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Results of Surface Water Quality Monitoring of the Western Bug River Basin in Lviv Region

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ABSTRACT

The article describes the steps for organizing and conducting the ecological monitoring of surface water in order to shift Ukraine to the European standards in the field of water use and protection. The main water users-pollutants of the Western Bug River basin in the Lviv region were identified. The results of the water samples taken from the control bodies in 2018 were analyzed. A promising way to improve the work of the water basin management of the Western Bug River was proposed.

Keywords: the Western Bug River, river basin, EU Water Framework Directive, monitoring, quality of surface waters.

INTRODUCTION

Excessive impact of the anthropogenic activity causes a degradation of the aquatic ecosystems productivity and a disturbance of the ecological balance. The organization of qualitative and quantitative status of the surface and groundwater (aquatic and hydro-ecological monitoring) studies system in order to predict the risks of river ecosystem functioning in the future is relevant.

The Western Bug River is one of the 5 most polluted rivers in Ukraine. Numerous scientific studies on the ecological status of the transboundary river have been undertaken through the creation of the Euroregion Bug Cross-Border Association. The status of the surface water quality of the river basin, the analysis of natural and anthropogenic sources of surface water pollution, and the need for joint transboundary monitoring were investigated by IB Koynova, MR Zabokritskaya, N.M. Wozniuk and others [Bilyk et al. 2009; Kojnowa 2007; Koynova et al. 2012; Khilchevskyi et al. 2016a; Nina Hagemann et al. 2014]. The monitoring studies of the hydro-ecological status of the river basin continue to this day, already with the use of GIS technologies. They help not only to reflect the dynamics of the water quality changes on maps, but also to track the cause and effect of anthropogenic pollutants on the aquatic ecosystem in order to predict quality in the future [Gopchak et al. 2019].

The necessity of transition of Ukraine to the European standards and norms in the field of use and protection of the surface waters, harmonization of the monitoring methods, assessment of the water quality and typology of the study on the hydrographic network is presented in [Khilchevskyi et al. 2016b]. The abiotic typology of surface waters takes into account the main features of the natural conditions of the catchments, due to their physical, geographical and altitude position, geological structure and morphometric features.

Owing to the National Security Strategy of Ukraine [Stratehiia… 2015], it is planned to bring national legislation into line with EU environmental policy, in particular the Water Framework Directive [Dyrektyva 2000/60/ EU]. The WFD defines an integrated basin model of the water management in the EU countries in order to achieve the "good" ecological status of the surface and groundwater masses. An integrated approach to water management is a water management system that guarantees environmental safety and accessibility of water for the population and natural objects, based on the consideration of all water sources, the balance of sectoral interests and all levels of water use, widespread involvement of all water users, as well as rational use of water resources [Klymchyk 2018]. It is implemented through the hydrographic and water management of the territory of Ukraine, the development of river basin management plans, the development of water management balances, the determination of the powers of central and local authorities [Upravlinnia dovkilliam... 2014]. For Ukraine, the introduction of the Basin Principle is, first of all, decentralization in the field of water management, since the Basin Councils involve both representatives of state authorities and local governments, as well as water users (at least 30%) and environmental NGOs. The Basin council decisions are taken into account when developing the basin management plans and implementing the measures for the rational use of water resources and water protection.

In order to comply with the provisions of the WFD, Ukraine adopted [Zakon Ukrainy 2016], according to which nine areas of river basins were formed. According to [Postanova KMU № 758 2018], the new monitoring system for surface water, groundwater and marine water is a step towards the implementation of EU standards in the field of water quality and water management. The State Agency of Ukraine plans to implement the following 5 steps in 2019 to develop a river basin management plan:

- Step 1. Determination of water masses, their typology – till 01.07.2019;
- Step 2. Analysis of anthropogenic impacts, quantitative and qualitative status of waters – till 01.11.2019;
- Step 3. Description of the river basin district – till 01.09.2019;
- Step 4. Register of protected areas – till 01.12.2019;
- Step 5. Development of the monitoring program – by 31.12.2019.

According to [Nakaz № 4, 2019], the main criteria for determining the surface water mass include: ecoregion; surface water category; typology; geographical and hydromorphological differences; change of ecological status; the zones (territories) to be protected.

According to [Nakaz № 5, 2019], the ecological status of the surface water mass class should be determined by biological, hydromorphological, chemical and physicochemical parameters:

- for the biological indicators – for the five classes corresponding to the environmental statuses “excellent”, “good”, “satisfactory”, “bad” and “very bad”;
- for chemical and physicochemical indicators – for the three classes corresponding to the ecological states “excellent”, “good” and “satisfactory”;
- for specific synthetic and non-synthetic contaminants within the chemical and physicochemical parameters – for the two classes corresponding to the ecological states “good” and “satisfactory”.

The purpose of the work was to analyze the results of the monitoring studies of surface waters of the Western Bug River, conducted quarterly by the Water resources basin management of Western Bug and Syan, during 2018 in control bodies within the Lviv region.

MATERIALS AND METHODS

The flow of the river basin of the transboundary Western Bug River is formed on the territory of three states – Poland (49.2% of the area), Ukraine (27.4%) and Belarus (23.4%). The Western Bug River is a left tributary of the Narew River (the Vistula River Basin). The length of the territory of Ukraine is 404 km, 363 km of which is the natural border between the Republic of Poland, Ukraine and the Republic of Belarus, i.e. it is a transboundary watercourse. The Western Bug River is a mixed-type river that feeds from the melted spring and summer rainfall with little groundwater. The highest water level is observed in March and April during snowmelt, as well as in the first half of summer, when the highest rainfall occurs. The lowest water level is in August-September and December-February. The main tributaries are: right-bank – Solotvyna, Bilyy Stik, Spasivka; left bank – Zolochivka, Poltva, Kam`yanka, Rata, Solokiya. A common feature of the tributaries is their small basins (from 240 to 570 km^2) and wide wetlands [Zabokrytska et al. 2006]. There is a well-developed hydrological network in the Western Bug basin. The average density of the river network is 0.35 km^2 [Edited by Herenchuk 1972].

A surface water monitoring system was established in the 1980s to control the discharges of industrial enterprises in the coal, energy and alcohol industries. Currently, most businesses have ceased to exist, so utilities are the main pollutants of the Western-Bug River Basin. The water resources of this river are first and foremost a source of the technical water supply for the industrial power, heat, fishery and agricultural enterprises. The largest water users are [Baseinove upravlinnia… 2019]:

- *industrial enterprises* – SE «Dobrotvirskaya TPS» (PJSC DTEK «Westenergy»), LLC «Radekhivsky cukor», PJSC «Company «Enzym», PJSC «Lviv Coal Company», SE «Lvivvugillya» (separate subdivisions of the mine: «Velykomostivska», «Stepova», «Chervonogradska»), SE «Ukrspirt» («Vuzlivske», «Stronibabske», «Strutinske», «Rava-Ruske»), SE «Danish Textile»;
- *agricultural enterprises* – LLC «Kunin», LLC «Yakymiv Fish», Private agricultural firm «Bilyy Stik», tenant Fedorchak R. V., PJSC «Lviv Regional Fish Production Plant» (WG «Krasne», WG «Yaniv»);
- *housing and communal enterprises* – MCC «Zolochivvodokanal», CE «Kam'yankavodokanal», CE «Zhovkivske VUVKG», CE «Chervonogradvodokanal», Sokalsk MCC WSE, LMCC «Lvivvodokanal»;
- *transport industry* – enterprises of PJSC «Ukrainian Railways».

Only groundwater is used for the drinking and sanitary needs of the Lviv region population, as the water from the Western Bug is not suitable for drinking.

There are two types of sources of water pollution: point (wastewater from enterprises and water utilities / municipal wastewater treatment plants) and diffuse sources (pesticides and mineral fertilizers of farmland, livestock farms, landscape transformation, bank unauthorized waste landfills).

The total wastewater discharge in the Lviv region is 135.31 million m^3 of volume (192.7% of the intake). This is explained by the presence of water intakes at the Lvivvodokanal LCM in the Dniester River basin, and all the wastewater is discharged into the Poltva River. Out of the total discharge: 93.33 million m^3 – waste water, normatively purified at treatment facilities; 35.48 million m^3 – contaminated effluents (when the discharges have exceeded at least one indicator of the approved MPD standards individually for each enterprise); 3.3 million m^3 – normatively clean without treatment at treatment plants; 3.2 million m^3 are uncategorized, mine waters. In 2018, contaminated water was discharged by: Lvivvodokanal – 33.0 million m^3 into the Poltva River (which accounts for 93.1% of the volume of all polluted effluent); Sokal MCC WSE – 0.88 million m^3 into the Western Bug River; Chervonogradvodokanal – 0.7 million m^3 into the Western Bug River and Rata River; Rava-Ruska MSE «SE Ukrspirt» – 0.25 million m^3 into the Rata River; CE Kamyankavodokanal – 0.18 million m^3 in Kamianka River, Lviv National Academy of Sciences – 0.16 million m^3 in the Yarichevskyi River tributary, CE «Rava-Ruska BU №2» – 0.1 million m^3 in Rata River [Baseinove upravlinnia… 2019].

The state water quality monitoring network of the Lviv region in 2018 consisted of approved observation points (ranges) according to [Nakaz № 14, 2015]. The water samples in the Western Bug River basin in the Lviv region were collected in 6 ranges (see Figure 1 and Table 1).

The program [Nakaz № 6, 2018] provides the definition of the hydrochemical parameters pertaining to the quality of the Western Bug River, the analysis of the existing monitoring system and its adaptation to the requirements of the Water Framework Directive. The measurements of the water quality indicators at the points of state monitoring are carried out quarterly by the laboratory of the Lviv hydro-geological and reclamation expedition (now, the laboratory of the Water resources basin management of Western Bug and Syan). However, from the year 2019 [Nakaz №6, 2018], the observation points of the Western Bug River in the town of Dobrotvir and Stargorod village as well as the observation point on the Rata River in the Great Bridges have been excluded (see Table 2).

Hydrochemical and radiological control of the surface water quality is carried out by the laboratory of monitoring of waters and soils of the Lviv State Hydrological Station under the ACDEY program, according to 23 indicators (temperature, odor, points, transparency, hydrogen index, suspended solids, alkalinity, hardness, calcium, magnesium, potassium + sodium, hydrocarbonates, chlorides, sulfates, dry residue, ammonium ions, nitrite ions, nitrate ions, phosphates, total iron, COD, BOD$_5$, and dissolved oxygen).

Fig. 1. Map-diagram of the location of the control bodies in the Lviv region

RESULTS AND DISCUSSION

The water quality assessment was made according to the pollution factor [KND 211.1.1.106–2003, Table 7], compared with the MPC for fisheries water bodies, according to [Postanova KMU № 552, 1996, Table. 6]. Contamination coefficient (CC) is determined by the formulas. The obtained numerical values of the CP allow estimating the water status by pollution levels by the following values:

Table 1. Surveillance points at the surface waters in the Western Bug river basin in the Lviv region

No.	Name of the river	Item observation	Distance from the mouth, км
1.	Western Bug	c. Kamianka-Buzka	704
2.	Western Bug	Dobrotvirsky reservoir, lower beef	689
3.	Western Bug	v. Stargorod	669
4.	Western Bug	c. Sokal	637
5.	Poltva River, left tributary Western Bug River	v. Kamyanopil	30
6.	Rata River, left tributary Western Bug River	uts. the Great Bridges	22

- AC = 1 (uncontaminated (clean));
- CC = 1.01–2.50 (slightly contaminated);
- CC = 2.51–5.00 (moderately contaminated);
- AC = 5.01–10.00 (dirty);
- AC > 10 (very dirty).

In accordance with the Procedure for regulatory monetary valuation of non-agricultural lands (except for settlements), the coefficients that consider the qualitative status of water bodies are taken into account (QWO2). The results are presented in Table 2.

The data of radiological characteristics (cesium-137 and strontium-90) during 2016–2018 in all control establishments do not exceed the maximum permissible norms, which indicates a stable radiation status of the surface waters of the Lviv region. When comparing long-term data, there is a tendency to decrease the activity of cesium and strontium, which is associated with their decay.

The results of the quarterly 2018 studies on the most pollutants in the controls – ammonium nitrogen, phosphate, BOD_5 and iron (I) – are presented in Figures 2–5.

The Poltva River (the left tributary of the Western Bug) is the most polluted river in the basin as it acts as a wastewater collector in Lviv. In 2018, according to [KND 211.1.1.106–2003], its water was characterized as «very dirty» (see Table 2).

Table 2. Assessment of the surface water quality of the Lviv region according to the pollution factors

Range title	The value of the pollution factor, quarterly							QWO2
	I, 2018	II, 2018	III, 2018	IV, 2018	I, 2019	II, 2019	III, 2019	
r. Western Bug – c. Kamianka-Buzka	2.61	3.12	3.0	2.66	1.96	1.77	2.7	0.9
r. Western Bug – c. Dobrotvir	1.88	2.16	2.26	2.70				0.9
r. Western Bug – c. Starhorod	1.30	1.49	1.75	2.17				1.2
r. Western Bug – c. Sokal	1.20	1.43	1.76	2.05	1.38	1.84	1.85	1.2
r. Poltva – c. Kamyanopil	12.86	22.37	17.75	10.58	5.03	8.94	13.15	0.5
r. Rata – uts. the Great Bridges	1.27	1.45	1.53	1.38				1.2

In the range of ***Poltva river in the Kamyanopol village*** of Pustomitivskiy district (below treatment facilities), low content of dissolved oxygen (0.78–2.78 mgO_2/dm^3 at MPC $\geq$ 4 mgO_2/dm^3) as well as the exceedance of the BOD_5 limit values (5.17–19.68 times), COD (2.82–7.37 times), suspended solids (from 2.72 to 6.96 times), ammonium (6.1–50.9 times), nitrites up to 37, 25 times, phosphates (1.49–7.76 times), iron (2.8–8.4 times) and sulfates (up to 1.72 times) were observed.

The excessively high content of ammoniacal nitrogen, phosphates, suspended solids, COD and BOD_5 can be explained by the inflow of these pollutants from the sludge sites of the Lviv treatment plants with an area of 22 ha (2 million tons of sediment) (see Fig. 2). The wastewater collection for settlements not connected to the sewage network is carried out in individual septic tanks or sinkhole, the sewage of which is not treated and can be one of the potential sources of pollution of aquifers and surface waters. In 2018, as compared to 2017, the discharge of pollutants BOD_5, COD and suspended matter has reduced due to the reduction of the discharges volume and improvement of the CBS-2 LMCC «Lvivvodokanal» operation.

According to the nature of pollution, preliminary conclusions about the source of the pollution were drawn. If NH_4^+ ammonium ions are found in the water but no NO^{2-} and NO^{3-} nitrates are present, it indicates fresh contamination with faecal effluents. The water content of nitrites and nitrates demonstrates the contamination of the reservoir with organic substances. The high content of nitrites and phosphates is explained by the highly concentrated domestic effluent containing detergents and cleanser items, as well as by the use of excessive fertilizers by agricultural farms in the spring (see Fig. 3). Such pollutants cause the active development of algae and plants (eutrophication), as a consequence – a decrease in the concentration of dissolved oxygen in the hot period. Oxygen is known to be spent on breathing aquatic creatures and decomposing organic compounds. The dissolved oxygen deficiency causes destructive processes in any river ecosystem, and for the Poltva River it means that fish and other aquatic organisms cannot exist.

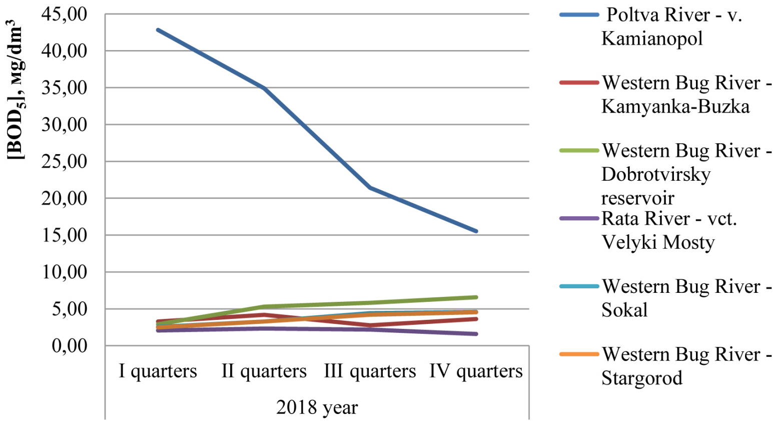

Fig. 2. Dynamics of changes in the concentrations of BOD_5.

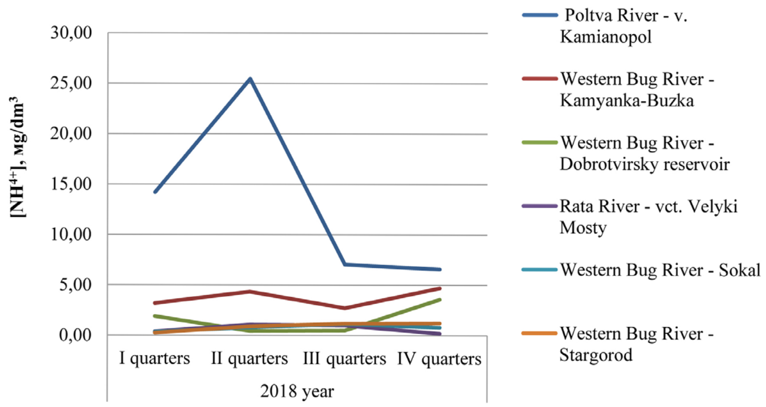

Fig. 3. Dynamics of changes in the concentrations of NH^{4+}.

Fluctuations in the concentration of iron are clearly seasonal, which depends on the changes in nutrition (see Fig.4). During spring floods the concentration of iron increases along with the water content, while the mineralization of water (sulphates and suspended matter) decreases. Conversely, in a limited period, mineralization sharply increases to the maximum due to underground feeding, and the dissolved oxygen concentration decreases to a minimum.

In the range of ***«R. Western Bug – Kamianka-Buzka»***, the water was «moderately contaminated», exceeded the maximum allowable levels of phosphates (up to 3.82 times) (see Fig.5), ammonium (from 5.42 to 11.72 times), BOD_5 (up to 1.86 times), iron (from 1.6 to 5.9 times), nitrites (from 6.75 to 27.5 times), suspended solids (up to 2.64 times) and sulfates (up to 1.34 times). The water quality of the facility is influenced by the wastewater of the CE «Lvivvodokanal» through the Poltava River, as well as the wastewater of the Busk WSE.

At the ***«r. Western Bug – Dobrotvir town»*** point of observation, the water was characterized as «moderately polluted», the exceedance of the maximum allowable BOD_5 standards (up to 2.62 times), ammonium (up to 13.16 times), nitrites (from 4.25 to 19.75 times), phosphates (up to 4.53 times), iron (up to 3.3 times), suspended solids (up to 2.04 times) was recorded, as well as a slight excess in sulfates and COD. The comparatively low water quality at the observation point is caused by the stagnation of water in the Dobrotvir reservoir and the impact of effluents from CE «Lvivvodokanal» across the river Poltva. The water quality at the range is affected by the wastewater of PJSC «Zakhidenergo», CE «Kamyanka-vodokanal» and unauthorized effluents.

In the left tributary of the Western Bug River, ***r. Rata (uts. the Great Bridges)***, the water was «slightly polluted», its quality was better than that of other basins. The exceedance of the maximum permissible norms of nitrites (up to 4.25 times), iron (up to 7.4 times), nitrogen (up to 2.12 times) and minor excess of phosphates were found. The quality of water at the range is affected by the wastewater of Zhovkva through the r. Svynya and c. Rava-Ruska.

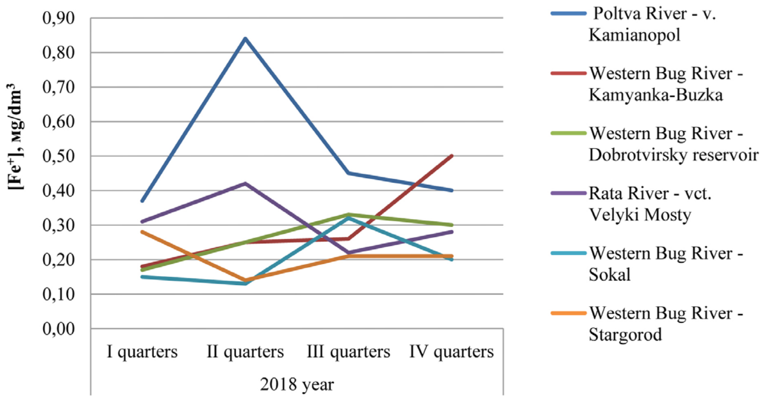

Fig. 4. Dynamics of changes in the concentrations of Fe^{+}.

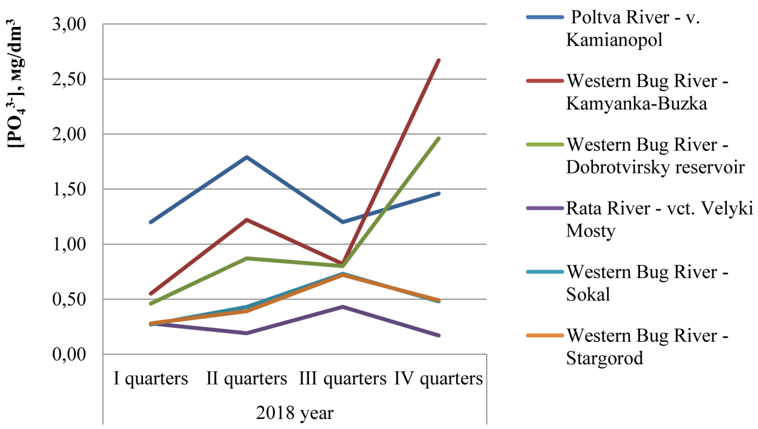

Fig. 5. Dynamics of changes in the concentrations of PO_4^{3-}.

At the ***«r. Western Bug – Sokal city»*** point of observation, *the* water was characterized as «poorly polluted», the exceedance of maximum permissible norms of BOD_5 (up to 1.55 times), ammonium (up to 3.38 times), nitrites (from 1.75 to 9.75 times), iron (from 1.3 to 3.7 times) and small increases in the concentrations of the suspended solids, sulfates, phosphates, COD were detected. The quality of water at the range is affected by the wastewater of CE «Chervonogradvodokanal».

At the ***«r. Western Bug – Stargorod village»*** point of observation, the water was «slightly polluted». The exceedance of the maximum allowable BOD_5 standards (up to 1.51 times), ammonium (up to 3.88 times), nitrites (from 1.25 to 10.25 times), iron (from 1.2 to 5.0 times) and (to a small extent) sulfates, phosphates, suspended solids were found. The quality of water at the point of observation is affected by the wastewater of c. Sokal.

It should be noted that in comparison with 2013–2015, the quality of water has deteriorated. In 2018, water intake in the basin from natural sources amounted to 70.22 million m^3, but only 8.65 million m^3 (only 12.3%) was collected from surface water bodies.

According to the results of the monitoring studies, compared to the previous years (2013–2017), the water quality in the control bodies of the basin is deteriorating; therefore, it is necessary to urgently take measures to improve the ecological status of the Western Bug River basins. The author [Bezsonnyi 2019] refers to the main disadvantages of the existing surface water monitoring system, in particular, the inability of fast registration of water bodies or streams emergency contamination due to the lack of systems for continuous control of the water quality characteristics.

Creating a web-based integrated system of real-time surface water quality monitoring using mathematical simulation models, mapping, GIS technologies, satellite remote sensing based on a stationary monitoring network is the main goal of ensuring the ecological safety of the aquatic ecosystem [Gunatilaka et al.; Qiaoling Chen et al. 2007].

In our opinion, one of the most effective measures for the improvement of operation is to equip the control facilities with automated remote hydrological posts (ARGP) and complexes (AGC) with autonomously operating equipment (continuously analysis of water, or with a given periodicity by 2–6 parameters) and the use of mobile laboratories (with the equipment for sampling and analysis of water in the field by 5 – 15 indicators).

CONCLUSIONS

1. The work of the State Agency of Ukraine for the implementation of EU standards in the field of water quality and water management during 2018–2019 has been analyzed.
2. The results of the analyses of the water samples from the control structures of the Western Bug River in the Lviv region, conducted by the laboratory of the Lviv hydro-geological-reclamation expedition on a quarterly basis during 2018, were presented. The Poltva River, after leaking from Lviv, is the most polluted river in the basin and is characterized as «very dirty».
3. Exceedance of the MPC in relation to BOD_5 was recorded up to 20 times, COD up to 7.37 times, suspended solids – 7 times, ammonium – 50 times, nitrites – 37 times, phosphates – 8 times, iron – 8.4 times and sulfates

– 1.72 times. The main source of contamination involves outdated Lvivvodokanal treatment plants and their sludge sites. The waters of all other years are classified as «moderately polluted» and «slightly polluted". One of the ways to improve the work of the water basin management of the Western Bug River is to equip the control facilities with automated remote hydrological posts.

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