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WATER QUALITY IN DRINKING WATER SOURCES IN DNIPROPETROVSK REGION DURING HOSTILITIES

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Abstract. Military actions in Ukraine have severely affected water sources, mainly due to the destruction of dams, pumping stations, treatment facilities, canals, and the seizure of water infrastructure. These events damaged water supply systems and contaminated drinking sources, reducing reserves in certain areas. The issue is intensified in Ukraine due to the high industrialization of regions near active conflict zones. This study focuses on the impact of war on drinking water in the Dnipropetrovsk region, located 105–150 km from the front line. Further risks to water quality stem from missile attacks, where debris from rockets and drones targeting cities like Dnipro, Samara, and Kamianske may alter the chemical state of nearby aquatic ecosystems. To evaluate water safety, we conducted a physicochemical analysis of 16 indicators, including pH, oxidation, alkalinity, conductivity, metals (iron, copper, cadmium, zinc), and nitrogen compounds. Results were benchmarked against national sanitary standards (DSanPiN 2.2.4-171-10, 2010) applicable to well and spring waters. Exceedances of pH and permanganate oxidizability were found in Kocherezhky and Novotroitske villages, while nitrate exceedance was recorded only in Bulakhivka. Water quality classes were determined using DSTU 4808:2007 standards. The poorest quality was in Bulakhivka's well, where 5 of 13 parameters fell into the 4th class (mediocre), while Kocherezhky's pump room showed the best quality, with 10 of 13 indicators rated as 1st class (excellent).

Keywords: drinking water quality, war impact, water pollution, environmental monitoring, sustainable development.

1. Introduction

One of the main challenges of the 21st century is the pollution of surface waters, which are essential for modern society as they provide clean drinking water for the population, as well as water for domestic and industrial use. In 2015, the United Nations General Assembly adopted Resolution "Transforming our World: The 2030 Agenda for Sustainable Development" (United Nations, 2024), which outlines the Global Sustainable Development Goals. Among them, Goal 6 – "Clean Water and Sanitation" – aims to enhance water quality by 2030. This includes reducing

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sources of pollution, prohibiting unauthorized waste discharge, limiting the spread of hazardous substances, decreasing the share of untreated wastewater, and greatly expanding the safe reuse and recycling of water resources worldwide.

Modern wars, since the First World War, are believed to have a greater impact on ecosystems than previous, less industrialized wars because of the higher potential of modern weapons to cause environmental damage. The consequences of war can materialize both directly, by damaging water resources and polluting the environment with weapon remnants, and indirectly, by increasing the frequency or intensity of harmful processes. Such processes can be natural, such as erosion, or man-made, such as industrial pollution (Popovych et al., 2025).

Research on environmental contamination during armed conflicts has highlighted multiple potential pathways through which pollutants enter ecosystems. For example, during the Gulf War, Kuwait's water resources were heavily polluted by oil spills after attacks on oil fields (Literathy, 1992), which led to increased concentrations of trace elements along the Gulf coast and affected regional aquaculture (Buolayan et al., 1998). During the civil war in Syria, the discharge of untreated wastewater into the environment, both intentional and accidental, degraded water quality in the affected areas (Faour & Fayad, 2014). After the civil war in Sri Lanka, explosive remnants of war, such as landmines, remained scattered across the landscape. Research (Gunawardana et al., 2018) reports higher than standard concentrations of heavy metals, fluoride, and calcium in groundwater in these areas. Other possible sources of contamination include hazardous waste from industrial plants and landfills, pathological waste from hospitals damaged during the conflict, unregulated burning of household waste, and the use of chemical weapons (Literathy, 1992).

Contamination of water resources due to infrastructure damage is a recurring theme in conflict impact studies. Specific examples include the damage to wastewater treatment plants in the Gaza Strip during Israel's military operations Cast Lead in 2008 (Mason et al., 2011) and Protective Edge in 2014 (Weinthal & Sowers, 2019), which leaked untreated wastewater, as well as damage to sewer lines and treatment plants in Israel during the 2006 Lebanon War, which resulted in large volumes of silt being released directly into the Mediterranean Sea (Zeitoun et al., 2014).

Unfortunately, large volumes of insufficiently treated wastewater from industrial enterprises continue to flow into Ukraine's surface waters. In parallel, military activities across the country have signifycantly exacerbated water quality issues. Between 2014 and 2025, the russian federation's armed aggression have caused extensive–and in many cases, irreversible–damage to essential infrastructure. This includes centralized water supply systems, municipal drainage networks, flood control facilities, and hydraulic components of irrigation systems. A substantial number of water treatment structures and irrigation canals were affected. Moreover, 22 instances of damage to urban water supply and sewage systems have been documented. These events led to repeated interruptions in the operation of water utilities and treatment plants, creating high risk for uncontrolled and acute contamination of natural water bodies (Denisov & Averin, 2017; Akhmetova & Kochmar, 2023). It should be noted that in general, the consequences of hostilities have exacerbated problems related to water quality and its natural environment.

The country has a lar ge number of reservoirs and water storage facilities, and their destruction may lead to flooding of large areas and impede the population's access to drinking water. The hostilities have had a significant impact on Ukraine's water resources, causing pollution of water bodies with heavy metals and various chemicals, which are also released following the explosion of dams, pumping stations, treatment facilities and the seizure of water infrastructure. Damage to the water supply system and contamination of drinking water sources have reduced water supplies in some regions (Popovych et al., 2018).

A substantial portion of Ukraine's water infrastructure has already suffered destruction due to ongoing hostilities. This includes more than 1.947 kilometers of water distribution pipelines, 25 water treatment plants, and 182 pumping stations–primarily concentrated in the Kharkiv, Luhansk, and Donetsk regions. In addition, 159 wells have been either destroyed or severely damaged, with the majority located in the Kharkiv region. The conflict has also affected laboratory facilities responsible for monitoring and analyzing drinking water quality, leading to the loss or damage of many such institutions. Preliminary assessments indicate that over 582 kilometers of sewerage systems have been impacted, and at least 183 sewage pumping stations have been partially or entirely demolished, most of which are again situated in the Kharkiv region. Overall, 51 sewage treatment plants are believed to have been destroyed or damaged. This harms public health, causing increased morbidity among the population. The russian army regularly attacks critical infrastructure, including water pumping stations, water supply and treatment systems, and wastewater treatment systems. The loss of such infrastructure results in substantial challenges for environmental safety and public health (Tsyganenko-Dzyubenko et al., 2023).

Consequently, polluted wastewater discharges into the Dnipro River, leading to a marked decline in water quality, disturbing aquatic habitats, and fostering the growth of pathogenic microorganisms.

Pollution of the environment and water resources due to a full-scale invasion is a danger that affects not only the areas of direct hostilities or areas adjacent to the front line, but also the whole of Ukraine, which is regularly subjected to missile strikes, UAV attacks, and pollution by ammunition and rocket fuel residues (Nikolajev & Stefurak, 2022). Therefore, assessing the environmental safety of drinking water sources is relevant today, as one of the greatest practical importance for humanity is the state of water bodies that perform important functions in the life of society.

The novelty of this study lies in the first assessment of decentralized drinking water sources in the Dnipropetrovsk region during hostilities. Unlike previous works focused only on general infrastructure damage, we provide empirical data from wells and springs located near missile impact areas. Applying DSTU 4808:2007 under war conditions and identifying exceedances of nitrates, orthophosphates, and alkalinity offer new baseline information for post-war monitoring.

The aim of this study was to assess the physicochemical quality of decentralized drinking water sources in the Dnipropetrovsk region, some of which are directly located near areas affected by military operations.

2. Materials and Methods

In January 2025, water samples were collected from selected drinking water supply sources using standardized sampling procedures (Fig. 1).

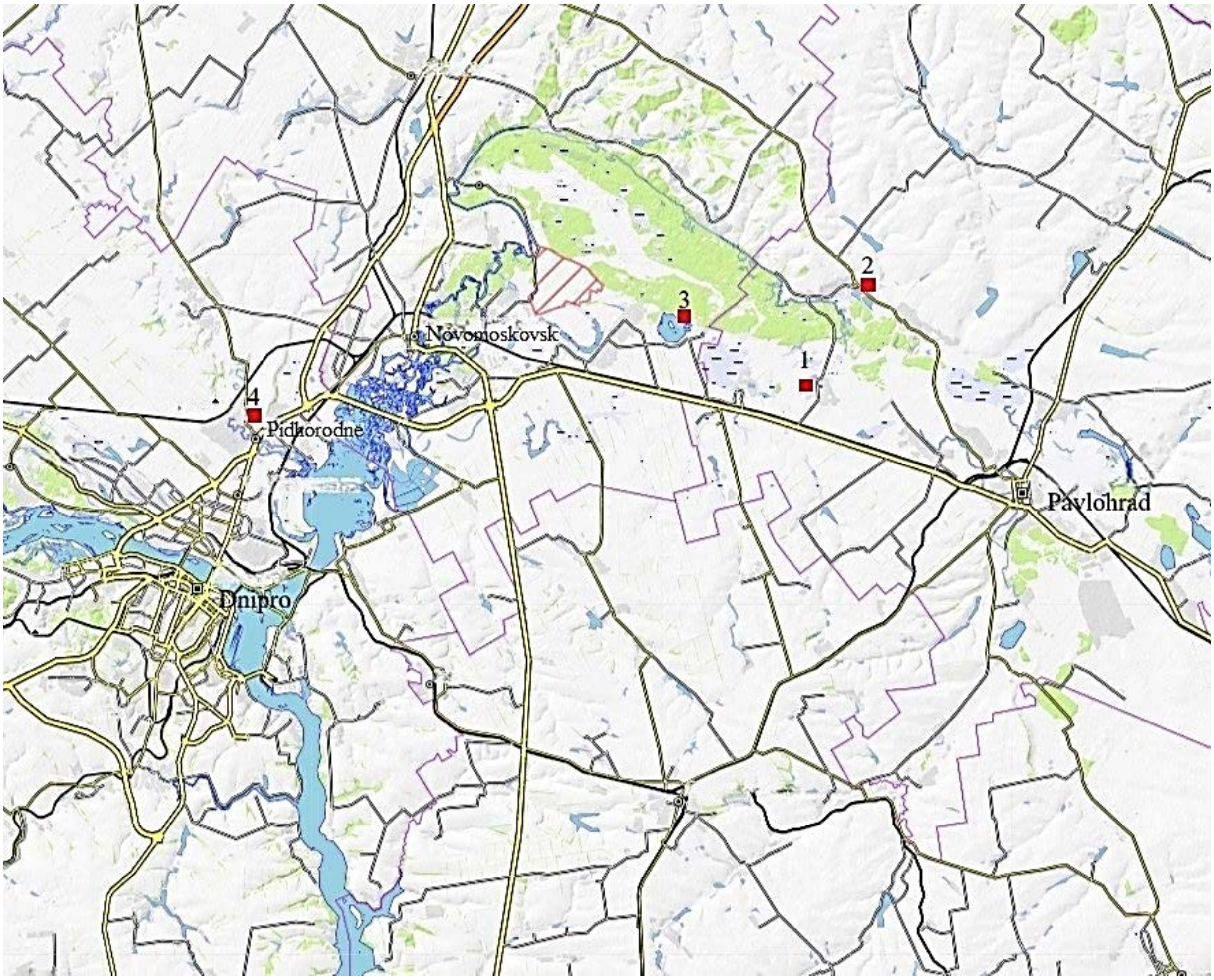

Fig. 1. Map of water sampling points within the Dnipropetrovsk region: 1 – well in Bulakhivka village; 2 – pump room in Kocherezhky village; 3 – spring near Solonyi Lyman lake; 4 – well in Pidhorodne town (Lviv: karta, mapa, 2025)

1. Dushi Krynytsia, a private well located in the village of Bulakhivka, Pavlohrad district, Dnipropetrovska oblast. It is located 18 km from the city of Pavlohrad and 48 km from the regional center, the city of Dnipro. There is no centralized water supply in the village, so most residents have their own boreholes and wells or collect water from local wells (Dnipropetrovska oblasna rada, 2020). The water sampling point was chosen because of the fall of the wreckage of a cruise missile that was destroyed by air defense forces near the village of Balakhivka in March 2024.

2. A pump room in the village of Kocherezhky. The village is located on the right bank of the Samara River, 31 km northwest of the district center, the city of Pavlohrad. There is no centralized water supply in the village, so the locals use wells and boreholes to meet their own household needs, but most of the villagers use water from the drinking column. Water from the pump room was selected as a control point because the well pumps deep groundwater.

3. The source is situated near Solonyi Lyman Lake in the vicinity of Novotroitske village, within the Novomoskovsk district of Dnipropetrovsk region. There is a source of drinking water on the shore of the lake, which is visited by patients and military personnel who are treated in the physiotherapy hospital and military hospital in the village of Novotroitske (Dnipropetrovska oblasna rada, 2020). Near the lake, air defense forces are constantly destroying missiles and enemy UAVs heading for cities such as Dnipro, Samara, and Kamianske.

4. A well in the town of Pidhorodne, "Kozatska Krynytsia". The town is located in the central part of the Dnipropetrovsk region on the banks of the Kilchenia River and is a northern suburb of the city of Dnipro. On June 4, 2023, the russian army fired an Iskander missile at the suburbs of Dnipro, damaging the wastewater disposal system.

Water samples were collected in sterilized polyethylene bottles with a volume of 1–2 L. Before sampling, all containers were rinsed three times with the water to be tested. The samples were taken from a depth of 20–30 cm below the water surface, preserved at +4 °C, and delivered to the laboratory within 24 hours. The procedure was carried out according to the national standard DSTU ISO 5667-3:2001 "Water quality – Sampling – Part 3: Preservation and handling of water samples".

The physicochemical parameters of the water were determined using gravimetric, titrimetric, photocolorimetric, and conductometric methods. The analysis included pH, electrical conductivity, alkalinity, hardness, nitrates, nitrites, phosphates, chlorides, sulfates, and iron content. All methods followed national standards and guidelines for drinking water quality control.

Analysis of water quality parameters was carried out in the water testing laboratory of the "Osnova Chemical Factory" LLC. The parameters were determined according to standard methods, namely: hydrogen index was determined by DSTU 4077-2001, permanganate oxidation according to MBB 38433478.003:2023, total alkalinity, carbonate and hydrocarbonate content according to MBB 38433478.005:2023, electrical conductivity according to MBB 38433478. 001:2023, total iron content according to DSTU ISO 6332:2003, copper ion content according to MBB 38433478.0011:2023, cadmium ion content according to MBB 081/12-0787-11, sulfate content according to MBB 38433478. 008:2023, chloride content according to DSTU ISO 9297:2007, orthophosphate content according to MBB 38433478.009:2023, zinc ion content according to MBB 081/12-0787-11, nitrite, ammonia and ammonium ion content according to MBB 38433478.007:2023, nitrate content according to MBB 38433478.007:2023.

The measured values of drinking water quality parameters were evaluated against the regulatory limits established in Sanitary and Epidemiological Norms 2.2.4-171-10 "Hygienic Requirements for Drinking Water Intended for Human Consumption" for water from wells and capped springs (DSanPiN 2.2.4-171-10, 2010). The water quality of wells and spring capacities was determined by DSTU 4808:2007 (DSTU 4808:2007, 2007), according to which the range of water quality indicators (criteria) for surface and groundwater is divided into 4 classes: Class 1 – excellent, desirable water quality; Class 2 – good, acceptable water quality; Class 3 – satisfactory, acceptable water quality; Class 4 – mediocre, limitedly suitable, undesirable water quality.

The overall water quality was assessed using the Water Pollution Index (WPI) according to DSTU 4808:2007 "Sources of centralized drinking water supply. Hygienic and ecological requirements for water quality and rules of choice". The WPI was calculated as the arithmetic mean of the normalized concentrations (Ci/MPC i) for the selected indicators, where Ci is the measured concentration of a parameter and MPC i is its maximum permissible concentration. Based on the obtained values, each sampling point was assigned to a water quality class ranging from "clean" to "extremely polluted".

3. Results and Discussion

The studied water samples from wells and spring catchments are characterized by different values of pH, permanganate oxidation and total alkalinity at all sampling points (Fig. 2). It should be noted that the pH value of the water does not meet the standard values of 6.5–8.5 in the village of Kocherezhky, where the water is acidic – pH 6.0, and in the village of Novotroitske, where the water is alkaline – pH 9.07. In the village of Bulakhivka, an excess of the integral indicator of permanganate oxidation was detected, which exceeds the MPC of 5.0 mg/L by 1.2 times. In accordance with DSanPiN 2.2.4-171-10, total alkalinity reflects the buffering capacity of water, primarily due to the presence of weak acid anions such as carbonates and bicarbonates. This parameter is not typically assessed for water extracted from wells or surface intakes, while for bottled drinking water, the acceptable limit is 6.5 mmol/L. In the analyzed samples, total alkalinity varied between 0.9 and 14.2 mmol/L, with the maximum value recorded in the sample collected from Bulakhivka village.

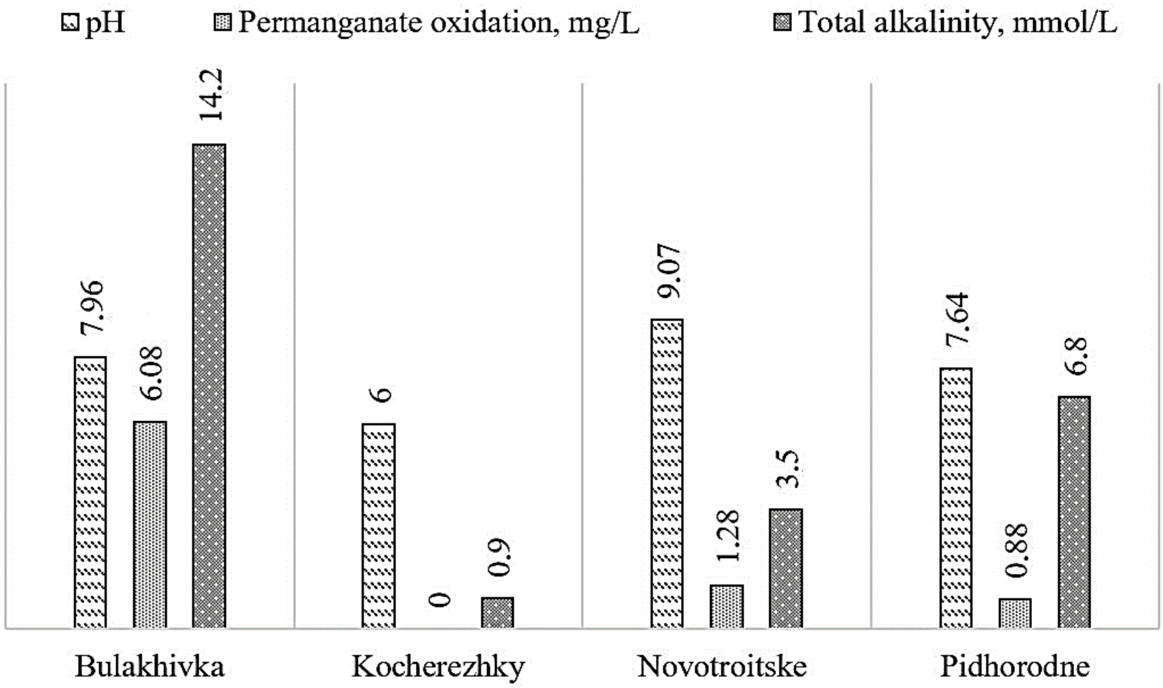

Fig. 2. Characterization of general water quality indicators

Notably, the concentrations of hydrocarbonates, chlorides, sulfates, and nitrates varied considerably across the analyzed water samples (Fig. 3). Hydrocarbonate concentrations ranged from 54.9 to 866.2 mg/L, with the peak level observed in Bulakhivka village, showing a strong relationship with the water's total alkalinity. Chloride levels remained below the maximum permissible concentration (350 mg/L), fluctuating between 4.55 and 209.91 mg/L. The MPC for sulfates in water from wells and water captures is 500 mg/L; in the tested samples, they were detected in water from Bulakhivka village (16.13 mg/L) and Pidhorodne town (118.95 mg/L), while their content is within the normal range. Also, no exceedance of the MPC (3.3 mg/L) for nitrite content was detected in all sources of non-centralized water supply, and their content ranges from 0.003 mg/L in Kocherezhky village to 0.013 mg/L in Bulakhivka village. However, the nitrate content in the water from Bulakhivka village exceeds the MPC of 50 mg/L by 4.2 times, while in Kocherezhky, Novotroitske, and Pidhorodne samples nitrates remainned within the permissible limits. The electrical conductivity of the selected water samples, which depends mainly on the degree of mineralization (concentration of dissolved mineral salts), was also investigated and found to increase in the following order: Kocherezhky village, Novotroitske village (66.5 μS/cm) – Pidhorodne (1317 μS/cm) – Bulakhivka village (2740 μS/cm).

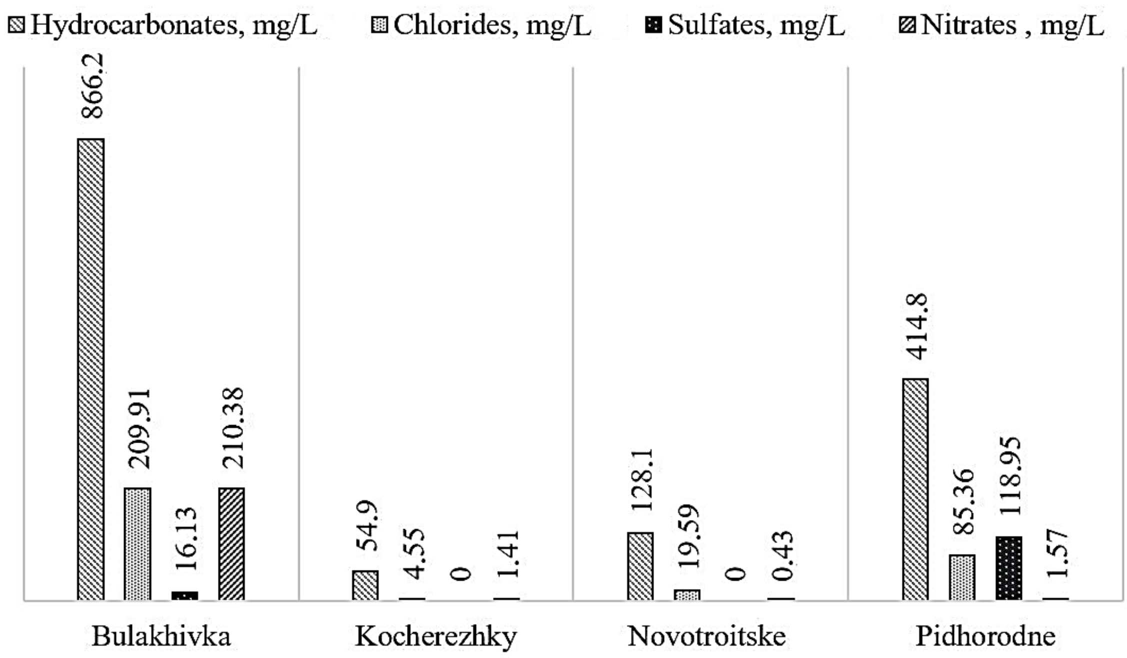

Fig. 3. Anion content in water samples

Fig. 4 presents the findings for total iron, copper, and zinc concentrations; cadmium was absent in all analyzed samples. The data indicate that total iron levels remain below the maximum permissible concentration of 1.0 mg/L. Copper concentrations ranged between 0.01 and 0.06 mg/L, while zinc levels varied from 0.02 to 0.2 mg/L.

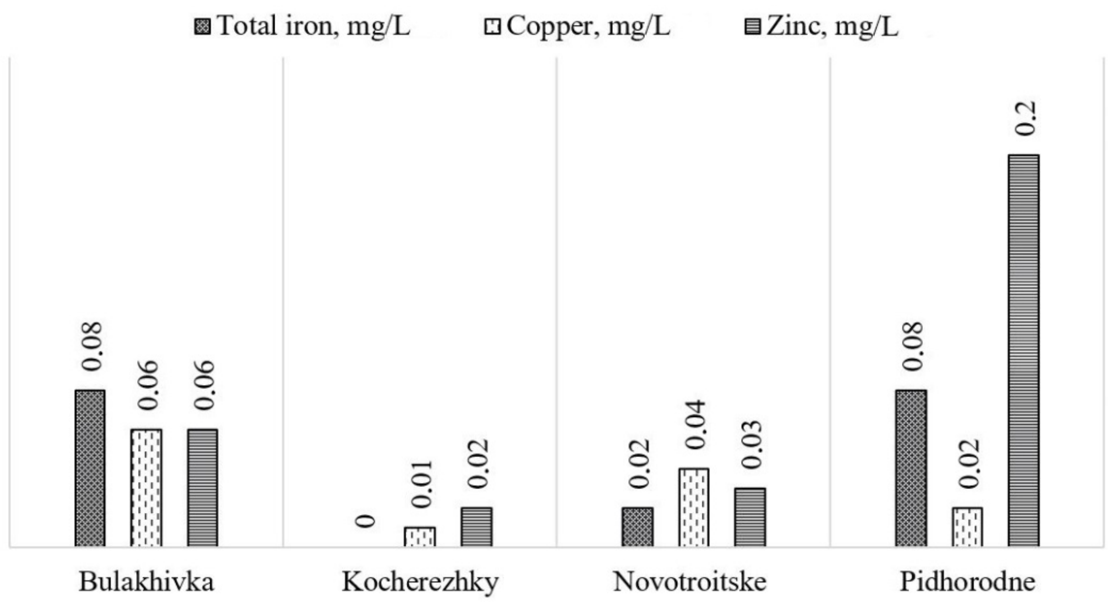

Fig. 4. Cation content in water samples

To evaluate the condition of the water, the concentrations of eutrophication-related compounds were also analyzed in the collected samples. Ammonia and ammonium were absent in samples from Kocherezhky village, while the highest concentrations were recorded in Bulakhivka. Nonetheless, all values remained below the maximum permissible concentration of 2.6 mg/L. Orthophosphate levels varied from 0.06 mg/L in Pidhorodne to 1.23 mg/L in Bulakhivka's water supply.

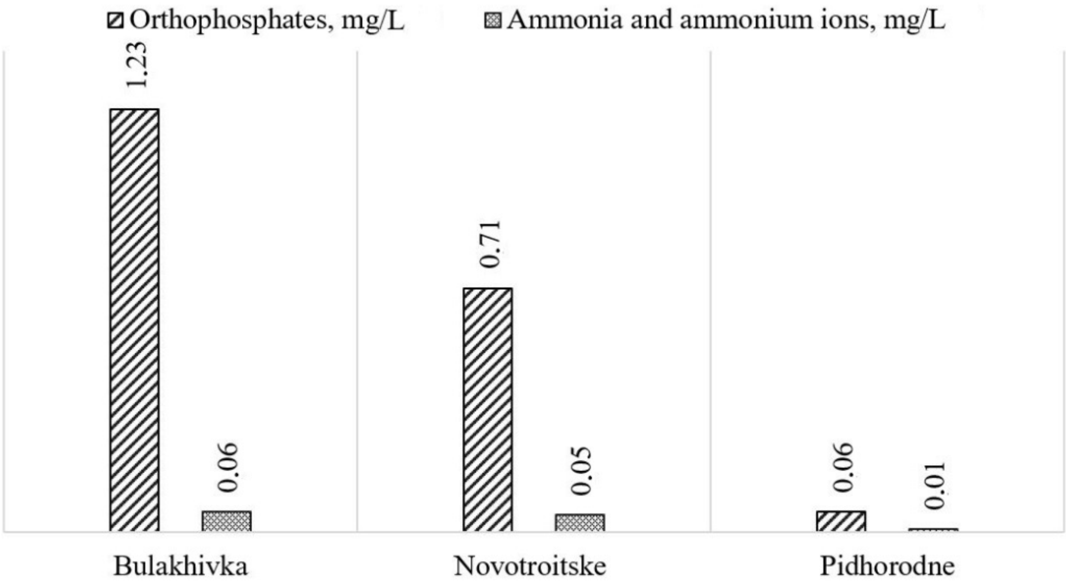

Fig. 5. Eutrophic agents content in water samples

To assess the water quality of wells and spring capture, we used DSTU 4808:2007 (DSTU 4808:2007, 2007), which defines water quality classes for each study site according to individual indicators (Fig. 6).

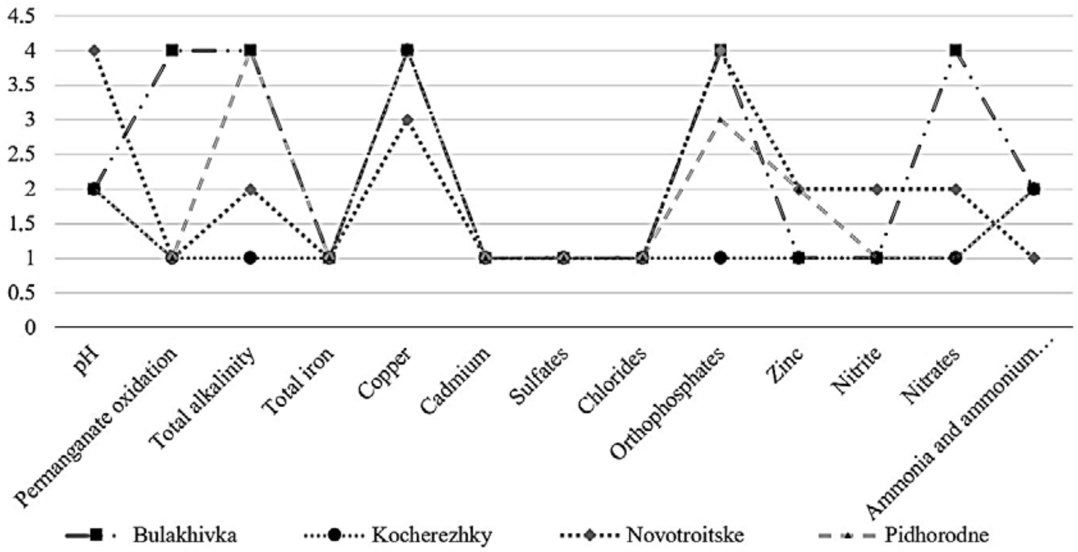

Fig. 6. Distribution of water quality classes by individual indicators

The water quality in the pump room of Kocherezhky village predominantly corresponds to Class I standards, accounting for 76.9 % of the analyzed parameters. An additional 15.4 % of the indicators align with Class II, while only 7.7 % fall under Class IV, indicating isolated concerns regarding specific characteristics. The water from the spring near the Solonyi Lyman Lake in Novotroitske village corresponds to the 1st class of water quality in 46.1 % of the studied indicators, 30.77 % – to the 2nd class of water quality, 7.7 % – to the 3rd class of water quality, 15.4 % – to the 4th class of water quality. The water from the well in Pidhorodne corresponds to the 1st class of water quality in 53.8 % of the studied indicators, 23.1 % – to the 2nd class of water quality, 7.7 % – to the 3rd class of water quality, 15.4 % – to the 4th class of water quality. The worst water quality should be recognized as the well in the village of Bulakhivka, as 46.1 % of the studied indicators correspond to the 1st class of water quality, 15.4 % – to the 2nd class of water quality, 38.5 % – to the 4th class of water quality.

The analysis of nitrate and other parameters showed significant variation among the studied sites.

A more detailed analysis of the studied water sources demonstrates pronounced variation between sites. The control site in Kocherezhky village exhibited the best water quality, with almost all parameters well below the maximum permissible concentrations. The only deviation was a slightly acidic pH (6.00), which may affect taste and accelerate corrosion in pipelines, potentially releasing trace metals.

In Novotroitske village (spring near Solonyi Lyman Lake), the water showed generally favorable characteristics such as low mineralization (66.5 μS/cm) and reduced permanganate oxidation values. However, excessive alkalinity (pH 9.07), a high carbonate concentration (42 mg/L), and elevated orthophosphates (0.71 mg/L) pose risks of eutrophication and algal blooms.

In Pidhorodne, the local well water had high total mineralization (1317 μS/cm), with substantial hydrocarbonates (414.8 mg/L) and sulfates (118.95 mg/L), which may increase hardness and alter taste. Although nitrates and organic substances were absent, elevated mineral content may pose risks of chronic kidney stress.

The poorest quality was observed in Bulakhivka, where water was highly mineralized (2740 μS/cm), with high alkalinity (14.2 mmol/L) and hydrocarbonates (866.2 mg/L). Critically, nitrates exceeded the maximum permissible concentration by a factor of 4.2, creating a potential risk of methemoglobinemia in children. High permanganate oxidizability and orthophosphates also indicated organic contamination.

A summary of all m easured parameters, their exceedances, classification according to DSTU 4808: 2007, and potential health implications is presented in Table.

Summary of water quality indicators, exceedances, classes, and possible health risks in the Dnipropetrovsk region

Sampling site	Main exceedances / deviations	Water Quality Class (DSTU 4808:2007)	Exceedance of MPC	Possible health risk / impact
Bulakhivka well	Nitrates (×4.2 MPC), high alkalinity, orthophosphates, permanganate oxidizability	Class IV (poor)	Yes	Methemoglobinemia in infants; gastrointestinal disorders; unsuitable without treatment
Kocherezhky pump room	Slightly acidic pH (6.0), minor copper deviation	Class I (excellent)	No	Generally safe; minor corrosion risk due to low pH
Novotroitske spring (Solonyi Lyman)	Alkaline pH (9.07), orthophosphates ↑, elevated carbonates	Class II–III (satisfactory to good)	Partial	Risk of eutrophication, algal blooms; digestive irritation
Pidhorodne well	High mineralization, hydrocarbonates ↑, sulfates ↑, copper ↑	Class III (satisfactory)	Borderline	Kidney stress from high hardness; altered taste, possible chronic effects

Based on pH values, three of the four studied decentralized water sources–Bulakhivka, Kocherezhky, and Pidhorodne–fall into Class II, indicating good and acceptable water quality. In contrast, the sample from Novotroitske corresponds to Class IV, which denotes mediocre quality with limited suitability for use. With respect to permanganate oxidation, the water from Kocherezhky, Novotroitske, and Pidhorodne meets Class I standards, suggesting excellent quality, while the sample from Bulakhivka aligns with Class IV. Assessment of total alkalinity shows that water from Kocherezhky meets the criteria for Class I, Novotroitske ranks as Class II, and both Bulakhivka and Pidhorodne fall under Class IV, reflecting undesirable quality. For indicators such as total iron, cadmium, sulfates, and chlorides, all sampled locations demonstrate Class I quality, indicating high compliance with environmental norms. Copper concentrations vary: the sample from Novotroitske falls within Class III, whereas the others are categorized as Class IV due to elevated levels. General water quality evaluation shows that Kocherezhky maintains Class I status; Pidhorodne is rated as Class III, and both Bulakhivka and Novotroitske remain within Class IV. As for zinc, water from Bulakhivka and Kocherezhky corresponds to Class I, while Novotroitske and Pidhorodne are grouped under Class II, denoting good quality. Regarding nitrites, Novotroitske alone meets Class II standards, while the other three locations conform to Class I, indicating excellent quality. A different pattern emerges when examining nitrate levels: Kocherezhky and Pidhorodne meet Class I criteria, Novotroitske falls into Class II, and Bulakhivka, showing the poorest result, is rated as Class IV. Finally, the content of ammonia and ammonium ions places Novotroitske in Class I, while all remaining water sources are classified under Class II. Among the surveyed wells and spring catchments, the highest water quality was observed in Kocherezhky village, while Bulakhivka exhibited the most unfavorable parameters. Notably, the limiting tors for water quality in Bulakhivka include deviations in pH, elevated permanganate oxidation, increased total alkalinity, and higher concentrations of copper, orthophosphates, and nitrates. In Novotroitske, the constraints are related to pH and orthophosphates; in Pidhorodne – to total alkalinity and copper; and in Kocherezhky – primarily to copper levels. The elevated concentrations of these components may carry potential health risks for local populations relying on these water sources for drinking purposes.

The obtained results indicate that several exceedances of nitrates, orthophosphates, and heavy metals can be linked to the consequences of hostilities in the region. Intensive shelling and explosions release nitrogen oxides, which are further transformed into nitrates in water bodies. Damage to sewage infrastructure and fuel storage facilities may explain the increased levels of phosphates and petroleum-derived compounds. The detection of elevated iron and zinc concentrations in some wells can be associated with corrosion of damaged pipelines and military debris. Such processes are consistent with earlier observations in conflict zones such as Syria (Faour & Fayad, 2014) and Kuwait (Buolayan et al., 1998), where war-related pollution significantly affected groundwater quality.

Exceedances of nitrates above the maximum permissible concentration (MPC) pose a particular risk for infants, as they may cause methemoglobinemia ("blue baby syndrome") (DSanPiN 2.2.4-171-10, 2010). Elevated phosphates and increased permanganate oxidetion values indicate a high content of organic matter, which may lead to bacterial growth and gastrointestinal disorders (Popovych et al., 2018). The increased hardness and alkalinity observed in some samples may contribute to chronic kidney stress (Tsyganenko-Dzyubenko et al., 2023). Overall, the combination of these factors reflects a deterioration of drinking water safety during wartime conditions.

4. Conclusions

This article provides an evaluation of contamination levels in selected drinking water sources within the Dnipropetrovsk region. It reveals that water quality is influenced by multiple factors, including the geographical location of the source, environmental conditions of the surrounding area, proximity to pollution sources, and the sanitary-technical state of the water supply infrastructure. Importantly, the ongoing full-scale war in Ukraine, now in its fourth year, has severely damaged numerous water management facilities, such as sewage and wastewater treatment plants. These disruptions may significantly compromise the quality of surface and underground water sources in affected areas.

The obtained laboratory data allow for comparing water quality across the examined sites. The control site in Kocherezhky demonstrated the highest quality, with almost all parameters below maximum permissible concentrations except for slightly low pH (6.00), which may affect taste and increase pipeline corrosion. The spring near Solonyi Lyman Lake in Novotroitske showed low mineralization and reduced organic matter but had excessive alkalinity (pH 9.07), high carbonates (42 mg/L), and elevated orthophosphates (0.71 mg/L), posing risks of eutrophication. The well in Pidhorodne was marked by high mineralization (1317 μS/cm), hydrocarbonates (414.8 mg/L), and sulfates (118.95 mg/L), which may increase hardness and alter taste, though no nitrates or organic contamination were found. The poorest quality was in Bulakhivka, where water was highly mineralized (2740 μS/cm), with high alkalinity (14.2 mmol/L), hydrocarbonates (866.2 mg/L), and nitrates exceeding the MPC by 4.2 times, creating serious health risks, especially for children.

In summary, the primary contributors to the deterioration of drinking water quality in the context of ongoing military operations include the destruction of treatment plants, industrial sites, and civilian infrastructure. These damages have led to the release of sewage and hazardous substances into the environment, causing unintentional contamination of water sources. Although such pollutants as heavy metals have not yet been detected in the samples taken, it should not be forgotten that their impact on water is delayed and may manifest itself later. These findings emphasize the urgent need for systematic monitoring of decentralized water sources in conflict-affected areas, both during active hostilities and in the post-war period.

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