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THE WAR ANTHROPOGENIC IMPACT ON THE CONDITIONS OF THE DESNA RIVER SURFACE WATERS

Purpose. To provide a comprehensive environmental assessment of the condition of the surface waters of the Desna River in order to identify the main anthropogenic factors of impact, in particular the consequences of the war.

Methods. System analysis, statistical data processing methods, retrospective dynamics analysis, and forecasting of future trends.

Results. An analysis was carried out using long-term data from the Water Monitoring Laboratory of the Desna Basin Water Resources Authority for the monitoring stations: Chernihiv, Brovary and Kyiv. The research was conducted for the following indicators: biochemical oxygen demand over 5 days (BOD_5) and dissolved oxygen, phosphate ions and ammonium ions, nitrite ions and nitrate ions, sulfate ions and chloride ions. Special attention was paid to the analysis of pollution of the surface waters of the Desna River originating from the territory of the Russian Federation. It was established that in 2024 the most significant pollution was recorded in Chernihiv. An increase in the BOD_5 level was observed, exceeding the MPC (maximum permissible concentration) levels, along with a sharp decrease in the dissolved oxygen level. This indicates the entry of organic pollutants into the waters of the Desna River, which led to intensified decomposition processes. After September 21, 2024, the situation improved, as evidenced by a decrease in the BOD_5 level and an increase in dissolved oxygen. It was proven that this resulted from the entry into the river of phosphate and ammonium ions, as well as nitrite ions. Similar studies were carried out for the Brovary and Kyiv stations. It was found that the inflow of pollutants from the territory of the Russian Federation into the Desna River after August 26, 2024, did not affect the BOD_5 values and dissolved oxygen levels at these sites.

Conclusions. The study identified the main environmental problems of the Desna River, in particular organic and mineral pollution, disturbance of the hydrological regime, and a decrease in oxygen levels. It was established that in 2024 the Desna River near Chernihiv (Chernihiv station, 200 km) experienced the greatest anthropogenic impact. Deterioration of water quality indicators was recorded for all analyzed parameters. The situation was better at the other two stations. Pollution of the Desna River with nitrite ions was observed only at the Chernihiv (200 km) station and was not significant at the Brovary (20 km) or Kyiv (3 km) stations. Since the BOD_5 and dissolved oxygen indicators normalized at the end of September, there is reason to believe that self-purification of the surface waters in the river occurred.

KEYWORDS: *Desna River, surface waters, environmental monitoring, phosphates, ammonium, sulfates, chlorides, dissolved oxygen, BOD_5, nitrates, nitrites, anthropogenic impact, consequences of the war*

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Introduction

The ecological state of Ukraine's rivers attracts constant attention from scientists, as economic activity, species exploitation, and discharge of insufficiently treated wastewater lead to negative anthropogenic impacts [1-19]. The Desna River basin is no exception. Under wartime conditions, Ukraine's water resources, in particular the Desna River basin, are suffering significant environmental losses. This region plays a key role in ensuring water supply and maintaining ecosystem balance. Military actions cause direct pollution of water bodies with explosive substances, fragments of military equipment, petroleum products, and toxic chemicals, leading to a decline in water quality and loss of biodiversity within the river basin and surrounding natural complexes. The destruction of water treatment facilities and hydraulic structures contributes to the uncontrolled entry of pollutants into the river system.

The case of the Kakhovka hydroelectric power station explosion, which caused massive flooding of territories, leaching of pollutants from soils, chemical warehouses, cemeteries and cattle burial grounds, is particularly illustrative. The destruction of treatment facilities in frontline regions, such as Zaporizhia region, led to the discharge of thousands of cubic meters of untreated wastewater into rivers. Damage to hydraulic structures disrupts water level regulation, causes bank erosion and changes in the hydrological regime. Additional pressure is created by forced population migration and changes in land use. Eliminating the consequences of these environmental losses and monitoring them is critically important for preserving environmental stability in the strategic perspective. A thorough analysis of the impacts of the war on the water resources of the Desna basin should form the basis for the development of effective measures for restoration and prevention of further degradation. Special attention is required to study the situation during 2024-2025, since in addition to the anthropogenic impacts of enterprises on the state of surface waters of the Seim River basin [20] within the Kursk Oblast of the Russian Federation, the consequences of hostilities in this territory have been added, which may be potential sources of additional pollution of the Desna River.

Objects and Research Methods

For the purpose of assessing the anthropogenic load, including that caused by the war, on the condition of the surface waters of the Desna River, an analysis of water condition indicators was carried out for the monitoring stations: Chernihiv, 300 km (51°39′42″ N, 31°27′12″ E); Brovary, 20 km (50°61′61″ N, 30°70′61″ E); and Kyiv, 3 km (50°55′10″ N, 30°56′90″ E). The analysis was based on data from the Water Monitoring Laboratory of the Desna Basin Water Resources Authority. The study was conducted for the following indicators: biochemical oxygen demand over 5 days (BOD_5) and dissolved oxygen, phosphate ions and ammonium ions, nitrite ions and nitrate ions, sulfate ions and chloride ions.

Results and Discussion

Physico-geographical and hydrological characteristics. The Desna River is the largest left-bank first-order tributary of the Dnipro and belongs to the large rivers of Ukraine. The total length of the river is 1,130 km, of which 575 km lie within Ukraine. The catchment area covers

88.9 thousand km², with 33.8 thousand km² within Ukraine's borders. The average density of the river network in the sub-basin is 0.24 km/km², which indicates a well-developed hydrographic system. The medium-sized tributaries of the river with a catchment area of more than 2 thousand km² include the Seym, Kleven, Sudost, Snov, and Oster rivers (Fig. 1).

Lake formations in the basin are mainly represented by floodplain oxbow lakes formed as a result of channel meandering. Lakes on low above-floodplain terraces are remnants of ancient riverbeds. Within Ukraine, the Desna has no regulated sections, however, on its tributaries – mainly in the Seym basin – 23 reservoirs have been created, serving general water-use functions [5].

The hydrological regime of the Desna is formed mainly due to snowmelt, which causes a distinctly expressed spring flood of the meltwater–rain type. The summer–autumn period is characterized by declining water levels, and in winter the river is under ice cover for an average of 3–4 months. Seasonal fluctuations in discharge and water levels have a significant impact on the channel's morphology and the condition of riparian ecosystems [6].

Hydrochemical characteristics and water quality assessment. The hydrochemical composition of the Desna River's water is formed under the influence of natural factors (geological structure, climate, hydrological regime) and anthropogenic factors (wastewater discharges, agricultural land use in the basin). According to state monitoring conducted by the Desna Basin Water Resources Authority, the river water is regularly tested for priority organic and inorganic pollutants in accordance with the EU Water Framework Directive. Among the main indicators monitored are sulfate content, chloride content, ammonium nitrogen, nitrites, nitrates, phosphates, as well as BOD_5 and COD as indicators of organic pollution [5].

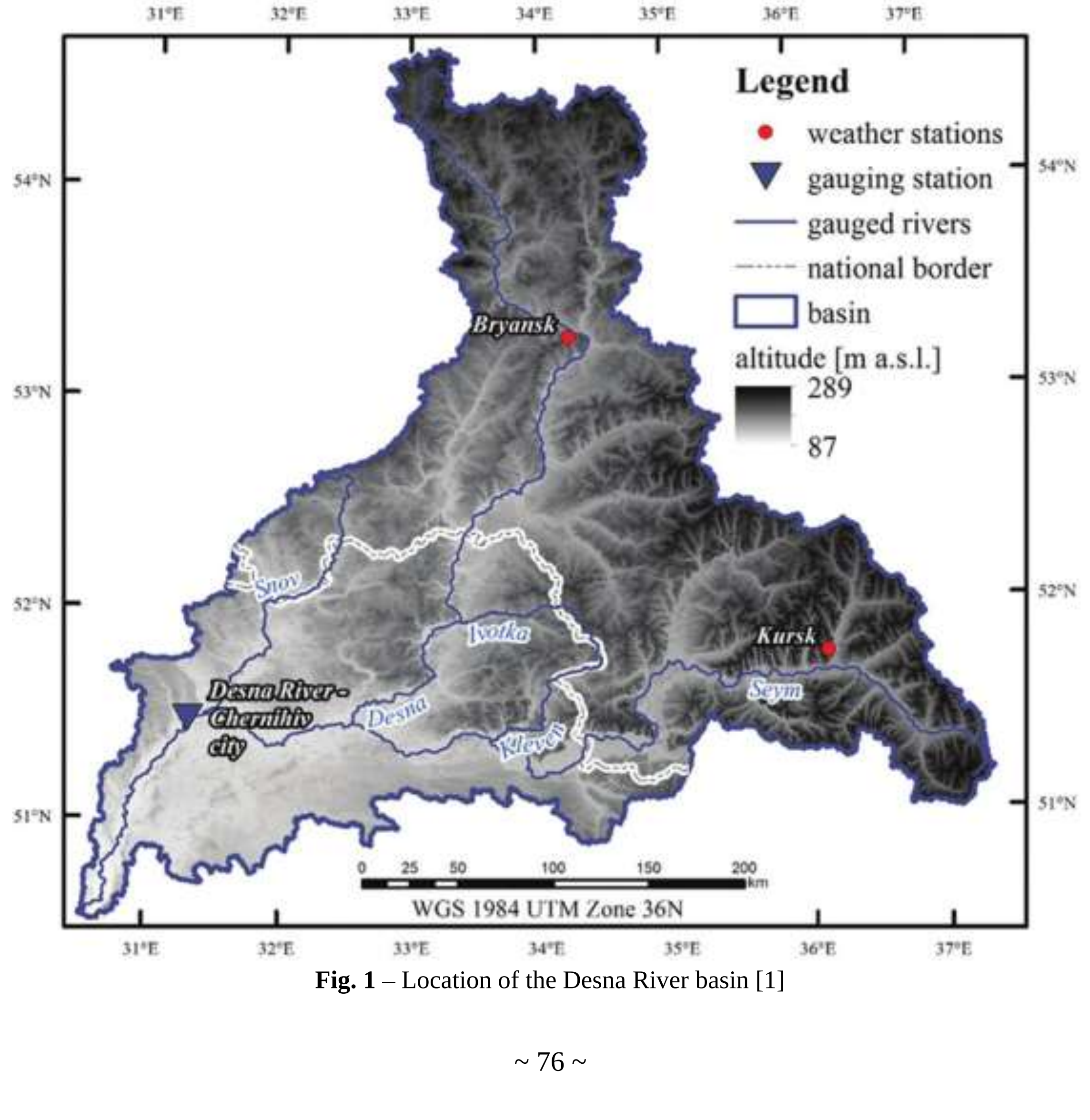

Fig. 1 – Location of the Desna River basin [1]

Results of hydrochemical observations show that elevated concentrations of biogenic elements (nitrogen, phosphorus) can lead to the development of eutrophication processes. Luzovytska Yu.A., Osadcha N.M., and Artemenko V.A. established that the presence of increased concentrations of nitrogen and phosphorus compounds in the water stimulates intensive phytoplankton growth and the phenomenon of "water blooming," which worsens organoleptic properties and reduces dissolved oxygen content [7].

Research by Kovalenko S.A. confirms that the quality of the Desna's water depends not only on local pollution sources but also on the influence of upstream tributaries. A mathematical model developed by the author shows that pollutants, in particular sulfates and chlorides, can persist in the water flow and spread over long distances downstream, creating a cumulative effect at confluences [8].

The impact of anthropogenic load is also confirmed by studies conducted in the Seym basin and other Desna tributaries, where exceedances of pollutant content standards were detected in summer, when hydrological conditions favor the concentration of dissolved substances [8 – 10].

Climatic features of the basin. The Desna basin is located in a temperate continental climate zone with mild winters and warm summers. The average annual air temperature is +6…+8 °C, the average temperature in January is –6…–8 °C, and in July +18…+20 °C. The average annual precipitation ranges from 550 to 650 mm, with a maximum in summer, which makes possible the formation of rain-induced floods. Winter is characterized by a stable snow cover that feeds the spring flood [6].

According to Shakirzanova Zh.R. and coauthors, long-term trends indicate a decrease in average spring runoff values, yet the likelihood of high-water and even catastrophic floods remains. Such events are particularly dangerous as they lead to flooding of floodplains and settlements and to the disruption of transport infrastructure. For forecasting the hydrological situation in the Desna basin, a methodology for regional long-term forecasts of maximum spring flood discharge is applied, taking into account a complex of hydrometeorological factors. Climate change manifests itself in the increased frequency of extreme meteorological events—from warm winters with short ice cover to intense summer downpours capable of causing short-term but high flood waves [6, 11].

Ecological aspects. The ecological state of the Desna basin is determined by a combination of natural processes and anthropogenic impacts. The main sources of pollution are agricultural runoff, untreated or insufficiently treated municipal and industrial wastewater, as well as diffuse sources associated with soil erosion. The influence of these factors is particularly noticeable in the summer–autumn period, when water levels drop and pollutant concentrations increase [9, 10. 12].

Studies by Kovalenko S.A. and other authors confirm the importance of a basin-wide approach to water resources management. In particular, the influence of upstream tributaries on the ecological state of the main channel is significant, and ignoring this factor can lead to underestimation of pollution levels. Constructed isolines of sulfate and chloride concentrations show a consistent increase in the content of these components downstream, confirming the cumulative effect [8].

Processes of eutrophication are also recorded, developing due to an excess of biogenic elements in the water. This creates the threat of toxic blooms and reduced water transparency, which negatively affects the biodiversity of aquatic ecosystems [2, 3, 7].

The works of Luzovytska Yu.A., Osadcha N.M., and Artemenko V.A. have examined the content of biogenic elements and determined their role in the development of eutrophication processes in the Desna. Shakirzanova Zh.R. and coauthors have developed and tested a methodology for forecasting maximum spring flood discharge in the basin under climate change conditions. Kovalenko S.A. created a mathematical model for assessing the influence of upstream tributaries on water quality, showing the cumulative effect of pollutant spread. Materials from the state monitoring conducted by the Desna Basin Water Resources Authority detail the physico-geographical and hydrochemical characteristics of the river, as well as sources of anthropogenic impact. Together, these studies form a comprehensive understanding of the current state of the Desna River and the factors that determine it [5 – 9].

Water bodies of Ukraine under wartime conditions experience additional anthropogenic impacts. One such case became known on August 26, 2024, when there was a critical deterioration in the ecological condition of the Seym River in Chernihiv region. Visual evidence of environmental danger included the change in water color to black and mass fish kills. The State Agency for Land Reclamation and Water Management of Ukraine promptly released information stating that the primary cause of the pollution was the inflow of contaminated water masses from Kursk region of the Russian Federation, where active hostilities were ongoing at the time.

It is worth noting that pollution of the Seym River on Russian territory had been recorded as early as mid-August 2024. Local sources reported the movement of polluted water characterized by high toxicity and causing biota death. In response to the environmental crisis, on August 29, 2024, the Ministry of Environmental Protection and Natural Resources of Ukraine issued an official statement emphasizing that the situation with water quality in the Seym and Desna rivers was under control. The statement also noted that, at present, there was no threat to drinking water supply for the population; however, the issue of long-term environmental consequences remains open and requires further scientific research and monitoring.

In addition, according to open sources, there are 23 polluting enterprises in the Seym River basin within Kursk region of the Russian Federation (LLC "Tyotkino Sugar Plant", JSC "Tyotkinospirt", Kursk NPP, LLC "Kursk Leather", JSC "Kurskvodokanal" and others) that may be potential sources of pollution affecting Sumy and Chernihiv regions [13].

Data on anthropogenic pollution and the condition of water in the Desna River were analyzed using monitoring data from the Chernihiv station, 200 km, over the period from 2014 to February 2025. An analysis was carried out on the temporal changes in biochemical oxygen demand over 5 days (BOD_5) in water bodies of the city of Chernihiv for the period from 2007 to 2025 (monitoring data for 2019–2023 are unavailable) (Fig. 2).

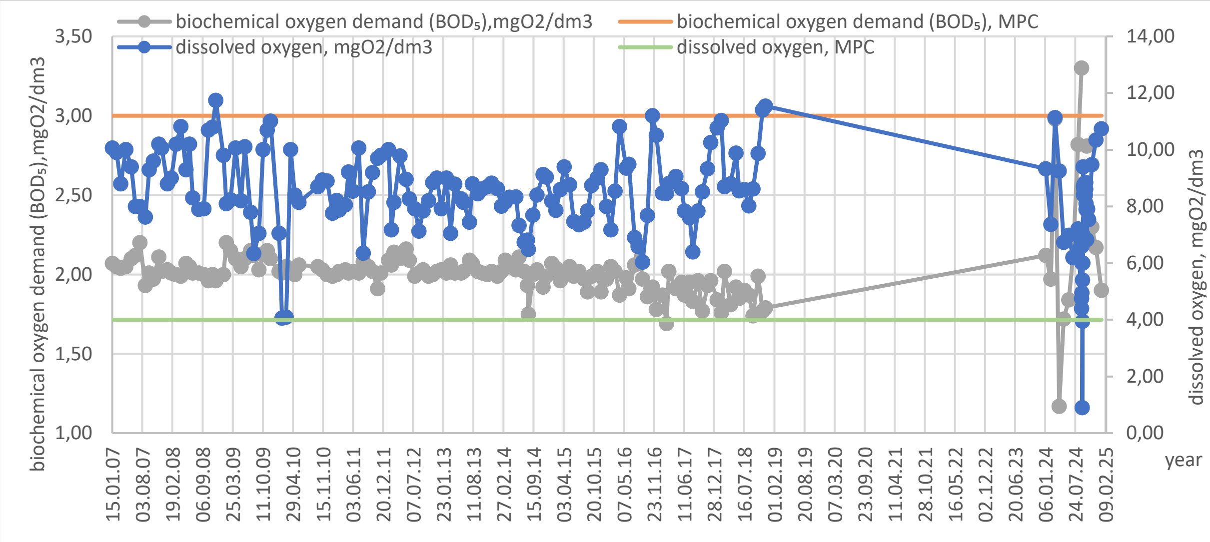

Fig. 2 – Dynamics of changes in indicators: biochemical oxygen demand over 5 days (BOD_5) and dissolved oxygen (O_2) during 2007–2025

Based on these data, several significant fluctuations can be noted. At the beginning of 2014, a relatively high BOD_5 level (about 2.5 mgO_2/dm^3) is observed, showing a tendency to increase in the first half of 2014, reaching a peak value of about 3.0 mgO_2/dm^3. In the second half of 2014 and at the beginning of 2015, there is a sharp drop in the indicator to its lowest point (approximately 1.2 mgO_2/dm^3), which may indicate an improvement in water quality during this period or changes in anthropogenic load. From 2015 to 2017, BOD_5 values fluctuate within the range of 1.8–2.2 mgO_2/dm^3, showing relative stability.

In 2017–2018, a gradual increase in the indicator begins, which may be associated with an increase in organic matter pollution. The largest fluctuations are observed in the period 2019–2020, when BOD_5 values rapidly rise to almost 2.7 mgO_2/dm^3, then sharply drop to 1.0 mgO_2/dm^3, after which they again increase steeply. This indicates instability in the ecological situation during this period.

Figure 3 presents detailed data for the period 2024 – early 2025. The situation in 2024 with regard to BOD_5 fully corresponded to its seasonal variations. It should be noted that its level was below the MPC. At the beginning of 2024, it was relatively high, then sharply decreased, and subsequently rose again, reaching peak values in the second half of 2024. The level of dissolved oxygen also underwent significant changes but generally showed a trend opposite to

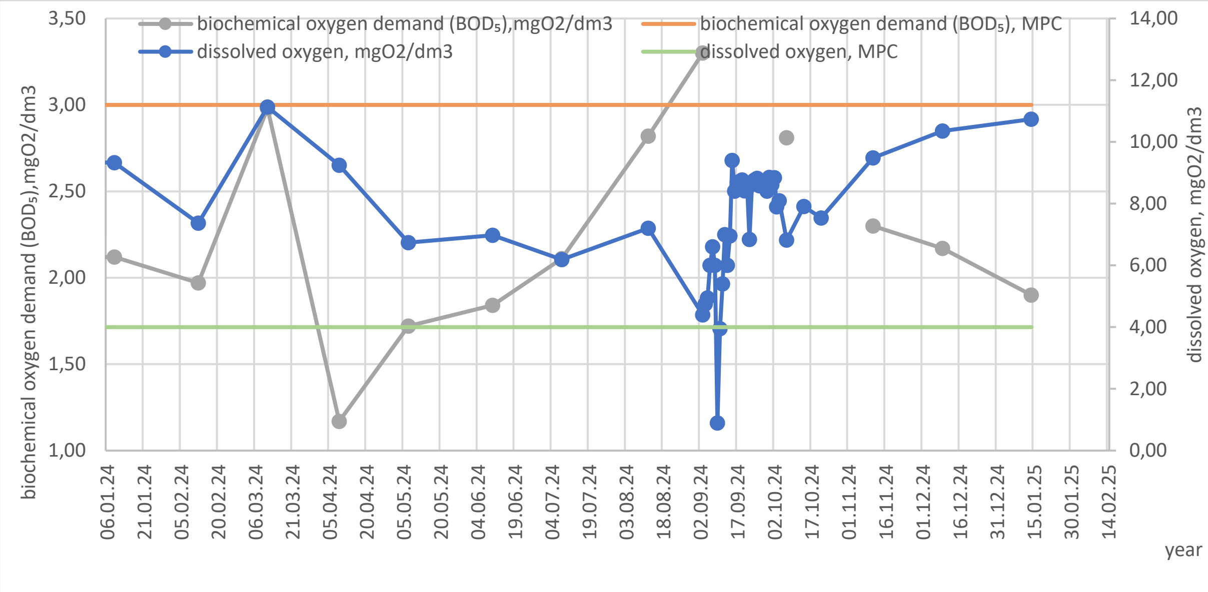

Fig. 3 – Dynamics of changes in indicators: biochemical oxygen demand over 5 days (BOD_5) and dissolved oxygen (O_2) during 2024–2025

that of BOD_5. In summer, a decrease in dissolved oxygen levels and an increase in BOD_5 were observed due to higher temperatures and the intensification of organic matter decomposition processes. In autumn and winter, by contrast, as temperatures decreased, the biological activity of microorganisms and the decomposition of organic matter slowed down, leading to a reduction in oxygen consumption. As a result, the level of dissolved oxygen increased, and BOD_5 decreased.

The inflow of pollutants from the territory of the Russian Federation into the Desna River can be traced to the period after August 26, 2024. As we can see, there is a significant increase in BOD_5 accompanied by a sharp decrease in dissolved oxygen levels, and this continued until the end of September 2024. Furthermore, the BOD_5 level exceeded the MPC (3 mgO_2/dm^3), and the dissolved oxygen level also dropped below the critical MPC level (4 mgO_2/dm^3). This indicates the entry of organic pollutants into the waters of the Desna River, which led to intensified decomposition processes. After September 21, 2024, the situation improved, as evidenced by a decrease in BOD_5 levels and an increase in dissolved oxygen levels.

To clarify the causes of the observed changes in dissolved oxygen and BOD_5 levels, we conducted an analysis of the dynamics of concentrations of the main pollutants.

A study was conducted on the content of sulfate and chloride ions in the Desna River. As can be seen, the content of sulfate ions significantly exceeds that of chloride ions throughout the observation period (Fig. 4).

Fluctuations in sulfate ion content were observed as follows: in March and April 2013 – maximum concentration (about 50.00 mg/dm³); June and July 2013 – a sharp decrease to 30.00 mg/dm³; December 2013 – January 2014 – a significant increase to 45.00 mg/dm³; October–November 2014 – the lowest recorded level (25.00 mg/dm³).

The concentration of chloride ions remained relatively stable (15.00–20.00 mg/dm³), with a slight increase in May–July 2014. Autumn–winter 2014 was characterized by the lowest levels of both ions, which may be related to changes in the city's water supply or to natural hydrological factors.

The situation in 2024–2025 showed that sulfate ion concentrations had significant fluctuations, from high values (50 mg/dm³) at the beginning of the period to a sharp decrease, followed by rises and drops (25–45 mg/dm³). Chloride ions showed smaller but still noticeable fluctuations within the range of 15–25 mg/dm³. However, the overall concentration levels during this period did not exceed the values of previous years.

Thus, it can be noted that among the pollutants that entered the Desna River from the territory of the Russian Federation after 26.08.2024, no increase was observed in the content of sulfate or chloride ions in the water.

An analysis was carried out of the content of ammonium ions and phosphate ions in the Desna River during the study period (Fig. 5).

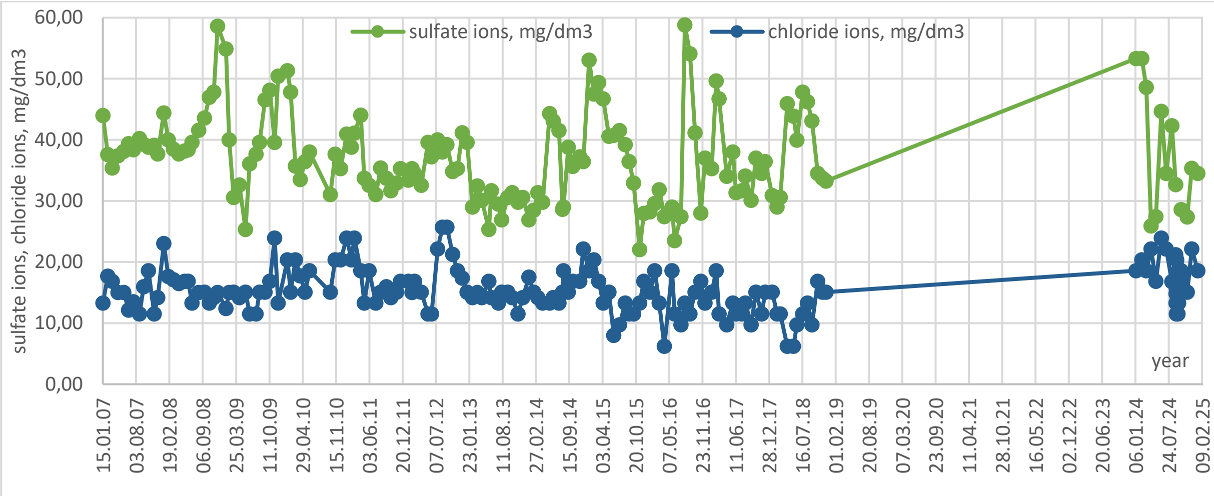

Fig. 4 – Dynamics of changes in indicators: sulfate ions and chloride ions, 2024–2025

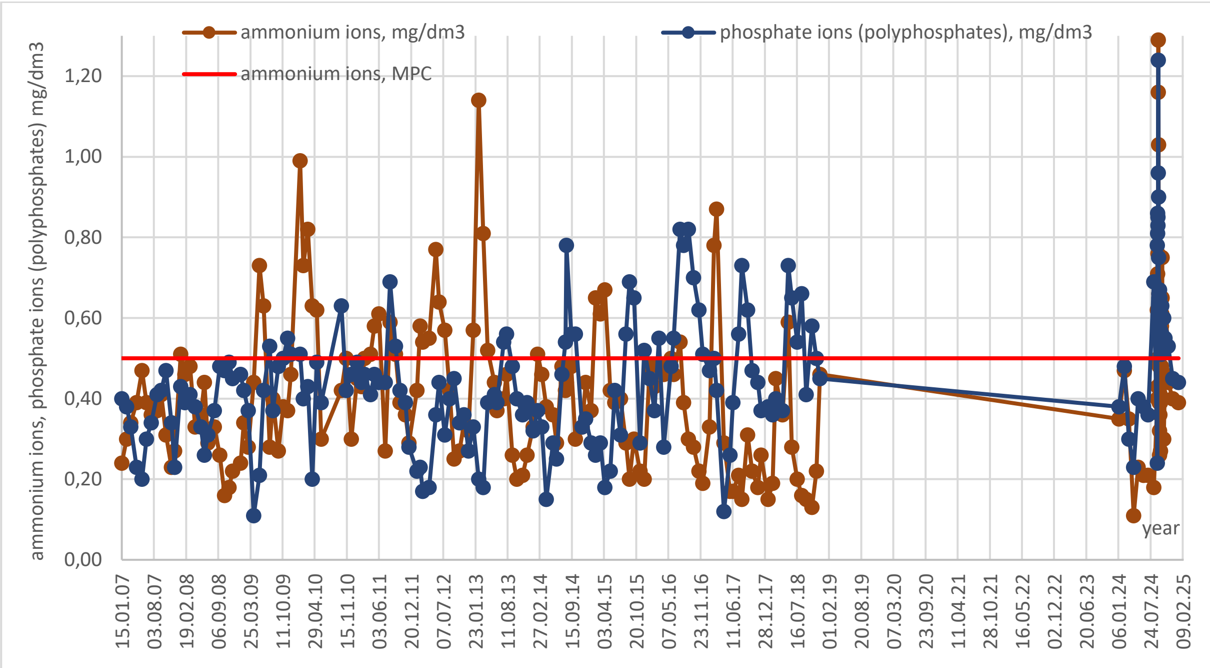

Fig. 5 – Dynamics of changes in indicators: ammonium ions and phosphate ions in 2024–2025

For most of 2014, the indicators showed relative stability: ammonium ion concentration fluctuated within the range of 0.1–0.45 mg/dm³ (below MPC = 0.5 mg/dm³), phosphate ions within 0.2–0.4 mg/dm³. At the end of 2014 – beginning of 2015, a sharp increase in both indicators was recorded. In December 2014, phosphate ion concentration peaked at about 1.1 mg/dm³, and in January 2015, ammonium ion content reached a maximum of approximately 1.2 mg/dm³, more than twice the MPC.

After the peak values in January–February 2015, a gradual decrease in concentrations was observed. Ammonium ions showed significant fluctuations with several smaller peaks, while phosphate ion levels decreased more smoothly. By mid-2015, both indicators stabilized at a level close to the initial values, but slightly higher compared to the same period in 2014. Such significant fluctuations in the winter of 2014–2015 may indicate a temporary deterioration in water quality associated with seasonal factors or changes in anthropogenic load.

Figure 6 presents the dynamics of ammonium ion and phosphate ion (orthophosphate) concentrations, as well as the MPC for ammonium, for 2024 – early 2025.

In 2024 – early 2025, the dynamics of ammonium ion and phosphate ion concentrations were unstable. At the beginning of the year, the

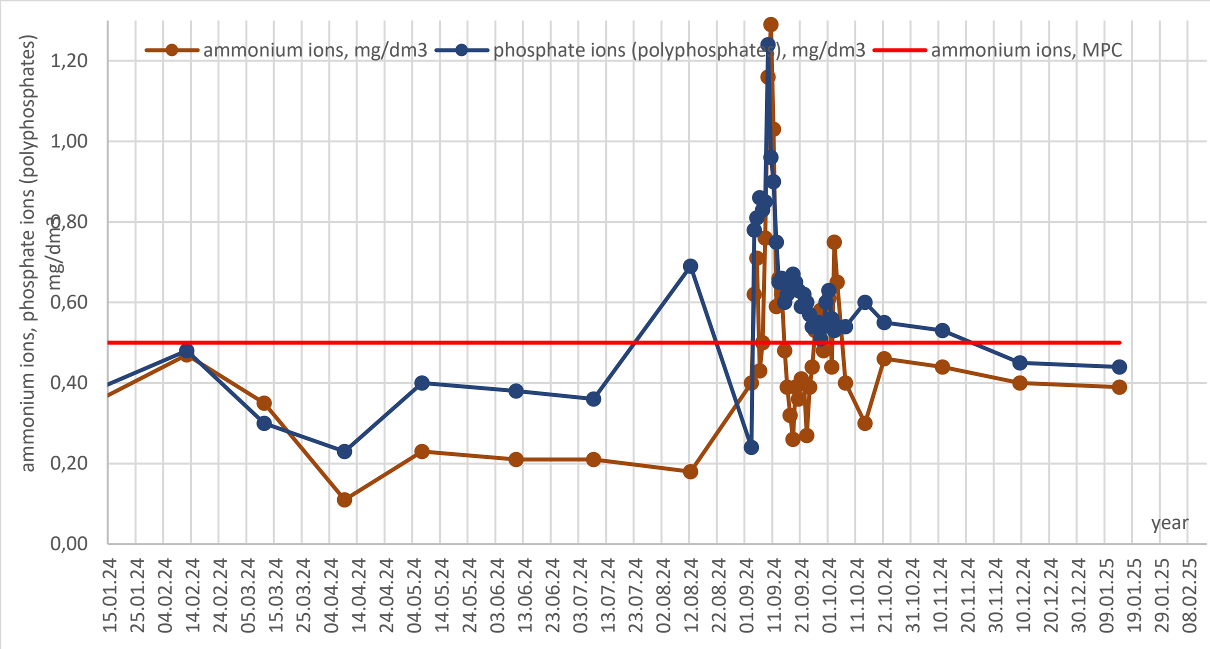

Fig. 6 – Dynamics of changes in indicators: ammonium ions and phosphate ions in 2024–2025

levels were low, but in September 2024 there was a sharp spike in both indicators, with the concentration of ammonium ions exceeding the MPC by 2.5 times. After the peak, the levels decreased but remained higher than the initial values, showing further fluctuations.

These trends can be considered a consequence of the inflow of pollutants from the territory of the Russian Federation into the Desna River after 26.08.2024. There is reason to believe that the significant increase in BOD_5 accompanied by a sharp decrease in dissolved oxygen levels, described above, is the result of contamination of the Desna River water with ammonium ions and phosphate ions.

We also studied the indicators of nitrate and nitrite pollution in the Desna River (Fig. 7).

At the beginning of the period (12.02.14 – 14.02.14), a high nitrate level was observed – about 2.0–2.2 mg/dm³ – after which there was a sharp decrease in concentration to approximately 1.2 mg/dm³. From March to June 2014, nitrate concentration remained relatively stable – within 1.2–1.3 mg/dm³.

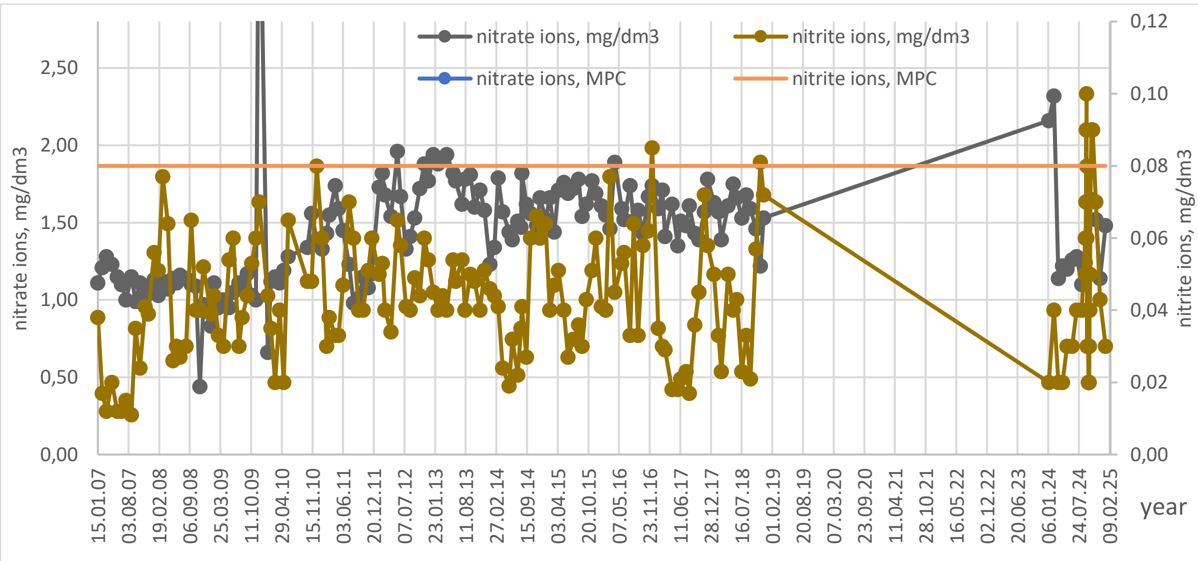

Fig. 7 – Dynamics of changes in indicators: nitrite ions and nitrate ions, 2007–2025

The most significant fluctuations in nitrite concentration were recorded in the summer–autumn period of 2014 (07.07.14 – 11.09.14), when values rose sharply from 0.04 to 0.1 mg/dm³, reaching a peak of approximately 0.1 mg/dm³ in August. In September 2014, there were substantial fluctuations in nitrite concentration with sharp rises and drops within the range of 0.02–0.09 mg/dm³.

At the end of the period (October–November 2014), a decreasing trend in nitrite concentration was noted, while nitrate levels began to gradually increase, reaching approximately 1.5 mg/dm³ at the last measurement point.

Figure 8 shows the dynamics of nitrate and nitrite concentrations in the water in Chernihiv during 2024 – early 2025.

At the beginning of 2024, the nitrate level was high, then sharply decreased, after which it rose again and showed several peaks and drops throughout the year.

Nitrite concentration also demonstrated significant fluctuations, especially during the period of pollutant inflow from the territory of the Russian Federation. In September 2024, there was a sharp increase in nitrite ion content, with its concentration exceeding the MPC of 0.08 mg/dm³. After the peak, levels decreased, but in October there was another rise above the MPC, most likely caused by other factors.

These trends can be considered a consequence of the inflow of pollutants from the territory of the Russian Federation into the Desna River after 26.08.2024. There is reason to believe that the significant increase in BOD_5 accompanied by a sharp decrease in dissolved oxygen levels, described above, is the result of contamination of the Desna River water with nitrite ions.

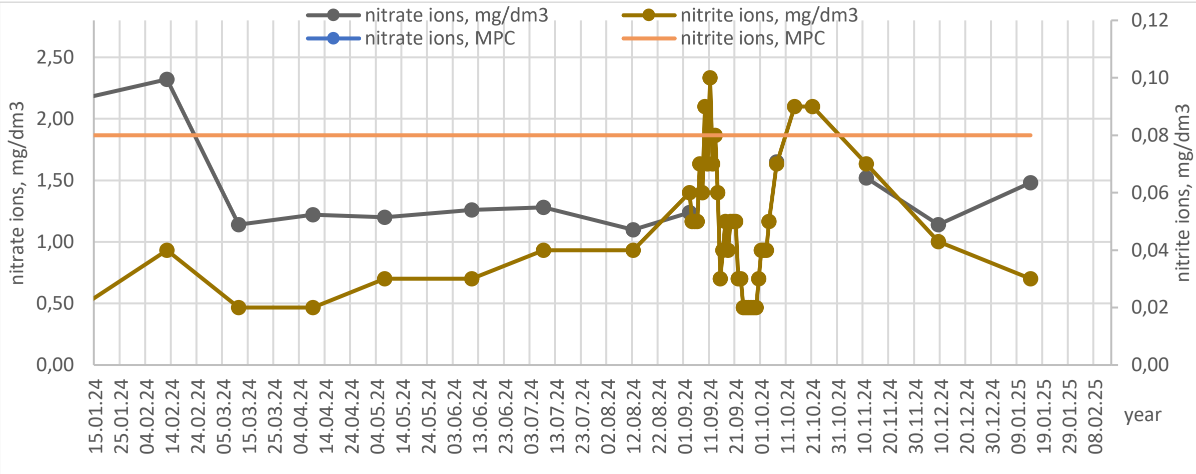

Fig. 8 – Dynamics of changes in indicators: nitrite ions and nitrate ions, 2024–2025

Similar studies were carried out for the Brovary station, 20 km. The analysis covered the period from 2019 to 2025.

Figure 9 presents data on biochemical oxygen demand and dissolved oxygen content. BOD_5 shows significant fluctuations (0–7 mgO_2/dm^3), while oxygen content (blue line) remains relatively stable.

Peak BOD_5 values were recorded in April 2021 (5 mgO_2/dm^3), August–September 2021 (6 mgO_2/dm^3), and March–April 2022 (7 mgO_2/dm^3, maximum). The lowest BOD_5 values were recorded in January–February 2022 (about 0) and May–June 2022 (about 0). A seasonal dynamic was observed, with higher BOD_5 in the spring–summer period and lower values in autumn–winter. The largest fluctuation occurred between December 2021 and April 2022, when BOD_5 first dropped almost to zero and then sharply increased to the maximum value.

During 2024, there was a sharp increase in BOD_5, followed by a decrease. Dissolved oxygen levels also fluctuated significantly throughout the year, with a noticeable decline in the middle of the year followed by an increase.

Exceedances of the MPC (3 mgO_2/dm^3) for BOD_5 during the study period were recorded multiple times, but after August 26, 2024, no exceedances were observed. Dissolved oxygen levels did not fall below the MPC (4 mgO_2/dm^3). Therefore, the inflow of pollutants from the territory of the Russian Federation into the Desna River after 26.08.2024 did not affect the BOD_5 values or the dissolved oxygen levels.

Figure 10 presents data on the dynamics of changes in indicators: sulfate ions and chloride ions during 2019–2024.

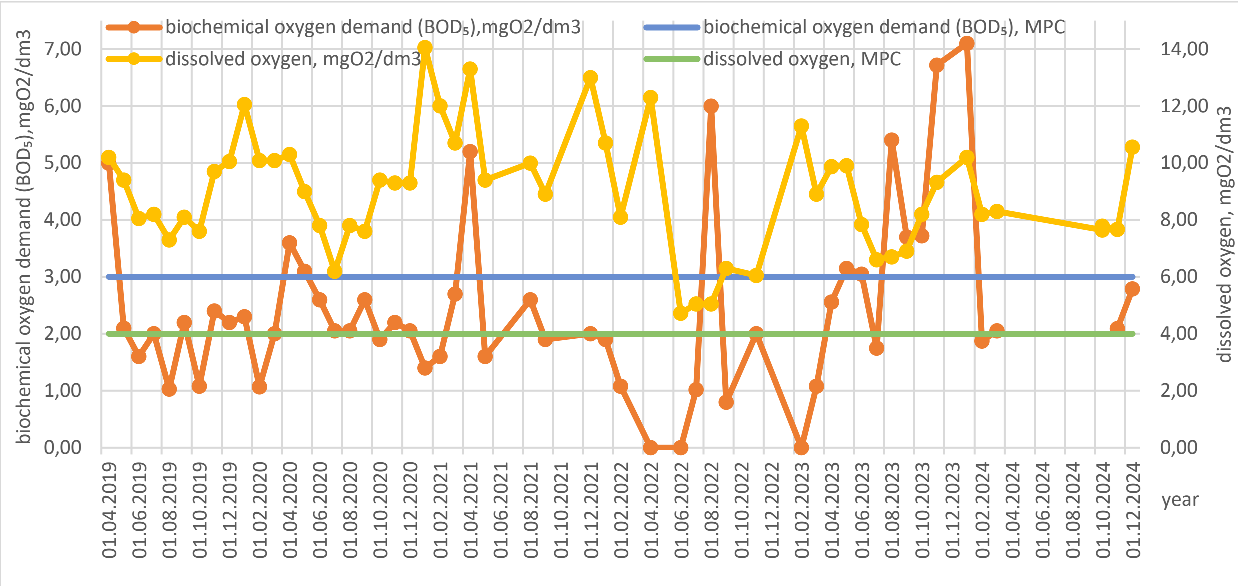

Fig. 9 – Dynamics of changes in indicators: biochemical oxygen demand (BOD_5) and dissolved oxygen (O_2) during 2019–2024

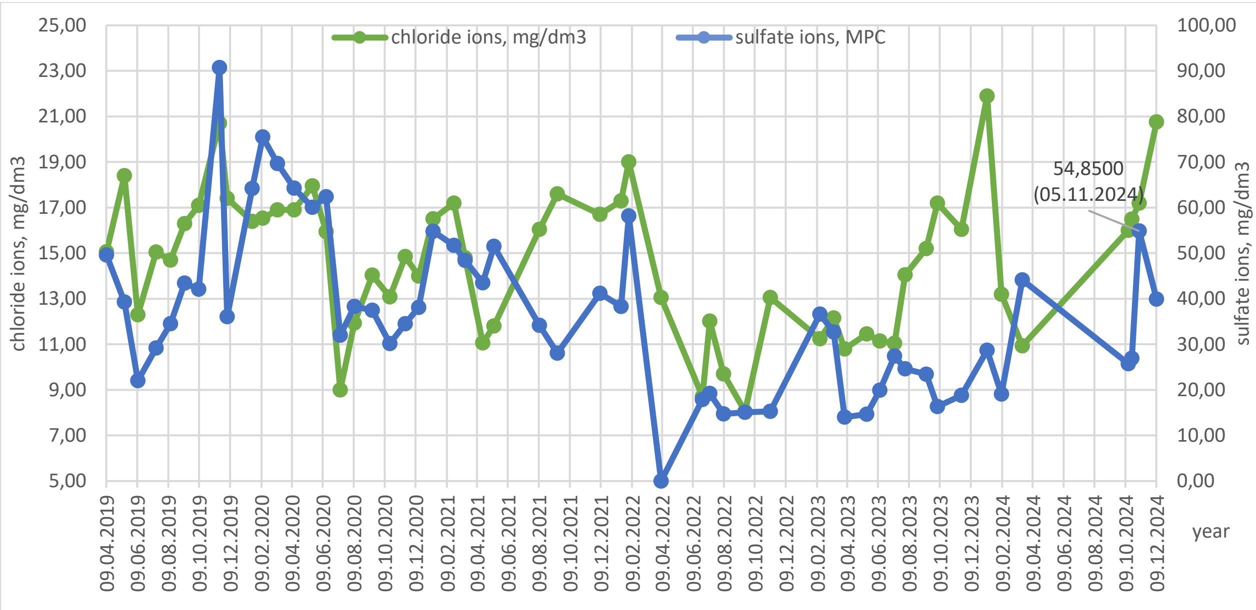

Fig. 10 – Dynamics of changes in indicators: sulfate ions and chloride ions in 2019–2024

The maximum concentration of chloride ions was recorded on 05.11.2020 (23 mg/dm³). Sulfate ions reached their peak concentration at the beginning of the observation period (about 23 mg/dm³), while the minimum value (about 5 mg/dm³) was recorded in the middle of the period. In the second half of 2020, there was a trend toward a gradual increase in the concentration of both ions. Chloride ion and sulfate ion concentrations often showed opposite trends, which may indicate different sources of their inflow. Both indicators remained within the permissible MPC limits despite seasonal fluctuations.

At the beginning of 2024, the chloride ion level decreased, then rose again slightly, and by the end of the available period (November 2024) showed a downward trend once more. The sulfate ion level also fluctuated throughout 2024, though without such sharp jumps as in chloride ions. By the end of the available period, an increase was observed. Therefore, the inflow of pollutants from the territory of the Russian Federation into the Desna River after

26.08.2024 did not affect sulfate ion and chloride ion values.

Figure 11 presents data on the dynamics of changes in indicators: ammonium ions and phosphate ions during 2019–2025.

The maximum concentration of ammonium ions was recorded on 19.02.2020 – 1.90 mg/dm³, and in June 2020 – 1.32 mg/dm³. The minimum concentration was at the beginning of 2020 – 0.10–0.20 mg/dm³, and in September 2020 – about 0.15 mg/dm³. Average values fluctuated within the range of 0.40–0.80 mg/dm³. The maximum concentration of phosphate ions was in July 2020 – 0.58 mg/dm³. The minimum concentration was in May 2020 – about 0.10 mg/dm³, and in August 2020 – 0.15 mg/dm³. Average values were mostly in the range of 0.30–0.50 mg/dm³.

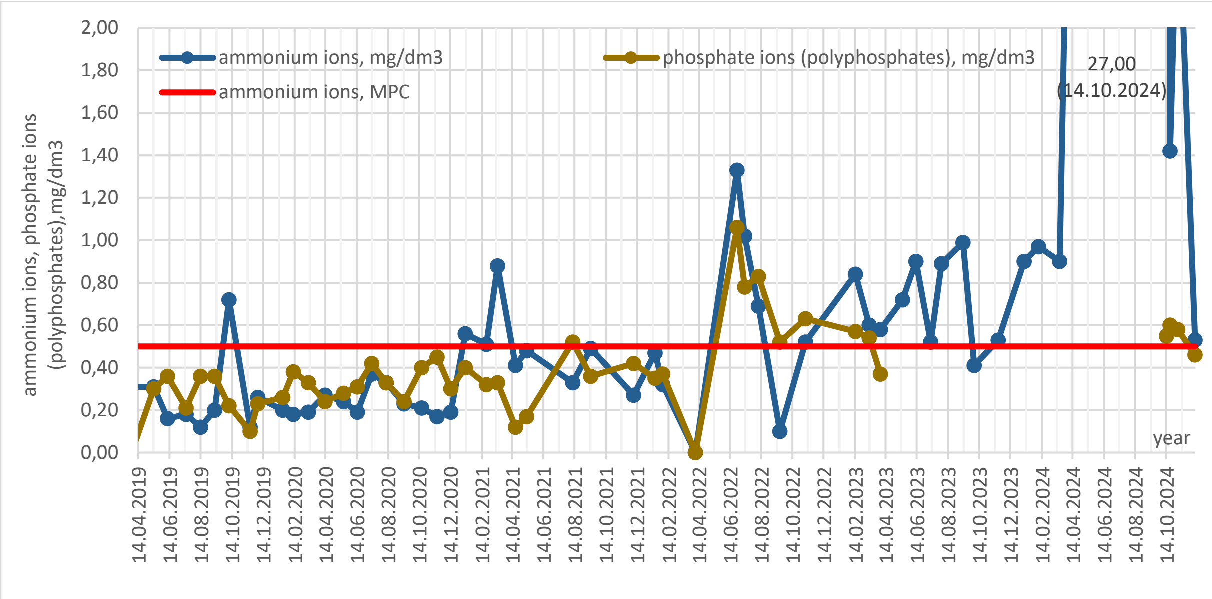

Fig. 11 – Dynamics of changes in indicators: ammonium ions and phosphate ions in 2019–2025

The period of June–July 2020 was characterized by a synchronous increase in the concentrations of both ions. In October 2020, there was a significant increase in ammonium ion concentration (up to 1.90 mg/dm³) with a simultaneous decrease in phosphate ion concentration (to 0.30 mg/dm³). At the end of the study period, the concentration of ammonium ions reached its maximum (2.00 mg/dm³), while the concentration of phosphate ions remained stable (0.50 mg/dm³).

Thus, throughout 2023–2024, there was almost constant exceedance of the MPC for ammonium ion content (0.5 mg/dm³), with the critical value reached on 14.10.2024 – 27 mg/dm³. These data indicate the presence of both traditional anthropogenic impacts, which were intensified by the inflow of pollutants from the territory of the Russian Federation on 26 August 2024. High ammonium ion content may result from the activities of livestock farms, the use of ammonium fertilizers, as well as industrial wastewater. These are sources of “traditional” anthropogenic impacts.

Comparison of ammonium ion content at the Brovary station (20 km) with the content upstream in the Desna River (Chernihiv, 200 km) indicates the presence of additional ammonium ion pollution.

The concentration of phosphate ions during this period remained relatively stable, although with some fluctuations. However, considering the acceptable values of BOD_5 and dissolved oxygen, there is reason to believe that the presence of phosphate ions and ammonium in the water did not stimulate eutrophication of surface waters.

Figure 12 presents data on the dynamics of changes in indicators: ammonium ions and phosphate ions during 2019–2025. The first peak was observed in March–April 2020, when nitrate ion concentration reached approximately 6.2 mg/dm³. The second significant peak occurred in April–May 2021 with values of about 6.0 mg/dm³. Another notable peak was recorded in April 2022, when the concentration reached nearly 6.0 mg/dm³. In September–October 2023, a smaller peak of about 3.5 mg/dm³ was

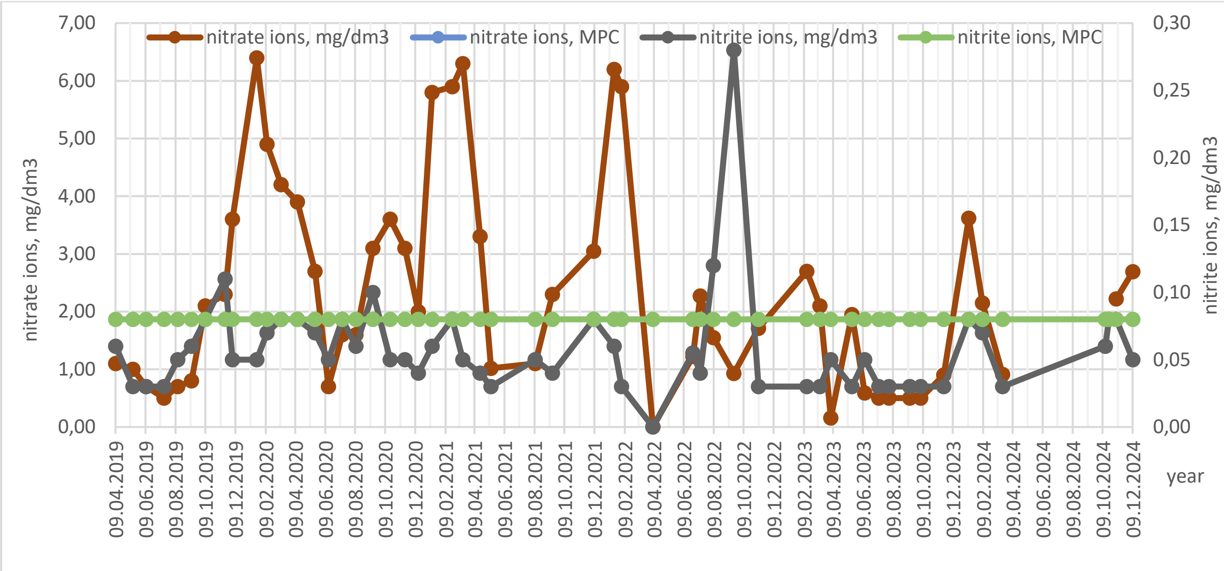

Fig. 12 – Dynamics of changes in indicators: nitrite ions and nitrate ions in 2019–2025

observed. At the beginning of 2024, there was also a noticeable rise to about 3.0 mg/dm³.As for nitrite ions, their concentration remained relatively stable throughout the entire period, fluctuating within 0.0800–0.1200 mg/dm³, with slight rises and drops. A particularly noticeable increase in nitrite ion concentration was recorded in May 2022, when the value reached approximately 0.1500 mg/dm³.

The maximum nitrate ion concentrations were recorded in the spring period (March–May) in almost every year of observation, which may be associated with seasonal factors such as snowmelt, increased precipitation, or agricultural activity.

In 2024 and early 2025, the dynamics of both nitrite and nitrate ions were unstable. Levels of both indicators experienced significant fluctuations but did not exceed the MPC.

The obtained results indicate that pollution of the Desna River from the territory of the Russian Federation on August 26, 2024, did not affect water quality in Brovary (20 km).

Similar studies were conducted for the Kyiv station, 3 km. The analysis covered the period from 2015 to 2025.

Figure 13 presents data on the dynamics of changes in indicators: biochemical oxygen demand (BOD_5) and dissolved oxygen (O_2) during 2015–2025.

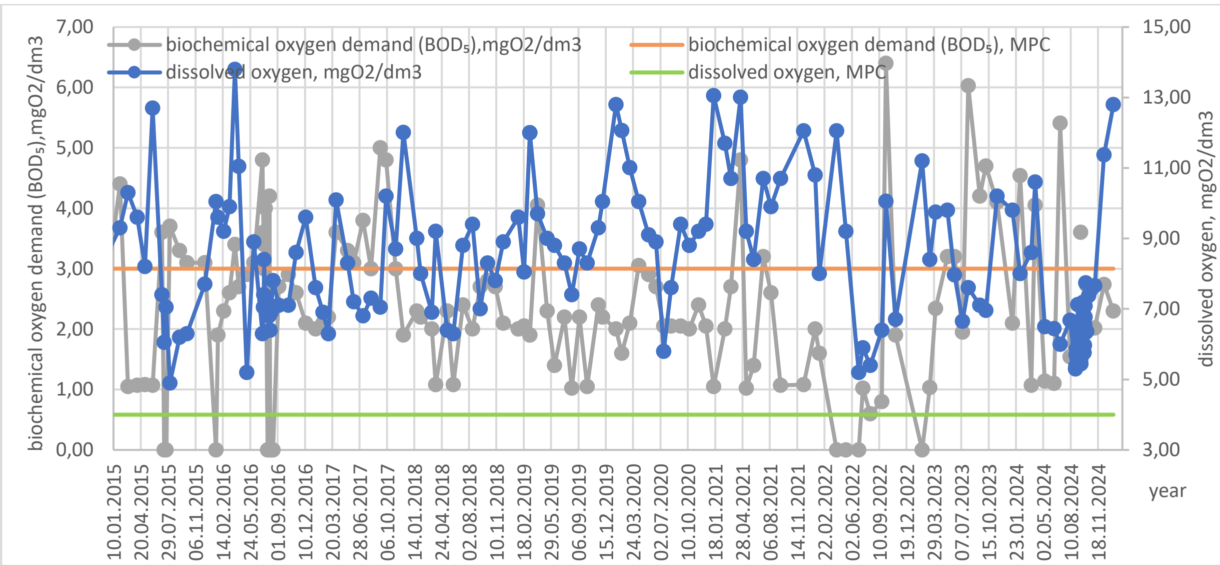

Fig. 13 – Dynamics of changes in indicators: biochemical oxygen demand (BOD_5) and dissolved oxygen (O_2) during 2015–2025

Significant fluctuations in the indicators began in November–December 2018, when a sharp decrease in BOD_5 was observed (from about 4 mgO_2/dm^3 to 1 mgO_2/dm^3), accompanied by a gradual increase in oxygen levels. In April–May 2019, there was a sharp rise in BOD_5 to a peak value of about 4.5 mgO_2/dm^3, with oxygen levels showing a downward trend. In September–October 2019, the most significant increase in BOD_5 was recorded, reaching the maximum value (about 5.2 mgO_2/dm^3), accompanied by a decrease in dissolved oxygen concentration. In February–March 2020, BOD_5 dropped sharply to its minimum level, while oxygen concentration remained relatively stable.

From May to July 2020, frequent fluctuations in dissolved oxygen concentration were observed, which may indicate instability in the ecological state of the water bodies during this period. From August 2020 to March 2021, there was a steady trend of increasing dissolved oxygen levels to the highest values for the entire period, while BOD_5 remained relatively low with minor fluctuations.

In 2024, there was significant instability in biochemical oxygen demand (BOD_5), with sharp peaks and drops. Dissolved oxygen levels tended to decline for most of 2024 but then began to rise at the beginning of 2025. The results indicate that pollution of the Desna River from the territory of the Russian Federation on August 26, 2024, did not affect water quality in Kyiv (3 km).

Studies were also conducted on the dynamics of changes in sulfate and chloride ion content. Figure 14 presents data on the dynamics of changes in indicators: sulfate ions and chloride ions in 2015–2025.

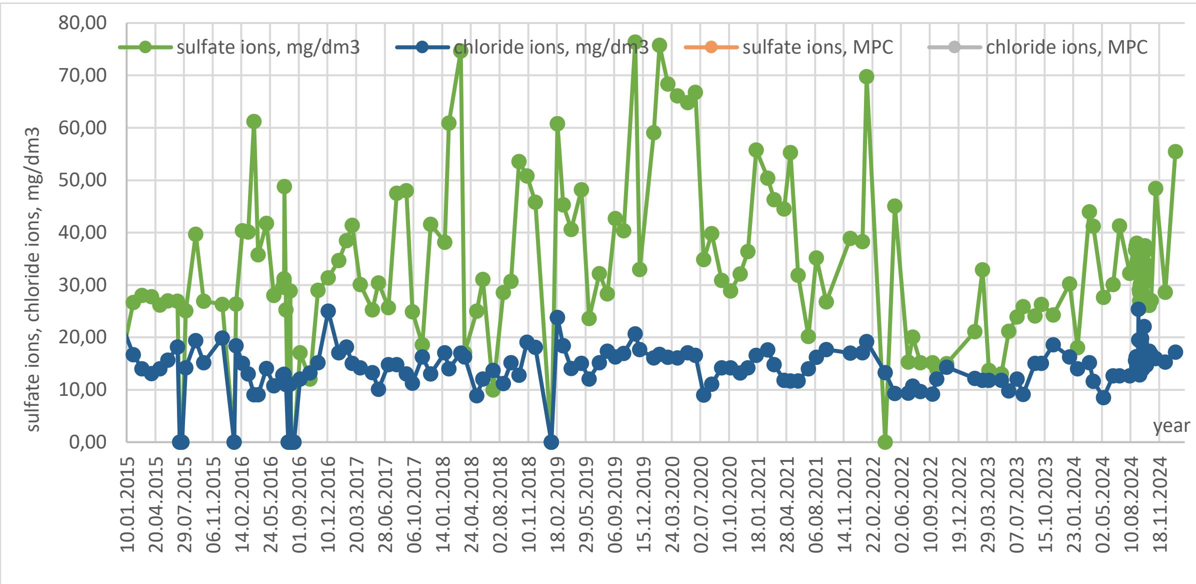

Fig. 14 – Dynamics of changes in indicators: sulfate ions and chloride ions in 2015–2025

Sulfate ions have higher concentrations (20–50 mg/dm^3) compared to chloride ions (10–15 mg/dm^3). Significant sulfate peaks occurred in March–April 2019 (45–47 mg/dm^3), September–October 2021 (50 mg/dm^3), and February–March 2023 (50 mg/dm^3). Chloride ion concentration was mostly stable, except for short-term peaks up to 15–17 mg/dm^3 in mid-2021. The lowest sulfate concentrations were recorded in the summer months of 2018, 2020, and 2022 (25–30 mg/dm^3). There is seasonal variability in sulfate ions with a trend toward increasing levels in recent years, while chloride ion concentration remains relatively stable.

In 2024, the sulfate ion level tended to increase with some fluctuations. The chloride ion level remained relatively stable for most of 2024 but showed a sharp spike in autumn. At the beginning of 2025, the sulfate ion level continued to rise, while the chloride ion level decreased again after the spike. The results indicate that pollution of the Desna River from the territory of the Russian Federation on August 26, 2024, did not affect the level of sulfate and chloride ions in the water at Kyiv (3 km).

Studies were also conducted on the content of ammonium and phosphate ions in the water of the Desna River **(**Fig. 15**).**

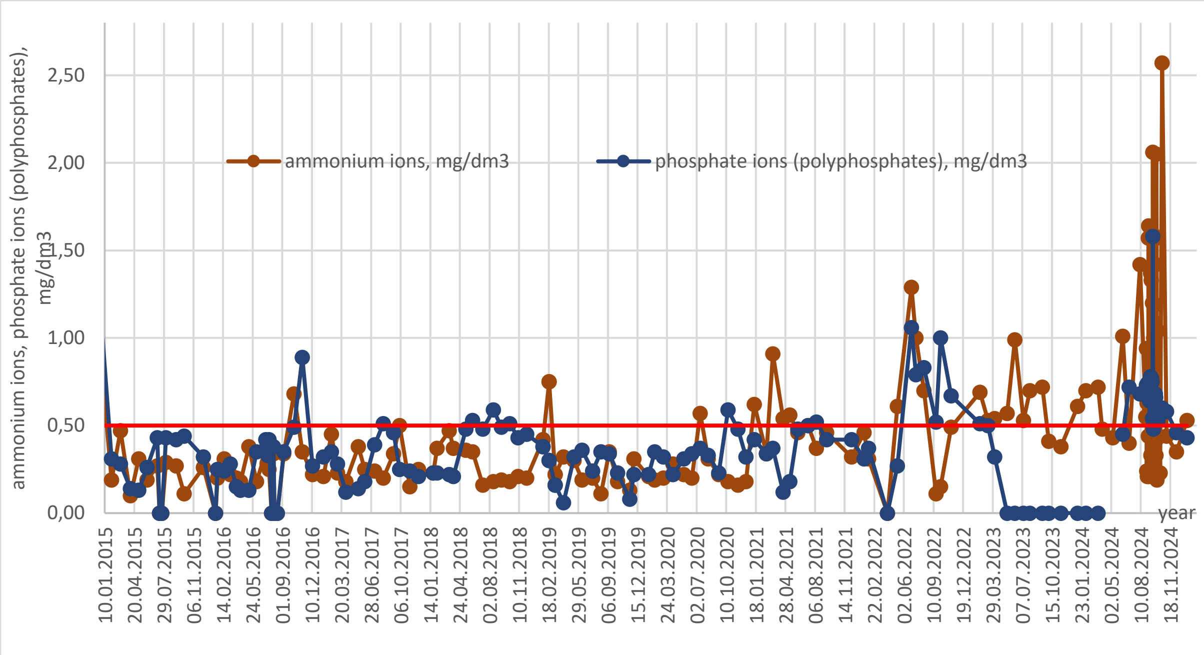

Fig. 15 – Dynamics of changes in indicators: ammonium ions and phosphate ions in 2015–2025

The concentration of ammonium ions mostly remained at around 0.5 mg/dm³ but showed significant peaks in January–February 2021 (up to 1.0 mg/dm³). The highest values were recorded in April–June 2021, with a maximum of about 2.5 mg/dm³ in May, which significantly exceeded the MPC. Phosphate ions showed moderate fluctuations, with a maximum of about 1.0 mg/dm³ in March–April 2021. After the summer peaks, ammonium ion concentration returned to its baseline level in the second half of 2021.

Sharp spring–summer fluctuations may have been caused by seasonal factors such as increased anthropogenic load, accidental discharges, or the impact of agricultural activity.

Figure 16 presents data on the dynamics of changes in indicators: ammonium ions and phosphate ions in 2024–2025. In 2024, the ammonium ion level was almost constantly above the MPC (0.5 mg/dm³). The critical value was reached on 20.10.2024. The obtained results indicate that after the pollution of the Desna River from the territory of the Russian Federation on

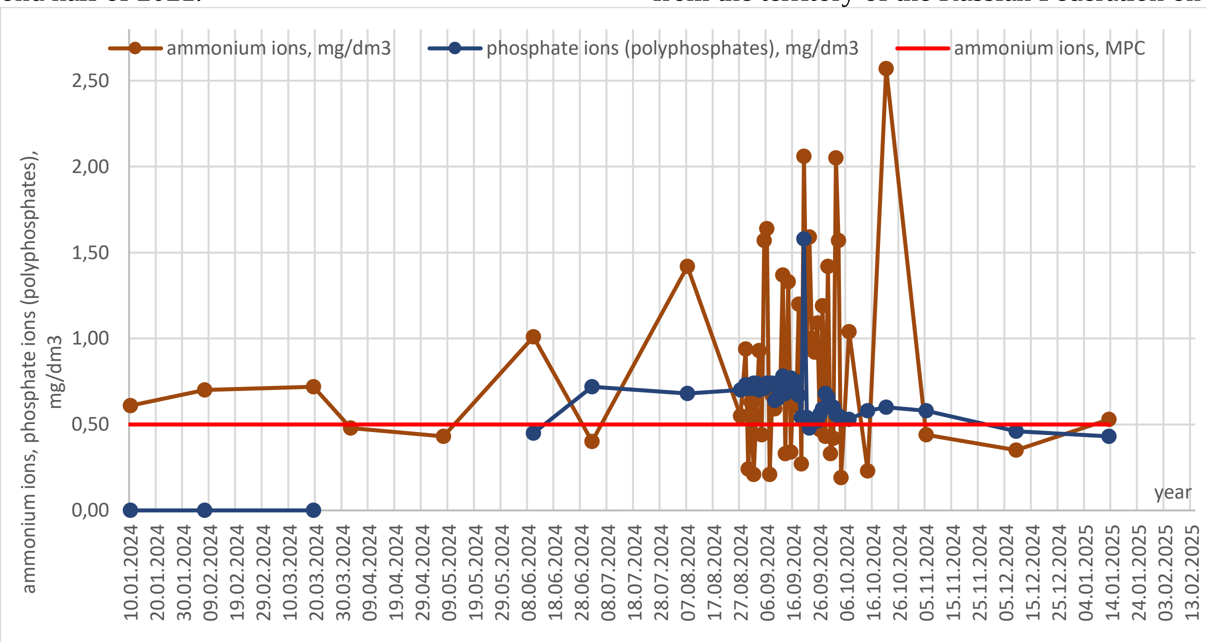

Fig. 16 – Dynamics of changes in indicators: ammonium ions and phosphate ions in 2024–2025

August 26, 2024, the ammonium ion content in the water increased in September and this continued until November 2024. Thus, the data show the presence of both traditional anthropogenic impacts, which were intensified by the inflow of pollutants from the territory of the Russian Federation on August 26, 2024.

Comparison of ammonium ion content at the Chernihiv station (200 km) and the Brovary station (20 km), located upstream on the Desna River, indicates the presence of additional ammonium ion pollution.

The concentration of phosphate ions during this period remained relatively stable, although with some fluctuations.

Comparison with the above values of BOD_5 and dissolved oxygen suggests that the content of phosphate ions and ammonium in the water was not as significant as at the Chernihiv station (200 km).

Studies were also carried out on nitrate and nitrite ion content (Fig. 17**).** Nitrate ion concentration shows significant fluctuations. The highest values were recorded in November–December 2020 at about 3.5–4.0 mg/dm³. A substantial decrease to 1.0–2.0 mg/dm³ occurred in January–February 2021, followed by relative stability at about 2.0 mg/dm³ in March–June 2021. There was a gradual decrease to minimum values (about 0.5–1.0 mg/dm³) in July–August 2021, then an increase in autumn 2021, returning to 2.5–3.0 mg/dm³ in November 2021.

Nitrite ion concentration remained stable at 2.0–3.0 mg/dm³ for most of the period, with a sharp peak in May 2021, reaching a maximum of about 4.5 mg/dm³. Both indicators display seasonal dependence: nitrate ions tend to decrease in summer and increase in winter, while nitrite ions have their highest concentrations in spring.

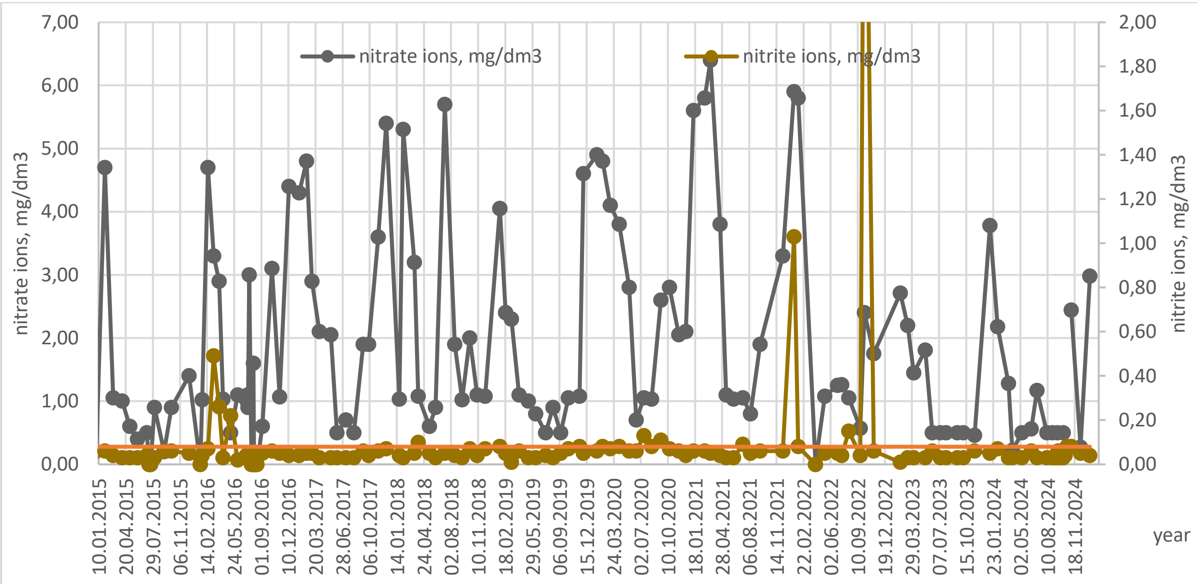

Fig. 17 – Dynamics of changes in indicators: nitrite ions and nitrate ions in 2015–2025

The most significant fluctuations for both parameters were observed in spring and early summer 2021.

Figure 18 presents data on the dynamics of changes in indicators: nitrite ions and nitrate ions in 2024–2025.

In 2024, nitrate ion levels fluctuated significantly but generally remained below the maximum permissible concentration (MPC). Nitrite ion levels also fluctuated, but for most of the year were close to zero, with several sharp but short-term increases exceeding the MPC. At the beginning of 2025, nitrate ion levels slightly decreased, while nitrite ion levels remained low.

Thus, for the Kyiv station (3 km), the inflow of pollutants from the territory of the Russian Federation into the Desna River after 26.08.2024 was not significant. There is reason to believe that BOD_5 and dissolved oxygen levels confirm this conclusion.

The analysis showed that nitrite ion pollution of the Desna River was observed only at the Chernihiv station (200 km) and was not significant at the Brovary station (20 km) or at the Kyiv station (3 km).

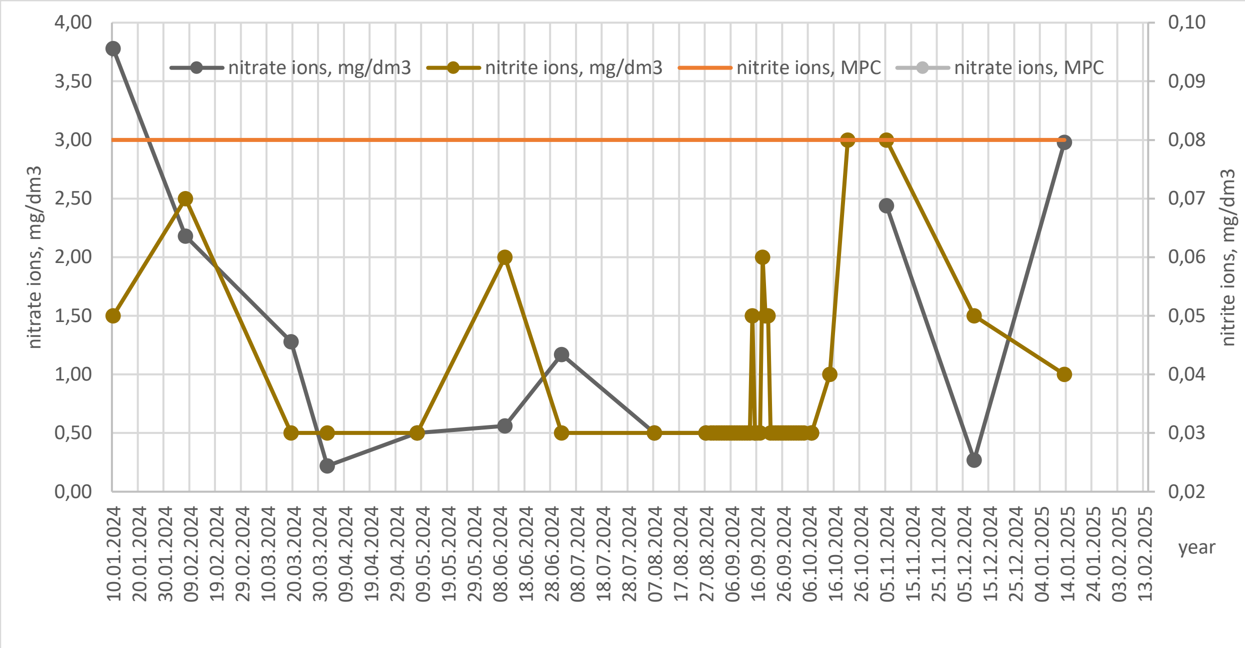

Fig. 18 – Dynamics of changes in indicators: nitrite ions and nitrate ions in 2024–2025

Conclusions

The analysis revealed that pollution of the surface waters of the Desna River from the territory of the Russian Federation was most significant in the city of Chernihiv. There was an increase in BOD_5 accompanied by a sharp decrease in dissolved oxygen levels, lasting until the end of September 2024. In addition, the MPC for BOD_5 (3 mgO_2/dm^3) was exceeded, and dissolved oxygen levels dropped below the critical MPC (4 mgO_2/dm^3). This indicates the entry of organic pollutants into the Desna River, which led to the intensification of their decomposition. After 21.09.2024, the situation improved, as evidenced by the decrease in BOD_5 levels and the increase in dissolved oxygen levels.

Unlike BOD_5 and dissolved oxygen, the inflow of pollutants from the territory of the Russian Federation did not cause significant changes in the content of sulfate and chloride ions in the water.

Regarding phosphate and ammonium ions, in 2024 – early 2025 their concentrations were unstable. At the beginning of the year, levels were low, but in September 2024 there was a sharp spike in both indicators, with ammonium ion concentration exceeding the MPC by 2.5 times. These trends can be considered a consequence of the inflow of pollutants from the territory of the Russian Federation. This supports the conclusion that the significant increase in BOD_5 accompanied by a sharp decrease in dissolved oxygen levels was due to contamination of the Desna River water with ammonium and phosphate ions.

Nitrate and nitrite concentrations fluctuated significantly, especially during the period of pollutant inflow from the territory of the Russian Federation. In September 2024, there was a sharp increase in nitrite ion content, with concentration exceeding the MPC of 0.08 mg/dm^3. The increase in nitrite ions was also associated with the observed rise in BOD_5 and the simultaneous decrease in dissolved oxygen levels.

Similar studies for the Brovary station (20 km) showed that the inflow of pollutants from the territory of the Russian Federation after 26.08.2024 did not affect BOD_5 or dissolved oxygen levels. A comparison of ammonium ion levels at Brovary with those at Chernihiv indicates additional ammonium ion pollution. Phosphate ion concentration remained relatively stable, with some fluctuations. These results indicate that the pollution incident on 26 August 2024 did not affect water quality in Brovary (20 km).

At the Kyiv station (3 km), BOD_5 and dissolved oxygen levels also indicated no impact from the 26.08.2024 pollution event. Comparison of ammonium ion levels at Chernihiv (200 km) and Brovary (20 km) with those upstream confirmed additional ammonium ion pollution, but phosphate ion concentration remained relatively stable. Therefore, pollutant inflow after 26.08.2024 was not significant for the Kyiv station (3 km).

Overall, the Desna River near Chernihiv (Chernihiv station, 200 km) experienced the greatest anthropogenic impact. Deterioration in water quality was recorded for all analyzed parameters. The situation was better at the other two stations. Nitrite ion pollution of the Desna was observed only at Chernihiv and was not significant at Brovary or Kyiv. Since BOD_5 and dissolved oxygen levels normalized at the end of September, there is reason to believe that self-purification of the surface waters in the river occurred.

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. Furthermore, the authors have fully adhered to ethical norms, including avoiding plagiarism, data falsification, and duplicate publication.

Authors Contribution: all authors have contributed equally to this work.

The work does not use artificial intelligence resources.

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АНТРОПОГЕННИЙ ВПЛИВ ВІЙНИ НА СТАН ПОВЕРХНЕВИХ ВОД РІЧКИ ДЕСНА

Мета. Надати комплексну екологічну оцінку стану поверхневих вод річки Десна з метою визначення основних антропогенних факторів впливу, зокрема наслідків війни.

Методи. Системний аналіз, методи статистичної обробки, аналіз динаміки у ретроспективі та прогнозування майбутніх тенденцій.

Результати. Проведений аналіз багаторічних даних Лабораторії моніторингу вод Деснянського БУВР для постів: Чернігів, Бровари, та Київ для показників: біохімічне споживання кисню за 5 діб (BSK5) та кисень розчинений, фосфат-іони та амоній-іони, нітрит-іони та нітрат-іони, сульфат-іони та хлорид-іони. Окрема увага приділена аналізу забруднення поверхневих вод р. Десна з території РФ. Встановлено, що найбільш відчутним забруднення у 2024 році було у м. Чернігів, де зафіксоване зростання рівня $БСК_5$ з перевищенням ГДК з одночасним різким зменшенням рівня розчиненого кисню. Це свідчить про потрапляння органічних забруднень у води річки Десна, що призвело до активізації їх розкладання. Після 21.09.2024 року ситуація покращилась, про що свідчить зниження рівня БСК5 та підвищення рівня розчиненого кисню. Доведено, що це стало результатом потрапляння у річку фосфат- та амоніт-іонів, а також нітрит-іонів. Аналогічні дослідження проведені для поста Бровари та Київ. Встановлено, що потрапляння забруднюючих речовин з території РФ в річку Десна після 26.08.2024 р. не позначилось на величині показників БСК5 та рівня розчиненого кисню.

Висновки. Визначено органічне й мінеральне забруднення, порушення гідрологічного режиму та зниження рівня кисню. Встановлено, що найбільшого антропогенного впливу у 2024 році зазнала річка Десна біля м. Чернігова. Погіршення показників щодо якості води зафіксовано за всіма проаналізованими показниками. Внаслідок того, що в кінці вересня нормалізувались показники щодо $БСК_5$ та розчиненого кисню, є підстави вважати що відбулось самоочищення поверхневих вод у річці.

КЛЮЧОВІ СЛОВА: *річка Десна, поверхневі води, екологічний моніторинг, фосфати, амоній, сульфати, хлориди, розчинений кисень, $БСК_5$, нітрати, нітрити, антропогенний вплив, наслідки війни*

Конфлікт інтересів

Автори заявляють про відсутність конфлікту інтересів щодо публікації цього рукопису. Крім того, автори повністю дотримувалися етичних норм, включаючи уникнення плагіату, фальсифікації даних та дублювання публікацій.

Внесок авторів: всі автори зробили рівний внесок у цю роботу.

В роботі не використано ресурс штучного інтелекту.

Список використаної літератури

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