THE IMPACT OF DRINKING WATER QUALITY FROM NON-CENTRALIZED WATER SUPPLY SOURCES ON THE POPULATION MORBIDITY IN THE REGION OF ZHYTOMYR (UKRAINE)

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Key-words: drinking water, water quality, water safety assessment, diseases, nitrates, total iron, correlation.

Abstract. Poor quality drinking water can cause various human diseases, particularly affecting rural populations relying on non-centralized water supply sources, where water quality is often untested and does not meet sanitary standards. The aim of this study was to comprehensively assess the content of nitrates and total iron in drinking water from non-centralized water supply sources in the rural settlements of Zhytomyr Oblast of Ukraine, as well as to rigorously investigate the potential health impacts associated with these contaminants. Statistical processing was conducted using advanced statistical methods in the R programming language, and geographic data visualization was performed using the ArcGIS Pro software so as to enhance the interpretation of results. The correlation analysis revealed significant associations: nitrates are positively correlated with 33.3% of all disease types, while iron is linked to 94% of the same, indicating a substantial link between water quality and public health outcomes**.** For nitrates, the average correlation level was characteristic of prostate disease (R^2 = 0.33). Weak associations were found for stomach diseases, including gastritis and duodenitis (R^2 = 0.25), and the number of children born with congenital defects (R^2 = 0.05). A medium degree of association between iron content in drinking water and colorectal cancer (R^2 = 0.45) and epilepsy (R^2 = 0.31) was found. Additionally, iron has a weak effect on various other diseases. This study contributes novel insights into the connection between nitrate and total iron concentrations in drinking water and the incidence of diseases in the rural population, establishing a crucial foundation for future epidemiological research. The findings underscore the urgent need for policy interventions and public health strategies aimed at improving water quality and safeguarding community health in the region.

1. INTRODUCTION

Quality and safe drinking water and adequate sanitation are fundamental human rights as they support the dignity of all people and their quality of life (UN, 2019). Providing a population with quality drinking water is a national priority and is of particular importance for communities whose rural settlements rely on non-centralized water sources for their drinking water, where the water quality often does not meet the established standards. Rural areas are mostly not provided with centralized water supply and sewerage, which may be the reason for the decline in drinking water quality. In particular, according to the Ministry of Communities and Territories Development of Ukraine, as of 2020, 26.9%

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of villages in Ukraine, or one in five villages, were provided with centralized water supply systems, and only 1.8% with centralized sewerage systems (Ministry of Communities, Territories and Infrastructure of Ukraine, 2023). Thus, it can be said that Ukraine, especially when it comes to its remote villages, remains a "land of cesspools"; in terms of drinking water supply, Ukraine ranks 125th out of 180 countries (Ekonomichna Pravda, 2019).

Some of the non-communicable and communicable diseases can be caused by drinking water that does not meet the hygiene standards. Non-communicable diseases refer to health conditions that are not transmitted from person to person, such as cardiovascular diseases, diabetes, and certain cancers, which can arise due to prolonged exposure to harmful substances in contaminated water. In contrast, communicable diseases are those that can be spread from one individual to another, often resulting from pathogens present in unsafe drinking water, leading to illnesses such as cholera and dysentery. The quality of drinking water is crucial not only for preventing immediate infectious outbreaks, but also for mitigating long-term health risks associated with chronic conditions. Therefore, high-quality and epidemiologically safe drinking water is essential to maintain and improve public health. However, such water is supplied to the population only through a centralized water supply, which is constantly monitored for quality. At the same time, as of 2022, 30% of Ukraine's population lives in villages and urban-type settlements that use wells and shallow boreholes as sources of non-centralized water supply. The quality of water in such sources is often untested, and the sanitary conditions of the water sources are unsatisfactory (Danchyshyn, 2023).

In the Zhytomyr Region, only 30% of rural settlements are provided with a centralized water supply and only 13.7% with centralized sewerage (Ministry of Communities, Territories and Infrastructure of Ukraine, 2023). Groundwater quality is considered to be higher than surface water quality, but it is affected by several factors, such as urbanization, industrial water supply, sanitation, and intensive agriculture. Nitrates are one of the most common contaminants in drinking water, especially in rural areas, owing to agricultural practices and poor sanitation within private households (Valerko *et al.*, 2022). Studies conducted in the rural areas of Ukraine have shown that the exceedance rate of the normative content of nitrates in drinking water from non-centralized water supply sources ranged from 1.3 to 13.6 (Romanchuk *et al.*, 2021).

Constant consumption of high-nitrate-content water puts a strain on the immune system, which in turn leads to the exacerbation of chronic and new diseases of the respiratory, nervous, and cardiovascular systems (Kornatskyi *et al.*, 2013). In addition, prolonged hypoxia manifests as rapid fatigue, decreased performance and mental activity, and dystrophic disorders of the heart muscle (Lototska-Dudyk *et al.*, 2020). Nitrates in drinking water have been shown to affect women's reproductive functions (spontaneous abortions and stillbirths) (Stayner *et al.*, 2017) and cause congenital anomalies in newborns (Sadler *et al.*, 2016; Holtby *et al.*, 2014). Nitrates in drinking water can increase the risk of colorectal cancer by converting them into carcinogenic N-nitroso compounds (Schullehner *et al.*, 2018), bladder cancer (Jones *et al.*, 2016), and kidney cancer (Ward *et al.*, 2018). Nitrates potentially affect thyroid function by competing with iodine uptake, thus affecting cancer etiology (Ward *et al.*, 2010). A positive association has also been observed with brain cancer in children and adolescents (Zumel-Marne *et al.*, 2019; Stayner *et al.*, 2021).

Among the wide range of groundwater pollutants, heavy metal contamination is also a serious concern, as most are toxic to humans, especially when concentrations exceed standards and accumulate over time. Iron is the most common heavy metal that can affect humans even at low concentrations. Excessive levels of iron in drinking water can be associated with dangerous phenomena such as Parkinson's disease, Huntington's disease, Alzheimer's disease, cardiovascular disease, hyperkeratosis, diabetes, pigmentation changes, and kidney, liver, respiratory, and neurological disorders (Powers *et al.*, 2003; Kell, 2010; Farina *et al.*, 2013). In addition, gastrointestinal disorders and dysfunction of many organs can occur because of the consumption of water with elevated amounts of iron (Heming *et al.*, 2011).

Currently, the assessment of the quality of drinking water from non-centralized water supply sources and its impact on public health has been described in many studies performed in Ukraine (Herasymchuk *et al.*, 2022; Valerko *et al.*, 2022; Romanchuk *et al.*, 2021; Huschuk *et al.*, 2018; Lototska & Prokopov, 2018), India (Karunanidhi *et al.*, 2021), Bangladesh (Ghosh *et al.*, 2020), Iran (Aghapour *et al.*, 2021), China (Yu *et al.*, 2020), Indonesia (Sadler *et al.*, 2016), Pakistan (Khalid *et al.*, 2018), the United States (Wheeler *et al.*, 2015), Spain (Zufiaurre *et al.*, 2020), Kenya (Nyambura *et al.*, 2020), and Romania (Moldovan *et al.*, 2020), etc. However, there is currently a lack of research in Ukraine, especially in the Zhytomyr region, on the direct link between poor quality drinking water and certain disease categories. Given that groundwater contamination in rural areas is becoming a global phenomenon, and the health of the rural population that consumes water for drinking purposes from non-centralized water supply sources directly depends on the quality of drinking water, monitoring the quality of such water and determining its impact on human health is becoming increasingly important and requires constant research.

Thus, the aim of this study was to carry out an environmental assessment of the condition of drinking water coming from non-centralized water supply sources within the rural area of the Zhytomyr Region, as well as to investigate the links between the quality of such water and certain groups of diseases.

2. STUDY AREA SECTION

The research was conducted in the Zhytomyr region, which as of July 2020 consisted of 23 administrative districts. The territory of the region covers 29,827 km², more than 50% of which is agricultural land. The region is situated within two natural and climatic zones: Forest-Steppe (19%) and Polissya (81%), which impacts the diversity of its soils and landscapes.

The region's strategic positioning, endowed with abundant natural resources, favourable soil conditions, and temperate climates, offers a conducive environment for the advancement of agriculture and industry.

According to the Center for Public Health, the population of the region decreased by 12,700 people in 2020, mainly due to a natural decline, which amounted to 10,314 people. As of 2021, 1,195,500 people lived in the region. The average life expectancy at birth in the Zhytomyr region is 69.72 years, whereas the national average is 71.35 years. This indicates the presence of certain factors that affect health and, consequently, the longevity of the population (Center for Public Health, 2021).

3. MATERIALS AND METHODS

The study was conducted as part of the research work “Ecological and social assessment of the state of rural settlements in the context of sustainable development” (state registration number: 0120U104233). Drinking water samples were collected from non-centralized water supply sources (wells and boreholes) in the rural settlements of the Zhytomyr region between 2020 and 2022. A total of 570 drinking water samples were collected in 23 administrative districts of the region (Fig. 1).

Analytical studies for nitrate content in the collected water samples were carried out at the Measuring Laboratory of the Polissia National University in accordance with the requirements of the quality management system using methods that comply with the regulatory framework of Ukraine. In addition to nitrate content, the analytical studies also encompassed the assessment of total iron levels in the water samples. The results for both parameters were derived exclusively from our own collected samples, ensuring the integrity and relevance of the data for the specific context of the Zhytomyr region. This comprehensive analysis not only adheres to the established regulatory standards, but also provides a holistic view of the drinking water quality issues rural communities are facing.

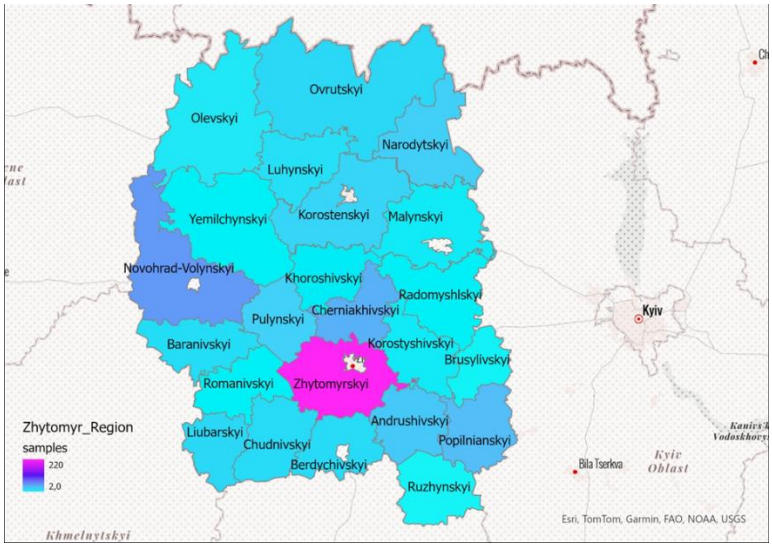

Fig. 1 – The number of drinking water samples collected by district in the Zhytomyr region, pcs.

The epidemiological retrospective study employed data from the Regional Information and Analytical Center for Medical Statistics of the Zhytomyr Regional Council for the years 2020–2022. Epidemiological surveillance included the impact of nitrates and total iron in drinking water on diseases of the circulatory, endocrine, urinary, genitourinary, and digestive systems.

Statistical processing of the results was performed using the R programming language, while the ArcGIS Pro software was used to graphically display the results. The statistical processing involved a variety of methods, including descriptive statistics to summarize the data, a correlation analysis to explore the connections between nitrate and iron concentrations and health outcomes, and the regression analysis was used to assess the predictive power of these variables on disease incidence. Statistical significance was evaluated using a p-value threshold of 0.05, allowing us to determine the reliability of our findings. This rigorous statistical approach ensures that the observed associations are not due to chance, but provide a solid foundation for interpreting the implications of our results.

4. RESULTS AND DISCUSSION

Nitrates are the most common anions naturally found in water resources. The concentration of nitrates in surface water and groundwater around the world is increasing as a result of anthropogenic activities. Our own research on the quality of drinking water from non-centralized water supply sources in the rural areas of the Zhytomyr region revealed an excess of nitrates in 15 districts of said region which amounted to 68%. The top five "leaders" in terms of average nitrate content are: Andrushivskyi district – 184.8 mg/dm^3, which exceeds the standard 3.7 times over, Chernyakhivskyi district – 155 mg/dm^3, 3.1 times more than the standard, Chudnivskyi district – 144.9 mg/dm^3, 2.9 times more than the standard, Lyubarskyi district – 107.7 mg/dm^3, 2.2 times more than the permissible amount, and Khoroshivskyi district – 101.9 mg/dm^3, 2 times more than the standard (Fig. 2).

Exceedances of up to two times the maximum permissible concentrations are typical for the districts of Emilchynskyi (average 99.04, exceeded 1.98 times), Pulynskyi (average 96.1, exceeded 1.9 times) and Radomyshlskyi (average 93.1, exceeded 1.86 times). In the districts of Zhytomyrskyi, Baranivskyi, Narodytskyi, and Romanivskyi, the average nitrate content exceeded the maximum level by a factor of 1.5. The average nitrate content in drinking water from non-centralized water supply sources in rural settlements in the Novohrad-Volynskyi, Ovruchskyi, and Korostenskyi districts was 1.37, 1.3 and,

respectively, 1.2 times higher. The average nitrate content in the drinking water of Olevskyi district is at the limit level and amounts to 48.5 mg/dm^3. In Ruzhynskyi, Korostyshivskyi and Popilnianskyi districts, the nitrate content ranges from 37.4–33.02 mg/dm^3, and in Berdychivskyi and Brusylivskyi districts – from 26.9–23.8 mg/dm^3. The lowest average nitrate content in drinking water was found in Malynskyi district, which is 12.5 mg/dm^3 (Fig. 2).

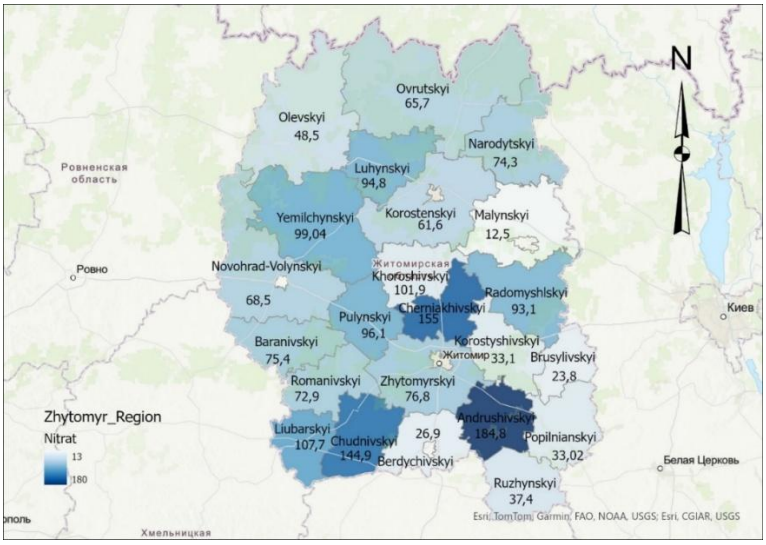

Fig. 2 – Average nitrate content in drinking water from non-centralised water supply sources in rural settlements of the Zhytomyr region, mg/dm^3.

According to Danchyshyn (2023), there are several reasons for the presence of nitrates in non-centralized water supply sources in regions where large areas are occupied by agricultural land. Firstly, farmers and villagers have unregulated the use of excessive amounts of organic and inorganic (ammonium) fertilizers. The chemicalization of agriculture is dangerous when technological standards for the use and storage of chemicals are violated. Secondly, owners of wells do not comply with the requirements of sanitary legislation when establishing and maintaining them, which leads to the contamination of drinking water with unregulated livestock farm runoff and local fecal matter, making it unsuitable for human consumption. Thirdly, and no less importantly is that in recent years, the amount of groundwater has decreased, especially in shallow mine wells, so the concentration of diluted substances, especially nitrates, has increased (Romanchuk *et al.*, 2021; Dancyshyn, 2023).

These research results coincide with the scientific work of A. F. Shcherbatiuk, who noted that in the villages of the Zhytomyr region for the 2001–2010 period, the nitrate content increased 5.7 times due to physical, geographical, meteorological, geochemical, geomorphological, hydrogeological conditions and anthropogenic impact. Reliable correlations between the nitrate content in drinking water and the application of nitrogen fertilizers and the inefficient use of livestock waste have also been shown (Shcherbatiuk *et al.*, 2012).

Studies in rural areas of the northern part of Zhytomyr Polissya, namely, in the Korostenskyi, Narodytskyi, and Luhynskyi districts, have shown that the quality of drinking water from non-centralized water supply sources is significantly affected by non-compliance with sanitary and hygienic requirements for the location of utility rooms and livestock facilities, as well as by the placement of manure pits in the vicinity of wells (Tamir, 2015).

Iron is the most naturally occurring element in nature and the second most abundant metal in the Earth's crust. Natural waters are enriched with iron through chemical weathering and mechanical destruction, as well as through the dissolution of rocks. The average iron content in surface waters is

approximately 0.7 mg/dm^3, while iron concentrations in groundwater usually do not exceed 0.5–10 mg/dm^3, but, according to the World Health Organization, it can reach 50 mg/dm^3 (WHO, 2003).

In the EU countries, the standard for iron in drinking water is set at 0.2 mg/dm^3, in Australia, Japan, China, the USA, and Canada – at 0.3 mg/dm^3, which corresponds to the standard approved by the WHO, which is limited to information only on changes in organoleptic properties when it is exceeded (WHO, 2011). Since 2010, Ukraine has had two iron content standards: 0.2 mg/dm^3 for centralized water supply and 1.0 mg/dm3 is allowed for water coming from non-centralized water supply sources (Sanitary and Epidemiological Norms, 2010).

Following the study of the quality of drinking water from non-centralized water supply sources in the rural settlements of Zhytomyr Oblast, the total iron content was found to be above the standard in five study areas. The highest level of total iron on average was recorded in Berdychivskyi district, which reached 2.02 mg/dm^3, exceeding the standard two-fold. The excess iron content rate within Novohrad-Volynskyi, Liubarskyi, Korostyshivskyi, and Olevskyi districts ranged from 1.22 to 1.04 (Fig. 3).

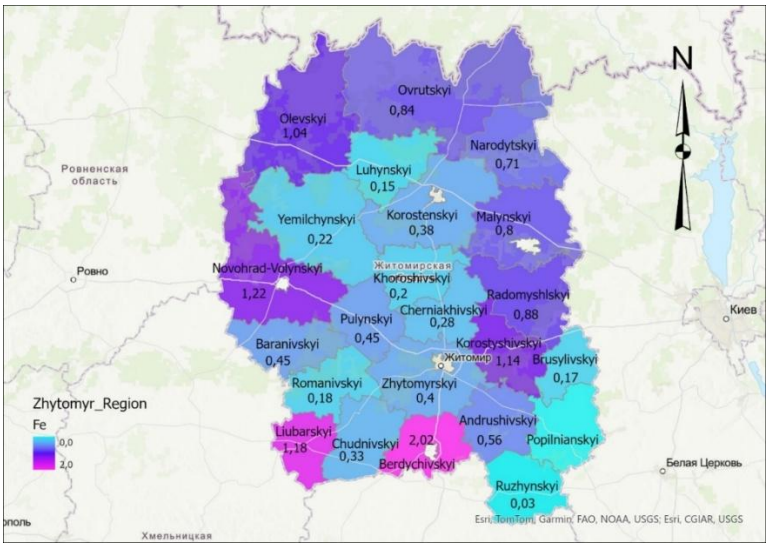

Fig. 3 – Average content of total iron in drinking water from non-centralized water supply sources in rural settlements of the Zhytomyr region, mg/dm3.

Increased iron content in drinking water from non-centralized water supply sources was also recorded during the monitoring of groundwater in Polissya by Zakharkevych and Zapolsky. In particular, in the studied districts of the Zhytomyr region, the iron content fluctuated within the following limits: in Korostyshivskyi district – 0.57–3.15 mg/dm^3, in Brusylivskyi district – 0.47–2.7 mg/dm^3, in Ruzhynskyi district – 0.39–1.00 mg/dm^3, in Narodytskyi district – 2.05–2.31 mg/dm^3, and in Ovrutskyi district – 2.23–3.23 mg/dm^3. According to scientists, this may be due to the relatively high corrosive activity of groundwater (Zakharkevych and Zapolsky, 2011).

Since the quality of drinking water is one of the factors affecting population morbidity, the next stage of our research was to analyse the morbidity of the rural population of Zhytomyr Oblast and investigate the possible link between the quality of drinking water coming from non-centralized water supply sources and diseases of different groups.

The peculiarity of the Zhytomyr region is that it was one of the most affected by the Chernobyl disaster. Studies conducted within radioactively contaminated areas of the region have established a close connection between public exposure doses and the risk of malignant tumors (R = 0.7353) (Herasymchuk *et al.*, 2019). High values of infant mortality rates in radioactively contaminated areas were also recorded in different years; in particular, in 2002, these values were highest in the

Emilchynskyi (18.7) and Novohrad-Volynskyi (17.7) districts; in 2005 in Narodytskyi district (22), in 2010 in Emilchynskyi (23.4) and Narodytskyi (18.5) districts, and in 2015 in Narodytskyi district (32.4), in 2020 – in Luhynskyi (27.4), and Ovruchskyi (14.7) districts (Romanchuk *et al.*, 2023).

According to the National Cancer Registry of Ukraine, an increase of 13.6% in malignant neoplasms was registered in the Zhytomyr region in 2021, compared to 2020. However, in 2020, there was a sharp decline in the incidence, which, according to experts, was due to a decrease in calls for cancer care during the COVID-19 pandemic (Fig. 4) (National Cancer Registry of Ukraine, 2023).

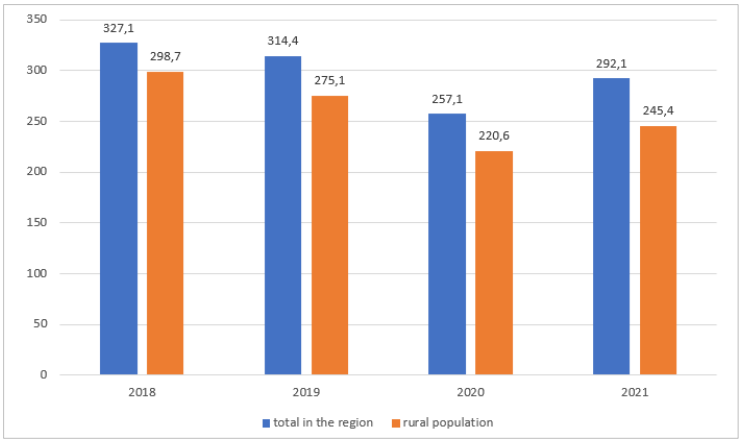

Fig. 4 – Incidence of malignant neoplasms in the Zhytomyr region, per 100,000 people.

In terms of the individual districts in the region, the average incidence of malignant neoplasms for 2019 was recorded as follows: in Andrushivskyi district – 41.9%, Berdychivskyi district – 19.7%, Zhytomyrskyi district – 14.9%, Korostenskyi district – 13.2%, Luhynskyi district – 5.2%, Lubarskyi district – 11.7%, Ovruchskyi district – 14.3%, Romanivskyi district – 4.6%, Ruzhynskyi district – 10.1%, and Cherniakhivskyi district – 4.5% (Fig. 5).

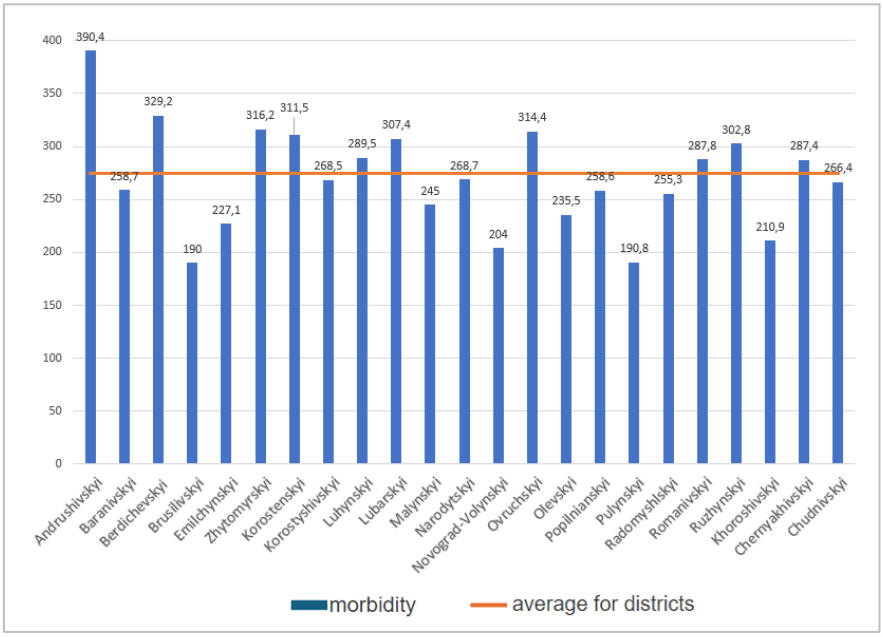

Fig. 5 – Incidence of malignant neoplasms in Zhytomyr region by districts, per 100,000 people.

One of the most sensitive indicators of a country's socio-economic well-being, an indicator of the overall health of the nation, and an important criterion for assessing quality of life is infant mortality. The mortality rate of children under the age of 1 has a positive trend in the region as a whole; in particular, from 2000 to 2020, this figure decreased from 131 to 54 children (Fig. 6).

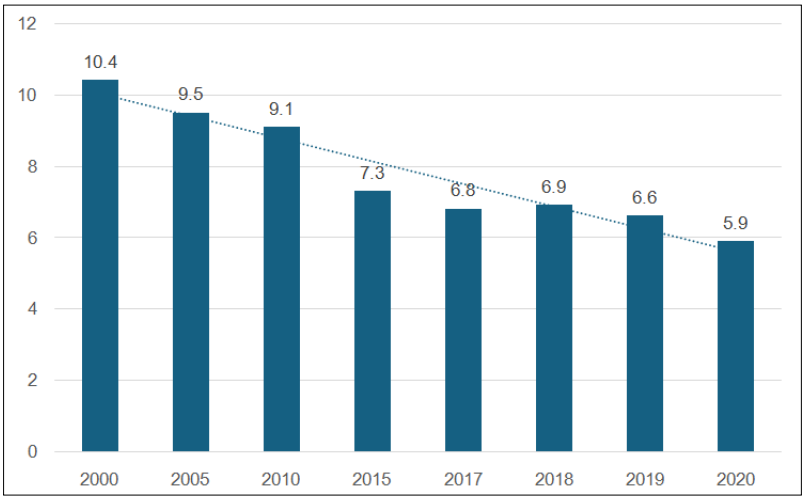

Fig. 6 – Mortality rates for children under the age of 1 in Zhytomyr region, per 1,000 live births.

In 2019, the average infant mortality rate exceeded the average level in Andrushivka district 3.4 times, in Baraniv district 1.4 times, in Korostyshiv district 2 times, in Novohrad-Volynskyi district 1.3 times, in Ovruch district 1.75 times, in Popilnyanskyi district 1.1 times, in Pulyn district 1.8 times, in Radomyshl district 1.3 times, in Khoroshiv district 1.1 times, and in Cherniakhiv district 1.2 times. However, it should be noted that in the districts of Berdychiv, Luhyn, Lubar, Narodychi, Romaniv, and Ruzhyn, there were no cases of infant mortality in 2019 (Fig. 7).

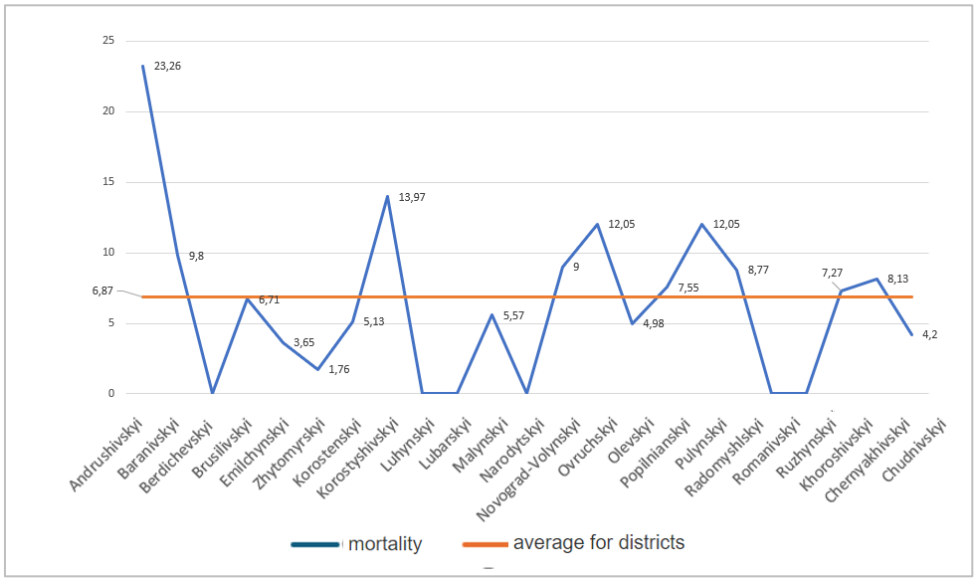

Fig. 7 – Mortality rates for children under the age of 1 in Zhytomyr Oblast, by district, per 1,000 live births, 2019.

Diseases of the circulatory system prevail in the mortality structure of the population of the Zhytomyr region, accounting for 68% of all deaths. By 2021, neoplasms ranked second among the mortality causes; in particular, in 2021, neoplasms there behind 9% of all deaths. In 2021, the second leading cause of death was COVID-19, which resulted in 2,624 deaths in the region during that year. Mortality from diseases of the digestive system is 3% (Fig. 8) (Main Department of Statistics in Zhytomyr Oblast).

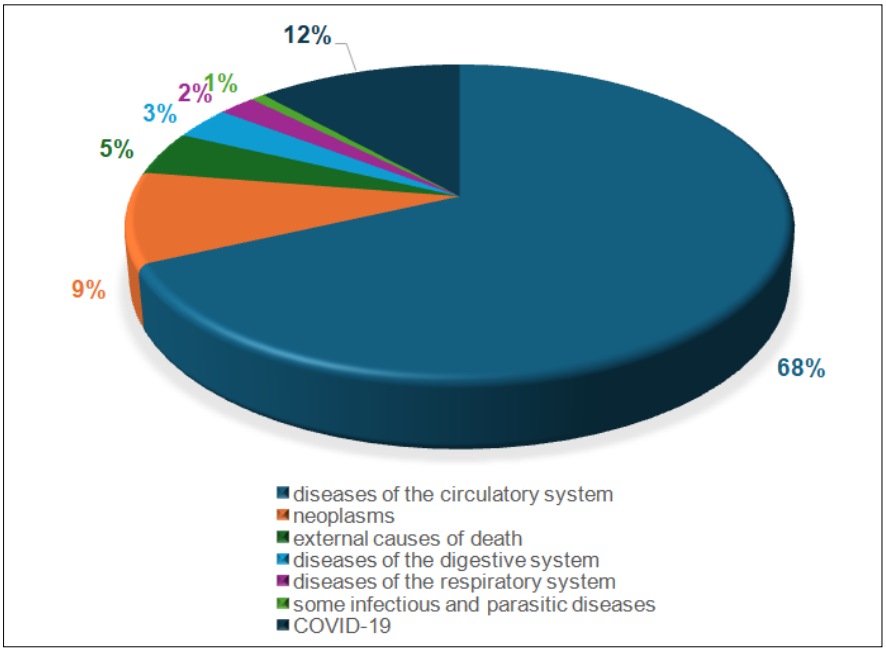

Fig. 8 – Mortality structure of the population of Zhytomyr region by individual causes in 2021, %.

The above analysis of morbidity in the Zhytomyr population shows a steady increase in morbidity and mortality in the region. In addition to social and political factors, the reasons for this may also be the poor state of the environment, including the quality of the drinking water.

Over the course of our own research, we conducted a correlation analysis between the content of nitrates and total iron in drinking water from non-centralized water supply sources and various diseases in the rural population of Zhytomyr Oblast. In terms of nitrate content and diseases, medium and low levels of correlation were observed. In particular, a moderate level of correlation was characteristic of prostate disease ($R^2 = 0.33$). Weak connections were found for stomach diseases including gastritis and duodenitis ($R^2 = 0.25$). In addition, weak associations were also found between nitrate content in water and the number of children born with birth defects ($R^2 = 0.05$), menstrual disorders in women ($R^2 = 0.05$), urinary tract diseases ($R^2 = 0.04$), prostate cancer, pancreatic diseases, pyelonephritis, and cholecystitis ($R^2 = 0.03$) (Fig. 9).

These results correlate with those of similar studies conducted in the United States and Canada. In particular, studies by American scientists have shown that high levels of nitrate in the drinking water in Iowa and Texas consumed by mothers during the first trimester of pregnancy are associated with congenital anomalies in newborns (Brender, 2013). Holtby *et al.* (2014) found an increased risk of birth defects associated with water with a concentration of 1.5–5.56 mg/dm3 and a tendency to increase with nitrate intake at concentrations above 5.56 mg/dm3, indicating that nitrate can increase the risk of birth defects even at concentrations below the standard (Holtby *et al.*, 2014).

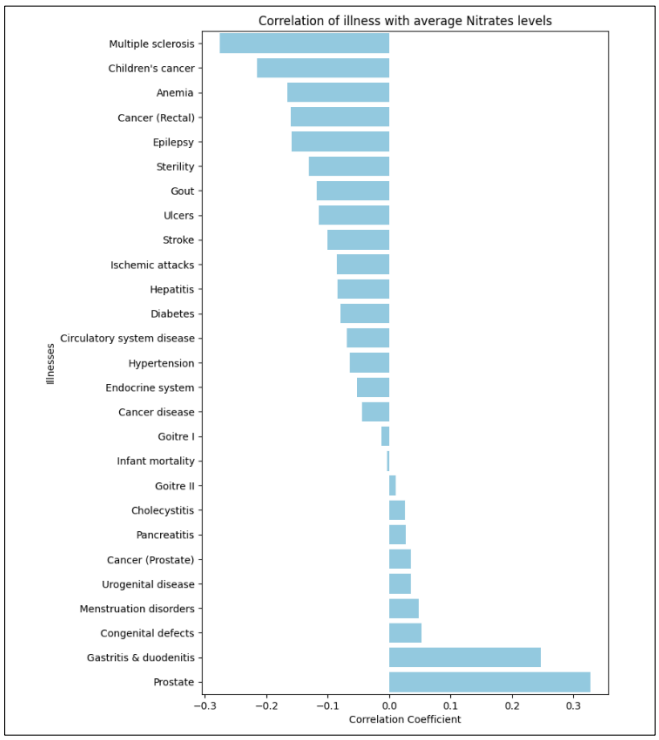

Fig. 9 – Correlations between the content of nitrates in drinking water and the incidence rate of the population of Zhytomyr region

In general, it has been shown that nitrate content affects the development of 33.3% of all diseases studied.

A moderate correlation between the iron content in drinking water was found for colorectal cancer (R^2 = 0.45) and epilepsy (R^2 = 0.31). Weak correlations within 20% were observed for the following diseases: iron deficiency anemia (R^2 = 0.28), multiple sclerosis, pancreatic diseases (R^2 = 0.27), anemia (R^2 = 0.26), diseases of the nervous system (R^2 = 0.25), circulatory system (R^2 = 0.24), mental and behavioural disorders (R^2 = 0.23). For diseases such as diabetes (R^2 = 0.19), cholecystitis, liver cirrhosis (R^2 = 0.17), hepatitis (R^2 = 0.13), and ischemic attacks (R^2 = 0.11), the correlation was found to be within 10%. A weak correlation of less than 10% was also observed for Parkinson's disease (R^2 = 0.09) (Fig. 10).

In general, a positive correlation was found between the iron content in drinking water and 94% of all diseases studied.

Similar studies have been conducted in other regions of Ukraine and other countries. In particular, Likho O. A. and Gakalo O.I. (2010), during their research in the Rivne region, found a high degree of correlation at the level of 0.7–0.9 between the incidence of diseases of the blood and hematopoietic organs, circulatory system, stomach ulcers, gastritis and duodenitis and the iron content in drinking water (Likho and Gakalo, 2010). Hryhorenko L.V. and Shevchenko O.A. proved that, out of all the factors studied, iron was the most important factor for the incidence of circulatory system diseases in adults (Hryhorenko and Shevchenko, 2019). It has been established that the constant consumption of water high in iron contributes to an increase in the level of overall morbidity, has a negative impact on the reproductive function, and increases the risk of developing heart attacks, peptic ulcer disease (Heming *et al.*, 2011), allergy-related diseases, bone diseases, blood diseases, liver diseases, kidney disorders, anemia, and neurological disorders (Ghosh *et al.*, 2020).

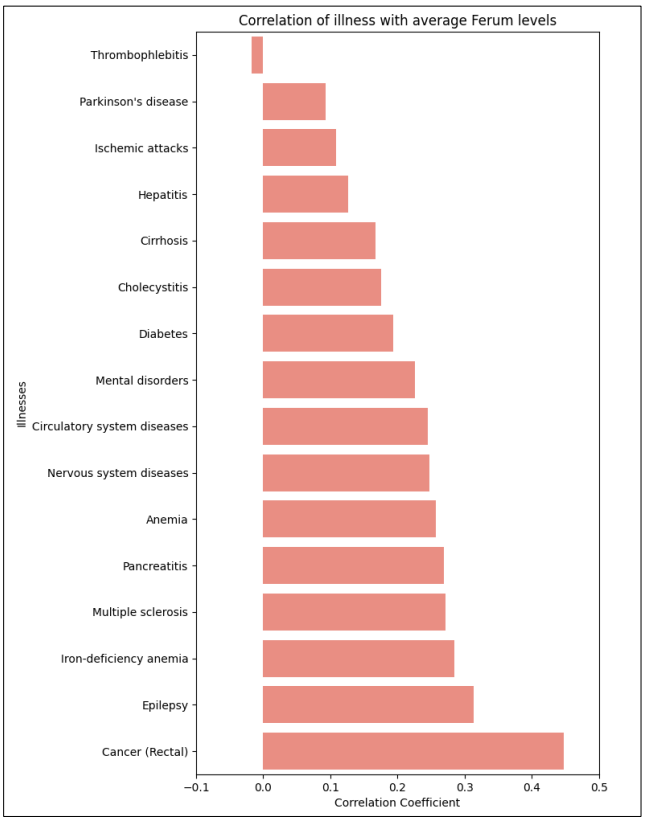

Fig. 10 – Correlations between the content of total iron in drinking water and the incidence of diseases in the Zhytomyr region.

5. CONCLUSIONS

The study confirmed that the inadequate quality of drinking water from non-centralized water supply sources in the rural areas of Zhytomyr Oblast is a serious problem with the potential to adversely impact public health. The presence of elevated concentrations of nitrates (ranging from 1.2 to 3.7 times the standard) and iron (from 1.04 to 2.2 times the standard) points to a probable health hazard.

The analysis of correlations indicated that elevated nitrate and iron levels in water are associated with an increased incidence of certain diseases, including colon cancer and epilepsy. It is noteworthy that excessive iron levels have been recorded in only a few areas; therefore, it can be assumed that its impact on human health is observed even at concentrations that do not exceed the standard.

Prospects for further research

1. Further research should focus on studying the cause-and-effect connections between water quality and public health, as well as assessing the impact of other environmental factors on morbidity in rural areas.
2. The role of other environmental factors, such as soil quality, air pollution, and agricultural practices, should be examined. This will facilitate a more comprehensive understanding of the environmental factors that impact public health.

3. Research should examine socio-economic factors that may influence access to clean water and a good quality of life in rural areas, including an analysis of financing mechanisms for water supply and sanitation infrastructure.
4. A study of international experience in water management and water quality control is also recommended, with the aim of adapting successful practices to the conditions of Ukraine.

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