ASSESSMENT OF THE QUALITY OF SURFACE WATERS IN KHMELNYTSKYI REGION BASED ON SANITARY, HYDROLOGICAL, AND TOXICOLOGICAL INDICATORS

Olga Togachynska*, Olena Semenova, Andriy Kotynskyi, Evgenia Omelchenko

National University of Food Technologies

** Author for correspondence: tytyn29@ukr.net*

Abstract. *The article provides an analysis of enterprises located in the Khmelnytskyi region, their characteristics are described, and an analysis of their impact on water ecosystems is conducted. Their sanitary protection zone and hazard class have been determined. It has been determined that the largest water user is the municipal water supply and sanitation enterprise in the city of Krasyliv, the communal enterprise "Miskvodokanal", the communal enterprise "Izyaslavvodokanal", Theofipol Housing and Utilities Management Production Department, and Aslan-Textile LLC. These companies are the largest water consumers in terms of volume and also discharge significant amounts of wastewater into surface waters.*

According to the monitoring studies presented in the article, concentrations of pollutants in the control sections of water bodies in Khmelnytskyi region were within the permissible limits in surface waters. However, it was noted that all samples of the collected water exceeded the norm for BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand), except for the water in the Sluch River, Korzhivka village section..

The article presents the results of the ecological assessment of water resources in Khmelnytskyi region based on sanitary and hygienic indicators. The impact of environmentally hazardous objects on the state of surface waters was determined, and concentrations of pollutants in water ecosystems were identified. As a result of the conducted research, it was found that the surface waters of Khmelnytskyi region, in terms of sanitary and toxicological condition, correspond to an acceptable and moderate level of pollution. The indicator of the limiting criterion of harmfulness ranged from 0.4 to 1.0 units of measurement.

DOI: 10.24263/EDSD-2023-5-23

Introduction. The use of water is increasing at such a rate that questions arise regarding the control of surface waters and obtaining ecologically safe water for consumption. According to literary sources, it has been established that in Ukraine, there is no water body that has not been altered by human anthropogenic activities or their consequences [1].

According to literary sources, it has been proven that there is also a deterioration in the quality of water resources in European Union countries due to excessive anthropogenic influence. For instance, in the Czech Republic and Slovakia, two-thirds of rivers are polluted by industrial and agricultural waste. In Poland, some rivers fall into the moderately polluted category, and three-quarters of Hungary's rivers contain chemical pollutants. [2; 3].

In most cases, anthropogenic interventions lead to water bloom, which is known as anthropogenic eutrophication, resulting in a high influx of biogenic compounds into water bodies [4; 5]. The process of eutrophication is characterized by a sharp increase in biomass of algae, higher aquatic vegetation, and phytoplankton due to the input of nutrient-rich biogenic substances, resulting in oxygen depletion and subsequent occurrences of hypoxia. Decomposition of plant organisms occurs, leading to the release of toxic substances into the water, posing a significant threat to the survival of aquatic organisms and being hazardous to both animals and humans [5].

As a result of scientific research, it has been determined that chemical, food, and petroleum processing industries initially impact the quality of surface waters, leading to the alteration of organoleptic, microbiological, and physicochemical properties of aquatic ecosystems due to the presence of pollutants. These processes further enhance the accumulation, migration, and translocation of these pollutants within natural water ecosystems. Therefore, the study of pollutant accumulation and migration in surface waters, as well as the development of methods for water ecosystem purification, is being undertaken by researchers such as L.V. Levandovsky, O.I. Semenova, I.V. Shumigay, and N.O. Bublienko [6; 7].

Materials and methods. The analysis of sanitary-toxicological assessment of surface waters in the Khmelnytskyi region was conducted based on the pollutant content data obtained from observations conducted by the Khmelnytskyi Regional Hydrometeorology Center during the period of 2020-2021.

The determination of sanitary-hygienic indicators was carried out in the control sections of rivers in the Khmelnytskyi region. Water samples were collected from the main stream at a depth of 0.2-0.5 meters below the water surface. In the case of deep rivers, samples were taken from multiple layers to reflect the average composition of the water. Water samples for analysis of organic and chemical substances were collected in chemically clean or carefully prepared bottles with tightly sealed stoppers made of durable glass or polyethylene [8].

The determination of ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, phosphates, sulfates, chlorides, total iron, and heavy metals content was carried out according to generally accepted methods [8-12].

The research objects were environmentally hazardous objects that influence the processes of forming the indicators of water resource quality and surface water in the Khmelnytskyi region. The subject of the study was the level of pollution of rivers in the regions of the Khmelnytskyi region.

The analytical and methodological parts of the work were carried out during the years 2020-2021. The program of analytical research included the performance of an ecological assessment of the state of water ecosystems based on sanitary and hygienic indicators.

A comprehensive ecological assessment based on sanitary-toxicological indicators of surface waters was calculated separately for each pollutant that contributes to the harmfulness criteria.

$$W = 1 + \frac{\sum_{i=1}^{n}(g_i - 1)}{n} \qquad (1)$$

Where:

W - comprehensive assessment of water pollution level based on the limiting criterion of harmfulness;

n - number of indicators used in calculations;

g_i - multiplicity of exceeding the actual concentration of the i-th ingredient in the water (Ci) over the normative value of a single indicator.

$$g_i = \frac{C_i}{N_i} \qquad (2)$$

Where:

N_i - normative value of a single indicator (usually equal to MAC - Maximum Allowable Concentration).

The degree of water pollution, depending on the magnitude of the comprehensive assessments W calculated based on the limiting criterion of harmfulness, is determined by the classification of W value ranges (sanitary-toxicological indicators): acceptable pollution level corresponds to 1.0 W units, moderate pollution level ranges from 1.0 to 3.0 W units, high pollution level ranges from 3.0 to 10.0 W units, and extremely high pollution level exceeds 10.0 W units.

Research results and their discussion. The study included a monitoring assessment of the quality of surface water. Table 1 presents the volumes of wastewater discharge and pollutant levels in the surface water of the Khmelnytskyi region for the years 2020-2021.

In the territory of Khmelnytskyi region, there are numerous enterprises that have a negative impact on the environment, particularly on the water ecosystem. Regular inspections of these enterprises have been carried out annually. However, the list of hazardous facilities at the national level is presented in Table 2. From this table, it is evident that the largest water users are the water supply and sewage utilities of Krasyliv city, the municipal enterprise "Miskvodokanal," "Izyaslavvodokanal," Theofipol Production Management of Housing and Communal Services, and Aslan-Textile Private Enterprise. Since these enterprises are the largest water users, they also discharge significant volumes of wastewater into the surface water.

The total discharge of wastewater amounted to 1661.8 thousand cubic meters, and the volumes of wastewater discharge increased. In 2021, it reached 3312.4 thousand cubic meters, while in 2020, it was 2790.5 thousand cubic meters. One such enterprise, "Starokostiantynivsky Specialized Quarry" CJSC, is involved in the extraction of decorative and building stone, limestone, gypsum, chalk, and clayey shale, as well as the production of concrete products for construction, production of concrete mixtures ready for use. Therefore, this facility falls into the second hazard class, and the sanitary protection zone should be at least 500 meters. The main hazard of this enterprise in the production of building materials is the formation of quarry water, which becomes contaminated with mechanical particles and chemical compounds through the erosion of excavation waste rocks and useful minerals, as well as mineral oils, alkalis, phenols, and other substances used in drilling, excavation, extraction, and transportation machinery.

The company "Protein Invest" LLC is engaged in the production of oils and animal fats. Its technological process is high-powered, placing it in the fourth hazard class, and the sanitary protection zone should be at least 300 meters. The wastewater generated during the production of oil products includes neutral fats, phospholipids, organic acids, and other organic substances. These pollutants are insoluble in water and contribute to the formation of stable emulsions in the form of suspended matter.

"Vinkivtsi Cheese Factory" LLC is engaged in milk processing and the production of butter and cheese, resulting in the formation of whey and buttermilk, which are subsequently used as secondary raw materials. The wastewater generated during the production of butter and cheese falls into the category of highly concentrated water, characterized by the presence of suspended solids and marked with highly acidic properties. The COD level is approximately 4000-4500 mg/O2, and the BOD level ranges from 3000-3375 mg/O2. Therefore, this company belongs to the fourth hazard class, and the sanitary protection zone should be at least 300 meters.

Table 1.

Enterprises that discharge wastewater and pollutants into surface waters

Object name	Water supply source	Discharge volume of wastewater, thousand cubic meters	Quantity of pollutants discharged with wastewater, t (tons).
1. Water supply and sewerage enterprise, Krasyliv city.	Sub-basin of the Pripyat River	562,5	375
2. Municipal Enterprise "Iziaslavvodokanal", Iziaslav city, Shepetivka district.	Sub-basin of the Pripyat River	281,3	157,7
3. Private Enterprise "Aslan - Textile", Basalia village, Khmelnytskyi district.	Sub-basin of the Pripyat River	103,6	122,3
4. Public Joint-Stock Company "Starokostiantyniv Specialized Quarry", Krasnosilka village, Khmelnytskyi district, (quarry waters)	Sub-basin of the Pripyat River	27,5	12,3
5. Municipal Enterprise "Bilogirya Spectransbud", Bilohirya village	Sub-basin of the Pripyat River	27,5	6,0
6. Theophilpol Production Management of Housing and Communal Services, Theophilpol town	Sub-basin of the Pripyat River	90,5	73,0
7. Municipal Enterprise "Lozove Communal Service", Lozove town, Khmelnytskyi district.	Southern Bug River basin	20,4	15,5
8. Municipal Enterprise "Zlagoda", Letychiv town.	Southern Bug River basin	40,4	32,0
9. Limited Liability Company "Podol-Expo", Khmelnytskyi district.	Southern Bug River basin	19,0	5,0
10. Municipal Enterprise "Starokostiantyniv Central Water Supply and Sewerage System No. 1", Stara Syniava village, Khmelnytskyi district.	Southern Bug River basin	17,4	1,0

11. Municipal Enterprise "City Water Utility", Dunayivtsi city.	Dniester River basin	280,9	227,0
12. Non-Governmental Organization "Victoria", Yarmolyntsi town.	Dniester River basin	33,9	35,0
13. Municipal Enterprise "Vinkovetsky Communal Service", Vinkivtsi town.	Dniester River basin	48,8	38,5
14. Municipal Enterprise "Satanevskye", Satanev town, Horodotsky district.	Dniester River basin	15,7	16,0
15. Water Utility State Enterprise, Nova Ushytsia town.	Dniester River basin	39,0	30,0
16. LLC "Diada D," Nova Ushytsia town.	Dniester River basin	47,6	34,5
17. LLC "Protein Invest," Dunayivtsi town, Dunayevetsky district.	Dniester River basin	10,5	8,0
18. LLC "Vinkivtsi Cheese Plant," Vinkivtsi town.	Dniester River basin	12,0	22,0
19. Municipal Enterprise "Komunservis," Chemerivtsi village, Khmelnytskyi district.	Dniester River basin	56,4	41,4
20. LLC "Vesna 21" Agricultural Enterprise, village of Humentsi, Kamianets-Podilskyi district.	Dniester River basin	2,0	0,0

Accordingly, a monitoring quality control of surface waters was conducted. Table 2 presents the concentrations of pollutants in the monitoring points of water bodies in the regions of the Khmelnytskyi Oblast (Table 2).

Based on sanitary and hygienic indicators, the results of the water analysis from the monitoring points comply with the safe level standards. However, in almost all water samples taken, there is an exceedance of the norm for BOD and COD, except for the water in the monitoring points of the Sluch River in Korzhivka village.

Possible reasons for exceeding the permissible norms of BOD and COD in the monitoring points of rivers could be the discharge of wastewater from industrial enterprises. This can be explained by the low efficiency of pollutant removal in the treatment facilities, indicating an intensified anthropogenic impact on natural water bodies.

Furthermore, the water quality was assessed using aquatic plants (macrophyte index) and macrozoobenthos (Maier and Woodiwiss indices). Based on the available bioindicators, the Southern Bug River in the vicinity of Khmelnytskyi and Kopystyn villages can be classified as a eutrophic water body with polluted water. The pollution level based on the macrophyte index was 6, Maier index was 12, and Woodiwiss index was 7. This can be attributed to the fact that the investigated sections of the river are located directly near industrial pollution sources and domestic wastewater discharge points.

An increase in the total iron content was also observed in all monitoring points of the rivers, exceeding the standard limit (0.3 mg/dm3). The elevated iron content can be attributed to the relatively high corrosive activity of the water.

Regarding the limiting criterion of harmful substances (phosphates, ammonium nitrogen, nitrite nitrogen, heavy metals) for objects of domestic and cultural use, they are characterized as toxic.

The water samples collected from the river monitoring points, as presented in Table 4, showed variations within the maximum permissible concentrations for heavy metals, phosphates, sulfates, and chlorides.

The nitrate nitrogen content in the river monitoring points ranged from 0.023 to 0.077 mg/dm3, while the concentration of nitrite nitrogen ranged from 0.439 to 2.172 mg/dm3.

Elevated levels of ammonium nitrogen were observed in the monitoring points of the Pivdennyi Bug River, specifically in the vicinity of Kopystyntsi village, where its concentration reached 10.62 mg/dm3. Such an increase indicated water pollution by organic substances and fertilizers from agricultural and industrial enterprises located in Kopystyntsi village.

Table 2

Sanitary-toxicological indicators of water in river reservoirs based on data from wastewater dischargers into surface waters (mg/dm³).

Indicator	Maximum Permissible Concentration (MPC)	Measured value				
		River Buzhok, town Medzhybizh	River Southern Bug, city Khmelnytskyi	River Southern Bug, village Kopystyntsi	River Styr, village Krasnosilka	River Sluch, village Korzhivka
Chlorides	300	20,25	43,95	73,05	47,67	42,85
Sulfates	100	12,3	13,14	18,04	18,75	19,62
BOD (Biochemical Oxygen Demand) mgO_2/dm^3	30	35,51	32,86	55,32	37,26	31,97
COD (Chemical Oxygen Demand) mgO_2/dm^3	6	6,10	6,01	6,67	6,27	4,763
Ammonium nitrogen	2,0	0,95	0,78	10,22	3,44	2,19
Nitrite nitrogen	0,1	0,03	0,02	0,05	0,07	0,04
Nitrate nitrogen	10	0,45	0,39	2,17	0,71	0,43
Phosphates	3,5	0,05	0,20	0,66	0,32	0,19
Total iron	0,3	0,5	0,7	0,54	0,4	0,3
Copper	0,005	0,002	0,003	0,004	0,003	0,026
Zinc	1,0	0,44	0,21	0,77	0,39	0,29
Nickel	0,1	0.05	0,05	0,05	0,05	0,05

Table 3.

Comprehensive ecological assessment of surface waters.

River name	Comprehensive assessment, W.	Level of pollution
River Buzhok, town of Medzhybizh	0,5	Permissible
Southern Bug River, city of Khmelnytskyi	0,6	Permissible
Southern Bug River, village of Kopystyń	1,0	Moderate
Sluch River, village of Krasnosilka	0,4	Permissible
Sluch River, village of Korzhivka	0,5	Permissible

Based on monitoring studies, it has been proven that the ecological state of surface waters in the regions of Khmelnytskyi Oblast, according to sanitary-toxicological indicators, corresponded to an acceptable and moderate level. This can be explained by the fact that discharges from agricultural and industrial enterprises, in inadequately treated condition, enter surface water bodies, resulting in the concentration of pollutants that are present in wastewater contributing to their contamination. According to the limiting criteria of harmfulness, the rivers' pollution level corresponded to an acceptable level, ranging from 0.4 to 0.6 TU (Toxic Units).

However, it should be noted that in the Pivdennyy Bug River, which flows through Kopystyntsi village, the pollution level reached 1.0 TU and approached a moderate level of contamination. From Table 3, it can be seen that the Pivdennyy Bug River in Kopystyntsi village exhibited an increased concentration of ammonium nitrogen, with a content of 10.22 mg/dm3. Such an increase indicates contamination of water with organic substances and fertilizers, which subsequently led to a decrease in dissolved oxygen content in the water and the occurrence of hypoxic conditions in the water body.

Conclusions. Based on the conducted research, it has been established that the waters of all reservoirs in the Khmelnytskyi region meet the acceptable and moderate levels of pollution according to sanitary-toxicological indicators. The indicator of the limiting criterion of harmfulness varied within the range of 0.4 to 1.0 TU.

It should be noted that the water sample from the reservoir of the Southern Bug River in the village of Kopystyn has a value of 1.0 TU, which is close to the moderate level of pollution. This can be attributed to the negative anthropogenic impact on surface waters caused by the presence of agricultural-industrial enterprises (LLC "Karmaliuk YuA", private farm "MAISS," and others) in the village. It is possible that the insufficient efficiency of the existing wastewater treatment facilities contributes to the pollution of the water body.

References:

1. Hryniuk, V. I, (2017). Improvement of the environmental safety management system of surface waters at the level of an industrial enterprise. *Environmental safety and balanced rsource use,* 1 (15), 72-81. URL: http://nbuv.gov.ua/UJRN/ebzp_2017_1_12. (in Ukrainian).

2. Antonenko I. (2020). The ecological situation of the countries of the European Commonwealth. Elimination of rare accidents at technologically dangerous facilities. *Materials of the All-Ukrainian scientific and practical Internet conference of higher education graduates and young scientists "Metro-logical aspects of decision-making in the conditions of work at technologically dangerous objects". Kharkiv*, *Ukraine*, 182 – 186. URL: https://er.chdtu.edu.ua/bitstream/ChSTU/1674/1/sbornik_konf_2020.pdf#page=182. (in Ukrainian).

3. Posthuma, L., Michiel, C. Zijp, Dick, De Zwart, Dik, Van de Meent, Globevnik, L., Koprivsek, M., Andreas, Focks, Jos, Van Gils, Birk. S. (2020). Chemical pollution imposes limitations to the ecological status of European surface waters. *Scientific Reports*, 10:14825, 132 – 144. DOI: https://doi.org/10.1038/s41598-020-71537-2.

4. Bila, A.T., Lyashenko E.V., & Okhrimenko O.V. (2020). Investigation of phosphate content in surface waters. *Aquatic bioresources and aquaculture*, 1, 111-116. DOI: https://doi.org/10.32851/wba.2020.1.10. (in Ukrainian).

5. Stepova, O.V., & Gah, T.O. (2020). Ecological state of surface waters of the Poltava region. *Environmental sciences,* 2(29), T. 2., 82-86. URL:. http://ecoj.dea.kiev.ua/archives/2020/2/part_2/15.pdf. (in Ukrainian).

6. Levandovsky, L.V., Bublienko, N.O., & Semenova, O.I. (2013). Environmental technologies and equipment. Kyiv: National University of Food Technologies. (in Ukrainian).

7. Tretyakov, O.V., Bezsonniy, V.L., Ponomarenko, R.V., & Borodych, P.Yu. 2019. Increasing the effectiveness of forecasting the impact of man-made pollution on surface water bodies. *Problems of emergency situations,* 1(29), 61–78. URL http://repository.hneu.edu.ua/handle/123456789/22686.

8. Shumygai, I.V., Yermishev, E.V., & Manishevska, N.M. (2021). Ecological assessment of heavy metal contamination of underground waters of Kyiv region. *Agroecological journal,* 1, 88-97. DOI: https://doi.org/10.33730/2077-4893.1.2021.227244. (in Ukrainian).

9. *Water quality. Determination of the mass concentration of nic kel by an express non-extraction photometric method. State standard of Ukraine 7150:2010*. (2011). Kyiv: State consumer standard of Ukraine. (in Ukrainian).

10. *The water is drinkable. Requirements and methods of quality control. State standard of Ukraine 7525:2014*. (2015). Kyiv: Ministry of Economic Development of Ukraine. (in Ukrainian).

11. *Quality water. The method of determining the mass concentration of nitrate ions by the chemiluminescent method. State standard of Ukraine 8931:2019.* (2020). Kyiv: State enterprise "Ukrainian research and training center for problems of standardization, certification and quality". (in Ukrainian).

12. *Water quality. Sampling of samples. Part 6. Guidelines for taking samples from rivers and streams. State standard of Ukraine ISO 5667-6:2009*. (2012). Kyiv: State consumer standard of Ukraine. (in Ukrainian).