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WATER QUALITY FROM THE SOURCES OF NON-CENTRALIZED WATER SUPPLY WITHIN THE RURAL SETTLEMENTS OF ZHYTOMYR REGION

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Abstract

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The research was conducted within the territories of rural settlements of Zhytomyr region. A total of 72 sources of non-centralized water supply were surveyed. Water quality was assessed by physical and chemical (pH, iron total, total water hardness) and toxicological (nitrites, nitrates, and ammonium) indicators, the content of which was compared with the norms given in the State Sanitary Regulations and Standards 2.2.4-171-10 "Hygienic Requirements for Drinking Water Intended for Human Consumption." The assessment of drinking water quality was carried out in accordance with DSTU (National Standards of Ukraine) 4808:2007 and with the water quality index (WQI). It was found that the largest deviations from the norm among toxicological indicators were observed for nitrates – 63.9%. In terms of water quality classes according to DSTU 4808:2007, drinking water from sources of non-centralized water supply of villages showed the following distribution: 2.8% of the samples belonged to class 1 (excellent water quality), 72.2% to class 2, and 25% to class 3. According to WQI, 16.7% of the examined sources of non-centralized water supply had excellent water, 63.9% had good water, and 19.4% had poor water. Despite the fact that the water from the investigated sources of non-centralized water supply was of acceptable quality, it is impotable due to the excessive nitrate content. The results obtained show that there is a need for monitoring of drinking water quality from the sources of non-centralized water supply, especially in rural settlements that are not provided with centralized water supply.

Key words: wells, nitrate content, limiting index, sanitary standards, water quality index (WQI), degree of quality.

Introduction

A number of legislative acts of Ukraine regulate the guaranteed provision of the population with quality and safe drinking water, in particular, the "Law of Ukraine on Drinking Water and Drinking Water Supply" No. 2918-III dated January 10, 2002 and the National Target Program "Drinking Water of Ukraine" for 2011–2020 dated March 03, 2005 No. 2455-IV. Quality drinking water is essential for maintaining a healthy population. According to the World Health Organization (WHO), nearly 1 billion people are devoid of access to improved water supply, 80% of human diseases and 2 million deaths per year are associated with poor water quality, and 4% of the global diseases could be prevented by improving the water sources.

The quality of fresh water in soil and surface systems is of great concern worldwide. In particular, water quality from the sources of non-centralized water supply has been studied in the US by Zheng, Flanagan (2017) and Schaider et al. (2019) (in particular, the report by DeSimone et al., 2009 indicated that more than one in five [23%] domestic wells contained one or more contaminants at a concentration greater than a human health benchmark), in the shallow wells of Keiyo Highlands (Kenya) by Mbaka et al. (2017), in Ireland by Hooks et al. (2019), in Tai'an City (China) by Wu-yuan (2010), in Pakistan by Daud et al. (2017), in eastern Slovakia by Sasakova et al. (2018), and in Limpopo Province (South Africa) by Edokpayi et al. (2018). A number of researchers have studied the factors that have impact on water quality (Khatri, Tyagi, 2014) and assessed it by the content of specific pollutants such as nitrates (Schaider et al., 2019; Petlušová et al., 2019), arsenic (Shiber, 2005; Zheng, Flanagan, 2017), and heavy metals (Edokpayi et al., 2018). Gibson and Kelsey Water Quality Improvement Strategy (2017) and the implementation of individual components (Malecki et al., 2017; Eggers et al., 2018) are also worth noting. A series of studies are also devoted to determining the water quality index (WQI) (Sadat-Noori et al., 2014, Sukumaran et al., 2018, Sahu, Sikdar, 2008).

About 80% of the population of Ukraine use water from surface waterbodies to meet their drinking needs. At present, these sources are characterized by excessive anthropogenic load. Concerns about the provision of population with drinking water are also caused by the fact that in Ukraine, 62.2% of the housing stock is equipped with water supply and 60% with sewerage. In particular, in rural settlements, these figures are only 32.3 and 28.5%, respectively, compared to urban settlements with 77.5 and 76.5%, respectively (according to the State Statistics Service of Ukraine). As an alternative to centralized water supply, spring

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and well water is used; its quality is unsatisfactory, especially in terms of nitrate content (Gerasymchuk, 2015; Myslyva et al., 2016; Valerko, Herasymchuk, 2020; Romanchuk et al., 2021).

The low level of environmental consciousness along with the pollution factors makes it impossible to drink such water without further purification. In addition, complex investigation into water quality from wells is not being conducted currently, and control measures are occasional.

Based on the above, monitoring of the water quality from the sources of non-centralized water supply is essential.

The purpose of the research was environmental assessment of the drinking water quality from the sources of non-centralized water supply within the rural settlements of Zhytomyr region (Ukraine).

Material and methods

The investigation was conducted on the territory of Zhytomyr region (Ukraine). In total, 72 sources of non-centralized water supply were examined in the territory of Zhytomyr Raion; they are located in the central part and in the outskirts of the villages Vertokyivka, Holovenka, Kodnya, Zarichany, Myrolyubivka, Ozeryanka, Pryazhiv, Rudnya-Horodyshche, Sinhury, Troyaniv, Lishchyn, Luka, Pisky, Stanyshivka, Turovets, Berezyna, Hadzynka, Hlubochytsia, Levkiv, Veresy, Kamyanka, Oliivka, Hlybochok, Denyshi, Vysoka Pich, Zamozhne, Pokostivka, Teterivka, Barashivka, Berezivka, Vasylivka, Ivanivka, Sadky, Cheremoshne, and also in the small towns Novohuivynske and Ozerne of the Zhytomyr Raion. These sources of non-centralized water supply are particularly popular with the local population.

Analytical investigation of water quality was carried out on the basis of a Certified Measuring Laboratory of the Educational and Scientific Center for Ecology and Environmental Protection of Polissya National University according to the following methods: aquatic pH – potentiometric, total water hardness – according to GOST (All-Union State Standard) 4151-72, total iron – according to KND (Guiding Normative Document)-211.1.4.040-95, nitrate ion content – according to GOST (All-Union State Standard) 18826-73, nitrites – according to DSTU (National Standards of Ukraine) ISO 6777-2003, and ammonium – according to DSTU (National Standards of Ukraine) ISO 6778-2003.

The obtained values of quality indicators of drinking water from the sources of non-centralized water supply were compared with the norms indicated in the DSaNPiN (State Sanitary Regulations and Standards) 2.2.4-171-10 "Hygienic Requirements for Drinking Water Intended for Human Consumption." The assessment of drinking water quality from the sources of non-centralized water supply was carried out in accordance with DSTU (National Standards of Ukraine) 4808:2007 "Sources of Centralized Drinking Water Supply. Hygienic and Environmental Requirements for Water Quality and Withdrawal Rules" and with the WQI.

According to DSTU (National Standards of Ukraine) 4808:2007, the quantitative basis for assessing water quality in the sources of non-centralized drinking water supply is the classification of water quality by hygienic and environmental criteria, according to which there are four classes: excellent, desirable water quality (class 1) (the average value of block indexes within 1.00–1.50); good, acceptable water quality (class 2) (block indexes: 1.51–2.50); satisfactory, acceptable water quality (class 3) (block indexes: 2.51–3.50); and moderate, partially potable, undesirable water quality (class 4) (block indexes: 3.51–4.50).

We carried out a thorough assessment of water quality in the underground sources of non-centralized drinking water supply by the values of several high-priority indicators (incomplete assessment) that clearly demonstrate the satisfactory or unsatisfactory condition of sources: general sanitary chemical (total hardness, pH, nitrate, nitrite, and ammonium content) and toxicological (total iron).

The methodology for determining the WQI, which is calculated in terms of human consumption (in turn, the quality of water and its suitability for drinking purposes can be investigated by determining its quality index), was described in detail in the works of Sahu, Sikdar (2008), Tyagi et al. (2013), Sadat-Noori et al. (2014), and Sukumaran et al. (2018). To calculate the WQI, standards regarding water for drinking purposes as recommended by WHO were used. Each of the investigated indicators that determine the water quality in the sources of non-centralized drinking water supply and directly affect human health was assigned the corresponding weight, and the relative weight of each was calculated. The quality rating was then calculated for each analyzed indicator as the ratio of the content (concentration) of the individual parameter to the normative values of WHO standard. Five types are distinguished according to the WQI values: "excellent water" (WQI <50), "good water" (WQI = 50–100), "poor water" (WQI = 100–200), "very poor water" (WQI = 200–300), and "water unsuitable for drinking" (WQI >300).

Results

Rural residents use spring and well water as an alternative to centralized water supply; the quality of such water throughout Ukraine, and in the Zhytomyr region in particular, is extremely unsatisfactory today, especially in terms of nitrate content. We conducted a detailed assessment of the ecological state of water from the sources of non-centralized water supply in its territory in terms of the sanitary and chemical indicators of safety and quality of drinking water (which included physical and chemical indicators [hydrogen index, iron total, total water hardness] as well as toxicological indicators [nitrites, nitrates, ammonium]) (Table 1).

During sampling of water, inspection of the areas where wells are located, and communication with the local residents of the investigated rural settlements, it was found out that water quality in the sources of non-centralized water supply was unsatisfactory, which was related to specific sources of pollution and low level of environmental consciousness of the local residents. Chaotic construction of household plots, arrangement of cesspools, dungyards, compost pits, latrines, and buildings for stock and poultry at a small distance from the sources of non-centralized water supply without taking into account the requirements of sanitary legislation, as well as excessive use of nitrogen-based mineral fertilizers, violating the regulations for their use in combination with inadequate sanitary and technical care, are the causes of recent degradation of water quality in the sources of non-centralized water supply.

All investigated water samples from the sources of non-centralized water supply in the rural settlements were characterized by pH values within 5.42–8.35 units (variation coefficient – 7.32) (distribution bar chart is shown in Fig. 1).

Table 1. Sanitary and chemical indicators of safety and quality of water from the sources of non-centralized water supply in rural areas, 2019–2020, *N* = 72.

Indicator	Interval content of physical and chemical water quality indicators (% of samples with corresponding value)						% Of samples that do not meet the standards
pH value	5.4–5.99	6.0–6.49	6.5–6.99	7.0–7.49	7.5–7.99	8.0–8.5	19.4
	4.17	15.28	36.11	38.89	4.17	1.39	
Total iron content, mg/dm³	0.02–0.10	0.101–0.40	0.401–0.70	0.701–0.1	1.01–1.30	1.301–3.20	4.2
	13.89	66.67	11.11	4.17	1.39	2.78	
Total water hardness	0.70–3.9	4.0–6.9	7.0–9.9	10.0–12.9	13.0–15.9	16.0–19.0	27.8
	22.22	29.17	20.83	15.28	9.72	2.78	
Nitrate content, mg/dm³	1.0–25.0	25.01–50.0	50.01–100.0	100.01–150.0	150.01–200.0	200.01–410.0	63.9
	25.0	11.11	25.0	15.28	12.5	11.11	
Nitrite content, mg/dm³	0.002–0.01	0.0101–0.02	0.0201–0.05	0.0501–0.1	0.101–0.5	0.501–1.2	-
	30.56	5.6	22.2	22.2	13.8	5.6	
Ammonium	0.1–0.4	0.41–0.8	0.81–1.2	1.21–1.6	1.61–2.0	2.01–2.4	-
	30.56	45.83	6.94	9.72	4.17	2.78	

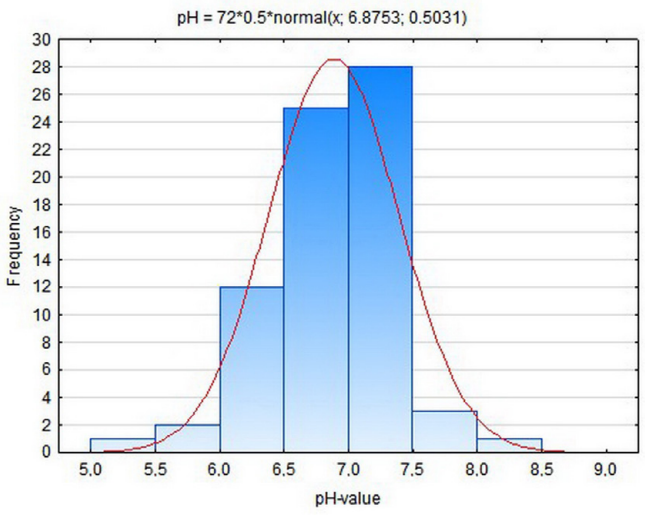

Fig. 1. Bar chart of the distribution of pH levels in water from the sources of non-centralized water supply in the rural settlements.

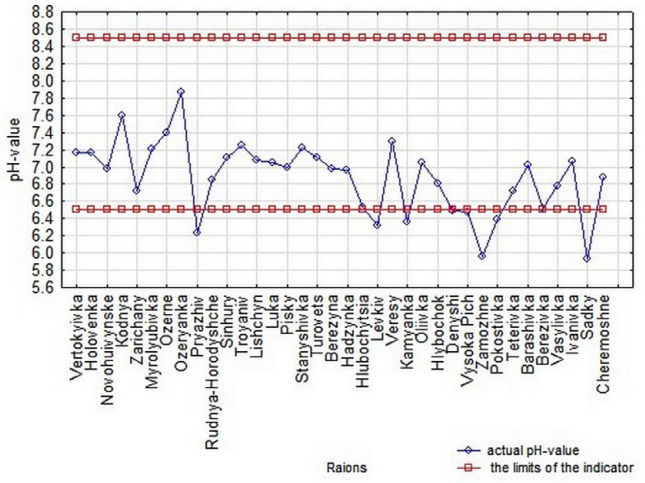

Fig. 2. pH level of water from the sources of non-centralized water supply.

It was found out that 19.4% of the selected water samples had deviations in the range of 0.04–1.1 pH units from the lower limit of the hydrogen index (villages Pryazhiv, Hlubochytsia, Levkiv, Kamyanka, Denyshi, Vysoka Pich, Zamozhne, Pokostivka, Barashivka, Berezivka, and Sadky) (Fig. 2).

The total iron in water from the sources of non-centralized water supply varied from 0.02 to 3.16 mg/dm³ (variation coefficient – 127.32) (Fig. 3). This indicator exceeded the established standards according to DSanPiN 2.2.4-171-10 by 1.03–3.2 times in 4.2% of water samples (in village Teterivka, it exceeded the standard by 1.03 times, in Rudnya-Horodyshche by 1.3 times, and in Berezivka by 3.2 times).

In terms of the total water hardness, 27.8% of water samples deviated from the standards established by DSaNPiN. The level of total water hardness ranged from 0.7 to 18.2 mmol/dm³ (variation coefficient – 55.82). A general bar chart of the distribution of the water hardness level is given in Fig. 4.

It should be noted that in general, physical and chemical water quality indicators in the sources of non-centralized water supply did not conform to the standards in 17.1% of the samples.

Among the sanitary and toxicological indicators, we investigated the content of the nitrogen group (ammonium nitrogen, nitrates, and nitrites) in water from the sources of non-centralized water supply, which, in turn, is rather informative and important. Amount of nitrites and ammonium in water did not exceed the established standards (DSaNPiN) and were 0.002–1.2 (variation coefficient – 203.3) (Fig. 5) and 0.17–2.4 mg/dm³ (variation coefficient – 74.3) (Fig. 6), respectively.

Nitrate content is one of the limiting indexes that determine the water quality in the sources of non-centralized water supply and cause an increased level of noncarcinogenic health risk. According to DSanPiN 2.2.4-171-10, the norm of nitrate content is 50 mg/dm³. The nitrate content in water from the sources of non-centralized water supply in the territory of rural settlements of Zhytomyr Raion fluctuated in a rather wide range – from 4.0 to 410.0 mg/dm³ (variation coefficient – 84.13) (Fig. 7).

In terms of nitrate content, 63.9% of the water samples from the sources of non-centralized water supply did not conform to

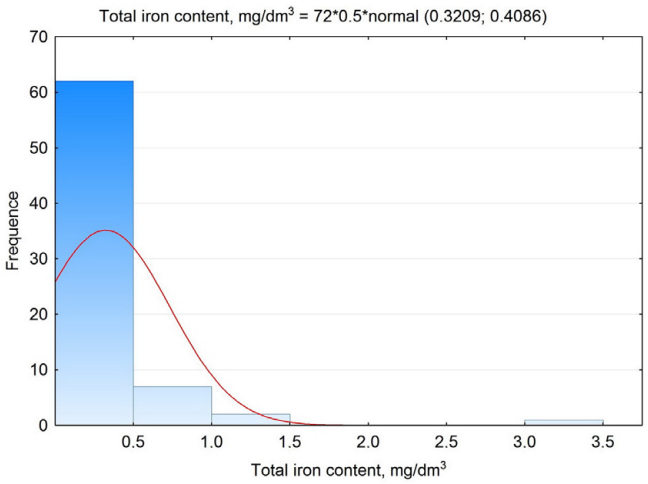

Fig. 3. Bar chart of the distribution of total iron content in water from the sources of non-centralized water supply in the rural settlements.

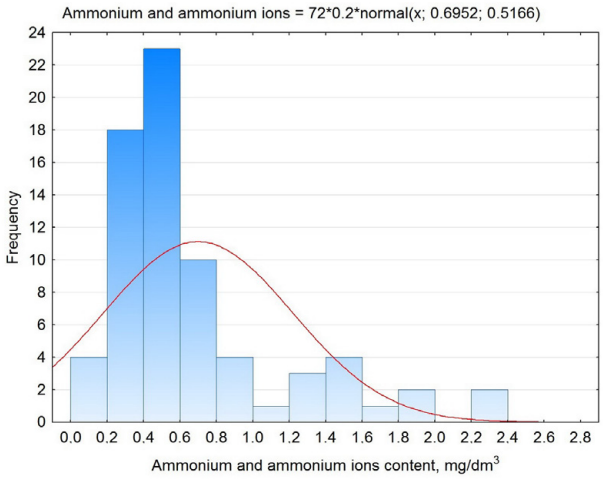

Fig. 4. Bar chart of the distribution of the total water hardness level in water from the sources of non-centralized water supply in the rural settlements.

the norm and exceeded it by 8.2 times (maximum exceeded levels occurred in the settlements Berezyna – by 3.2–8.2 times, Barashivka – by 6.4 times, and Kodnya – by 2.3–5.0 times) (Fig. 8).

The next stage of our research was assessing the quality of water in the sources of non-centralized drinking water supply. The assessment was performed on the basis of an analysis of the quantitative characteristics of the high-priority water quality indicators, which clearly demonstrate the satisfactory or unsatisfactory condition of drinking water sources (Fig. 9) in terms of the following:

In terms of the pH value, 33.3 and 52.8% of the examined sources of non-centralized water supply belonged to the first (excellent, desirable water quality) and second ("good," pure water of acceptable quality) class of water quality. Also, 13.9% of the sources had water of the third class of quality – "satisfactory," slightly polluted water of acceptable quality.

In terms of total iron content, 69.4% of the investigated sources belonged to the first class of water quality, 27.8% to the second class, and 2.8% to the third class.

In terms of total water hardness, 22.2% of the examined sources had the first and third class of water quality, 25% had the second class, and 30.6% had the fourth class (moderate, partially potable, undesirable water quality).

In terms of nitrate content, 94.4% of the sources of non-centralized water supply were characterized by the fourth class of water quality.

In terms of nitrite content, water of the desired quality (first class) was found in 41.7%, water of acceptable quality (second class) in 52.8%, and water of satisfactory quality (third class) was found in 5.6% of the investigated sources.

In terms of ammonium content, the quality of water in the examined sources of water supply belonged to the second class in 41.7%, to the third class in 55.6%, and to the fourth class in 2.8% of the investigated sources.

According to the contribution to the formation of water quality in the sources of non-centralized water supply, the investigated indicators are ranked as follows: nitrates (28.2%) > ammonium and ammonium ions (18.9%) > total water hardness (18.2%)

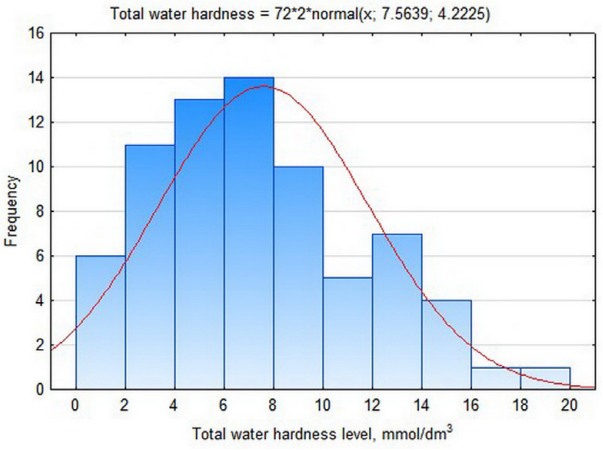

Fig. 5. Bar chart of the distribution of the ammonium content and ammonium ions in water from the sources of non-centralized water supply in the rural settlements.

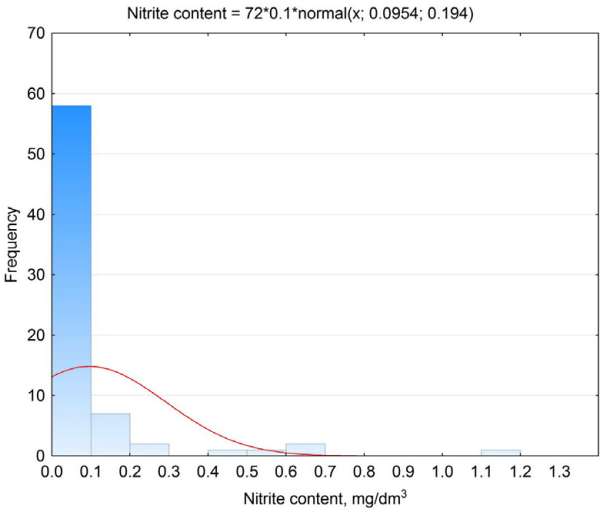

Fig. 6. Bar chart of the distribution of the nitrite content in water from the sources of non-centralized water supply in the rural settlements.

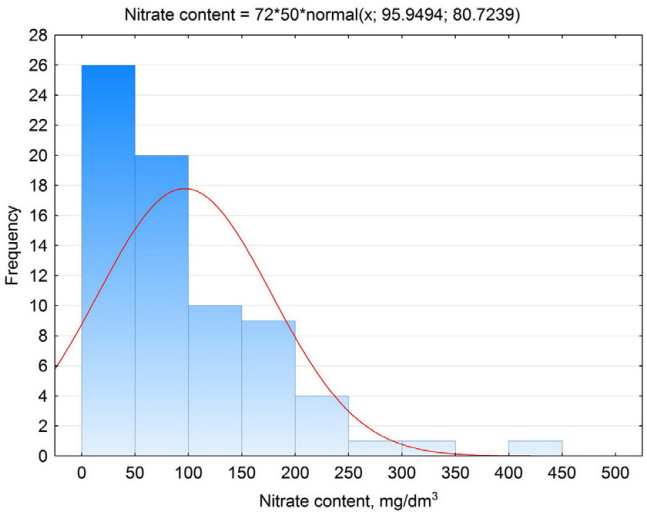

Fig. 7. Bar chart of the distribution of the nitrate content in water from the sources of non-centralized water supply in the rural settlements.

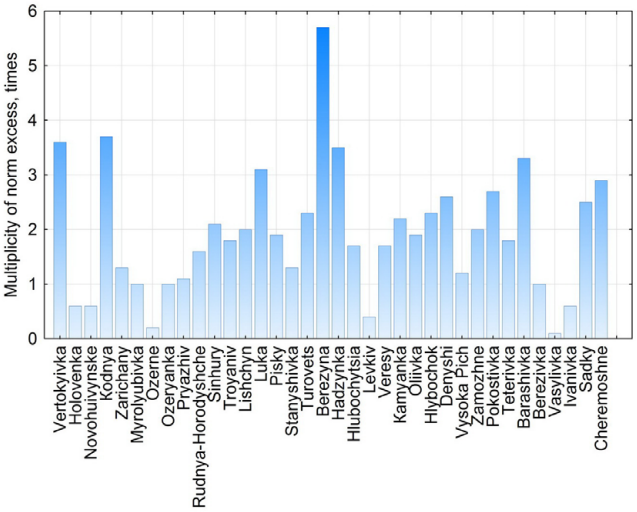

Fig. 8. Multiplicity of excess nitrate content in water from the sources of non-centralized water supply in the rural settlements.

> hydrogen index (13.1%) > nitrites (11.6%) > total iron (9.9%).

Given that it is the content of nitrates that mainly determines the water quality in the sources of non-centralized water supply, attention should be paid to the sources of its receipt and the nitrate content should be constantly monitored.

On the whole, it has been proved that in only one settlement (village Vasylivka), the water quality in the sources of non-centralized water supply corresponded to the first class of quality (average value of the block index – 1.33 ["excellent," very pure water tending to the class "good," pure water of the desired quality]). Twenty-six rural settlements had water of acceptable quality (second class) in the sources of non-centralized water supply: 8.3% with an average value of block indexes within 1.76–1.99 ("good," pure water tending to the "excellent" class, very pure: small town Novohuivynske, villages Rudnya-Horodyshche and Vysoka Pich), 25% within 2.0–2.25 ("good," pure water of acceptable quality: villages Holovenka, Zarichany, Pryazhiv, Levkiv, Denyshi, Pokostivka, Teterivka, Berezivka, and the small town Ozerne), and 38.9% within 2.26–2.5 ("good," pure water tending to "satisfactory" class, slightly contaminated acceptable quality: villages Kodnya, Myrolyubivka, Ozeryanka, Sinhury, Troyaniv, Pisky, Hlubochytsia, Kamyanka, Oliiivka, Hlybochok, Zamozhne, Barashivka, Ivanivka, Cheremoshne) (Figs 10, 11).

The third class of water quality (satisfactory, acceptable quality) was noted in the sources of non-centralized water supply in nine rural settlements: 22.2% with the average value of block indexes within 2.51–2.75 (water transitional in quality from "good," clean to "satisfactory," slightly contaminated: villages Vertokyivka, Lishchyn, Luka, Stanyshivka, Turovets, Hadzynka, Veresy, and Sadky); "satisfactory," slightly polluted water tending to the class of good, pure water was typical for the sources of non-centralized water supply in village Berezyna (average value of block indexes – 2.83) (Figs 10, 11).

We also evaluated water quality based on one of the most effective and informative indicators, the WQI. According to the calculations, the WQI values varied within a fairly wide range, from 24.4 to 189.1 (the distribution bar chart is shown in Fig. 12). Excellent water was present in 16.7%, good water in 63.9% and poor water in 19.4% of the examined sources of non-centralized water supply (Fig. 13).

According to the contribution to the formation of WQI in the sources of non-centralized water supply, the investigated indicators are ranked as follows: nitrates (58.2%) > hydrogen index (16.9%) > total water hardness (13.8%) > ammonium and ammonium ions (6.5%) > total iron (3.9%) > nitrites (0.7%) (Fig. 14).

On the whole, the data obtained regarding the water quality in the sources of non-centralized water supply based on this methodology and the results according to DSTU (National Standards of Ukraine) 4808:2007 coincide: the best water quality was found in the wells of Vasylivka village and the worst in the wells of Berezyna village (Fig. 14). Exceptions were only the sources of non-centralized water supply in villages Barashivka, Cheremoshne (which had marginal values of indicators), and Kodyna, which were assigned to the second class of quality (acceptable quality) according to DSTU (National Standards of Ukraine), while according to WQI, the water was classified as poor.

Although the water of the examined sources of non-centralized water supply was of acceptable quality, such water is impotable because of excessive nitrate content.

The obtained results of the research indicate that it is necessary to monitor water quality in the sources of non-centralized drinking water supply, especially in rural settlements which are not provided (or provided only partially) with centralized water supply. After all, the population that consumes drinking water from wells is at greater risk of carcinogenic and noncarcinogenic risks due to the impact of pollutants on their health than those who use centralized water supply.

The obtained results indicate the importance and need for a larger scale study, including an assessment of the health risks of the population that consumes water from the sources of non-centralized water supply to meet its drinking needs.

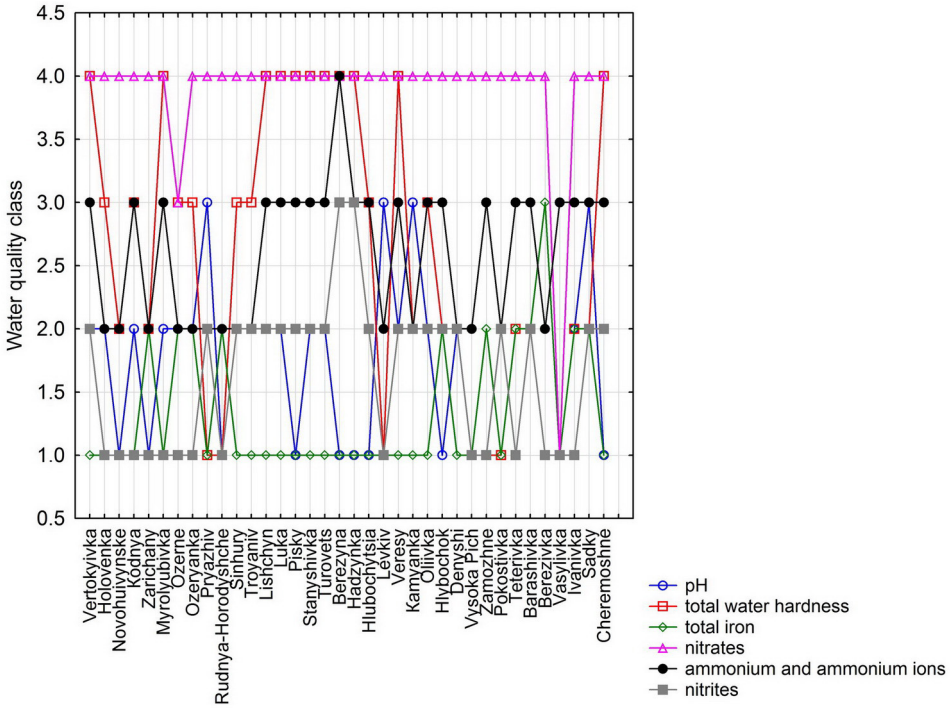

Fig. 9. Distribution of water quality classes in the sources of non-centralized water supply in terms of individual indicators.

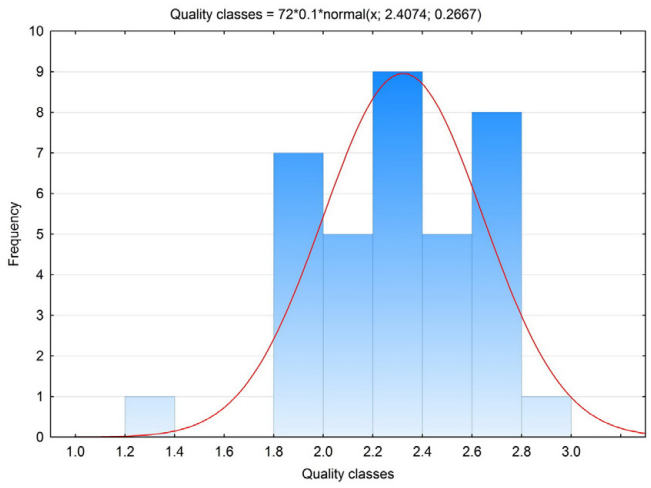

Fig. 10. Bar chart of the distribution of water quality classes in the sources of non-centralized water supply in the rural settlements.

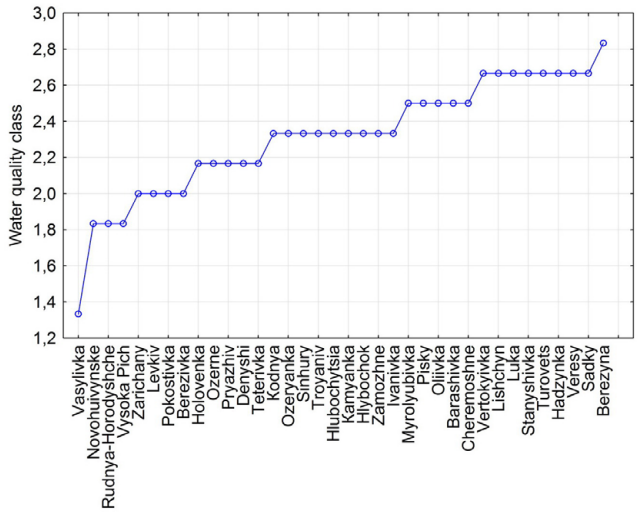

Fig. 11. Water quality classes in the sources of non-centralized water supply in the context of individual rural settlements.

Discussion

Quality water supply is one of the top priority problems, especially for the rural population. This is confirmed by the data of the national report on drinking water quality and the state of drinking water supply in Ukraine in 2018. According to this report, 229 rural settlements out of 1613 (i.e., 13.7%) are provided with centralized water supply in the Zhytomyr region (in 2017, 179 rural settlements or 11.1%), 53.1 out of 371.6 thousand people (or 14.3%) and among small towns, 38 out of 43 small towns (or 88.4%) are provided with centralized water supply, 59.7 out of 141.1 thousand people (or 42.3%). Overall, as of 2018, only 39.9% of the housing stock was equipped with water supply and 39.5% with sewerage in Zhytomyr region.

In Ukraine, water quality in the sources of non-centralized water supply is determined in accordance with the State Sanitary Regulations and Standards "Hygienic Requirements for Drinking Water Intended for Human Consumption" (DSaNPiN 2.2.4-171-10) approved by the order of the Ministry of Health of Ukraine No. 400 dated May 12, 2010. According to the defini-

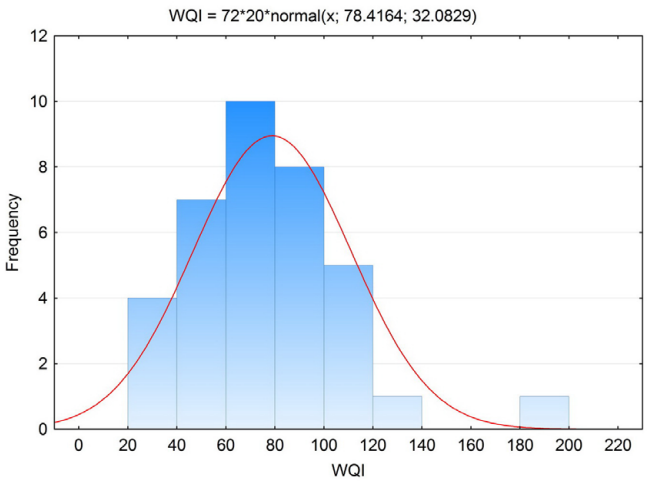

Fig. 12. Bar chart of the distribution of obtained WQI (water quality index) values in the sources of non-centralized water supply.

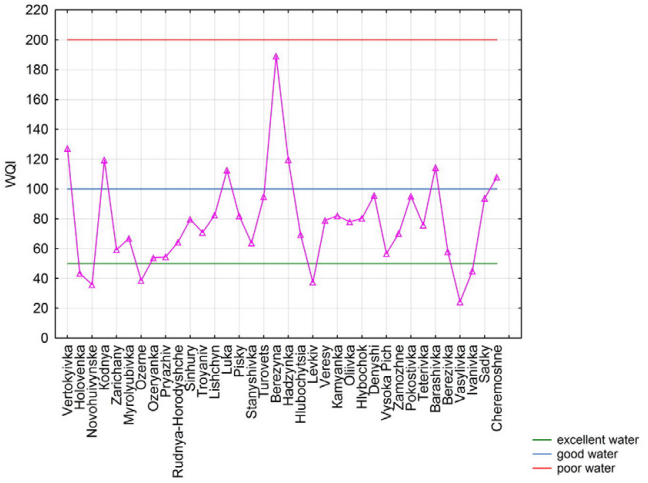

Fig. 13. WQI (water quality index) in the sources of non-centralized water supply in the context of individual rural settlements.

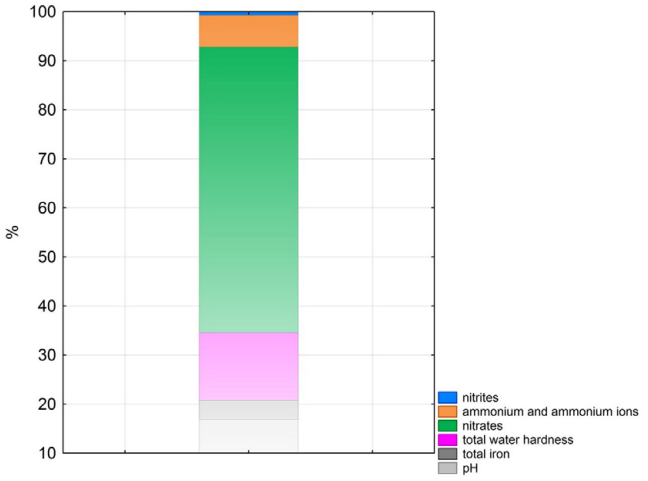

Fig. 14. Contribution of individual indicators to the value of WQI (water quality index).

tion given in DSaNPiN 2.2.4-171-10, drinking water intended for human consumption should have composition that meets the requirements of the state standards and sanitary standards in terms of organoleptic, physical and chemical, microbiological, parasitological and radiological parameters and it should be intended to meet the physiological, sanitary, hygienic, household, and economic needs of the population, as well as meet the standards for the production of products requiring the use of drinking water. The water quality in the sources of non-centralized water supply depends on a complex of the following factors: location, condition of the adjacent territory, sources of pollution nearby, sanitary and technical condition of the source itself, and measures for its proper maintenance.

Both natural and anthropogenic processes have a direct impact on the quality of such water. Private farms often operate in rural settlements and near them. They often do not comply with the requirements of applying fertilizers and plant protection agents, which leads to contamination of soil, vegetable products, and groundwater with toxic substances, in particular, nitrates (Valerko et al., 2018). The problem of water quality from the sources of non-centralized water supply is exacerbated by the fact that at present, there are no comprehensive studies of their quality. Complex investigations into water quality from wells are not being conducted currently, and the control measures are occasional. These factors are the major barriers to providing residents, who consume water from the sources of non-centralized water supply, with safe water. This is confirmed by the research of Gibson, Kelsey (2017).

Khatri, Tyagi (2015) noted that anthropogenic factors that affect water quality in rural areas (use of fertilizers, herbicides, and pesticides, river silting, excess quantity of nutrients in water, runoff from degraded forest areas, livestock) are qualitatively different from those in urban areas (industrialization, sewage discharge). Daud et al. (2017) pointed out that anthropogenic activity causes water-related diseases, which account for about 80% of all diseases and 33% of deaths. Schaider et al. (2019) indicated that communities with low income (in our case, rural residents) face a disproportionately high amount of pollutants.

Given that it is the content of nitrates that mainly determines the water quality in the sources of non-centralized water supply, attention should be paid to the sources of its receipt and nitrate content should be constantly monitored. Nitrate content is one of the limiting indexes that determine the water quality in the sources of non-centralized water supply and cause an increased level of noncarcinogenic health risk. According to the information available on the EPA (2021), high levels of nitrate/nitrite in drinking water can cause methemoglobinemia or "blue baby syndrome." These substances reduce the blood's ability to carry oxygen. Infants below 6 months who drink water with high levels of nitrate can become seriously ill and die.

Sasakova et al. (2018) noted that the levels of nitrate-N in the range from 100 to 200 mg/l (from 443 to 885 NO^{-3}) affect the health of the general population, but the impact on any individual depends on many factors. Schullehner et al. (2018) indicated that it can also increase the risk of cancer in adults, since nitrates are reduced to nitrites and form nitro compounds (NOC), which are highly carcinogenic and may act systemically.

Schaider et al. (2019) noted that even nitrate levels that are significantly below the standard level, such as 1 mg/l and above,

are associated with anthropogenic impact; therefore, nitrates can be an indicator for identifying sources of drinking water that may also contain a number of other hazardous substances.

Although the water of the examined sources of non-centralized water supply was of acceptable quality, such water is impotable because of excessive nitrate content. A similar conclusion is drawn in the work of Sukumaran et al. (2018) (water belongs to the category "good water," but it is impotable due to high levels of iron and coliform contamination).

Based on the above, the responsibility for ensuring water safety in the sources of non-centralized water supply is still with individual households. This statement is also reflected in the work of Zheng, Flanagan (2017), Hooks et al. (2019), and Munene, Hall (2019).

In the work of Lee and Murphy (2020), it is stated that more extensive private well monitoring will help identify wells at greater risk of contamination, and in turn, public health efforts can focus on education and outreach to improve monitoring, maintaining, and treating private wells in these communities. Community interventions need to be coupled with stricter regulations and financing mechanisms that can support and protect private well owners.

Gibson and Kelsey (2017) identified the major barriers to providing safe water to residents who consume it from wells (private wells database is unavailable; widespread use of wells for drinking purposes in less-urbanized areas; lack of monitoring observations, information, and resources on source maintenance; and support programs do not have sufficient resources). They also identified the key steps to improve water quality, which are as follows: the Department of Public Health (DPH) or the Department of Environmental Quality (DEQ) must collect and coordinate all data related to local private wells; funding for research to identify and prioritize areas not connected to water supply; development of marketing campaigns to promote private testing and maintenance of non-centralized water supplies; assistance to households with low income to cover the costs of monitoring and servicing of such sources; assistance in finding accredited laboratories for water quality assessment, interpretation of obtained results, and selection of water treatment technologies; allocating resources to build an interactive mapping tool to detect poor-quality water in sources; and creating a nationwide network of professionals that would provide information and training related to the sources of non-centralized water supply.

Eggers et al. (2018) also emphasized that providing access to safe drinking water and educating the public are urgent priorities for health care for the people consuming well water, especially in rural areas. Malecki et al. (2017) argued that understanding the target population's perception of risk and knowledge is an important element to consider when designing actions to improve management effectiveness.

Therefore, the importance of adequate quantitative and qualitative provision of population with water for health care cannot be overestimated.

That is why amalgamated territorial communities should immediately pay attention to this strategy for improving the water quality in the sources of non-centralized water supply. There is also an urgent need for the development and financing of the regional program "Drinking Water of Zhytomyr Region" within the framework of the National Target Program "Drinking Water of Ukraine" for 2011–2020 and 2022–2026.

Conclusion

Poor water quality in the sources of non-centralized water supply has been identified, which is associated with the specific sources of pollution and the low level of environmental consciousness of the local population. The investigated water samples from the sources of non-centralized water supply were characterized by pH values within 5.42–8.35 units (19.4% of the water samples had deviations), total iron content from 0.02 to 3.16 mg/dm^3 (4.2% of the samples had deviations), level of total water hardness from 0.7 to 18.2 mmol/dm^3 (deviation in 27.8% of the samples), nitrate content 4.0–410.0 mg/dm^3 (deviation in 63.9% of the samples), nitrite content 0.002–1.2 mg/dm^3, and ammonium content 0.17–2.4 mg/dm^3. Although the investigated sources did not have poor quality water (excellent water – 16.7%, good water – 63.9%, poor water – 19.4% [by WQI]), they are unfit for drinking because of the high nitrate content, which is a limiting indicator of its quality. The results obtained indicate the need for monitoring of water quality in the sources of non-centralized water supply, creating a strategy for improving the water quality in the sources of non-centralized water supply, development of the regional program "Drinking water of Zhytomyr region," and assessing the health risks of people consuming water from the sources of non-centralized water supply to meet their drinking needs.

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