Vol. 8, No. 4, 2023

ANALYSIS OF SURFACE WATER QUALITY INDICATORS IN THE DNIPRO-BUG ESTUARY REGION IN THE FIRST MONTHS AFTER THE DESTRUCTION OF THE KAKHOVKA HYDROELECTRIC POWER STATION DAM

Ganna Trokhymenko[1], Natalia Magas[1], Oleksandra Shumilova[2], Volodymyr Klochko[3]

[1] Admiral Makarov National University of Shipbuilding,
9, Heroiv Ukrayiny Ave, Mykolaiv, 54025, Ukraine
[2] Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB),
310, Müggelseedamm, Berlin, 12587, Germany
[3] State Institution "Mykolaiv Regional Centre for Disease Control and Prevention
of the Ministry of Health of Ukraine",
1, Lazurna Str., Mykolaiv, 54000, Ukraine
nataly.magas@gmail.com

https://doi.org/10.23939/ep2023.04.231

Received: 26.10.2023

Abstract. The article presents the results of the analysis of surface water quality indicators changes in water bodies near settlements in the Mykolaiv region in the areas that were flooded after the destruction of the Kakhovka HPP. The analysis of critical water quality monitoring data on sanitary, chemical and microbiological indicators revealed a deterioration in water quality in the Dnipro-Bug Estuary and the Ingul, Ingulets and Southern Bug rivers. Particularly dangerous levels of pollution were observed in the Inhulets River, where a significant increase in water levels and flooding of civilian infrastructure, residential buildings and households were observed in June 2023. The main reason for the high level of water pollution is sewage, pollution from the destruction of cattle cemeteries, and a large amount of washed-up garbage from flooded areas.

Keywords: surface water pollution, water quality assessment, sanitary and chemical indicators, microbiological indicators.

1. Introduction

As you know, on 6 June 2023, the Russian occupation forces blew up the dam of the Kakhovka hydroelectric power station, which led to an environmental disaster. Given the large scale of flooding of urban and industrial areas, agricultural land, and drainage of water bodies, it is necessary to constantly monitor the condition of the affected territories and water areas. Today, it is difficult to assess the full extent of the danger and predict the long-term consequences of this disaster. However, it can be expected that the risks of pollutant accumulation and the spread of infections will only increase. The flooding of the areas below the dam and subsequent drainage of the reservoir bottom affected flora, terrestrial and aquatic fauna, benthos, rare biotypes in the nature reserve fund and the Emerald Network, wetlands of international importance, and caused flooding of rivers. Restoring the ecological balance will take many decades.

The issue of the general environmental, humanitarian, demographic, energy, socio-economic consequences of the destruction of the hydroelectric power plant was discussed both on social media and at various scientific communication events. Some of the biggest challenges facing Mykolaiv region after the Kakhovka HPP explosion are:

1) the destroyed water supply system and lack of access to clean drinking water for both people and animals;

2) large quantities of heavy metals, pesticides, fertilisers, especially nitrates and phosphates, which are mutagenic and toxic in high concentrations, entering water bodies;

For citation: Trokhymenko, G., Magas, N., Shumilova, O., Klochko, V. (2023). Analysis of surface water quality indicators in the Dnipro-Bug Estuary region in the first months after the destruction of the Kakhovka hydroelectric power station dam. *Journal Environmental Problems*, *8*(4), 231–240. DOI: https://doi.org/10.23939/ep2023.04.231

3) the presence of ideal conditions for the reproduction of various pathogens in small reservoirs left after the water level has been lowered, the possibility of the emergence of new, more aggressive strains of pathogenic viruses and bacteria;

4) ideal conditions for the reproduction of pathogens in river ecosystems, especially salmonella, cholera pathogens, rotaviruses, which pose an infectious and environmental threat to the population (Tukalo et al., 2023).

5). a critical situation for agricultural areas in need of irrigation.

The work is closely related to the tasks set out in the Water Strategy of Ukraine until 2050 (Pro skhvalennia Vodnoi stratehii Ukrainy, 2022) the Comprehensive Environmental Protection Programme of Mykolaiv Oblast for 2021-2027 (Pro zatverdzhennia Kompleksnoi prohramy okhorony dovkillia Mykolaivskoi oblasti, 2020) the Order of the Head of the Regional Emergency Response to the Man-Made Emergency Situation Related to the Undermining of the Kakhovka HPP by the russian federation of 15. 06.2023 No. 6, Orders of the State Water Agency of Ukraine of 06.06.2023 No. 2753/4/1/11-23 and Mykolaiv Regional Military Administration of 07.06.2023 No. 71-d, regarding the crisis monitoring of the hydrological situation, water pollution and the consequences of the emergency due to the undermining of the Kakhovka HPP dam on the Kakhovka reservoir by the russian federation.

The Kakhovka Reservoir played a critical role in providing energy, drinking water, irrigation and river transport in various regions of southern Ukraine, as well as in supplying water to industrial enterprises in cities such as Kryvyi Rih, Nikopol, Marhanets and others (Magas et al., 2023).

As a result of the undermining of the Kakhovka HPP dam on 6 June 2023, a significant water column moved downstream, causing a sharp rise in water levels and flooding of large areas, leading to catastrophic consequences (Magas et al., 2023). Rises in water levels caused by the flooding of the Dnipro River were observed in the estuarine areas of the rivers that flow into the Dnipro River, in the Dnipro-Bug Estuary and in the Southern Bug, Ingul and Ingulets Rivers.

The rise in water levels in water bodies caused negative impacts on water areas, erosion in coastal areas, destruction of the surface soil layer, damage to vegetation, agricultural land and crops, and destruction of houses, infrastructure and other structures (Magas et al., 2023; Flooding due to the destruction of the Kakhovka Dam, 2023).

This situation poses a significant threat to the Dnipro-Buh estuary region and the Black Sea. Along with river water from the flooded areas, these water bodies carry large amounts of fuel and lubricants, hundreds of thousands of tonnes of soil, thousands of dead animals and birds, and uprooted trees. In addition, there is waste from destroyed sewerage systems and cesspools, residues of fertilisers and other chemicals, not to mention mines and other munitions that detonate right in the water. The “big water” also washes away cemeteries and cattle graveyards (Kozova, 2023). This toxic mixture is likely to affect all aquatic life. The bottom sediments of the Kakhovka Reservoir, which contain many toxic chemicals, primarily salts, heavy metals, organochlorine compounds and even DDT, also pose a significant danger (Vidbyrannia prob. Chastyna 6., 2012). Water supply interruptions alone could affect more than one million people, and the destruction of hydroelectric power plants could have long-term socio-economic consequences for the south-eastern macro-regions, affecting up to 1.5 million people.

Through surface water, harmful substances can get into groundwater and groundwater, which increases the level of threat to public health. This indicates a difficult environmental situation in the region and the need for a detailed study and analysis of the state of water resources.

The purpose of this study is to determine the level of pollution and assess the impact on the quality of surface water in the Dnipro-Buh estuary region as a result of the destruction of the Kakhovka HPP dam.

2. Materials and Methods

As a result of the explosion of the Kakhovka HPP dam, since 6 June 2023, a complex man-made hydrological situation has been observed in the Kakhovka Reservoir and the Dnipro River estuary, which has led to the transfer of a significant amount of pollutants from flooded areas.

Determination of the dynamics of surface water quality indicators in the Dnipro-Bug estuary region and analysis of the level of bacterial contamination of water bodies was performed on the basis of the obtained and processed results of sanitary, chemical and microbiological laboratory studies of water in seven sampling points in the Mykolaiv region (Fig. 1).

The studies were conducted in 6 laboratories: microbiological and sanitary-hygienic laboratories of the State Institution “Mykolaiv Regional Center for Public Health”, microbiological and sanitary-hygienic laboratories of the Mykolaiv District Department of the State Institution “(MRCDCP)”, microbiological and sanitary-hygienic laboratories of the Berezansky Laboratory of the Mykolaiv Regional Department of the State Institution "Mykolaiv Regional Center for Public Health". Sampling was carried out in accordance with DSTU ISO 5667-6:2009. Water quality. Sampling. Part 6. Guidelines for sampling water from rivers and streams (Water quality. Sampling. Part 9, 2012), DSTU ISO 5667-9:2005 Water quality. Sampling. Part 9: Guidelines for sampling of sea water (Water quality. Sampling. Part 9, 2005). Crisis monitoring of surface water quality was carried out for 11 chemical and 2 microbiological indicators. Methods of measurement (MOM) of the indicators are given in Table 1.

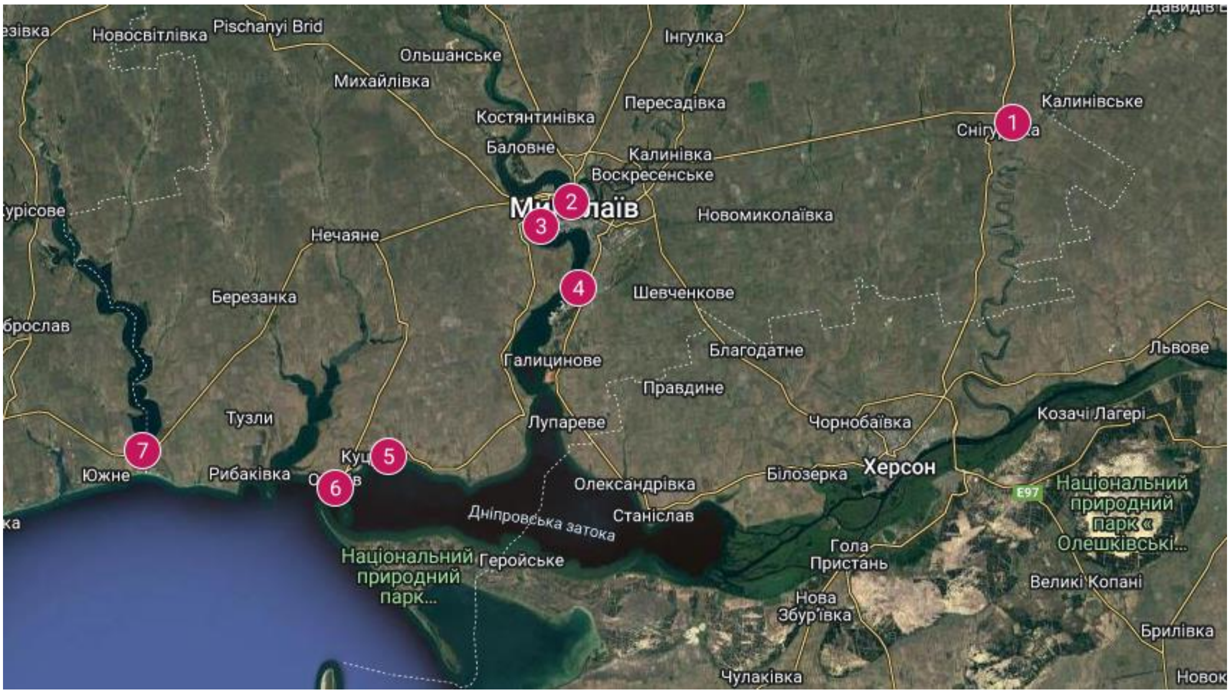

Fig. 1. Spatial distribution of surface water sampling sites for assessing the level of water pollution caused by the destruction of the Kakhovka HPP dam:
1 – Ingulets River, Snihurivka village; 2 – Ingul River, Mykolaiv city; 3, 4 – Bug Estuary, Mykolaiv city; 5 – Dnipro-Bug Estuary, Kutsurub village; 6 – Dnipro-Bug Estuary, Ochakiv city; 7 – Tylihul Estuary, Kobleve village

Table 1

Methods of measurement (MOM) and limit values for water quality indicators

	Indicator	Maximum permissible concentrations of chemicals in water bodies		Measurement techniques and method
		for drinking, household and other needs of the population (MPC) (Hihiienichni normatyvy yakosti vody, 2022)	sea waters and estuarine waters (MPC) (Pravyla okhorony, 2022)	
1	2	3	4	5
1.	Odour, points	1	1	RM № 6 – KH Vyznachennia zapakhu ta prysmaku orhanoleptychnym metodom u vodi pytnii ta zapakhu u vodi vidkrytykh vodoim
2.	Hydrogen pH	6.5–8.5	6.5–8.5	DSTU 4077-2001 Vyznachennia pH MVV 081/12-0008-01 Metodyka vykonannia vymiriuvan masovoi kontsentratsii rozchynenoho kysniu metodom yodometrychnoho tytruvannia za Vinklerom

Continuation of Table 1

1	2	3	4	5
3.	Oxygen dissolved mgO_2/L	> 4.0	> 4.0	MVV 081/12-0008-01 Metodyka vykonannia vymiriuvan masovoi kontsentratsii rozchynenoho kysniu metodom yodometrychnoho tytruvannia za Vinklerom
4.	BOD5, mgO_2/L	3.0	3.0	DSTU ISO 5815-1:2009 Yakist vody. Vyznachennia biokhimichnoho spozhyvannia kysniu pislia n dniv (BSKn). Chastyna 1. Metod rozvedennia ta zasivannia z dodavanniam aliltiosechovyny
5.	Salinity, mg/L	1000	1000	MVV № 081/12-0109-03 Metodyka vyznachennia masovoi kontsentratsii sukhoho zalyshku (rozchynenykh rechovyn) hravimetrychnym metodom
6.	Total iron, mg/L	0.3	0.5	RM № 9 – KH Vyznachennia zahalnoho zaliza kolorymetrychnym metodom v vodi pytnii ta vodi vidkrytykh vodoim
7.	Chlorides, mg/L	350	11900	DSTU ISO 9297:2007 Yakist vody. Vyznachennia khlorydiv. Tytruvannia nitratom sribla iz zastosuvanniam khromatu yak indykatora (metod Mora)
8.	Sulphates, mg/L	500	3500	MVV № 081/12-0177-05 Metodyka vykonannia vymiriuvan masovoi kontsentratsii sulfativ tytrymetrychnym metodom
9.	Nitrites (by NO_2), mg/L	3.3	0.08	KND 211.1.4.023-95 Metodyka fotometrychnoho vyznachennia nitryt-ionivz reaktyvom Hrisa v poverkhnevykh ta ochyshchenykh stichnykh vodakh
10.	Nitrates (by NO3), mg/L	45	40	RM № KH – 2 Vyznachennia nitrativ kolorometrychnym metodom v vodi pytnii ta vodi vidkrytykh vodoim
11.	Ammonium nitrogen, mg/L	0.5	0.5	MVV № 081/12-0106-03 Metodyka vykonannia vymiriuvan masovoi kontsentratsii amonii-ioniv fotokolometrychnym metodom z reaktyvom Neslera
12.	Lactose-fermenting coliform bacteria (LPC)	No more than 5,000/L		Metodycheskye ukazanyia 2285-81 Po sanytarno-mykrobyolohycheskomu analyzu vodu poverkhnostnukh vodoemov.1981h.
13.	Coliphages (in plaque-forming units)	No more than 100/L		Metodycheskye ukazanyia 2285-81 Po sanytarno-mykrobyolohycheskomu analyzu vodu poverkhnostnukh vodoemov.1981h.
14.	Viable eggs of helminths (hookworms, roundworms, toxocara, fasciola), oncospheres of taeniids and viable cysts of pathogenic intestinal protozoa	Must not be contained in 1 L		Metodycheskye ukazanyia 2285-81 Po sanytarno-mykrobyolohycheskomu analyzu vodu poverkhnostnukh vodoemov.1981h.

3. Results and Discussion

The destruction of the Kakhovka HPP dam caused a sharp rise in water levels not only in the Dnipro River but also in the Ingulets River. Due to massive flooding of civilian infrastructure, residential buildings and households in settlements located along the river in the Mykolaiv region, significant pollution of river water was observed. An analysis of the results of surface water quality studies in the Ingulets River showed that there was an excess of the established standards, as well as an increase in the values during the observation period for such indicators as odour, BOD-5, mineralisation (dry residue), sulphides and chlorides, total iron (Figs. 2–4), and a decrease in the amount of dissolved oxygen in the period before the water level began to decline. A particularly high level was observed in the Lactose-fermenting coliform bacteria index, which reached values of up to 240 million units (exceeding the standards by 48.000 times) (Table 2).

This situation indicates both an increase in the level of microbial contamination due to the erosion of cesspools, sewage, and pollution due to the destruction of cattle cemeteries on the reservoir's shore, and a large amount of washed-out garbage. Moreover, the concentration of dry residue in the water was steadily increasing, despite the drop in water level. Consequently, the amount of dissolved substances only increased. The level of microbial contamination fluctuated, reaching its maximum values in mid-June and mid-July.

A strong odour is caused by decay processes and the waste products of ferrous and sulphurous bacteria, which is fully correlated with an increase in the level of total iron and sulphates. However, the increase in the amount of sulphates and chlorides after the water level has dropped indicates the concentration of these substances.

A similar pollution situation was observed at the sampling sites on the Ingul River. The maximum coliform bacteria indicator of the did not exceed 70 thousand units, which is 14 times higher than the norm.

Table 2

Results of sanitary and microbiological monitoring of water quality in the Ingulets River near the Snihurivka town

Data	Lactose-fermenting coliform bacteria index, CFU/ 100 cm^3 (5000)
09.06.2023	24.000
10.06.2023	28.000
11.06.2023	5.000
12.06.2023	240.000
13.06.2023	24.000
14.06.2023	130.000
15.06.2023	240000.000
16.06.2023	24.000
17.06.2023	500.000
18.06.2023	1900.000
19.06.2023	6,200
20.06.2023	24.000
21.06.2023	6.200
22.06.2023	6.200
23.06.2023	5.000
24.06.2023	90.000
25.06.2023	70.000.000
26.06.2023	2800.000
27.06.2023	2.300
28.06.2023	20.000
04.07.2023	19.000
18.07.2023	2.900.000

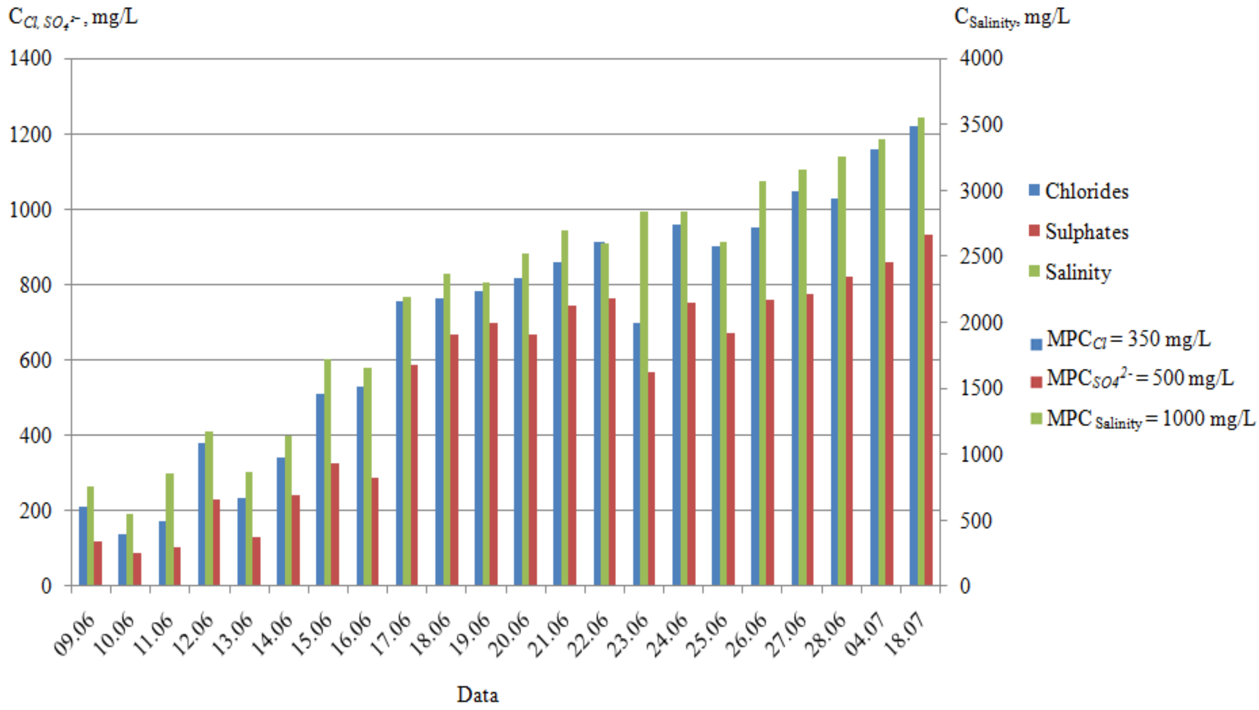

Fig. 2. Dynamics of chloride, sulphate ions and salinity in the water of the Ingulets River (OP No.1)

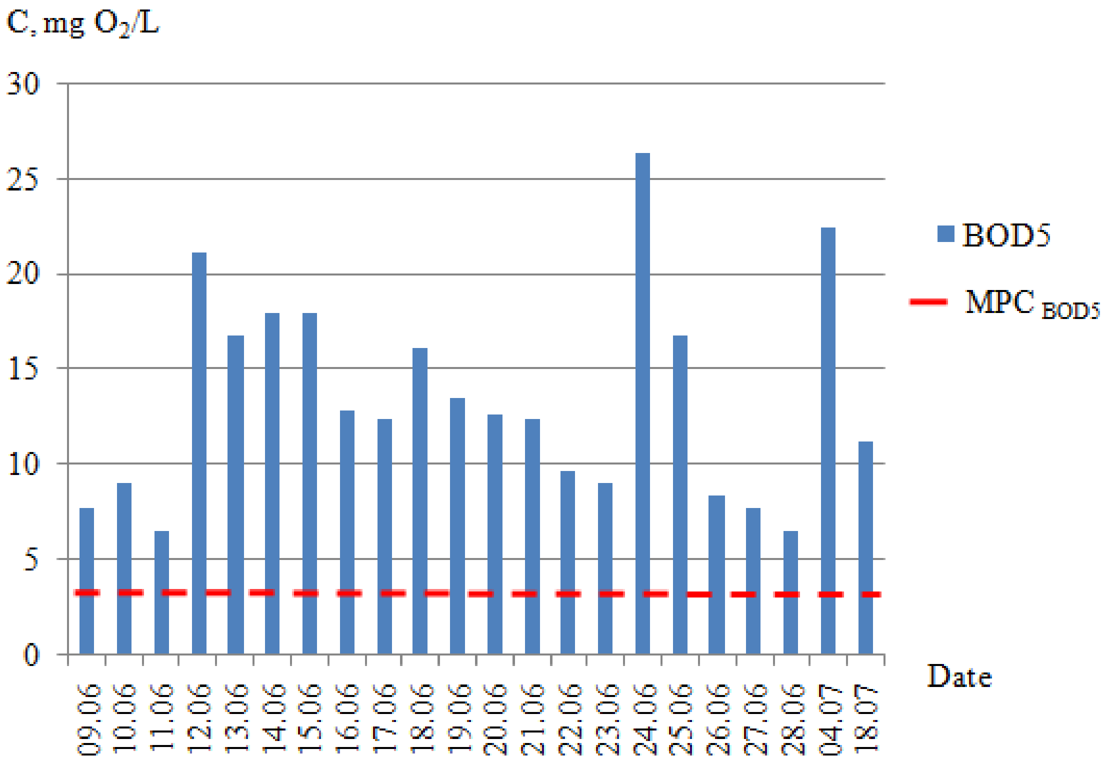

Fig. 3. Dynamics of biochemical oxygen consumption (BOD5) in the water of the Ingulets River (OP No. 1)

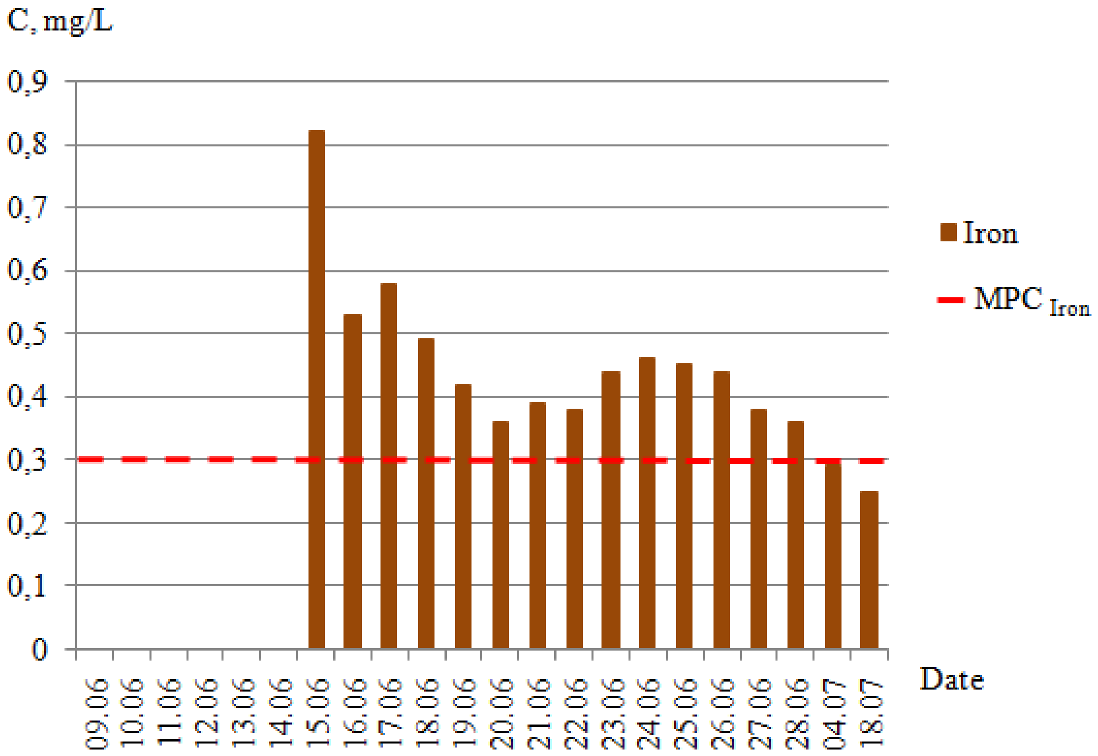

Fig. 4. Dynamics of total iron content
in the water of the Ingulets River (OP No. 1)

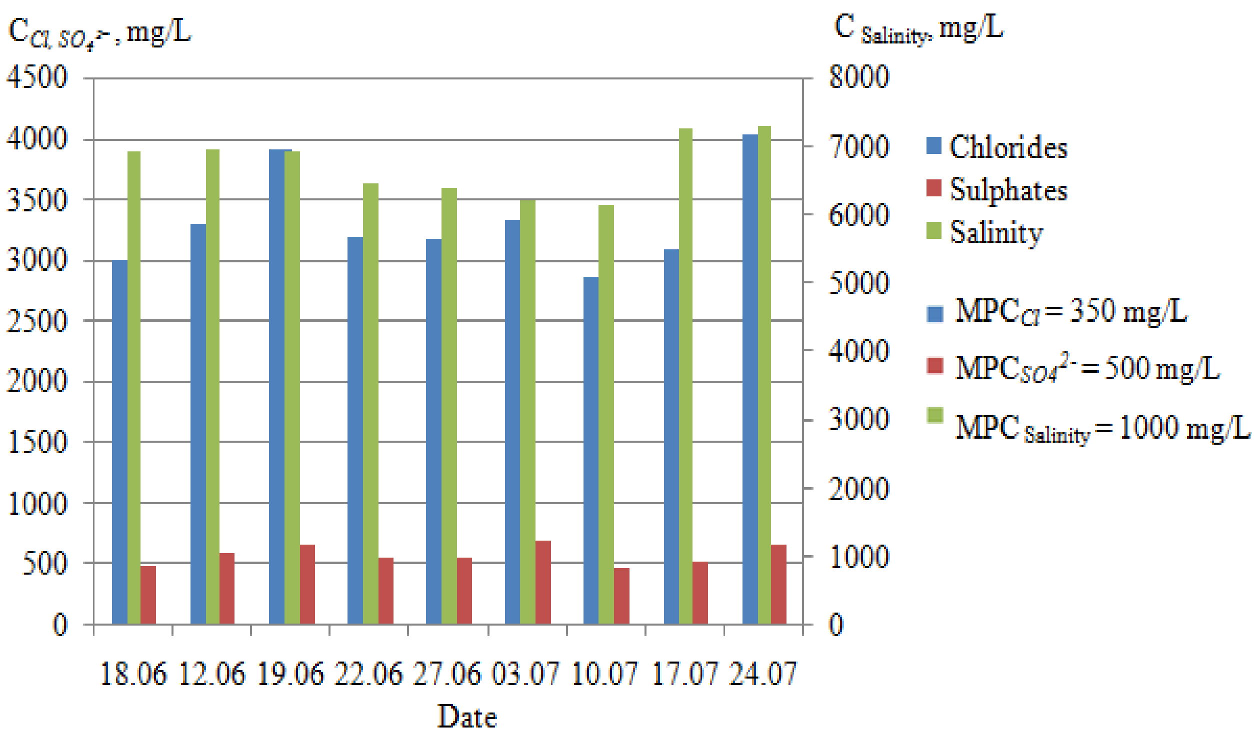

Fig. 5. Dynamics of chloride, sulphate ions and salinity
in the water of the Ingul River (OP No. 2)

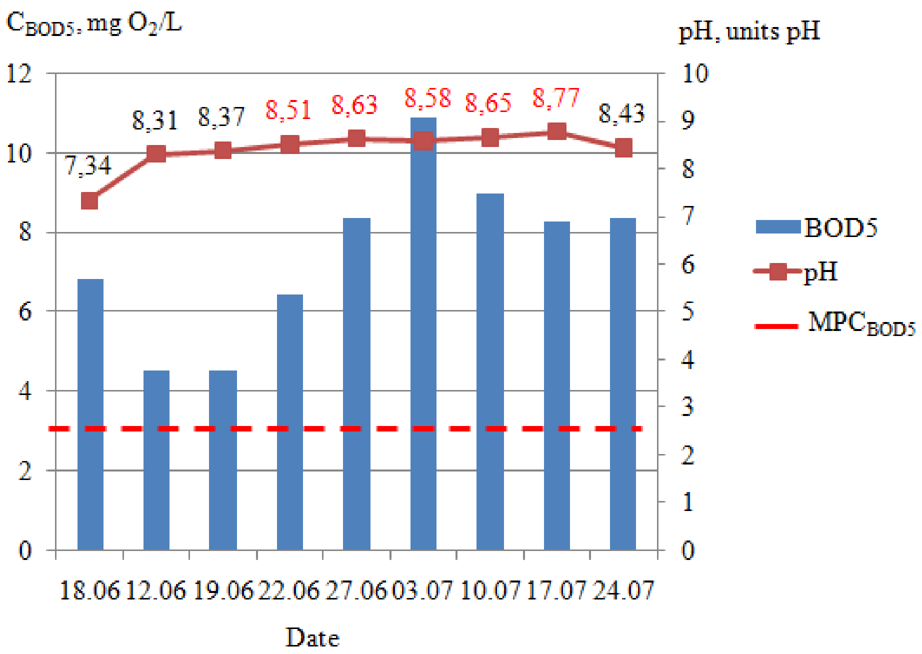

Fig. 6. Dynamics of pH and biochemical oxygen demand (BOD5) in the water of the Ingul River (OP No. 2)

At the sampling points on the Bug Estuary, in recreational areas in Mykolaiv, an increase in pH and biological oxygen consumption was observed in the first days. No exceedances were observed for the other indicators studied. However, it should be borne in mind that the normative indicators for comparison were used for estuarine waters, which are significantly different. BOD5 is an indirect indicator of the sum of all biodegradable organic substances in water. When the limit values are exceeded, oxygen-dependent aquatic organisms die, which was observed in June in the Ingulka and Bug estuaries.

The results of the water quality analysis of the Dnipro-Bug estuary showed alkalisation of water, as well as an increase in the level of biological consumption of oxygen and ammonia (Figs. 7, 8). Alkalisation could occur both naturally and as a result of silt and other solid particles deposited on the bottom of the estuary, as well as chemicals that were washed away from industrial and agricultural facilities. The maximum value of the Lactose-fermenting coliform bacteria index was 240 thousand units, which is 48 times higher than the norm.

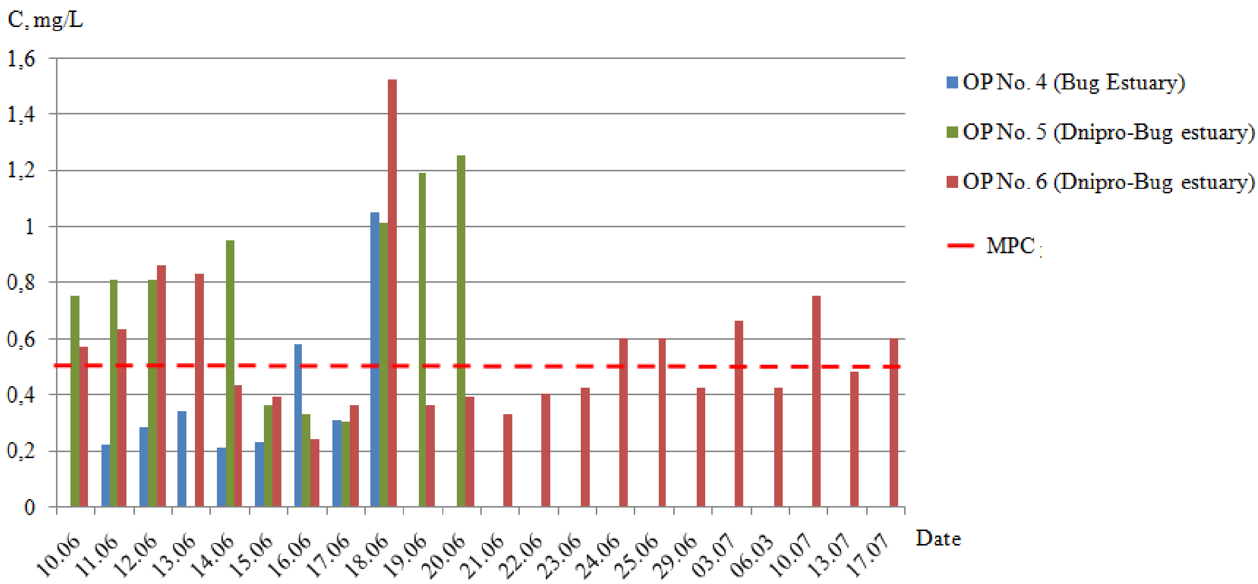

Fig. 7. Dynamics of ammonium nitrogen content in the surface water of estuaries

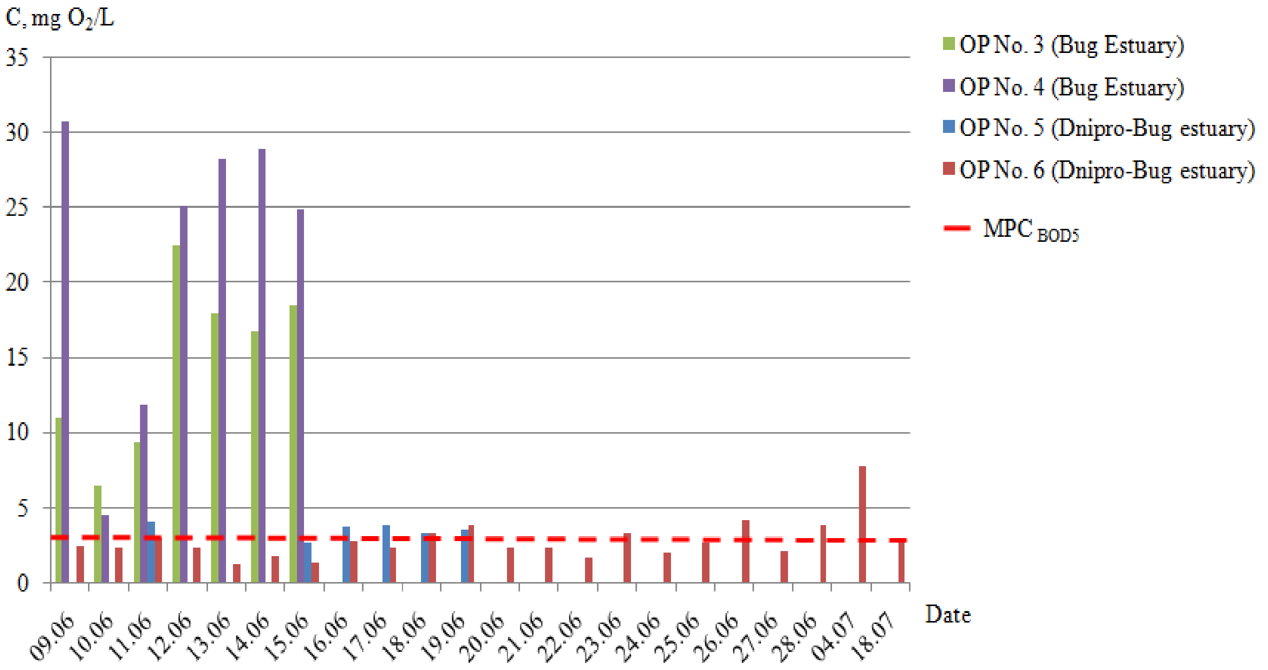

Fig. 8. Dynamics of biochemical oxygen demand (BOD5) in the surface water of estuaries

An increase in BOD along with an increase in ammonia concentration indicates anaerobic decomposition of organic matter, as well as pollution from agricultural runoff from fields, nitrogen fertilisers, or sewage and faecal matter.

At all observation points on the Tiligul Estuary, there was virtually no increase in water pollution during the study period. There was a slight excess of chloride concentration. In order to prevent polluted water from entering the Dnipro-Bug estuary, the water exchange channel connecting the estuary with the sea was closed after the Kakhovka HPP dam was blown up.

4. Conclusions

Hydroelectric dams have always been subject to increased technological hazards. The destruction of the Kakhovka hydroelectric power station dam led to a huge environmental disaster. Large areas of the southern region of Ukraine with unique biodiversity were flooded. The rise in water levels in water bodies caused negative impacts on water areas, erosion in coastal areas, destruction of the surface soil layer, damage to vegetation, farmland and crops, and destruction of houses, infrastructure and other buildings. The analysis of hydrochemical indicators of surface water quality revealed an increase in the level of pollution in water bodies following the rise in water levels in the southern region of Ukraine caused by the destruction of the Kakhovka HPP.

The main reason for the deterioration in water quality is pollutants transferred from flooded areas, including fuels and lubricants, garbage, agrochemicals, other hazardous materials, wastewater from treatment plants and sewage. Contamination of water sources poses a significant health risk. Chemicals and pathogens that can enter wells and open water bodies in the flooded areas pose a risk of disease and contributed to the massive fish kills that were subsequently observed in the Dnipro and Mykolaiv regions. A particularly dangerous level of pollution was typical for the Ingulets River hydrosystem. The river's resources are used by farmers to irrigate land in Mykolaiv and Kherson regions. After the destruction of the Dnipro water pipeline, water from the Ingulets River is the main source of water supply for the city of Mykolaiv. This indicates a challenging environmental situation in the region and the need to conduct a detailed study and develop measures to stabilise and prevent deterioration in surface water quality.

Prospects for using the research results. The results of the study and analysis of changes in the hydrochemical state of water bodies can be used to improve and develop measures to prevent the dangerous impact of man-made emergencies due to a dam (dam, sluice, etc.) breach with the formation of a breach wave, which leads to water pollution.

References

Flooding due to the destruction of the Kakhovka Dam –ACAPS: Briefing note (2023). Retrieved from https://www.acaps.org/fileadmin/Data_Product/Main_media/20230609_acaps_briefing_note_ukraine_flooding_due_to_the_destruction_of_the_kakhovka_dam.pdf

Hihiienichni normatyvy yakosti vody vodnykh obiektiv dlia zadovolennia pytnykh, hospodarsko-pobutovykh ta inshykh potreb naselennia: Nakaz Ministerstva okhorony zdorovia Ukrainy 2022, No. 721 (2022). Retrieved from https://zakon.rada.gov.ua/laws/show/z0524-22#Text

Kozova, L. (2023) *Katastrofa planetarnoho masshtabu: yakymy budut ekolohichni naslidky teraktu na Kakhovskii HES*. Informatsiine ahenstvo UNIAN. Retrieved from https://www.unian.ua/ecology/katastrofa-planetarnogo-masshtabu-yakimi-budut-ekologichni-naslidki-teraktu-na-kahovskiy-ges-12289350.html

Magas, N., Khorenzhenko, H., Zamuruieva, K., Beshevets, Yu., Ryndiuk, S., Barkar, V., Zamrii, M. & Bondar M. (2023). Analysis of the hydrological situation in the Dnipro-Bug estuary region following the destruction of the Kakhovka hydroelectric power station dam. *Ecological Science*, *4*(49), 15–25. doi: https://doi.org/10.32846/2306-9716/2023.eco.4-49.2

Pravyla okhorony vnutrishnikh morskykh vod i terytorialnoho moria Ukrainy vid zabrudnennia ta zasmichennia: Postanova Kabinetu Ministriv Ukrainy 2022, No. 431 (2022). Retrieved from https://zakon.rada.gov.ua/laws/show/ 269-96-%D0%BF#Text

Pro skhvalennia Vodnoi stratehii Ukrainy na period do 2050 roku: Rozporiadzhennia Kabinetu Ministriv Ukrainy 2022, No. 1134-r (2022). Retrieved from https://zakon.rada.gov.ua/laws/show/1134-2022-%D1%80#Text

Pro zatverdzhennia Kompleksnoi prohramy okhorony dovkillia Mykolaivskoi oblasti na 2021–2027 roky: Rishennia Mykolaivskoi oblasnoi rady 2020, No. 16 (2020). Retrieved from https://www.mk-oblrada.gov.ua/UserFiles/decree/16111249526007d0d8091a5.pdf

Tukalo, M., Tkachuk, Z. & Yanenko, Yu. (2023). Viina i biobezpeka v Ukraini. *Visn. NAN Ukrainy*, *8*. doi: https://doi.org/10.15407/visn2023.08.014

Water quality. Sampling. Part 6: Guidelines for sampling water from rivers and streams, ISO 5667-6:2005 (2012).

Water quality. Sampling. Part 9: Guidelines for sampling of sea water, ISO 5667-9:2005 (2005).