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ASSESSMENT OF THE ECOSYSTEM STATE OF THE BILE LAKE (RIVNE REGION) BASED ON A SET OF ECOLOGICAL INDICATORS

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At the present stage, there is no water body in Ukraine that has not been altered by human activity or its consequences. In most cases, such interventions lead to the “aging” of lakes. Along with the disturbance of aquatic ecosystem stability, the condition of adjacent terrestrial biocenoses such as wetlands, forests, and meadows also deteriorates, resulting in not only local but also regional impoverishment of the gene pool of flora and fauna.

Moreover, the impact of hydraulic engineering and land reclamation activities on lake ecosystems has not yet been quantitatively assessed, although the external manifestations are evident – disruption of water exchange, alteration of the water surface area and feeding conditions, as well as deterioration in fish productivity and overall water quality.

The article is devoted to the assessment of the ecosystem state of the Bile Lake based on a set of ecologically formed indicators. During recent years, the environmental situation in both natural and artificial aquatic ecosystems has been deteriorating due to increasing anthropogenic pressure, which has resulted in significant qualitative and quantitative changes in their ecological state. According to scientific research, many inland water bodies have become so heavily polluted that their ecosystems are undergoing complete degradation, leading to the loss of their economic and landscape value [4].

Of particular concern is the process of anthropogenic eutrophication of lakes and reservoirs, caused by the excessive inflow of biogenic elements. This process disrupts the balance between the formation of primary organic matter and its decomposition. The slowdown of decomposition processes leads to a deterioration of the sanitary condition of water bodies and a decline in water quality. Consequently, this complicates water treatment for both drinking and industrial use, as well as hinders the development of recreation, aquaculture, and fisheries.

The factors influencing the water quality of a Bile Lake were investigated, an integral assessment of the ecological state of the water body was carried out, the concentrations of heavy metals within the aquatic ecosystem were determined, and the levels of radionuclides present in the ecosystem were analyzed [8].

Key words: hydroecosystem, water quality, abiotic indicators, biotic parameters, ecological assessment, fish productivity.

Statement of the task. The aim of an article is comprehensive study and analyzes of the state of the aquatic ecosystem of a Bile Lake in the Rivne Region based on a set of ecological indicators.

Analysis of recent research and publications. The issue of comprehensive water quality assessment in Ukraine has been studied by many researchers, who have proposed a new approach to evaluating the ecological risk of aquatic ecosystem degradation under persistent anthropogenic pressure. This approach aims to determine the degree of environmental hazard associated with various types of natural resource use [9].

The assessment of aquatic ecosystem conditions and the identification of patterns in their functioning taking into account the hydrochemical and hydrobiological characteristics of water bodies under conditions of economic exploitation – are becoming increasingly relevant. Such studies provide a scientific basis for predicting future changes induced by anthropogenic factors and for developing appropriate compensatory and protective environmental measures.

It has been established that at the present stage there is no water body in Ukraine that remains unaffected by human activity or its consequences. In most cases, anthropogenic interference accelerates the "aging" of lakes. Alongside the degradation of aquatic ecosystems, the condition of adjacent terrestrial biocenoses, such as wetlands, forests, and meadows, also deteriorates. This leads not only to local but also to regional losses in the genetic diversity of flora and fauna. Furthermore, the impact of hydraulic engineering and land reclamation projects on lake ecosystems has not yet been quantitatively evaluated, although their external manifestations are evident: disruption of water exchange, reduction of the water surface area, alteration of hydrological and nutrient conditions, and declines in fish productivity and overall water quality [3].

Materials and methods. In the course of the study, a comprehensive methodological approach was applied, combining both field and laboratory investigations with analytical and statistical techniques. The research was conducted in several stages to ensure the reliability and representativeness of the obtained results.

At the initial stage, the collection and systematization of existing statistical and cartographic data were carried out. This included the analysis of long-term hydrological, meteorological, and environmental monitoring records related to a Bile Lake and its catchment area. Such data provided the baseline for identifying trends in anthropogenic pressure and natural dynamics affecting the aquatic ecosystem [10].

At the field research stage, on-site sampling of water and sediment was performed at various points across the lake to capture spatial variability. Samples were collected in accordance with national and international standards for environmental monitoring. Field measurements included determination of water temperature, pH, electrical conductivity, transparency, and dissolved oxygen concentration using portable multiparameter probes. Visual assessments of the shoreline condition, aquatic vegetation, and signs of eutrophication or pollution were also conducted [6].

The laboratory analysis phase focused on determining the physicochemical and hydrobiological parameters of the collected samples. Standard analytical procedures were used to assess concentrations of biogenic elements (nitrogen, phosphorus compounds), organic matter content, and key ions. Heavy metals such as lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), and iron (Fe) were quantified using spectrophotometry. To assess the radiological condition of the lake, the activity concentrations of radionuclides (in particular, ^{137}Cs and ^{90}Sr) were measured [2].

Hydrobiological investigations included the study of phytoplankton, zooplankton, and benthic invertebrates as bioindicators of the ecological state of the aquatic environment. The composition, abundance, and diversity indices of these biotic components were analyzed to evaluate the level of eutrophication and the overall biological productivity of the ecosystem [11].

At the analytical stage, all experimental data were subjected to statistical processing using modern software tools. Methods of variation statistics, correlation, and regression analysis were employed to determine the interrelationships among environmental variables and to identify the dominant factors influencing water quality. An integral ecological index was calculated to provide a generalized quantitative assessment of the ecological state of a Bile Lake [1].

Based on the obtained results, recommendations were developed aimed at improving the ecological condition of the lake. These include measures for reducing external pollutant inflow, enhancing the self-purification capacity of the aquatic system, maintaining optimal hydrobiological balance, and restoring the populations of native fish species through ecologically safe and sustainable management practices [12].

Result and discussion. The Bile Lake is located within the territory of the Rivne Region, which, in terms of its physical and geographical position, lies within the forest-steppe zone of Ukraine. Geographically, the region occupies the central and western parts of the Volyn-Podillia Upland, the western slope of the Ukrainian Crystalline Shield, and a small area in the northeastern part of the region that extends into the Prypiat Depression.

The Bile Lake is of karstic origin and is situated in the Volodymyrets District of the Rivne Region, within the basin of the Styr River, a tributary of the Prypiat River. A lake is located near the village of Bilska Volia. It has a total water surface area of 453 hectares, making it the second-largest lake in the Rivne Region, following Lake Nobel (figure 1). Morphologically, a Bile Lake consists of two funnel-shaped karst depressions with maximum depths of 22 meters and 26 meters, respectively [5].

The Bile Lake is considered a unique natural feature of the region. It represents an exceptional combination of wetland, lacustrine, and forest ecosystems characteristic of Western Polissia. Due to its high ecological, hydrological, and landscape significance, the lake is included in the system of protected water bodies of the Rivne Nature Reserve, which ensures the conservation of its natural complexes, rare species, and overall ecological balance.

Figure 1. **The Bile Lake on the map**

The water quality indicators of a Bile Lake, obtained as a result of the conducted research, are presented in Table 1. Based on the tabulated data, the indicators were classified into three main groups: those characterizing the salt composition, tropho-saprobiological condition, and specific state of the water body.

An analysis of the sanitary-chemical and microbiological parameters of a Bile Lake allows for the following conclusions. The transparency of the water has slightly increased but remains within acceptable limits according to fishery and biological standards. The pH level is within the normal range, and the concentration of dissolved oxygen averages around 8.4 mg/dm^3, which indicates that the self-purification processes in the lake are occurring at a satisfactory level.

Indicators of organic pollution include the biochemical oxygen demand (BOD), which varied between 4.3 and 5.8 mgO/dm^3. These values classify the water body from moderately polluted to polluted. Additional indicators of organic contamination and the degree of mineralization are the various nitrogen forms, the excess of which reflects the degree of water toxicity.

Table 1. **Water analysis data of a Bile Lake (average 2020-2021)**

№	Indicator	Sampling site	
		Near the recreation center	On the opposite shore from the recreation center
1	pH	7.8	7.1
2	Color, degrees	28	26
3	Odor, points	0	0
4	Transparency, cm	More 20	More 20
5	Suspended solids, mg/dm^3	5.9	4.6
6	Dry residue, mg/dm^3	78.2	84.1
7	Total alkalinity, $mg\text{-}eq/dm^3$	0.9	0.7
8	Total hardness, $mg\text{-}eq/dm^3$	1.1	2.3
9	Calcium, mg/dm^3	18.1	1.9
10	Magnesium, mg/dm^3	0.62	0.7
11	Dissolved oxygen, mgO_2/dm^3	8.4	8.2
12	Chemical oxygen demand (COD), mgO_2/dm^3	45.0	42.0
13	Biochemical oxygen demand (BOD_5), mgO_2/dm^3	5.8	7.13
14	Ammonium nitrogen, mg/dm^3	0.28	0.36
15	Nitrate nitrogen, mg/dm^3	0.37	0.35
16	Nitrite nitrogen, mg/dm^3	0.004	0.001
17	Sulfates, mg/dm^3	15.5	12.05
18	Chlorides, mg/dm^3	4.72	2.7
19	Phosphates, mg/dm^3	0.05	0.13
20	Fluorides, mg/dm^3	0.18	0.18
21	Iron, mg/dm^3	0.20	0.19
22	Nickel, mg/dm^3	Not detected	Not detected
23	Zinc, mg/dm^3	0.06	Not detected
24	Copper, mg/dm^3	0.12	0.07
25	Total chromium, mg/dm^3	Not detected	Not detected
26	Manganese, mg/dm^3	0.053	0.014

No exceedances were recorded for nitrite, nitrate, or sulfate concentrations. However, significant exceedances were observed among parameters of specific action – particularly for iron, copper, and zinc content. Although the primary sources of these elements have not yet been definitively identified, it is assumed that one of the main factors may be the geographical proximity of the water body to the 30-km impact zone of the Rivne Nuclear Power Plant, as well as residual consequences of the Chornobyl nuclear disaster [7].

Based on the obtained data, it can be stated that for the majority of water quality indicators of a Bile Lake, increased concentrations are observed in the area near the recreation base, which serves as evidence of anthropogenic impact on the ecosystem.

For the integrated assessment of water quality in aquatic ecosystems, the calculation of so-called water pollution indices is applied. These indices comprehensively characterize the sanitary condition and hydrochemical status of a water body (Table 2).

Table 2. **Distribution of the Bile Lake water quality indicators by three blocks of water quality categories**

First block (salt composition indicators)			Second block (tropho-saprobiological indicators)			Third block (toxic effect indicators)		
Indicator	**Value**	**Category**	**Indicator**	**Value**	**Category**	**Indicator**	**Value**	**Category**
Dry residue, mg/dm^3	78.2	1	pH	7.8	1	Fluorides, mg/dm^3	0.18	4
Sulfates, mg/dm^3	15.5	1	Transparency, cm	More 20 см	1	Iron, mg/dm^3	0.20	4
Chlorides, mg/dm^3	4.72	1	Suspended solids, mg/dm^3	5.9	1	Nickel, mg/dm^3	none	1
			Dissolved oxygen, mgO_2/dm^3	8.4	2	Zinc, mg/dm^3	0.06	5
			COD, mgO_2/dm^3	45.0	6	Copper, mg/dm^3	0.030	4
			BOD, mgO_2/dm^3	5.81	2	Chromium, mg/dm^3	none	1
			Ammonium nitrogen, mg/dm^3	0.28	3	Manganese, mg/dm^3	0.053	4
			Nitrite nitrogen, mg/dm^3	0.004	2			
			Nitrate nitrogen, mg/dm^3	0.36				
			Phosphates, mg/dm^3	0.05				
Blocked index	1-1		Blocked index	1-2.2		Blocked index	1-3.3	

According to the obtained results, the waters of a Bile Lake can be classified as follows:

• By the salt composition block – Class I, Category I, freshwater, hypohaline, excellent quality (I_e = 1);

• By the tropho-saprobiological block – Class II, Category II, very good, clean, mesotrophic, alpha-oligosaprobic waters (I_e = 2.2);

• By the block of toxic effect indicators – Class II, Category III, good, clean, mesoeutrophic, and beta-mesosaprobic waters (I_e = 3.3).

The overall ecological index of a Bile's Lake water quality is I_e = 2.2.

Thus, the hydrological regime of the studied lake is determined by the geological and geomorphological features of the area, the state of specific environmental factors, and the direction of the processes occurring within them.

The general water quality assessment of a Bile Lake corresponds to Class II. However, within the block of specific toxic substances, elevated concentrations were recorded: Category IV for copper content, Category V for zinc, and Category IV for iron.

Thus, the block of specific effect indicators causes the greatest concern in the water body and requires additional research.

The results of the study on the content of heavy metals in the water of a Bile Lake are presented in Table 3. An increased concentration of copper (Cu) was detected – approximately one and a half times higher than the maximum allowable concentration (MAC). The levels of iron (Fe) and zinc (Zn) do not significantly exceed fishery-related MAC standards. It should be emphasized that the research results indicate an overall increase in the content of heavy metals, particularly lead (Pb), which is associated with the intensification of anthropogenic pressure on the aquatic ecosystem of the lake.

Table 3 – Content of heavy metals in the water of the Bile Lake

Year	Heavy metals content, mg/dm					
	Cu	Mn	Cd	Pb	Zn	Fe
2020	8.3	12.4	0.1	6.0	0.20	1.3
2021	6.7	12.2	0.3	4.2	0.25	2.4

The total content of heavy metals in water, even at relatively high concentrations, may not necessarily be harmful to fish and aquatic organisms. It is well known that in low-flow or closed water bodies with low turbidity, more than 90% of heavy metals migrate in a dissolved state.

The Bile Lake is not characterized by intensive overgrowth of higher aquatic vegetation; however, it demonstrates low fish productivity and slow fish growth rates. These features indicate significant changes in the ecological state of the lake, which, in turn, influence the solubility and mobility of heavy metals in the aquatic environment.

The next stage of the trophic chain study in the aquatic ecosystem of a Bile Lake involved the analysis of heavy metal content in higher aquatic plants. The research covered both submerged and emergent species. Submerged plants included sago pondweed (*Potamogeton pectinatus L.*), shining pondweed (*Potamogeton lucens L.*), and common hornwort (*Ceratophyllum demersum L.*). Emergent plants included broadleaf cattail (*Typha latifolia L.*), narrowleaf cattail (*Typha angustifolia L.*), and common bulrush (*Scirpus palustris L.*).

Samples of higher aquatic vegetation were collected along the perimeter of the lake at three sampling points. The results of the analysis of heavy metal content in higher aquatic plants of a Bile Lake are presented in Table 4.

According to the research results, the dominant concentrations of heavy metals in the phytomass were zinc, manganes, copper, cadmium, and lead. The accumulation pattern of heavy metals in macrophytes was as follows:

$$Zn > Mn > Cu > Cd > Pb \quad (1)$$

Table 4. **Content of heavy metals in higher aquatic vegetation of the Bile Lake**

Назва рослини	Heavy metals content, mg/kg dry matter				
	Mn	Cu	Zn	Cd	Pb
Potamogeton pectinatus L.	12.4±1.2	4.8±0.2	48.4±1.26	0.09±0.002	0.17±0.006
Potamogeton lucens L.	13.2±1.02	3.2±0.12	36.2±1.27	0.13±0.08	0.004±0.005
Ceratophyllum demersum L.	15.6±0.86	6.17±0.44	17.4±1.14	0.21±0.004	0.005±0.006
Typha latifolia L.	26.3±1.05	8.02±0.32	22.7±1.21	0.08±0.007	0.003±0.004
Typha angustifolia L.	33.5±1.12	10.3±1.2	39.4±1.32	0.3±0.012	0.007±0.002
Scirpus palustris L.	27.4±0.94	8.6±0.47	17.4±0.57	0.11±0.006	0.009±0.004

Regarding the species distribution among macrophytes, the highest concentrations of heavy metals, in decreasing order, were observed as follows: *Potamogeton pectinatus* > *Potamogeton lucens* > *Ceratophyllum demersum* > *Typha angustifolia* > *Typha latifolia* > *Scirpus palustris*. The greatest sensitivity to water quality was found in submerged plants, as they maintain the most extensive contact with the aquatic environment.

The accumulation chains of heavy metals and organic pollutants often culminate at the top of the trophic pyramid of aquatic ecosystems, where fish typically occupy the highest level. Both predatory and non-predatory fish species actively accumulate heavy metals, which ultimately reduces their nutritional value and poses potential health risks to consumers.

The results of the analysis of heavy metal content in fish muscle tissue from Lake Bile are presented in Table 5.

Among all the studied organs of the European eel (*Anguilla anguilla* L.), the highest concentrations of heavy metals were found in the vertebral bones. The maximum levels were recorded for Cu (7.21±0.02 mg/kg), Zn (9.02±0.10 mg/kg), and Mn (4.3±0.03 mg/kg). The scales ranked second in terms of heavy metal contamination, followed by the gills.

The roach (*Rutilus rutilus*) ranked second in heavy metal accumulation, with the distribution pattern as follows: scales > skin > vertebral bone > gills > liver > muscles. The highest concentrations were observed for Zn (30.19±0.31 mg/kg) and Cu (2.73±0.03 mg/kg).

Table 5. **Content of heavy metals in fish body tissues from Lake Bile (n = 3-6; M± m)**

Fish tissues	Heavy metals content, mg/kg dry matter					
	Zn	**Cu**	**Pb**	**Cd**	**Mn**	**Co**
European eel (*Anguilla anguilla*), three-year-old						
Scales	8.12±0.12	4.51±0.06	0.58±0.07	0.58±0.06	4.03±0.1	0.01±0.1
Skin	6.12±0.22	6.61±0.04	0.34±0.04	0.53±0.03	5.64±0.22	0.003±0.2
Muscles	3.42±0.11	3.20±0.03	0.43±0.01	0.43±0.01	2.1±0.11	0.001±0.05
Gills	7.26±0.31	8.92±0.04	0.67±0.022	0.13±0.03	3.1±0.4	0.03±0.02
Liver	6.12±0.09	6.51±0.11	0.31±0.06	0.21±0.04	2.3±0.03	insignificant
Vertebral bone	9.02±0.01	7.21±0.02	0.83±0.43	0.94±0.04	4.3±0.03	0.02±0.006
Roach (*Rutilus rutilus*). one-year-old						
Scales	30. 19±0.31	1.98±0.30	0.63±0.09	0.040±0.09	1.20±0.30	0.031±0.17
Skin	18.53±0.13	2.51±0.03	0.53±0.03	00.53±0.03	0.90±0.32	0.028±0.17
Muscles	6.53±0.3	2.42±0.05	0.23±0.05	0.023±0.01	0.54±0.39	-
Gills	14.67±0.23	2.53±0.01	0.13±0.01	0.063±0.05	1.04±0.70	0.012±0.17
Liver	17.2±0.20	1.33±0.03	0.43±0.02	0.037±0.03	0.80±0.30	-
Vertebral bone	20.1±0.12	2.73±0.03	0.65±0.03	0.087±0.03	2.04±0.40	0.058±0.17
Pike (Esox lucius), two-year-old						
Scales	15 65±0 34	0.95±0.06	0.27±0.08	0.27±0.03	-	0.072±0.08
Skin	18.15±0.14	1.21±0.05	0.17±0.08	0.58±0.07	-	0.028±0.1
Muscles	10.35±0.38	0.86±0.01	0.20±0.06	0.34±0.04	-	-
Gills	12.55±0.51	1.25±0.03	0.15±0.04	0.43±0.01	-	0.02±0.06
Liver	11.65±0.34	0.76±0.062	0.29±0.02	0.27±0.022	-	-
Vertebral bone	21.67±0.34	1.95±0.16	0.28±0.05	0.61±0.06	-	0.058±0.07
Rudd (Scardinius erythrophthalmus). one-year-old						
Scales	4.6±0.2	0.68±0.15	0.19±0.06	0.09±0.01	2.23±0.24	0.067±0.03
Skin	5.07±0.59	1.4±0.11	0.24±0.04	0.06±0.04	2.19±0.05	0.05±0.02
Muscles	6.03±0.1	2.9±0.2	0.06±0.01	0.03±0.03	2.14±0.02	0.06±0.04
Gills	4.7±0.12	1.6±0.12	0.1±0.01	0.012±0.02	2.17±0.01	0.02±0.01
Liver	5.7±0.8	3.2±0.22	0.5±0.08	0.011±0.01	2.21±0.01	0.08±0.03
Vertebral bone	6.45±0.6	1.9±0.1	0.6±0.07	0.017±0.03	1.19±0.04	0.042±0.02

The third highest concentrations of heavy metals were recorded in the pike (*Esox lucius*), where, similar to the two previously mentioned species, the highest levels were observed for Zn (21.67±0.34 mg/kg) and Cu (1.95±0.16 mg/kg) in the vertebral bone.

The lowest concentrations among all studied species were found in the rudd (*Scardinius erythrophthalmus*). The dominant elements were Zn (6.45±0.6 mg/kg) in the vertebral bone, Cu (3.2±0.22 mg/kg) in the liver, and Pb (2.23±0.24 mg/kg) in the scales.

For radiological studies of the lake, samples of water, bottom sediments of various types, higher aquatic plants, and fish were collected. Among the plants, both submerged species – *Potamogeton pectinatus* L. (sago pondweed), *Potamogeton lucens* L. (shining pondweed), *Ceratophyllum demersum* L. (common hornwort) and emergent species – *Typha latifolia* L. (broadleaf cattail), *Typha angustifolia* L. (narrowleaf cattail), and *Scirpus palustris* L. (common bulrush) were sampled. Higher aquatic vegetation was collected along the lake perimeter at three sampling points.

Among mollusks, great pond snail (*Lymnaea stagnalis* L.) and oval pond snail (*Radix ovata* L.) were identified in the samples. Fish species included in the radiological study were common carp (*Cyprinus carpio* L.), silver crucian carp (*Carassius auratus*), roach (*Rutilus rutilus* L.), European eel (*Anguilla anguilla* S.), and perch (*Perca fluviatilis* L.).

The content of radionuclides in the water of Lake Bile reached ^{137}Cs – 0.36 Bq/L and ^{90}Sr – 0.032 Bq/L, which does not exceed the permissible levels for radionuclides in water. It is well known that bottom sediments act as the most active accumulators of radionuclides, particularly cesium-137. The degree of their radioactive contamination depends on numerous factors, including sediment type, bottom relief, water currents, and the degree of higher aquatic vegetation development. The highest concentration of ^{137}Cs (16.2 Bq/kg) was recorded in the 0-5 cm layer of silt sampled at a depth of 9.0 m. The concentration of ^{90}Sr in bottom sediments ranged from 0.2 to 1.6 Bq/kg.

To evaluate the processes governing radionuclide exchange within the "water-bottom sediment" system, it is important to consider their state and chemical forms in the sediments. The highest average concentrations of ^{137}Cs were observed in plants such as narrowleaf cattail (*Typha angustifolia*) – 2700 Bq/kg and sago pondweed (*Potamogeton pectinatus*) – 1600 Bq/kg. The study revealed that submerged plant species contained radionuclides at levels 2.5 times lower than emergent plants. Under global fallout conditions, submerged species are generally characterized by a high capacity for radioactive substance accumulation due to their physiological properties.

The number of mollusks in the studied lake is relatively small, and these hydrobionts do not significantly influence the overall radioecological condition of Lake Bile. Therefore, they were examined primarily as one of the components of the aquatic ecosystem to assess radionuclide migration patterns. The most common mollusks showed the following contamination levels: ^{137}Cs – 21.6 Bq/kg, ^{90}Sr – 13.6 Bq/kg in *Lymnaea stagnalis*.

The study of radioactive contamination in fish was carried out in two aspects. On one hand, fish represent an important component of the aquatic ecosystem that quickly responds to changes in radioecological conditions and occupies a terminal position in the trophic chain. On the other hand, fish are an essential element of both commercial and recreational fisheries and a key component of the human diet. Therefore, it was necessary to determine the dependence of radionuclide accumulation in fish on the overall radioecological situation in the lake.

The highest levels of contamination were recorded in roach (*Rutilus rutilus* L.) and European eel (*Anguilla anguilla* S.), with ^{137}Cs concentrations of 1181 Bq/kg and 1064 Bq/kg respectively, values exceeding the permissible limit for cesium-137. The concentration of ^{90}Sr in the studied fish species ranged from 1.24 to 12.7 Bq/kg, which did not exceed the allowable level of 35 Bq/kg.

Thus, the radioactivity of most components of Lake Bile is largely determined by ^{137}Cs. Water, whose total radioactivity is approximately 95 % attributable to cesium-137, serves as the main source of contamination for ichthyofauna. The obtained results indicate that radioactive contamination in Lake Bile is primarily caused by ^{137}Cs, with a noticeable trend toward increasing concentrations. Consequently, there are conditions that favor radionuclide accumulation within the lake ecosystem.

In particular, the distribution of strontium-90 within the trophic chain of the water body follows the pattern: ichthyofauna > vegetation > water > bottom sediments.

The analysis of radionuclide content in fish organisms revealed no exceedances of permissible levels in fish products. The radiological data for a Bile Lake confirm the presence of radionuclides within the aquatic ecosystem. Although the current situation remains within ecological safety limits, the observed accumulation of radionuclides in macrophytes which form part of the diet of herbivorous fish raises concern, as it may ultimately lead to the transfer of radioactive elements into the human food chain.

Conclusions. During the study period, the highest concentrations of heavy metals were detected in the silty bottom sediments. The overall distribution of elements among the components of the aquatic ecosystem was as follows: silt > macrophytes > zoobenthos > ichthyofauna > zooplankton > phytoplankton > water. The highest heavy metal content within the ichthyofauna of the Bile Lake was observed in the European eel, particularly in the vertebral bone. According to the block of specific toxic substances, the studied water body belongs to Class II of water quality, both in terms of heavy metal content and the concentration of radioactive elements. The toxicological and radiological assessment of fish products from the analyzed water bodies, based on the content of heavy metal ions and radionuclides, meets the sanitary and veterinary standards for food raw materials and products. The lowest capacity for biological accumulation of heavy metals and radioactive elements was observed in planktophagous species, while the highest was found in benthophagous and detritophagous species. The gills, skin, scales, and fatty tissues exhibited the greatest cumulative effect, whereas the muscle tissues demonstrated the lowest level of accumulation.

ОЦІНКА ЕКОСИСТЕМНОГО СТАНУ ОЗЕРА БІЛЕ (РІВНЕНСЬКА ОБЛАСТЬ) НА ОСНОВІ КОМПЛЕКСУ ЕКОЛОГІЧНИХ ПОКАЗНИКІВ

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На сучасному етапі в Україні немає жодного водного об'єкта, який не був би змінений господарською діяльністю або її наслідками. У більшості випадків ці втручання ведуть до «старіння» озер. Разом з порушенням стану екосистем водного середовища погіршується стан суходільних біоценозів боліт, лісів, луків, що прилягають до озер, і має місце не тільки локальне, але й регіональне збіднення генофонду флори та фауни. Крім цього вплив гідротехнічного та меліоративного будівництва на екосистеми озер не має кількісної оцінки, хоча зовнішні ознаки наявні – порушення водообміну, зміна поверхні водного дзеркала і умов живлення, погіршення рибопродуктивності і якості води.

Статтю присвячено оцінці екосистемного стану озера Біле на основі комплексу екологічно обгрунтованих показників. В останні роки екологічна ситуація як у природних, так і в штучних водних екосистемах погіршується через посилення антропогенного навантаження, що призводить до суттєвих якісних і кількісних змін їхнього екологічного стану. Згідно з науковими дослідженнями, багато внутрішніх водойм зазнали настільки інтенсивного забруднення, що їхні екосистеми перебувають у стані повної деградації, внаслідок чого вони втрачають своє господарське та ландшафтне значення [4].

Особливе занепокоєння викликає процес антропогенного евтрофування озер і водосховищ, спричинений надмірним надходженням біогенних елементів. Цей процес порушує рівновагу між утворенням первинної органічної речовини та її розкладом. Уповільнення процесів розкладу призводить до погіршення санітарного стану водойм і зниження якості води. У результаті це ускладнює її очищення для питних і промислових потреб, а також гальмує розвиток рекреації, аквакультури та рибного господарства.

Було досліджено чинники, що впливають на якість води озера Біле, здійснено інтегральну оцінку екологічного стану водойми, визначено концентрації важких металів у межах водної екосистеми та проаналізовано рівні радіонуклідів, присутніх у ній [8].

Ключові слова: гідроекосистема, якість води, абіотичні показники, біотичні параметри, екологічна оцінка, рибопродуктивність.

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