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ASSESSMENT OF DRINKING WATER QUALITY WITHIN AMALGAMATED TERRITORIAL COMMUNITIES

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Abstract. One of the main problems of rural residential areas is to provide the local population with quality drinking water, which is a major factor influencing their health. To solve this problem, it is necessary to implement effective measures not only at the state level but also at the regional and local levels. The main purpose of decentralization of power is to transfer the power and appropriate financial resources to the lowest levels of local self-government, which makes it possible for created amalgamated communities to use these resources to solve the priority issues. However, to determine the ecological state of rural settlements in the subsystem of drinking water quality, it is necessary to assess its quality in the territory where the community is situated. The investigation was carried out in 15 rural settlements of the Teterivka amalgamated community of the amalgamated Zhytomyr district. 36 water samples were selected from the sources of non-centralized water supply. Water quality classes were determined following DSTU (National Standards of Ukraine) 4808:2007 "Sources of Centralized Drinking Water Supply. Hygienic and Environmental Requirements for Water Quality and Selection Rules". As a result, it has been established that nitrates make the largest contribution to the pollution of drinking water. In 47 % of the selected samples, the nitrate content on average exceeded the norm; and in 46.7 % of the investigated settlements, water belongs to quality class 4, defined as "mediocre", "partially potable" of undesirable quality. A critical situation was recorded in the villages of Mykhailivka, Nova Rudnia and Staroshiika, where the nitrate content in all selected samples of the well water exceeded the norm. On average, 61 % of the selected water samples did not meet the standard and were below the standard. According to the pH indicator, the quality classes vary from "excellent", very pure water grading to the class of "good", pure water of the desired quality to "satisfactory", slightly contaminated water of acceptable quality. The total iron content exceeded the standard in 5.6 % of the selected samples.

Keywords: rural settlements, drinking water, water quality class, amalgamated communities, nitrates, hydrogen index, total iron, hardness.

1. Introduction

Access to a safe water supply is the major tool to ensure health promotion and reduce poverty, which is defined in the Sustainable Development Goals of Ukraine by 2030. In rural residential areas, the problem of providing a quality drinking water supply is the most acute. In Ukraine, such areas are provided with a centralized water supply only by 30 %. Drinking water from sources of non-centralized water supply often does not meet the quality standards for sanitary, toxicological and microbiological indicators, which is due to the high anthropogenic load within rural residential areas. Quite often, private farms are located in rural settlements or are adjacent to them. They often do not meet the requirements for the application of fertilizers and plant protection products. Furthermore, the owners and users of private plots do not know or neglect the rules of farm management, including the maintenance and location of wells and bores (Valerko et al., 2020). Thus, the achievement of the Global Sustainable Development Goals, including strategic goal No. 6 "Clean Water and Sanitation", will largely depend on implementing effective measures at the local and regional levels.

According to the Concept of Reformation of Local Self-Government and Territorial Organization of Power in Ukraine approved by the Cabinet of Ministers on April 1, 2014, the main goals of decentralization of power are reorientation of migration of rural population in the

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opposite direction, fight against poverty in rural areas, expansion of employment of rural residents and ensuring equal opportunities and needs, improvement of the quality of life through enhancement of the environmental, social and economic development of rural areas. These goals are being achieved by transferring authority and appropriate financial resources to the lowest levels of local self-government (Kozak et al., 2019; Cherniatina, 2015).

Thus, the created amalgamated communities have the right to independently control and direct financial and material resources for the comprehensive development of the community, including the state of the environment and measures to improve it. In particular, the most useful and applicable is the authority of the community to control deforestation, wastewater pollution, fly-tipping, hunting and poaching, nature reserve fund, land management, etc. (The Ukrainian Week, 2018). However, as mentioned above, one of the significant problems of rural areas is quality water supply, which is the main determinant of the health of the rural population. Therefore, the study of drinking water quality from the sources of non-centralized water supply and its constant control in the amalgamated rural and village communities deserves consideration by local self-government bodies However, as mentioned above, one of the significant problems of rural areas is quality water supply, which is the major determinant of the health of the rural population. Therefore, the study of drinking water quality from the sources of non-centralized water supply and its constant control in the amalgamated rural and village communities deserves consideration by local self-government bodies and requires the implementation of effective measures to improve its condition.

The study was carried out within the research "Environmental and social assessment of rural residential areas in the context of sustainable development" - state registration No.: 0120U104233. The results of the study can be used by representatives of village councils and amalgamated communities when approving programs for environmental protection and measures to improve water quality and water supply in rural settlements, as well as to inform residents about the condition of the environment in rural settlements of Zhytomyr oblast.

Thus, the purpose of this study is to carry out comprehensive monitoring in the territory of the amalgamated communities, which, unlike public authorities, are able to independently solve the problem of providing the rural population with quality drinking water.

An analytical review of literature sources on the problems of drinking water supply in rural settlements allows us to conclude that the provision of rural residents with quality drinking water is a relevant problem both in Ukraine and in the world. When there is no centralized water supply and water disposal systems in rural areas, drinking water, which comes from non-centralized sources (wells, bores, natural sources, etc.), is subject to significant anthropogenic pressure, which affects its quality. Such water may not meet the standards in terms of sanitary, toxicological and microbiological indicators.

According to the European Environment Agency, 26 % of underground water bodies in the European Union are in unsatisfactory condition. Due to pollution by nitrates and pesticides, agriculture is the major factor of pressure on drinking water sources. In particular, increased nitrate content was recorded in more than 18 % of the area of underground water bodies in the EU (European Environment Agency, 2018).

During 1991–2003, within the framework of the National Water-Quality Assessment Program (NAWQA) the U. S. Geological Survey selected 5,101 water samples from wells and bores in 51 areas throughout the United States. Nitrate concentrations were highest in shallow groundwater under agricultural land on well-drained soils, while their lowest concentrations were found in deep groundwater, where groundwater levels are low (Burow et al., 2010). Examination of drinking water from private wells and bores in southeastern New York City has shown that the entry of chlorides into water depends on the depth of the well and the distance from the nearest road (Kelly et al., 2018).

Chemical pollution of underground drinking water sources is widespread throughout Canada. According to Jones A.Q (Jones et al., 2006), 45 % of all waterborne outbreaks in Canada are associated with private water supply sources. Nitrate pollution at levels exceeding the maximum content is recorded in agricultural regions. In particular, an investigation of 535 bores in Saskatchewan, where approximately 45 % of residents use drinking water from underground sources, showed that in 35 % of the samples, the nitrate content exceeded the norm (Charrois, 2010).

During the studies conducted in rural settlements of the Irkutsk oblast of the Russian Federation, it was found that there is a significant excess of iron, nitrates, magnesium, manganese, sulfates, increased water hardness and the presence of coliforms in drinking water sources from the non-centralized water supply. In addition, a survey of the rural population found that residents lack quality drinking water (Bayanova, 2019).

The research of the Institute of Agroecology and Nature Management of NAAS, which has been conducted for a long time in different regions of Ukraine, found that the quality of drinking water from sources of non-centralized water supply in rural areas does not meet the requirements for nitrate content. In particular, in the Zhytomyr region, nitrate content exceeded the norm in

29 % of selected water samples. The highest levels of nitrate pollution were recorded in those households that did not follow the sanitary rules of livestock keeping, the distance between toilets, cesspool and water supply sources (Palapa, 2009; Palapa, 2015).

In the course of our own investigation conducted in rural settlements of different regions of Ukraine, we have recorded an excess of nitrate content in 10 of the 15 investigated regions. The situation in the Kherson region was critical, where the average nitrate content in the village of Maiachky reached 680 mg/dm^3, which exceeds the norm by almost 14 times (Valerko et al., 2020).

Quality control of drinking water from the system of centralized water supply is carried out by special controlling bodies, which carry out the constant monitoring of water quality. The quality of sources of non-centralized water supply in rural settlements is controlled only partially and in certain places, but the rest of the village remains unaddressed by controlling bodies.

2. Object and methods of research

In the course of the administrative-territorial reform on July 17, 2020, the Zhytomyr region was amalgamated. As a result, the territories of 12 regions and the city of regional significance Zhytomyr were fully and partially included in the Zhytomyr region. At present, the amalgamated Zhytomyr region includes 31 territorial communities, including 4 urban, 12 village and 15 rural ones (Verkhovna Rada of Ukraine, 2020).

The investigation was carried out on the territory of the Teterivka amalgamated community of the amalgamated Zhytomyr region, which is located southwest of Zhytomyr on the Zhytomyr-Liubar highway. Teterivka amalgamated community is a local self-government body that represents the interests of 15 settlements (Teterivka community, 2021). The population of the community is currently 10,264 people. Overall, 36 sources of non-centralized water supply in all 15 rural settlements of the community were examined: in the villages of Teterivka, Korchak, Denyshi, Buky, Vysoka Pich, Katerynivka, Perliavka, Mykhailivka, Ulianivka, Nova Rudnia, Rudenka, Tryhiria, Pokostivka, Rudnia-Poshta, Staroshyika.

Sampling took place during 2020–2021 and was carried out in the central and peripheral parts of the rural settlement.

The analytical study of water quality was conducted based on a certified measuring laboratory of the Training and Research Center for Ecology and Environmental Protection of Polissia National University according to generally accepted methods: hydrogen index with the help of potentiometric method, total iron according to KND (Guiding Normative Document)-211.1.4.040-95, nitrate ion content according to GOST (All-Union Standard) 18826-73, general hardness according to GOST (All-Union Standard) 4151-72.

The obtained values of quality indicators of drinking water from non-centralized water supply sources were compared with the standards specified in DSaNPiN (State Sanitary Rules and Regulations) 2.2.4-171-10 "Hygienic Requirements for Drinking Water Intended for Human Consumption" (Verkhovna Rada of Ukraine, 2010). Water quality from sources of non-centralized water supply was determined following DSTU (National Standards of Ukraine) 4808:2007 "Sources of Centralized Drinking Water Supply. Hygienic and Environmental Requirements for Water Quality and Selection Rules". According to this standard, four classes of water quality are distinguished (Fig. 1) (DSTU, 2007).

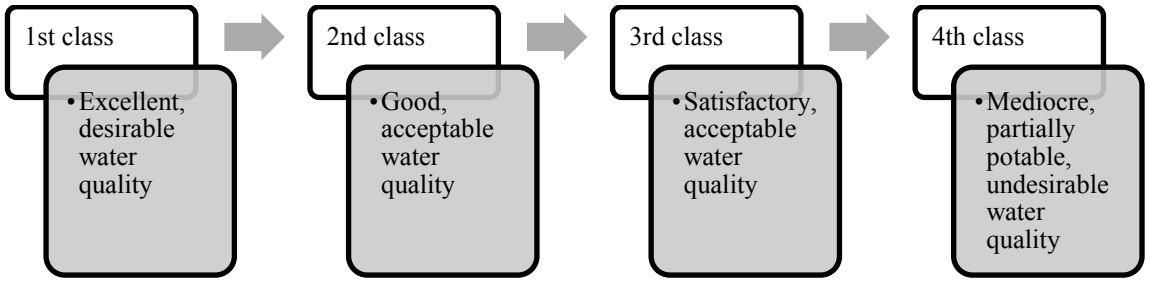

Fig. 1. Classes of drinking water quality (constructed by authors according to DSTU (National Standards of Ukraine) 4808:2007)

To assess the environmental integrated development index of rural settlements according to the indicators of drinking water quality, a 5-point scale was used: 1 – very bad, 2 – unsatisfactory, 3 – satisfactory, 4 – good, 5 – excellent (Pustovit, 2013).

3. Results and Discussion

The investigation was conducted in the rural settlements of the Teterivka amalgamated community of the amalgamated Zhytomyr region. As a result, it

was established that the standards of such indicators of drinking water as hydrogen index, nitrates, total iron and hardness were exceeded. The hydrogen index contributed the most to the contamination of drinking water; the excess pH content was recorded on average in 61.1 % of the selected samples. The situation with nitrate content is slightly better; on average 47.2 % of the selected water samples do not meet the standard. On average, in 5.6 and 2.8 % of the selected samples, the total iron content and total hardness index were exceeded (Table 1).

Hydrogen index (pH) is an indicator that characterizes the property of water which is determined by the presence of free hydrogen ions (DSTU, 2007). Depending on the pH value, water is classified from highly acidic to strongly alkaline (Table 2).

Table 1

Results of the analytical study of drinking water from sources of non-centralized water supply in Teterivka amalgamated community

Settlement	pH	Nitrates	Total iron	Hardness
Buky	7.7* 25	72.1 25	0.25 0	1.1 0
Vysoka Pich	6.87 0	36.6 33	0.52 0	–
Denyshi	6.5 67	63.2 33	0.26 0	–
Katerynivka	5.8 100	51.2 50	0.28 0	5.75 0
Korchak	7.0 0	17.8 0	0.09 0	3.1 0
Mykhailivka	5.55 100	189.1 100	0.029 0	4.05 0
Nova Rudnia	6.4 50	96 100	0.34 0	4.1 0
Perliavka	6.09 100	143.92 33	0.13 0	4.75 0
Pokostivka	6.4 67	87,3 67	0.39 0	5.85 0
Rudenka	6.45 50	17.98 0	0.37 0	2.15 0
Rudnia-Poshta	5.5 100	108.2 50	0.19 0	3.7 0
Staroshyika	6.17 100	82.35 100	1.19 50	1.7 0
Teterivka	6.4 50	47 50	0.3 0	2.25 0
Tryhiria	6.1 100	51.5 50	0.2 0	3.7 0
Ulianivka	6.26 100	179.93 50	1.37 50	9.05 50
Average in amalgamated community, %	61.1	47.2	5.6	2.8

Note: * – the numerator shows the average value of the indicator, the denominator shows the percentage of samples that do not meet the standard.

Table 2

Classification of drinking water according to pH value

Class of water	pH value
Highly acidic	Up to 3.0
Acidic	3.0–5.0
Faintly acidic	5.0–6.5
Neutral	6.5–7.5
Weakly alkaline	7.5–8.5
Alkaline	8.5–9.5
Strongly alkaline	more than 9.5

In Ukraine, this indicator is regulated by DSanPIN (State Sanitary Rules and Regulations) 2.2.4-171-10 "Hygienic Requirements for Drinking Water Intended for Human Consumption", which defines its safe standards, which range from 6.5 to 8.5, which corresponds to a neutral and weak alkaline reaction of water. Non-compliance with the pH standard, especially when it is below the standard, can have negative consequences for human health, because the acidification of the water medium increases the toxicity of pollutants present in the water.

Assessment of drinking water by its quality classes showed that in terms of the pH, quality classes vary from 1.5 ("excellent", very pure water grading to the class of "good", pure water of the desired quality) to 3 ("satisfactory", slightly contaminated water of acceptable quality) (Fig. 2). A critical situation was identified in the wells in the villages of Mykhailivka and Rudnia-Poshta, where the average pH value is 5.5, which corresponds to a weakly acidic reaction of drinking water.

Thus, according to the hydrogen indicator, only in 6 % of the investigated settlements drinking water belongs to the excellent quality class; 40 % of the selected samples belong to the classes of "good", pure water of acceptable quality and "satisfactory", slightly contaminated water of acceptable quality (Fig. 3).

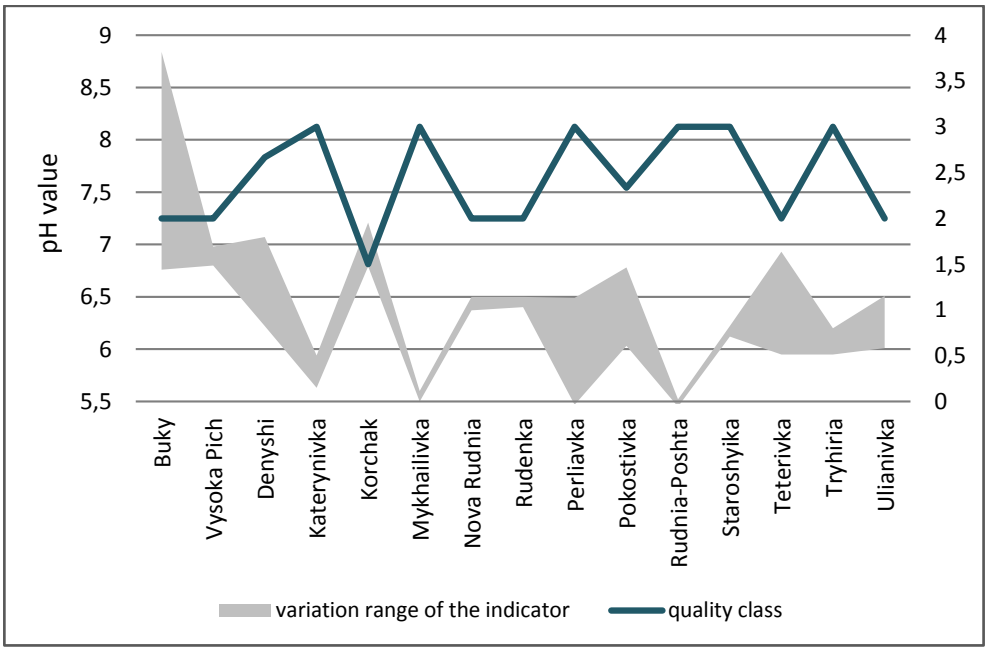

Fig. 2. Quality classes of water according to pH indicator

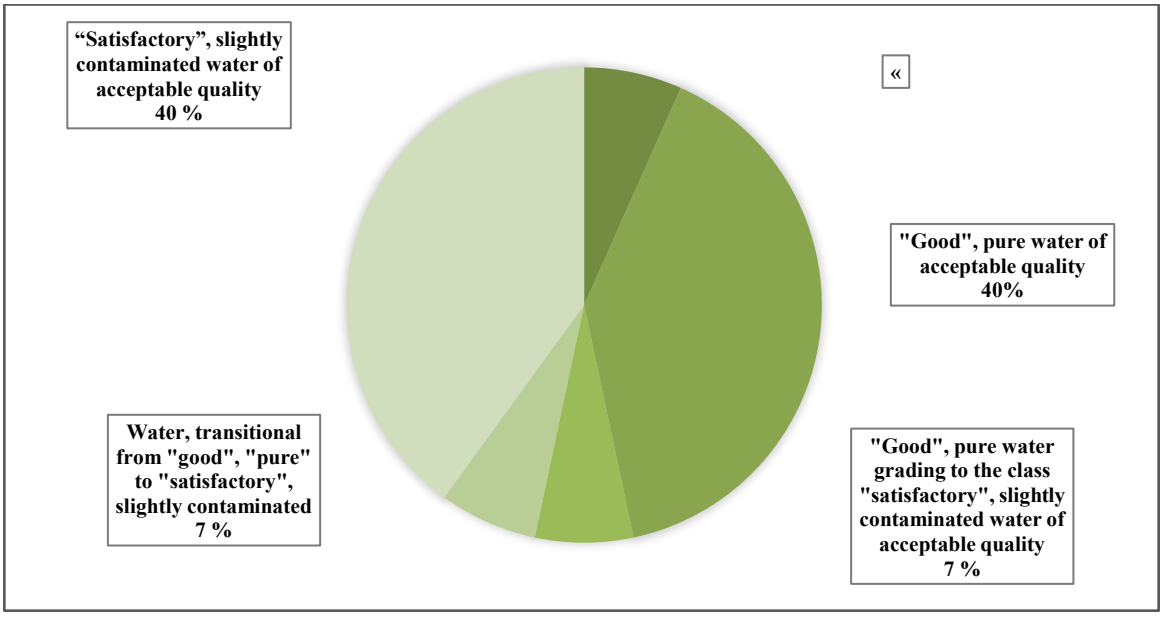

Fig. 3. Distribution of settlements according to pH indicator

Nitrates are salts of nitric acid that enter drinking water through surface wash from agricultural land, which may contain residues of organic and mineral fertilizers. In addition, non-compliance with the rules of arrangement of water supply sources, as well as sanitary distances between farm buildings (places where livestock is kept, toilets, cesspools) and sources leads to washing-off domestic sewage from household plots and yards, which can also increase nitrate concentrations in drinking water. The risk of water contamination with nitrates is primarily associated with methemoglobinemia, during which blood haemoglobin loses its ability to carry oxygen. This disease is especially dangerous for infants. For the adult population, constant consumption of water with increased nitrate content can lead to an increase in the total incidence, to cardiovascular disease, cancer, a decrease in fertility, etc. In Ukraine, the acceptable concentration of nitrates is regulated by DSanPIN (State Sanitary Rules and Regulations) and it is set at the level of 50 mg/dm^3. This standard is also set by the World Health Organization, but does not take into account the requirements of EU Council Directive 98/83 on the quality of water intended for human consumption, in which the nitrate content is set at 5 mg/dm^3, which is reflected in DSTU (National Standards of Ukraine) 7525: 2014 "Drinking Water. Requirements and Methods of Quality Control" (DSTU, 2014).

In terms of nitrate content, drinking water in rural settlements mostly belongs to the 4th quality class, which is defined as "mediocre", "partially potable" of undesirable quality. The average nitrate content in drinking water exceeded the norm in the rural settlements of Buky, Denyshi, Katerynivka, Mykhailivka, Nova Rudnia, Perliavka, Pokostivka, Rudnia Poshta, Staroshiika, Tryhiria and Ulianivka, which gives grounds for classifying such water as unfit for consumption (Fig. 4). Moreover, an excess of nitrate content was recorded in all selected samples in the well water in villages of Mykhailivka, Nova Rudnia and Staroshiika.

It should be noted that in most settlements (46.7 %) water is of undesirable quality and not potable (Table 3).

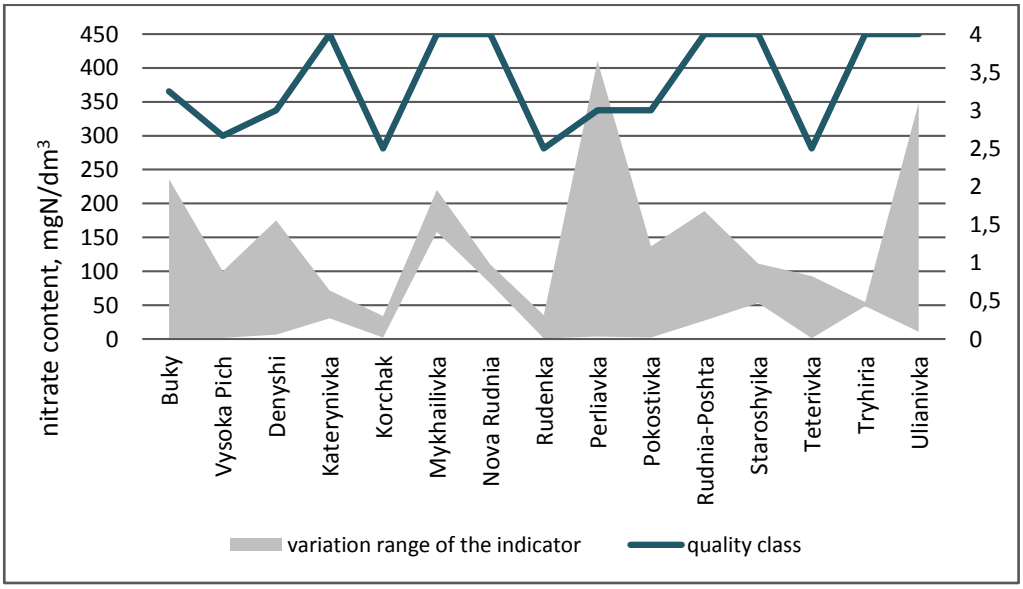

Fig. 4. Classes of water quality according to the nitrate content

Table 3

Distribution of settlements according to classes of water quality by the nitrate content, %

Quality class	Description	Nitrate content	
		Settlements	%
2.26–2.5	"Good", pure water grading to "satisfactory", slightly contaminated water of acceptable quality	Korchak, Rudenka, Teterivka	20
2.51–2.75	Water transitional from "good", pure to "satisfactory", slightly contaminated	Vysoka Pich	6.7
3–3.25	"Satisfactory", slightly contaminated water of acceptable quality	Buky, Denyshi, Perliavka, Pokostivka	26.7
4	"Mediocre", "partially potable" of undesirable quality	Katerynivka, Mykhailivka, Nova Rudnia, Rudnia-Poshta, Staroshyika, Tryhiria, Ulianivka	46.7

Being part of some enzymes, iron is a necessary element in the human body because it is involved in redox processes and immunobiological reactions. Moreover, human haemoglobin contains up to 70 % of iron. However, excessive iron content in drinking water contributes to the development of diseases of the cardiovascular system, can cause allergic reactions, diseases of the gastrointestinal tract. Constant consumption of water with high iron content causes its accumulation in the liver, which over time can destroy liver cells. The high iron content also has a negative effect on such organoleptic properties of water as taste and colour. Excessive iron content causes damage to the water supply network and household appliances (Bayanova, 2019; Likho et al., 2017). The maximum content of iron for sources of non-centralized water supply according to the standard in Ukraine is set at 1 mg/dm^3, but according to European legislation, its level is 5 times lower and is 0.2 mg/dm^3 (DSTU, 2014).

The total iron content does not significantly affect the quality of drinking water, which varies between 1–2.5, which is defined as "excellent", very pure water, and "good", pure water grading to the class "satisfactory", slightly contaminated water of acceptable quality (Fig. 5). The maximum content of total iron was recorded in the village of Ulianivka at the level of 2.6 mg/dm^3.

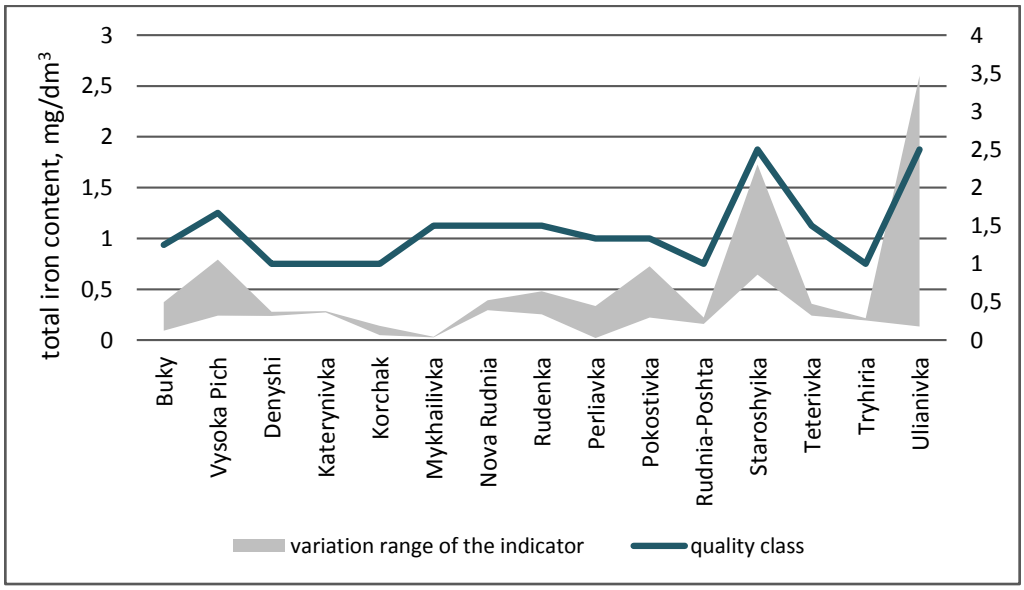

Fig. 5. Classes of water quality according to the total iron content

Total water hardness is an indicator that characterizes the property of water, related to the presence of dissolved salts of calcium and magnesium (sulfates, chlorides, carbonates, hydrocarbonates, etc.) (DSTU, 2007). According to hardness, water is classified from very soft to very hard (Table 4).

Table 4

Classification of water according to hardness

Class of water	Total hardness, mmol/dm^3
Very soft	Up to 1.5
Soft	1.5–4.0
Medium hardness	4.0–8.0
Hard	8.0–12.0
Very hard	more than 12.0

Scientists have proven that there is a high correlation relationship between increased hardness and urolithiasis and kidney disease (Turbinsky et al., 2011). In Ukraine, the standard of water hardness for sources of non-centralized water supply is set at 10 mmol/dm^3, while according to DSTU (National Standards of Ukraine) 7525:2014 its optimal level is determined in the range from 1.5 to 7 mmol/dm^3 (DSTU, 2014).

The highest value of total hardness was recorded in the village of Ulianivka at the level of 15.9 mmol/dm^3. In general, values of total hardness in the drinking water in the investigated rural settlements did not exceed the norm.

In general, groups of general sanitary and toxicological indicators determine the class of water quality of the investigated sources of non-centralized water supply according to the scale from 1.5, which corresponds to the subclass of "excellent", very pure water grading to the class of "good", pure water of desirable quality (the village of Korchak) to 3, which corresponds to "satisfactory", slightly contaminated water of acceptable quality (the village of Staroshyika) (Fig. 6).

It has been established that it is the group of general sanitary indicators that has the greatest influence on the formation of the general class of water quality (Fig. 7), which is primarily due to the high nitrate content in the examined sources of non-centralized water supply.

Fig. 6. Classes of water quality according to groups of general sanitary and toxicological indictors

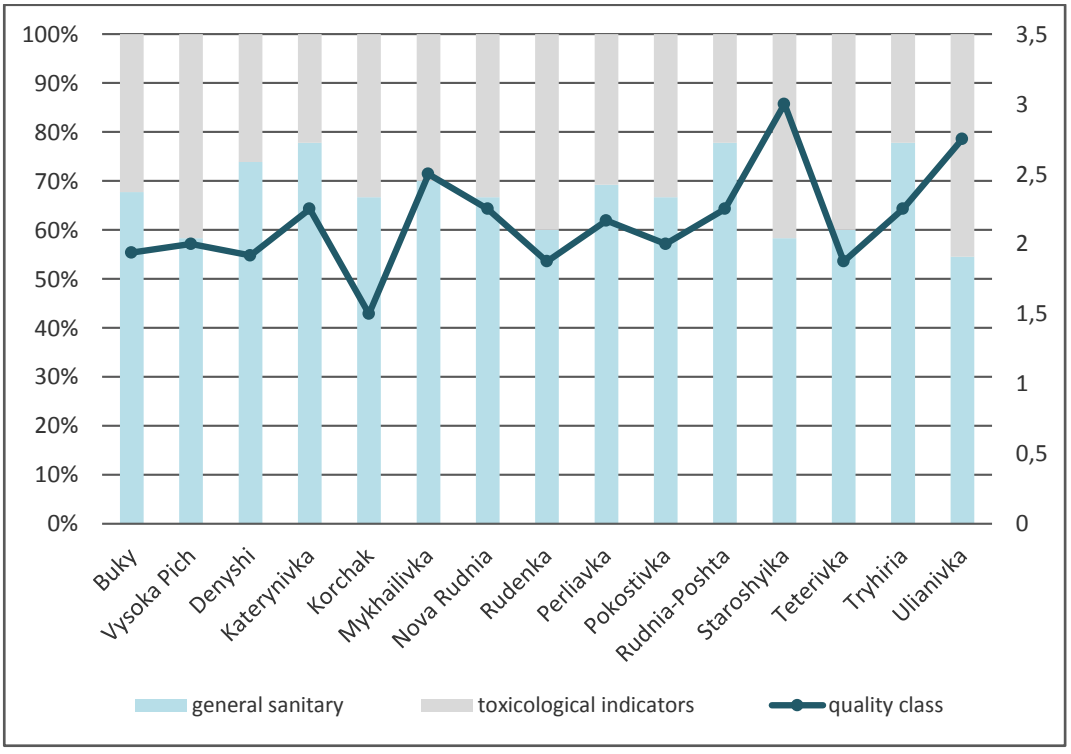

Fig. 7. Contribution of the investigated groups of indicators in the value of water quality class

The calculation of the integrated environmental index of the development of rural settlements has shown that 11 out of 15 investigated settlements have a satisfactory environmental condition. In particular, attention should be paid to the villages of Katerynivka and Ulianivka; the villages of Vysoka Pich, Denyshi, Mykhailivka, Nova Rudnia, Perliavka, Pokostivka, Rudenka, Rudnia-Poshta, Staroshyika, Teterivka, and Tryhiria need improvement; the villages of Buky and Korchak need to be maintained at the same level (Fig. 8).

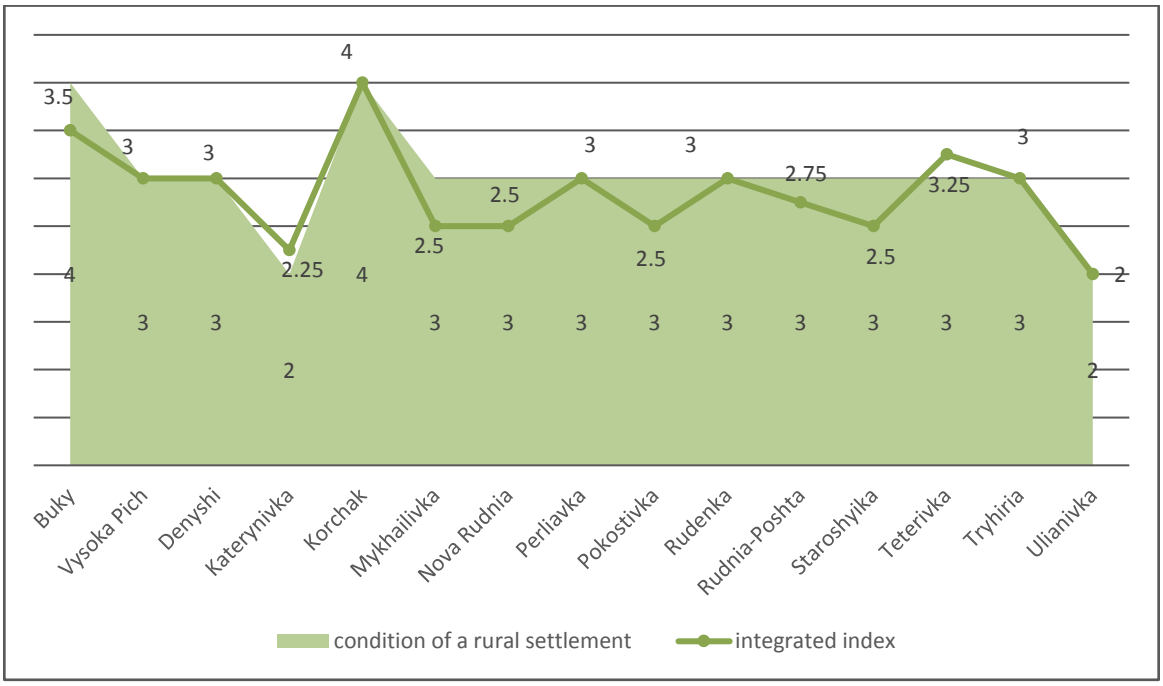

Fig. 8. Integrated environmental index of the development of rural settlements according to quality indicators of drinking water

Thus, it has been established that there is a serious problem with quality water provision to the rural population in the Teterivka amalgamated community of the Zhytomyr region. In turn, this requires priority intervention of local authorities, which represent the interests of the community, in the water supply of rural settlements.

4. Conclusions

– Thus, the investigation of drinking water quality within the Teterivka amalgamated community of the amalgamated Zhytomyr region gave us grounds to draw the following conclusions:

– in terms of nitrate content, the worst situation was recorded in the village of Mykhailivka, where its average content reached 189.05 mg/dm^3, which 3.8 times exceeds the norm; in addition, the excess of nitrate content was recorded in all selected samples in the villages of Mykhailivka, Nova Rudnia and Staroshyika; a critical situation regarding the pH indicator was recorded in the villages of Mykhailivka and Rudnia-Poshta, where the average value of the hydrogen index was 5.5; water in the village of Ulianivka is the most dangerous in terms of iron content, its average content was 1.367 mg/dm^3; the highest value of hardness (15.1) was also found in the village of Ulianivka;

– assessment of drinking water by its quality classes has shown that in terms of the pH, indicator quality classes vary from 1.5 to 3, in terms of the total iron content – from 1 to 2.5, and in terms of the nitrate content drinking water mostly belongs to the 4th quality class defined as "mediocre", "partially potable" of undesirable quality;

– calculation of the integrated environmental index of the development of rural settlements according to the indicators of drinking water quality showed that, first of all, attention should be paid to such rural settlements as Katerynivka and Ulianivka; 11 settlements need improvement; only 2 settlements (the villages of Buky and Korchak) need to be maintained at the same level.

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