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Environmental assessment of the war impact on the surface waters of the Dnipro River in the Zaporizhzhia city

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SUMMARY

This work analyzed the impact of anthropogenic pressure, including war, on the state of surface waters in the Dnipro River in Zaporizhzhia. The analysis utilized the Streeter-Phelps model approach, which allows for evaluating the balance between oxygen consumption in water and its restoration through diffusion from the atmosphere. Additionally, supplementary anthropogenic impacts were considered, namely the activities of industry, agriculture, and municipal enterprises. The impacts associated with the war were also assessed, specifically the destruction of the Kakhovka HPP dam (the elimination of the Kakhovka Reservoir) and the cessation of operations at the Dnipro HPP. It has been established that during 2023-2024, a process of self-purification of water occurred in the Dnipro River in the upper pool of the Dnipro HPP. It has been proven that the reduction in the level of contamination by phosphate and ammonium ions since the beginning of the war played an important role in improving drinking water quality. However, threats to further self-purification exist if pre-war levels of surface water pollution return, as evidenced by the research results obtained.

Introduction

Due to the significant deterioration of surface water quality in Ukraine as a result of anthropogenic impact in the late 20th - early 21st century, threats to the life and health of the population have emerged, as this is primarily associated with the deterioration of drinking water quality. The situation has further complicated since the beginning of the war due to additional contamination from explosives, ammunition residues, and other materials. The Dnipro River requires special attention in this context, as it is Ukraine's main waterway and plays a vital role in providing drinking water supply. Therefore, assessing the water quality in the Dnipro under current conditions is of paramount importance, as it allows us to understand the nature and degree of surface water pollution, not only from anthropogenic pressures from human activities but also from the impacts of military operations and the destruction of hydraulic structures. Click ONCE and select this paragraph, you will replace this text with your own text and it will be automatically formatted. All styles for this template are formatted for you.

Method and Theory

In the analysis, general-scientific methods (analysis and synthesis, induction and deduction) and special methods of phenomena and processes analysis (abstraction, econometric and econometric-mathematical modelling) have been used.

Examples

One of the indicators of the state of the aquatic (river) ecosystem and the level of pollution is its oxygen regime. Oxygen is crucial for the oxidation of organic substances that enter surface waters due to anthropogenic pressure from human activities and natural processes. The primary factors influencing oxidation processes include water temperature, river flow rate, and the content of biogenic and organic substances. Scientists have developed mathematical models to predict the course of these processes. One of the most well-known is the Streeter-Phelps model (dating back to 1925) (Streeter & Phelps, 1958). Despite its age, it remains widely used today as it allows for forecasting changes in dissolved oxygen content in surface waters as an indicator of the river ecosystem's condition. In Bezsonnyi & Nekos, 2022), using the Streeter-Phelps model, it has been shown that among the physicochemical and biological processes, the most significant are oxygen consumption during the oxidation of organic substances and its replenishment through atmospheric diffusion.

Results

To assess the impact of anthropogenic pressure, including the war, on the state of surface waters in the Dnieper River in Zaporizhzhia, an analysis of water quality indicators was conducted for the monitoring station: Dnieper River, 328 km, Zaporizhzhia, upper reservoir of the Dnieper Hydroelectric Station, city drinking water intake (DVS No. 1) (47°81′80″ N, 35°10′00″ E). The analysis was based on data from the Water Monitoring Laboratory of the Basin Water Resources Management of the Azov Rivers. The study considered the following parameters: biochemical oxygen demand over 5 days (BOD_5), dissolved oxygen (Oxygen), phosphate ions (Phosphate), and ammonium ions (Ammonium).

The Streeter-Phelps model approach considers the following processes. First, organic substances entering surface waters are utilized by microorganisms, consuming oxygen in the process. Thus, the biochemical oxygen demand (BOD) indicates how much oxygen is required for the complete oxidation of organic substances in the water body. As oxidation and decomposition progress, the BOD value decreases.

Second, alongside oxygen consumption, oxygen enters surface waters from the atmosphere, saturating the water with dissolved oxygen (Oxygen). This diffusion compensates for oxygen losses due to organic matter decomposition, with its rate depending on water temperature, flow rate, and the concentration of dissolved oxygen in the water body.

Effectively, the Streeter-Phelps model assesses the balance between oxygen consumption in water due to organic matter decomposition and its replenishment through atmospheric diffusion. This, in turn, helps evaluate water quality and its ability for natural self-purification. The primary indicators for such an analysis are biochemical oxygen demand over 5 days (BOD_5) and dissolved oxygen (Oxygen).

For a comprehensive assessment of water conditions, it is also essential to consider the influence of phosphate and ammonium ions.

The main sources of phosphate ion pollution in the Dnieper River are untreated or insufficiently treated wastewater from municipal, industrial, and agricultural enterprises, household detergent use, and surface runoff from agricultural lands using fertilizers.

Ammonium ions may enter the Dnieper River as a result of livestock farming activities, surface runoff from agricultural lands using ammonium fertilizers, and industrial wastewater discharges.
An increase in phosphate and ammonium concentrations in water can stimulate the growth of algae and higher aquatic plants, leading to the risk of eutrophication of surface waters. These processes intensify during summer as rising water temperatures accelerate the biochemical decomposition of accumulated biomass. Additionally, oxygen deficiency can cause fish die-offs.

Thus, using the aforementioned indicators allows for an assessment of the safety level of Dnieper River water at the drinking water intake point in Zaporizhzhia.

The analysis was conducted for the period from 2005 to 2024. Figures 1 and 2 present the dynamics of changes in indicators over part of this period, from 2017 to 2024.

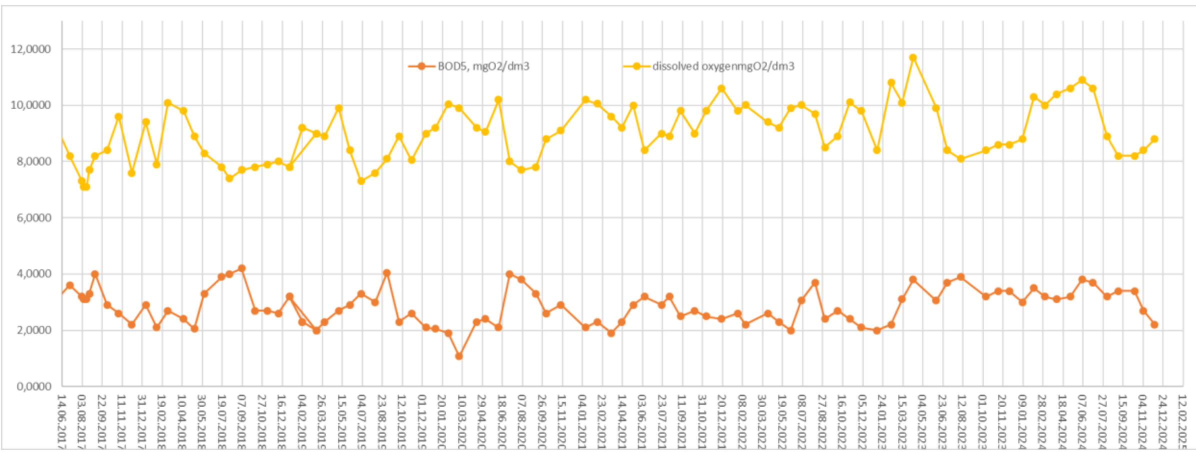

Figure 1 *Dynamics of biochemical oxygen demand over 5 days (BOD5) and dissolved oxygen (Oxygen) from 2017 to 2024.*

The analysis revealed that during 2005-2022, traditional interdependencies between BOD5 and Oxygen (dissolved oxygen) were observed, influenced by temperature. During summer, increased biological activity heightened oxygen demand and reduced its solubility, leading to lower dissolved oxygen levels and higher BOD5 values. In contrast, lower temperatures in autumn and winter slowed biological activity, reducing oxygen consumption for organic matter decomposition, increasing oxygen solubility, and resulting in higher dissolved oxygen levels and lower BOD5.

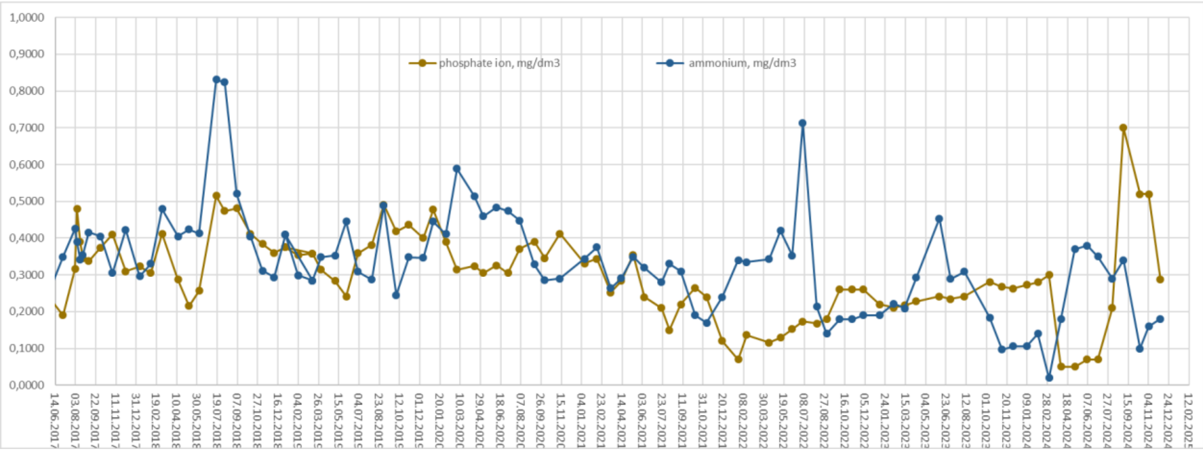

Figure 2 *Dynamics of phosphate and ammonium ion concentrations from 2017 to 2024.*

However, the situation in 2023-2024 differed from previous years. From March to May 2023, oxygen levels increased, but from July 2023 to February 2024, they dropped significantly. Unlike previous years, there was no traditional increase in dissolved oxygen in autumn and winter. Instead, its levels rose from March to September 2024. From September to October 2024, levels declined as in previous years, followed by an increase with falling temperatures (similar to the 2005-2022 trend). In 2023-2024, unlike in 2005-2022, seasonal fluctuations in BOD_5 were nearly absent.

To explain these anomalies, we analyzed changes in phosphate and ammonium ion concentrations. Figure 2 shows that until 2021, phosphate and ammonium levels followed consistent patterns, driven by industrial, municipal, and agricultural influences. However, since February 2021, phosphate levels decreased, reaching a minimum between February and August 2022. From September 2022 to February 2024, phosphate levels gradually increased (without seasonal variations), followed by a significant decline from April to July 2024, greater than any previous period since 2005. In September-October 2024, phosphate levels spiked to their highest recorded value before declining again.

Ammonium levels rose sharply in July 2022, dropped in August 2023, increased again, and reached a low in October 2023-February 2024.

These anomalies likely result from multiple factors. First, key sources of phosphate and ammonium pollution in the Dnipro River above Zaporizhzhia include industrial enterprises in Dnipro and Kamianske, such as PJSC "DniproAzot," "Dniprovsky Mineral Fertilizer Plant," and "ChemDivision" in Kamianske. Since the war began, production and wastewater discharge have significantly decreased.

The war also disrupted agricultural fertilizer supply. Before 2022, Ukraine relied heavily on Belarusian fertilizers, but this supply stopped. Ukrainian production was also affected, with plants like "Sumykhimprom" and "Severodonetsk Azot" shutting down. This reduced fertilizer use, consequently decreasing phosphate contamination in the Dnieper River.

Meanwhile, ammonium pollution trends were less dramatic, though the early 2024 decrease likely resulted from rising domestic fertilizer prices, leading to lower agricultural use and reduced ammonium runoff.

Regarding the situation with BOD_5 and dissolved oxygen levels, possible causes include the destruction of the Kakhovka Hydroelectric Power Plant dam on June 6, 2023, and the shutdown of the Dnipro Hydroelectric Power Plant due to shelling on March 22, 2024. The first event led to the flooding of territories and a reduction in the amount of water released from the upper reservoir of the DniproHPP into the lower reservoir. Damage to and the shutdown of the DniproHPP further complicated water discharge. As a result, the flow of the Dnipro River slowed within the Dnipro (Zaporizhzhia) reservoir, which is formed by the DniproHPP dam.

To ensure the operation of the cascade of hydroelectric power plants upstream of the DniproHPP, water must be released, but not as intensively as when the DniproHPP was operational. Thus, the prolonged decrease in dissolved oxygen levels in 2024 (including in the autumn-winter period) while BOD_5 values remained practically unchanged - even during an increase in dissolved oxygen levels—can be explained as follows.

In the summer of 2023, biological activity in the Dnipro reservoir intensified, but oxygen losses were compensated by diffusion from the atmosphere, as evidenced by the stable BOD_5 values. In winter, the decomposition of existing organic matter likely continued, leading to low dissolved oxygen levels despite the unchanged BOD_5. These processes occurred alongside a decline in phosphate and ammonium ion concentrations, preventing additional stimulation of algal growth. The necessary oxygen was supplied from the atmosphere.

The increase in dissolved oxygen levels from February to July 2024, while BOD_5 remained unchanged, suggests that decomposition processes in the waterbody became more active without additional stimulation for new organic matter formation. The traditional summer decline in dissolved oxygen levels was not accompanied by an increase in BOD5 due to the ongoing decomposition of organic matter.

These phenomena indicate that a self-purification process took place in the reservoir from 2023 to 2024. Despite a certain decrease in flow velocity in the upper reservoir, atmospheric oxygen diffusion compensated for the oxygen demand. At the same time, the reduction in phosphate and ammonium ion pollution positively affected water quality, supporting self-purification processes.

Conclusions

This work analyzed the impact of anthropogenic pressure, including war, on the state of surface waters in the Dnipro River in Zaporizhzhia. It has been established that during 2023-2024, a process of self-purification of water occurred in the Dnipro River in the upper pool of the Dnipro HPP. It has been proven that the reduction in the level of contamination by phosphate and ammonium ions since the beginning of the war played an important role in improving drinking water quality. However, threats to further self-purification exist if pre-war levels of surface water pollution return, as evidenced by the research results obtained.

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