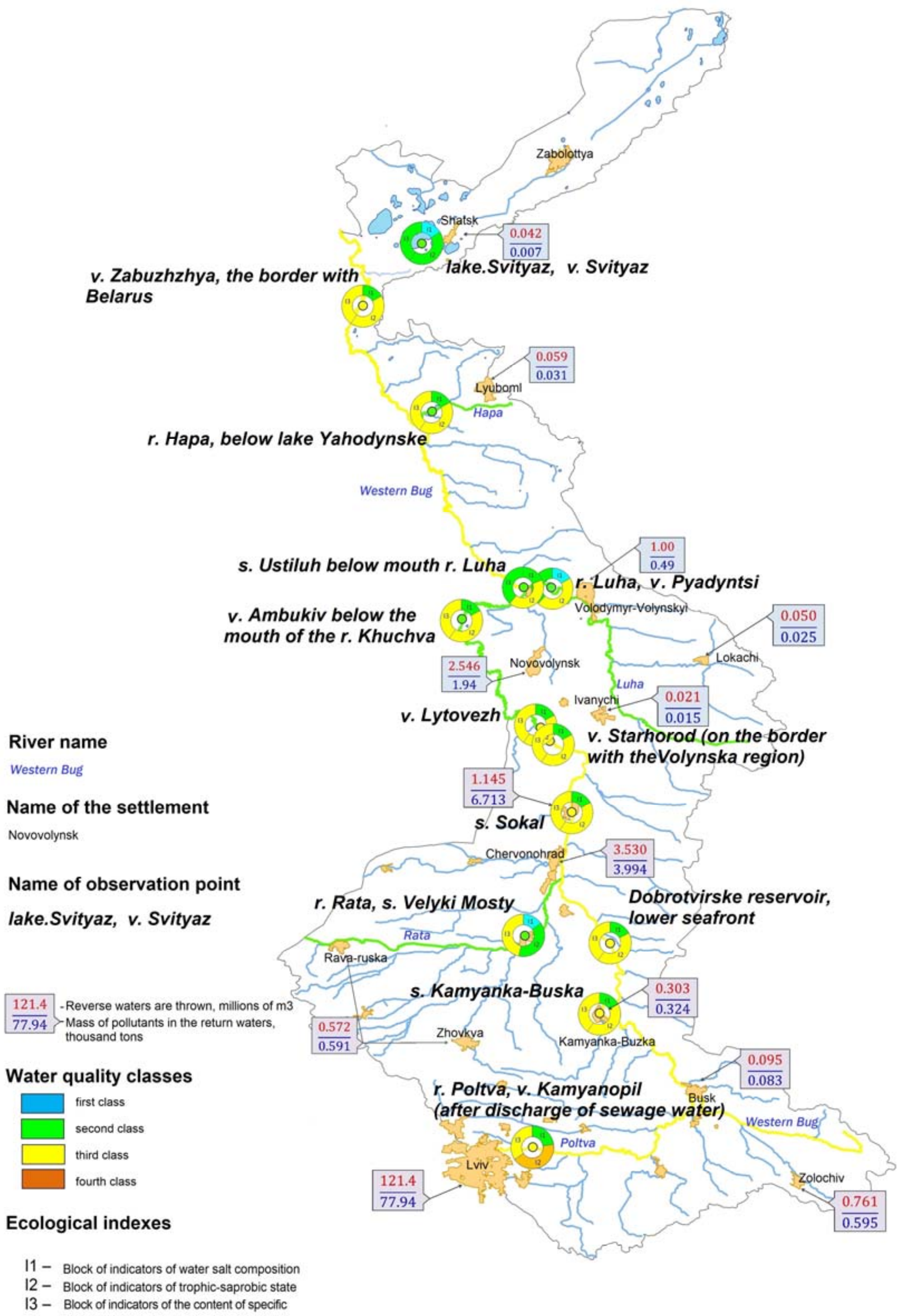

Fig. 3. Thematic map "Environmental assessment of the state of surface waters of the basin of the Western Bug"; source: own elaboration

prises dispose of 80% of the total waste, industry have 10.6% and agriculture have 8.7%. The main pollutants entering the river are: ammonium nitrogen, total iron, phosphates, nitrates, phenols, suspended matter, dissolved salts, petroleum products [CHMIELOWSKI *et al.* 2016; KLYMENKO *et al.* 2003; VOZNYUK *et al.* 2017].

The largest volumes of discharges in the Western Bug are carried by the Lviv water supply canal. The share of this enterprise in the total volume of waste water is about 90%.

In addition, in the basin of the Western Bug River within the Lviv and Volyn regions, according to official data, are more than 200 landfills are located on an area of about 200 ha, most of which do not have the necessary permits. The landfills near Kamenka-Buzka, Dobrotvora, Novy Yaricheva, Zapitova, which today have exhausted the project loadings and require reclamation, constitute a significant environmental hazard [BILYK, KOYNOVA 2009; KOYNOVA 2015; KOYNOVA *et al.* 2012].

Therefore, it is necessary to further introduce and implement measures aimed at restoring the quality of the water of the river basin by means of further reduction of discharges of sewage of settlements, construction of new and modernization of existing treatment facilities with a full cycle of sewage treatment, sewer networks, introduction of a system of fines for non-compliance with the requirements of the current water protection legislation [KLYMENKO, VOZNYUK 2010; KOZYTSKA, MUZYCHENKO 2015]. Solving these tasks requires improving the efficiency of the network of national and transboundary monitoring of surface water quality, creating organizational structures for the integrated management of the Western Bug basin, and integrating water protection measures by neighbouring states in accordance with the requirements [ILNICKI 2014; KLYMENKO, LIKHO 2009; KRENGEL *et al.* 2018; ZABOKRYTSKA 2011].

In determining the general trends of changes in the environmental condition of the surface water of the Western Bug River basin, a long-term observation period from 2013 to 2017 has been chosen. To the output data for ecological assessment of water quality in the Western Bug River we take the results of many years of systematic hydroecological monitoring of water quality carried out by the services of analytical control and monitoring of the West Bug River Basin Water Management (Ukr. Zakhidno-Buz'ke baseynove upravlinnya vodnykh resursiv); Lviv Regional Department of Water Resources (Ukr. L'vivs'ke oblasne upravlinnya vodnykh resursiv) and Volynsky Regional Department of Water Resources (Ukr. Volyns'ke oblasne upravlinnya vodnykh resursiv); Department of Ecology and

Table 2. Value of block and ecological indices by water quality categories of the Western Bug River

No.	Observation point (distance from the mouth of the river)	Year	Value of the block index, I_1	Water quality class	Value of the block index, I_2	Water quality class	Value of the block index, I_3	Water quality class	Value of the block index, I_E	Water quality class
1	Kamianka Buzka town (704 km)	2013	2.7	II	4.8	III	4.0	III	3.83	III
		2014	2.7	II	5.0	III	4.0	III	3.89	III
		2015	3.0	II	5.0	III	4.0	III	4.00	III
		2016	3.0	II	5.0	III	4.0	III	4.00	III
		2017	3.0	II	5.1	III	4.0	III	4.00	III
2	Dobrotvir reservoir, downstream pool (689 km)	2013	2.3	II	4.6	III	4.0	III	3.63	III
		2014	2.7	II	4.8	III	4.0	III	3.82	III
		2015	2.3	II	4.6	III	4.0	III	3.63	III
		2016	2.7	II	4.7	III	4.0	III	3.80	III
		2017	3.0	II	5.0	III	4.0	III	4.00	III
3	Sokal town (637 km)	2013	2.3	II	4.3	III	4.0	III	3.53	III
		2014	2.0	II	4.2	III	4.0	III	3.41	II
		2015	2.0	II	4.4	III	4.0	III	3.48	II
		2016	3.0	II	4.6	III	4.0	III	3.87	III
		2017	3.0	II	4.7	III	4.0	III	3.90	III
4	Stargorod vil. (632 km)	2013	2.3	II	4.1	III	4.0	III	3.47	II
		2014	2.7	II	4.2	III	4.0	III	3.63	III
		2015	2.7	II	4.7	III	4.0	III	3.78	III
		2016	2.0	II	4.4	III	4.0	III	3.47	II
		2017	3.0	II	4.6	III	4.0	III	3.90	III
5	Lytovezh vil. (631 km)	2013	2.3	II	4.1	III	5.0	III	3.80	III
		2014	2.3	II	3.7	III	5.0	III	3.67	III
		2015	2.3	II	3.9	III	5.0	III	3.74	III
		2016	2.0	II	3.9	III	4.0	III	3.30	II
		2017	2.7	II	4.0	III	4.5	III	3.70	III
6	Ambukiv vil. (584 km)	2013	2.3	II	3.9	III	4.0	III	3.40	II
		2014	2.3	II	3.8	III	4.0	III	3.37	II
		2015	2.3	II	4.2	III	4.0	III	3.52	III
		2016	2.0	II	4.0	III	5.0	III	3.67	III
		2017	2.7	II	3.9	III	4.0	III	3.50	II
7	Ustyluh town (569 km)	2013	1.3	I	3.9	III	4.0	III	3.07	II
		2014	2.3	II	3.7	III	4.0	III	3.33	II
		2015	2.0	II	3.8	III	4.0	III	3.26	II
		2016	1.7	II	3.7	III	5.0	III	3.47	II
		2017	1.7	II	3.8	III	3.5	II	3.00	II
8	Zabuzhzhia vil. (468 km)	2013	1.3	I	3.9	III	4.0	III	3.07	II
		2014	1.3	I	3.8	III	4.0	III	3.04	II
		2015	1.7	II	3.6	III	4.0	III	3.08	II
		2016	1.7	II	3.6	III	5.0	III	3.43	II
		2017	2.3	II	3.9	III	4.5	III	3.60	III

Source: own study.

Table 3. Generalized assessment of surface water quality in the Western Bug basin (2013–2017)

No.	Observation point (distance from the mouth of the river)	Value	Category	Subcategory	Characteristic	Water quality class
1	Kamianka Buzka town (704 km)	3.94	4	4(3)	satisfactory, slightly polluted water toward to good, fairly clean	III
2	Dobrotvir reservoir, downstream pool (689 km)	3.78	4	3–4	transient from good, fairly clean to satisfactory, slightly polluted	III
3	Sokal town (637 km)	3.64	4	3–4	transient from good, fairly clean to satisfactory, slightly polluted	III
4	Stargorod vil. (637 km)	3.65	4	3–4	transient from good, fairly clean to satisfactory, slightly polluted	III
5	Lytovezh vil. (631 km)	3.64	4	3–4	transient from good, fairly clean to satisfactory, slightly polluted	III
6	Ambukiv vil. (584 km)	3.49	3	3(4)	good, fairly clean water with a tendency to satisfactory, slightly polluted	II
7	Ustyluh town (569 km)	3.23	3	3	good, fairly clean water	II
8	Zabuzhzhia vil. (468 km)	3.34	3	3	good, fairly clean water	II
	Basin in whole	3.57	4	3–4	transient from good, fairly clean to satisfactory, slightly polluted	III

Source: own study.

Natural Resources of Lviv Oblast State Administration (Ukr. Departament ekolohiyi ta pryrodnykh resursiv L'viv-s'koyi oblasnoyi derzhavnoyi administratsiyi) and Department of Ecology and Natural Resources of Volynsky Oblast State Administration (Ukr. Departament ekolohiyi ta pryrodnykh resursiv Volyns'koyi oblasnoyi derzhavnoyi administratsiyi); Department of Ecology and Landscape Planning, Lviv City Council (Ukr. Upravlinnya ekolohiyi ta landshaftnoho planuvannya L'vivs'koyi mis'koyi rady) [Informatsiinyi... 2018; KLYMENKO, VOZNYUK 2010].

The analysis of the dynamics of changes in surface water quality indicators was performed on eight approved points (river cross section) of the monitoring of the state water quality monitoring network in the basin of the Western Bug River. The results of the environmental assessment of the surface water quality of the basin of the Western Bug River are shown in Table 2.

After analysing the long-term changes in the integral indicators of the surface water quality of the Western Bug River basin (within Ukraine), it should be noted that the quality of water by the values of salt block (I_1) corresponds mainly to categories 1–2 of quality classes I and II. In accordance with the environmental classification by class and category, the water quality by its condition is characterized as "excellent" – "very good", and by the degree of cleanness – "very clean" and "clean". In addition, the water quality of the Western Bug was rated to category 1/class I, as "excellent" by its condition and "very clean" by the degree of cleanness at the observation points of Ustyluh town (2013), Zabuzhzhia vil. (2013, 2014).

According to the trophic-saprobic indicators (I_2), the surface water of the Western Bug River is evaluated as intermediate between categories 4 and 5 of the class III that is, as "satisfactory" by its condition, "polluted" by the degree of cleanness. According to calculations, it was found that such elements as NO_2, NO_3 and NH_4 have the greatest impact on the deterioration water quality of this block.

The average values of specific indicators of toxic action (I_3) characterized the water quality as of category 4 of quality class III, "satisfactory" by the condition and "slightly polluted" by the degree of cleanness. However, due to the limited amount of source materials, this estimate is indicative.

It should be noted that the value of ecological and sanitary indicators (I_2) and indicators of specific substances of toxic activity (I_3) is the worst of the three block indices, and the salt index value (I_1) is the best.

The value of the ecological index (I_E) by the average values of water quality indicators in the Western Bug River ranges from 3.0 to 4.0. This gives reason to evaluate it as "good"–"satisfactory" by its condition; "fairly clean"–"slightly polluted" by the degree of cleanness (category 3–4, class II–III).

We also calculated the generalized value of the integral ecological index (I_E) of the water quality of the Western Bug over the entire study period (Tab. 3). It has been established that the water of the river is characterized mainly by category 4 of the class III, "satisfactory" by condition and "slightly polluted" by degree of cleanness. At the observation points Ambukiv vil., Ustyluh town, Zabuzhzhia vil. the water quality corresponds to category 3 of class II, as "good" by condition; and by the degree of cleanness – "fairly clean".

CONCLUSIONS

The conducted analysis of the dynamics of changes in the total values of integral indicators of surface water quality in the Western Bug River during the research period indicates that: 1) according to the indicators of the salt block, the water in the river belongs mainly to 1–2 categories, I and II classes of quality and is characterized as water "excellent", "very good" on condition, "very clean" and "clean" on the degree of cleanliness; 2) according to the trophic and saprobiological indicators of water, are assessed as intermediate between 4 and 5 categories of the III class, that is, "satisfactory" by condition, "polluted" by degree of purity; 3) according to the block of specific substances of toxic effect, the quality of water belongs to the

4th category of the III class of quality, the water is "satisfactory" by the condition and "slightly polluted" by the degree of cleanliness; 4) the values of the indicators of the ecological index varies within the 3–4 categories, II–III classes, which gives grounds to evaluate it as "good" – "satisfactory" by condition; "fairly clean"–"slightly polluted" by the degree of cleanliness; 5) calculation of the generalized integral index of the ecological status of the Western Bug River for the entire period of research indicates that the water in the river belongs to the 4th category, the III class is "satisfactory" by the condition and "slightly polluted" by the degree of cleanliness, except for the points of observation located in within the limits of the Volyn region, where the water quality corresponded to 3 categories of the II class, by the condition is "good"; and by the degree of cleanliness is "fairly clean".

Environmental assessment of the river water quality is important for generalizing information on the ecological condition of water bodies, forecasting its changes and developing scientifically based water protection recommendations for approving appropriate management decisions in the field of use, protection and reproduction of water resources. All this determines the prospect of further studies on the quality of surface water of the Western Bug River.

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Dynamika zmian wskaźników jakości wód powierzchniowych w basenie Bugu (Ukraina) określanych za pomocą technologii GIS

STRESZCZENIE

Środowiskową ocenę jakości wód powierzchniowych Bugu prowadzono z zastosowaniem systemu klasyfikacji wód powierzchniowych Ukrainy w zgodzie z przyjętą metodologią, która umożliwia porównywanie jakości wód odrębnych obszarów z różnych regionów. Obliczenia prowadzące do oceny jakości wody prowadzono w trzech blokach: blok składu mineralnego wód, blok wskaźników troficznych i saprobowych (ekologicznych i sanitarnych) oraz blok wskaźników substancji szczególnie toksycznych. Obliczono zintegrowane wskaźniki ekologiczne i przedstawiono je w formie zbiorczej oceny środowiskowej opartej na wnioskach z trzech wymienionych bloków. Całościowe badania zmian jakości wody w Bugu są prowadzone na terytorium Ukrainy od wielu lat. Zintegrowane wskaźniki odpowiadają w większości 4. kategorii i 3. klasie – woda ma stan „zadowalający" i jest „nieznacznie zanieczyszczona" (z wyjątkiem stanowisk w regionie Wołynia, gdzie jakość wody odpowiada 3. kategorii i 2. klasie. Jej stan jest „dobry" a woda jest „dość czysta"). Wizualizację i część analiz wykonano z zastosowaniem technologii GIS i programu ArcGIS 10.3.

Słowa kluczowe: *jakość wody, ocena środowiskowa, rzeka, technologie GIS, warunki środowiskowe, wody powierzchniowe, wskaźnik ekologiczny*