

HYDROCHEMICAL STATE OF WATER INTAKES IN CHERNIHIV REGION

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The water composition from water intakes of communities of Chernihiv region has been studied. It was established that the epidemiological safety, organoleptic properties, and sanitary-toxicological and physico-chemical indicators of the studied samples comply with the State Sanitary Norms and Rules 2.2.4-171-10. A distinctive feature of the water hydrochemical composition is the relatively low calcium ion content, especially in water intakes of Pryluky district, whereas the calcium ion content in water samples of Nizhyn district aligns with the standards of physiologically adequate water. Additionally, it was found that all samples comply with the standards for physiologically adequate water regarding Mg^{2+} ions content (10 - 50 mg/dm³), which is important for the cardiovascular system. At the same time, discrepancies with regulatory standards were identified regarding the concentration of total iron, manganese, ammonium and fluoride ions. The maximum deviation from the regulatory standard for total iron was established for Chernihiv district, with exceedances ranging from 6 to 25.4 times. Alongside the high iron content, significant excesses of Mn^{2+} and ammonium ions were recorded in the studied samples. Of the 15 studied water intakes, only 3 (20%) meet the physiologically adequate water standards for fluoride ions. While a fluoride ion deficiency is observed in the samples from Chernihiv district, all studied water intakes of Pryluky district are characterized by concentrations exceeding the standard by up to 1.2 times. A water treatment strategy which utilizes an integrated reagent-free water purification system Antares 777-1 has been proposed, and its effectiveness has been experimentally verified.

Keywords: Chernihiv region, drinking water, hydrochemical composition, water intakes, water treatment, water quality

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1. Introduction

Drinking water supply in Ukraine is mainly provided by fresh groundwater (Stavytsky et al., 2011), since the country's surface waters are mostly polluted. Groundwater resources amount to 61689.2 thousand m³/day, of which 57499.9 thousand m³/day have mineralization up to 1,500 g/dm³. However, the supply is unevenly distributed across the regions, with the highest concentration in the northern and western regions (Stavytsky et al., 2011). Chernihiv region holds significant groundwater resources, totaling 8326.7 thousand m³/day.

In hydrogeological terms, the territory of Chernihiv region is located within the Dnipro artesian basin, where the following aquifers and complexes are present (Prybylova, 2015): Quaternary aquifer; Kharkiv aquifer; Kaniv-Buchak aquifer; aquifer complex of Lower Cretaceous and Cenomanian deposits.

The Quaternary aquifer is replenished by atmospheric precipitation infiltration and is considered relatively protected from surface contamination. However, it is characterized by an uneven regime due to water level fluctuations of up to 1.5 m. The Kharkiv aquifer is stable and pressurized, but it

contains a significant amount of dissolved iron. The aquifer complex of Lower Cretaceous and Cenomanian deposits provides a stable supply of high-quality water; however, its utilization requires significant capital investment in construction work due to the significant depths of the strata (400 meters and more). The optimal aquifer for installing underground water intakes is the Kaniv-Buchak aquifer, located at a depth of 80-150 m in Chernihiv region.

The 2023 study of the region's public water supply found that 12.3% of water samples did not meet the requirements of the State Sanitary Rules and Norms (DSanPiN) 2.2.4-171-10 "Hygienic Requirements for Drinking Water Intended for Human Consumption". The studied water samples recorded violations of regulatory norms for turbidity, color, odor, total iron, chloride, and fluoride ion content. According to microbiological indicators, 2.6% of samples did not meet the requirements for the epidemic safety of drinking water. To solve the problem of providing the population with high-quality drinking water, the Regional Program "Drinking Water of Chernihiv Region for 2022-2026" was adopted. One of its key focuses is monitoring the quality of water intakes and developing effective water treatment methods, tailored to the specific composition of the water. Certain studies have been conducted in this direction, in particular, an assessment of the water quality of the Kyptivka territorial community (Kotelchuk et al., 2025).

The objective of this study was to examine the water composition of intakes in selected communities within Chernihiv region (Chernihiv, Nizhyn, and Pryluky districts), perform a comparative analysis based on physiological suitability, and propose

strategies for ensuring a supply of high-quality drinking water to the population format.

2. Materials and Methods

Water intake wells, from which 15 water samples were taken (autumn period 2024 and 2025), are located in the villages of Chernihiv region (Nizhyn district: Dmytrivka, Kobyzhcha, Kozatske, Kropyvne, Markivtsi, Makiivka; Pryluky district: Mala Divitsia, Lynovytsia; Chernihiv district: Velyki Osnyaki, Kuvechychy, Novy Shlyakh, Progres, Slabyn, Smolyn, Yagidne). This territory features a complex geological structure and lies in the northwestern part of the Dnipro-Donetsk rift, located between the Voronezh Shield in the north and the Ukrainian Shield in the south. All water intake wells are drilled into the aquifer in the Eocene sediments (P2). A confining layer present in the roof creates the groundwater artesian pressure and ensures reliable protection against surface contamination. This aquifer is formed by sediments of the Kyiv, Buchak and Kaniv formations; among these the Buchak formation contains the most water-enriched sediments, with the thickness not exceeding 20.0 m.

Epidemiological safety indices, organoleptic, sanitary-toxicological and physico-chemical indicators were studied in the selected water samples.

Epidemiological safety indices (total microbial count, presence of E.coli and Enterococci forms) were determined according to Methodological Guidelines 10.2.1.-113-2005.

Organoleptic indicators (odor at 20 °C and at 60 °C, taste, color and turbidity) were evaluated according to (Perlova & Perlova, 2019). Water odor intensity was characterized

using a five-point scale in accordance with the State Standard of Ukraine (DSTU) EN 1420-1:2004. Water color was measured in degrees following DSTU ISO 7887:2003. Turbidity was determined using the simulated kaolin scale (a series of distilled water suspensions with a white clay content ranging from 0.1 to 0.5 mg/dm³).

Water samples' acidity (Bila et al, 2020) was measured with a pH-meter MW 804 manufactured by "Milwaukee". The dry residue was determined by the gravimetric method from 50 cm³ of water sample at a temperature of 105 °C according to MVV 081/12-0109-03, permanganate oxidation - MVV 081/12-0016-01.

The total hardness of water was determined by the complexation method according to DSTU ISO 6059-2003, using 0.01 N Trilon B solution as the titrant and Eriochrome Black T as the indicator (Lalak & Poxodylo, 2009). The concentration of HCO₃⁻ ions was quantified by the direct acidimetry method: a water aliquot was titrated with 0.01N hydrochloric acid solution in the presence of methyl orange (Okhrimenko, Hafiatullina, 2011).

According to established regulatory State Standards of Ukraine standards were measured concentrations of cations and anions: Ca⁺², Mg⁺², Fe⁺² and Fe⁺³, Mn²⁺, Zn²⁺, Cu²⁺, Al³⁺, Mo²⁺, Na⁺ and K⁺ (using ion-selective electrodes), NH₄⁺, F⁻, SO₄²⁻, Cl⁻, NO₂⁻, NO₃⁻, PO₄³⁻.

Each indicator was determined in triplicate. Statistical data processing was carried out using Microsoft Excel software with generally accepted methods of variational statistics using the Student's t-test (Tarasova, 2008). The relative error for the reported values of the indicators does not exceed 5-10%.

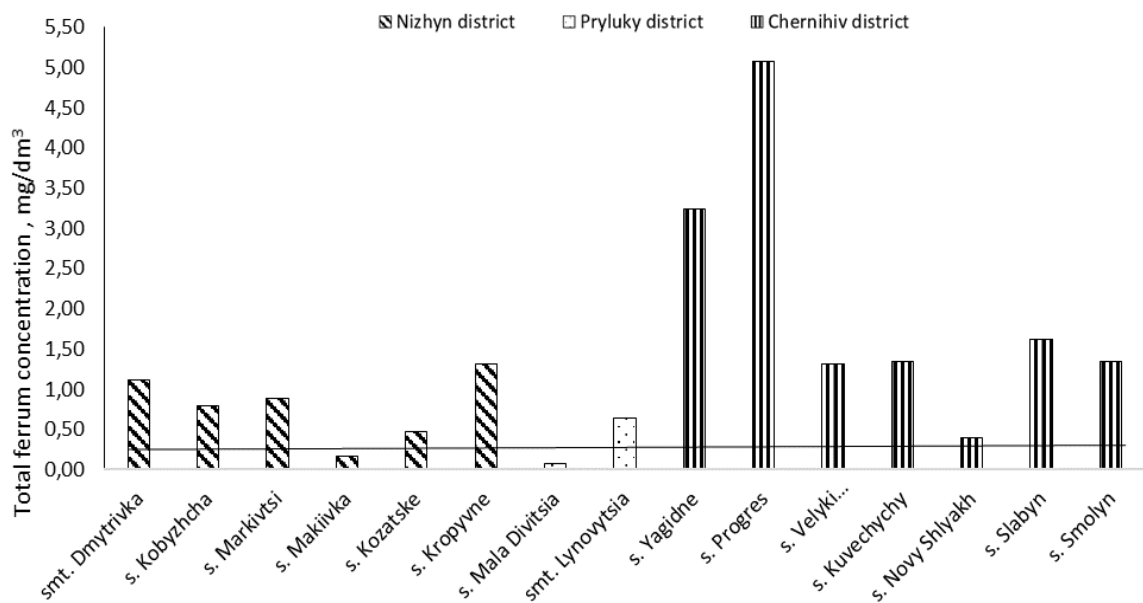
3. Results and Discussion

The study established that the organoleptic and microbiological indicators of the studied samples correspond to the sanitary-chemical indicators of safety and quality of drinking water according to DSanPiN 2.2.4-171-10 "Hygienic requirements for drinking water intended for human consumption". Physico-chemical indicators and the content of most individual cations and anions (Table 1) also do not exceed the regulatory values for tap water. At the same time, relatively low calcium ion content can be noted as a feature of the hydrochemical composition of water, especially in the water intakes of Pryluky district. In the water samples of Nizhyn district, calcium ion content corresponds to physiologically adequate water (25 - 75 mg/dm³) according to DSanPiN 2.2.4-171-10 (Appendix 4). Notably, all samples comply with the standards of physiologically adequate water regarding Mg²⁺ ion content (10-50 mg/dm³), which is important for the cardiovascular system. At the same time, the levels of total iron, manganese, ammonium, and fluoride ions were found to be non-compliant with regulatory standards (see Figs. 1-4).

The concentration of total iron exceeds the regulatory standards for all studied samples, except for the samples from the villages of Mala Divitsia (Pryluky district) and Makiivka (Nizhyn district).

Table 1. Cation and anion content (mg/dm³) in the tested water samples

Ions	Nizhyn district	Pryluky district	Chernihiv district	DSanPiN 2.2.4-171-10
Ca ²⁺	37.50 – 74.63	4.81 – 15.23	47.13 – 127.60	-
Mg ²⁺	6.70 – 20.67	9.73 – 13.4	6.08 – 33.44	-
Zn ²⁺	0.01 – 0.24	0.005 – 0.114	0.127 – 0.45	≤ 1
Cu ²⁺	0.01 – 0.04	0.02	0.02 – 0.03	≤ 1
Al ³⁺	0.02 – 0.10	0.02 – 0.04	0.02 – 0.074	≤ 0.20
Mo ²⁺	≤0.0025	≤0.0025	≤ 0.0025	≤ 0.07
Na ⁺ , K ⁺	26.14 – 160.70	139,30	7.00 – 30,80	≤ 200
SO ₄ ²⁻	0.04 – 4.72	14.20	0.02 – 18.70	≤ 250.00
Cl ⁻	7.50 – 64.00	28.08	4.00 – 15.60	≤ 250.00
NO ₂ ⁻	0.004 – 0.014	0.006 – 0.012	0.003 – 0.009	≤ 0.50
NO ₃ ⁻	< 0.001	< 0.001	< 0.001	≤ 50.00
Polyphosphates, PO ₄ ³⁻	< 0.01	< 0.01	< 0.01	≤ 3.50
HCO ₃ ⁻	421.00 – 585.80	416.8 – 504.0	274.6 – 585.8	-

**Fig. 1.** Concentrations of Fe²⁺ and Fe³⁺ ions in water intake samples from settlements in Nizhyn, Pryluky and Chernihiv districts of Chernihiv region compared to the standard value

The maximum deviation from the regulatory standard was found in Chernihiv district: 25.4 times for the village of Progres, 16.2 times for the village of Yagidne, 8.1 times for the village of Slabyn, more than 6 times for the village of Velyki Osnyaky, the

village of Kuvechychy, the village of Smolyn. These results are explained by the peculiarities of the Quaternary aquifer, which is in contact with sandy and clayey sediments containing iron minerals and organic matter.

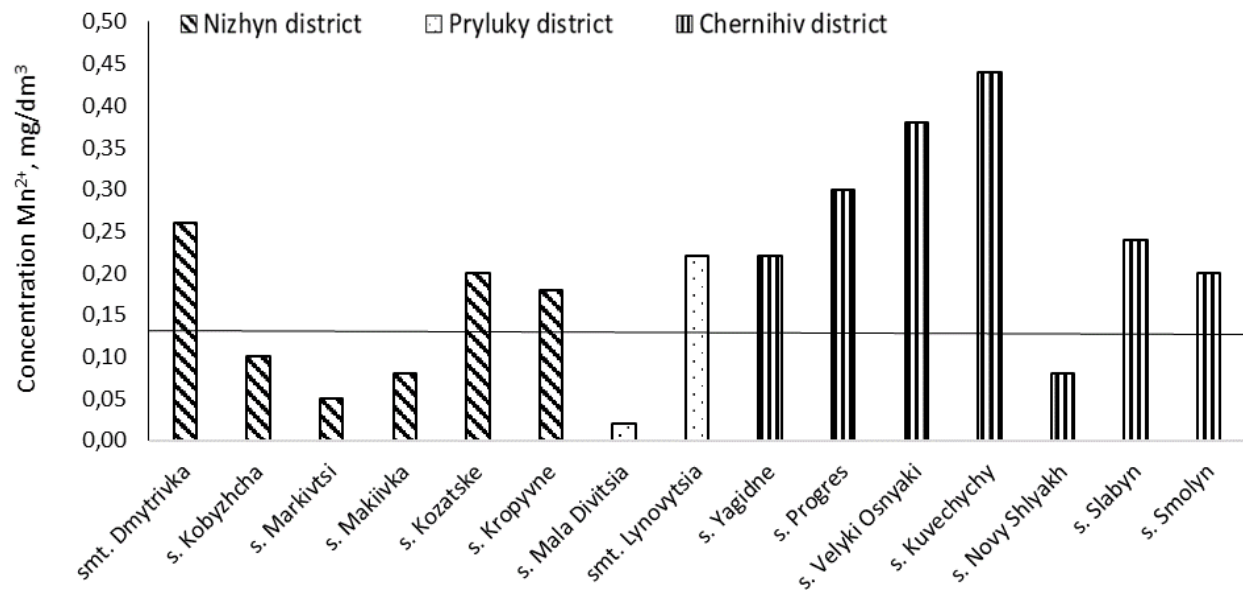


Fig. 2. Concentrations of Mn^{2+} ions in water intake samples from settlements in Nizhyn, Pryluky and Chernihiv districts of Chernihiv region compared to the standard value

In addition, humates are able to form stable soluble complex compounds with Ferrum ions. Simultaneously with the high iron content in the studied samples, a significant excess of Mn^{2+} ions was recorded, which was especially evident for the settlements of Chernihiv district. In particular, for the village of Kuvechyky, the excess of the norm is 3.7 times, for the village of Velyki Osnyaky – 3.2 times. It should be noted that all villages of Chernihiv district, where samples were collected, were located in areas significantly affected by active hostilities in 2022. This also contributed to the deterioration of water quality, in particular, an increase in the content of total iron and Mn^{2+} ions.

For most of the studied samples (Fig. 3), an excess of NH_4^+ ion concentration is also observed, the largest being 1.72 times (Kobyzhcha village, Nizhyn district) and 1.182 times (Lynovytsia village, Pryluky district).

This is likely due to the low oxygen concentration, which prevents the oxidation

of NH_4^+ to nitrites and nitrates, and is consistent with the high content of total iron and Mn^{2+} ions (Meng, et al, 2020).

Drinking water with an excess concentration of the above-mentioned ions has a negative impact on the human body, overloading the immune system. In particular, the accumulation of Fe^{2+} and Fe^{3+} ions in the tissues causes damage to the liver, heart and endocrine system, and Mn^{2+} is a specific neurotoxic poison. The particular danger of the presence of these ions in groundwater has been described in (Sharma et al, 2021).

As for the anionic composition of the studied water, a deviation in the fluoride ion content (Fig. 4) was established from the regulatory hygienic standards for Chernihiv region. As part of climatic zones I and II, the limit is 1.5 mg/dm³, while the range for physiological adequacy is 0.7–1.2 mg/dm³. It should be noted that Fluoride is one of the chemical elements that significantly affects human life as a whole.

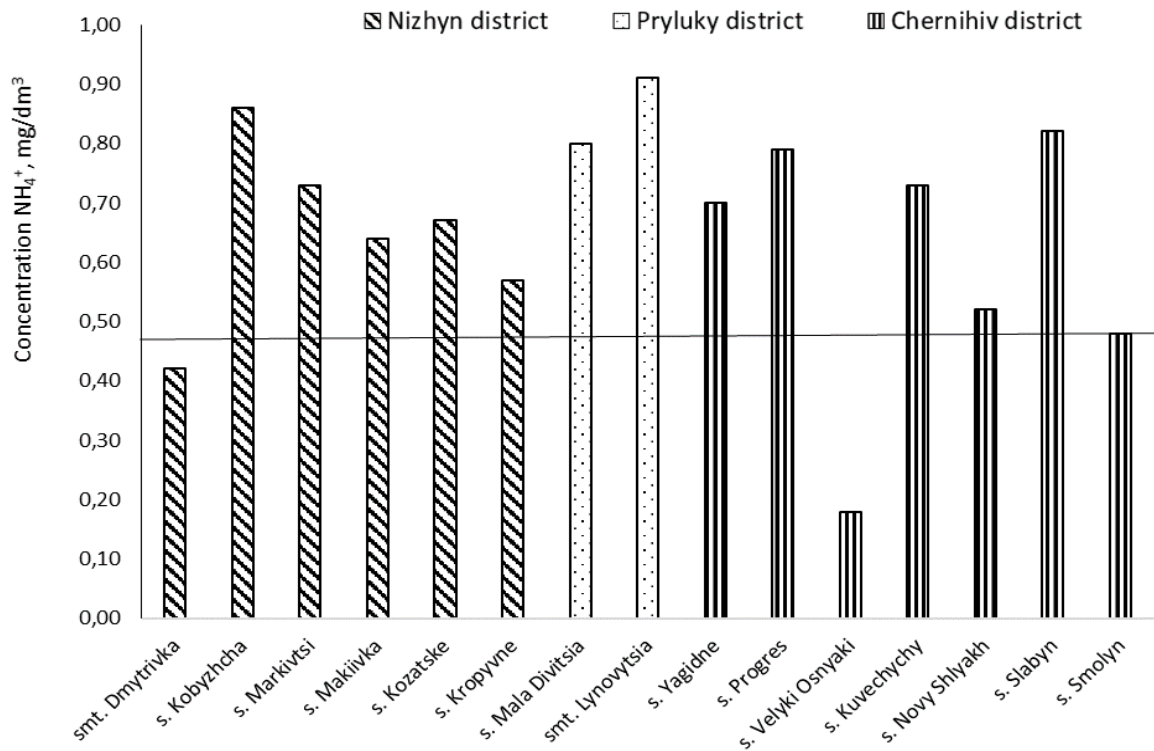


Fig. 3. Concentrations of NH_4^+ ions in water intake samples from settlements in Nizhyn, Pryluky and Chernihiv districts of Chernihiv region compared to the standard value

It is necessary for body metabolic processes and ranks seventh among vital elements after copper, zinc, iron, manganese, iodine and cobalt. This element is a specific inhibitor of the formation of lactic and hexose-diphosphoric acids, is related to blood clotting, thyroid gland functioning, and can inhibit intracellular processes that weaken the body's immunity and accelerate aging processes (Tryhub, 2013). A deficiency of fluoride ions increases the risk of dental caries and osteoporosis. At concentrations exceeding 1.5 mg/l, fluorosis can occur. Long-term overdose of fluoride ions can negatively affect the thyroid gland and nervous system, and cognitive functions of children (Kostenko et al, 2018).

Of the 15 water intakes studied, only 3 (20%) correspond to the water physiological adequacy. All the studied water intakes of Pryluky district are characterized by an increased (up to 1.2 times) concentration of

fluoride ions compared to the regulatory hygienic standards. The samples of Nizhyn district contained either an insufficient concentration of F^- (4 out of 6 studied) or a high one (1 out of 6 studied) compared to the physiological adequacy. The water samples of Chernihiv district are characterized mainly by the low content of fluoride ions, except for the water intakes of the villages of Yagidne, Slabyn, and Progress.

The obtained results indicate that although Chernihiv region is traditionally classified as a geochemical region with insufficient fluoride ion content, the utilization of resources from the Buchak aquifer, where the fluoride ion concentration ranges from 0.5 to 18 mg/dm³, can lead to different concentration levels. For example, the sample from the village of Progress exceeds the standards for physiological adequacy.

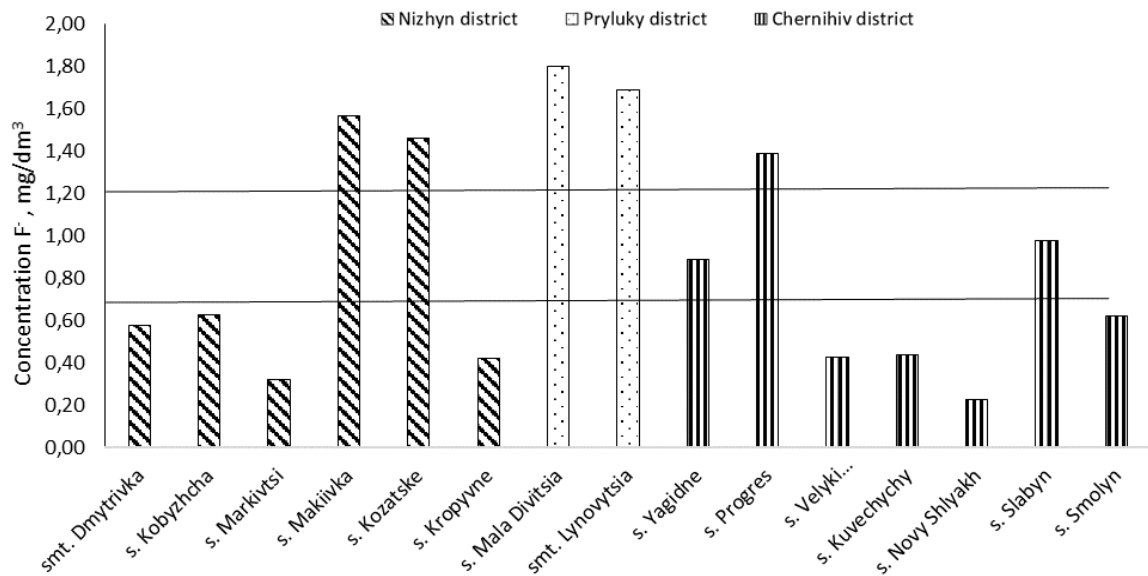


Fig. 4. Concentrations of fluoride ions in water intake samples from settlements in Nizhyn, Pryluky and Chernihiv districts of Chernihiv region compared to the standard value

For the treatment of drinking water with excessive levels of total iron, Mn^{2+} ions, ammonium and fluoride ions, it is proposed to install Antares 777-1, an integrated reagent-free water treatment system (capacity 1.0 - 1.5 m^3/h). The system features a turbodynamic aerator-flotator, which enriches water with oxygen and facilitates the flotation of iron and manganese ions. At the same time, hydrogen sulfide is separated using an internal vortex flow generated by a swirler and a turbine. After the aerator, the flotated and purified water enters a multimedia filtration column,

containing multilayer beds of quartzite, silicon, shungite minerals of various fractions, where further filtration occurs. The process concludes with a coconut shell carbon post-filter.

The results of using this system are presented in Table 2. The treatment efficiency for total iron is 94.7% for the water sample from the village of Progres, and 99.2% for the village of Velyki Osnyaky; for Mn^{2+} - 80.0% and 84.2%, respectively. During treatment, a 1.7-1.8-fold decrease in the fluoride ions concentration is observed.

Table 2 Comparison of selected quality parameters for raw and treated water

Parameter	Progres village		Velyki Osnyaky village	
	before treatment	after treatment	before treatment	after treatment
Total hardness, $mmol/dm^3$	8.17	8.15	6.75	6.55
Alkalinity, $mmol/dm^3$	9.60	9.30	7.80	7.50
Total iron (Fe^{2+} , Fe^{3+}), mg/dm^3	5.08	0.04	1.31	0.07
Mn^{2+} , mg/dm^3	0.30	0.06	0.38	0.06
NH_4^+ , mg/dm^3	0.79	0.43	0.18	0.12
F^- , mg/dm^3	1.39	0.80	0.43	0.24

Fluoride ion deficiency can be compensated for by well-known methods: adjusting the diet (seafood, buckwheat, oatmeal, apples, etc.), using fluoridated table salt, and toothpastes containing sodium fluoride. The levels of total hardness and alkalinity show no significant change.

4. Conclusions

The composition of water from intake points in certain communities of the Chernihiv region (Chernihiv, Nizhyn, Pryluky districts) meets epidemiological safety standards, and the organoleptic, sanitary-toxicological, and physicochemical parameters of the tested samples comply with the standards set forth in DSanPiN 2.2.4-171-10. A distinctive feature of the hydrochemical composition of the water is the relatively low content of calcium ions, particularly in the water intakes of the Pryluky district—4.81...15.23 mg/dm³—and the fact that the concentration of these ions in water samples from the Nizhyn district corresponds to that of physiologically complete water (25–75 mg/dm³). It was also established that all samples correspond to physiologically complete water in terms of Mg²⁺ ion content (10–50 mg/dm³). Exceedances of regulatory standards were detected for total iron, manganese ions, ammonium ions, and fluoride ions. The maximum deviation from the standard value for total iron was found in the Chernihiv district: an excess ranging from 6 to 25.4 times. At the same time, a significant 3.2–3.7-fold excess of Mn²⁺ ions was recorded. For most of the samples studied, an excess of ammonium ion concentration was observed, the highest being 1.72 times (Kobyzhcha village, Nizhyn District) and 1.182 times (Lynovytsia town, Pryluky District). Only 20% of the water intakes studied meet the criteria for

physiologically adequate water in terms of fluoride ions.

A water treatment system was proposed, consisting of the use of the Antares 777-1 comprehensive reagent-free water purification system, and its effectiveness was verified.

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ГІДРОХІМІЧНИЙ СТАН ВОДОЗАБОРІВ ЧЕРНІГІВЩИНИ

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Досліджено склад води з водозаборів окремих громад Чернігівщини. Встановлено, що показники епідеміологічної безпеки, органолептичні та більшість санітарно-токсикологічних і фізико-хімічних показників досліджених зразків відповідають нормативам за ДСанПіН 2.2.4-171-10. Особливістю гідрохімічного складу води є відносно низький вміст йонів кальцію, особливо у водозаборах Прилуцького району, та відповідність кількості цих йонів у зразках води Ніжинського району фізіологічно повноцінній воді. Також встановлена відповідність всіх зразків фізіологічно повноцінній воді по вмісту йонів Mg^{2+} (10 – 50 мг/дм³), що важливо для серцево-судинної системи. В той же час виявлено невідповідність нормативним показникам по вмісту загального заліза, йонів мангану, йонів амонію та фторид-йонів. Максимальне відхилення від нормативного значення по загальному залізу встановлено для Чернігівського району: перевищення від 6 до 25,4 разів. Одночасно з високим вмістом заліза у досліджених зразках зафіксовано суттєве перевищення йонів Mn^{2+} та амонію. З 15 досліджених водозаборів лише 3 (20%) відповідають фізіологічно повноцінній воді по фторид-йонам. Якщо для зразків з Чернігівського району спостерігається дефіцит фторид-йонів, то всі досліджені водозабори Прилуцького району характеризуються завищеною до 1,2 разів їх концентрацією. Запропонована система підготовки води, яка полягає у застосуванні комплексної безреагентної системи водоочищення Антарес 777-1, та перевірена її ефективність.

Ключові слова: водозабори, водоочищення, гідрохімічний склад, питна вода, Чернігівщина, якість води.