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ENVIRONMENTAL SAFETY OF DRINKING WATER SUPPLY IN RURAL SETTLEMENT AREAS

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Ukraine faces problems of pollution of underground water supply sources due to the low level of environmental protection and insufficient attention to water supply problems. Water pollution is caused by the uncontrolled dumping of toxic waste, soil contamination, and negligence in the storage and transportation of hazardous substances. The problems of contamination of underground water supply sources in Ukraine are currently serious and need to be addressed immediately. It is necessary to carry out systematic monitoring of water quality, develop and implement strategies to reduce emissions of hazardous substances and ensure proper storage of toxic waste. It is also important to raise public awareness of the need to protect the environment and use environmentally friendly technologies.

To ensure safe and quality drinking water for residents of rural settlements who use their own wells, boreholes, and natural sources for domestic water supply, a comprehensive approach to evaluating the quality of underground drinking water using GIS technologies is necessary.

The purpose of the study was to assess the quality of drinking water sources of non-centralized water supply in rural settlements of the united communities of Zhytomyr district and to create geo-informational models based on the research results. The following research methods were used during the research: analytical, field, laboratory, statistical, calculation and cartographic.

It has been proven that the average pH level in none of the studied settlements exceeded the norm. The average nitrate concentration in the drinking water from non-centralized water sources exceeded the norm by 1.4–3.5 times, specifically in the water of the Pulyn, Cherniakhiv, Vilshanka, Volytsia, and Oliivka communities, exceeding the MAC (Maximum Acceptable Concentration) limit by more than two times. Only in rural settlements in the Liubar community was the average iron content found to be above the norm by more than 1.9 times. It was determined that the highest contribution to the overall water quality was made by nitrate and iron content.

The obtained research results and models based on them can be used by local governments of the studied communities to inform the population about the quality of drinking water and to develop a plan for improving the state of drinking water supply with the aim of increasing the level of environmental safety of drinking water. *Key words:* water supply, water drainage, water quality, water objects, water pollutants.

Екологічна безпека питного водопостачання населених пунктів в сільській місцевості. Валерко Р.А., Герасимчук Л.О., Пацева І.Г., Покшевницька Т.В., Лук'янова В.В.

В Україні на сьогодні є актуальними проблеми забруднень підземних водних джерел, викликаних неналежним станом охорони навколишнього середовища та недостатньою суспільною увагою до водопостачання. Зокрема, забруднення води спричиняється неконтрольованим скиданням токсичних відходів, забрудненням ґрунту та недбалістю під час зберігання та транспортування небезпечних речовин. Проблеми забруднення підземних джерел водопостачання в Україні потребують невідкладного розв'язання. Отже, необхідно здійснювати систематичний моніторинг якості води, розробляти та впроваджувати стратегії зменшення викидів небезпечних речовин та забезпечення належного зберігання токсичних відходів. Також важливим є підвищення свідомості у населення щодо поліпшення охорони навколишнього природного середовища та ефективного використання екологічно безпечних технологій.

З метою забезпечення безпечною та якісною питною водою мешканців сільських населених пунктів, які використовують власні колодязі, свердловини та природні джерела для побутового водопостачання, необхідний комплексний підхід до оцінки якості підземної питної води з використанням ГІС-технологій.

Мета дослідження – оцінка якості джерел питної води нецентралізованого водопостачання в сільських населених пунктах об'єднаних громад Житомирського району та створення геоінформаційних моделей за результатами досліджень. Під час досліджень використовувалися такі методи вивчення: аналітичний, польовий, лабораторний, статистичний, розрахунково-картографічний.

Доведено, що середній рівень pH в жодному з досліджуваних населених пунктів не перевищував норму. Середня концентрація нітратів у питній воді з нецентралізованих джерел перевищила норму в 1,4–3,5 рази, зокрема у воді Пулинської, Черняхівської, Вільшанської, Волицької та Оліївської громад, перевищивши гранично допустиму концентрацію ГДК більш ніж удвічі. Лише в населених пунктах Любарської громади середній вміст заліза виявився вищим за норму більш ніж у 1,9 рази. Встановлено, що найбільший внесок у загальну якість води привніс вміст нітратів та заліза.

Отримані результати досліджень та моделі на їх основі можуть використовуватися органами місцевого самоврядування досліджуваних громад для інформування населення щодо якості питної води та розробки плану покращення стану питного водопостачання з метою підвищення рівня екологічної безпеки питної води. *Ключові слова:* водопостачання, водовідведення, якість води, водні об'єкти, забруднювачі води.

Introduction. Safe and adequate water supply is an important factor in maintaining human health, and therefore access to clean drinking water is now a basic human right. Universal access to quality drinking water and sanitation is a global development policy priority [1]. Currently, more than 700 million people, mostly in developing countries, do not have access to improved water supply and sanitation facilities [2]. The problem is particularly acute among rural settlements worldwide.

In particular, in Ukraine, as of the beginning of 2020, only 26.9% and 1.8% of rural settlements were provided with centralized water supply and sewerage, respectively [3]. Given this situation, the main sources of domestic water supply are private wells, boreholes, natural sources, etc., the water quality of which may be questionable and hazardous to the health of rural residents [4].

Munene et al. note that wells play an important role in providing water to rural populations, and agricultural activities have been identified as a significant risk factor for well water contamination [5]. The responsibility for maintaining water sources lies with their owners. Mena-Rivera & Quiros-Vega consider it important to pay attention to research on drinking water in rural areas, as there is insufficient data on its quality [6]. And given the low ecological culture of rural residents, which results in uncontrolled use of fertilizers, plant protection products, and large amounts of wastewater, which causes microbiological and chemical contamination of water sources, a large-scale study of the quality of drinking water from non-centralized water sources is needed. In Gibson & Kelsey, the lack of comprehensive research on the quality of drinking water in rural areas is recognized as one of the main barriers to providing safe water to residents who consume it from non-centralized water sources [7].

The main water pollutants in non-centralized water supply sources are microorganisms, organic matter, and heavy metals. The contamination of water with nitrates is of particular concern [8, 9]. Due to the presence of toxic elements, water has poor quality, becomes unfit for drinking, and threatens human health, which in turn causes a significant environmental problem that is currently characteristic not only of Ukraine but is also being studied by scientists around the world, including India [10], Bangladesh [11], Iran [12], China [13], Indonesia [14], New Zealand [15], the United States [16], Kenya [17], etc.

At the current stage of civilization development, geoinformation systems are of great interest, which allow for effective management decisions in many areas of human activity, including the field of drinking water supply in rural areas. The use of specialized application programs, which are developed based on geoinformation technologies, allows creating databases and geoinformation models of the qualitative composition of groundwater, which significantly increases the relevance of the conducted research.

The purpose of this study is to evaluate the quality of drinking water in rural settlements of territorial communities in the Zhytomyr district and to present its results thematically in the form of geoinformation models for effective management of environmental safety of water supply in the community.

Materials and methods. The research was conducted on the territory of the united territorial communities of the newly enlarged Zhytomyr district of Zhytomyr region. As part of the research, drinking water samples were collected from non-centralized water supply sources in rural and urban settlements within the following united territorial communities:

– city: Zhytomyr city territorial community;

– town: Liubar, Novohuivynske, Pulyny and Cherniakhiv territorial communities;

– village: Berezivka, Vilshanka, Volytsia, Hlybochytsia, Oliivka, Stanyshivka and Teterivka united territorial communities.

Analytical research on the quality of drinking water was carried out at the Measurement Laboratory of the Polissya National University based on the following indicators: pH, content of nitrates and total iron, which were determined by generally accepted methods. In particular, the pH indicator was determined by potentiometric method, the content of nitrates – by ionometric method, total iron – by photocolometric methods. The obtained results were compared with the standards that apply in Ukraine, namely: DSanPiN 2.2.4-171-10 "Hygienic Requirements to Drinking Water Intended for Human Consumption" [18].

The results of analytical studies on the quality of drinking water from non-centralized water supply sources, which were conducted within the rural settlements of the united territorial communities of the Zhytomyr consolidated district, were grouped into the relevant observation and testing databases and became the basis for creating geoinformation models of the studied objects. The construction of a geodatabase and output maps based on the research results was carried out using the ArcGIS Pro software package (developed by ESRI, USA), which provides access and management of geospatial data on a local network or via the Internet, contains a large number of tools for their processing and provides geocoding of large volumes of cartographic data suitable for processing in batch mode.

Results. The study results showed that on average none of the studied communities were found to be non-compliant with the pH indicator criteria. However,

in almost all communities, except for Liubar, Vilshanka, and Volytsia, a decrease in pH to the level of 5.45 was observed, indicating water acidification. An increase in pH up to 12.5 units was recorded in the water of the well at Nekrashivska gymnasium, located in the village of Nekrashiv of Oliivka community (Figure 1).

The average nitrate content in the drinking water of all the communities studied exceeds the standard (50 mg/dm^3) from 1.4 times in Novohuivynske community to 3.5 times in Volytsia (Figure 2). The maximum nitrate content of 660 mg/dm^3 was recorded in the well water of Veresy, a village that is part of the Zhytomyr community. In general, the concentration of nitrates varied within a fairly wide range from 0.508 to 660 mg/dm^3.

The communities were grouped according to the average nitrate content in drinking water. Thus, it has

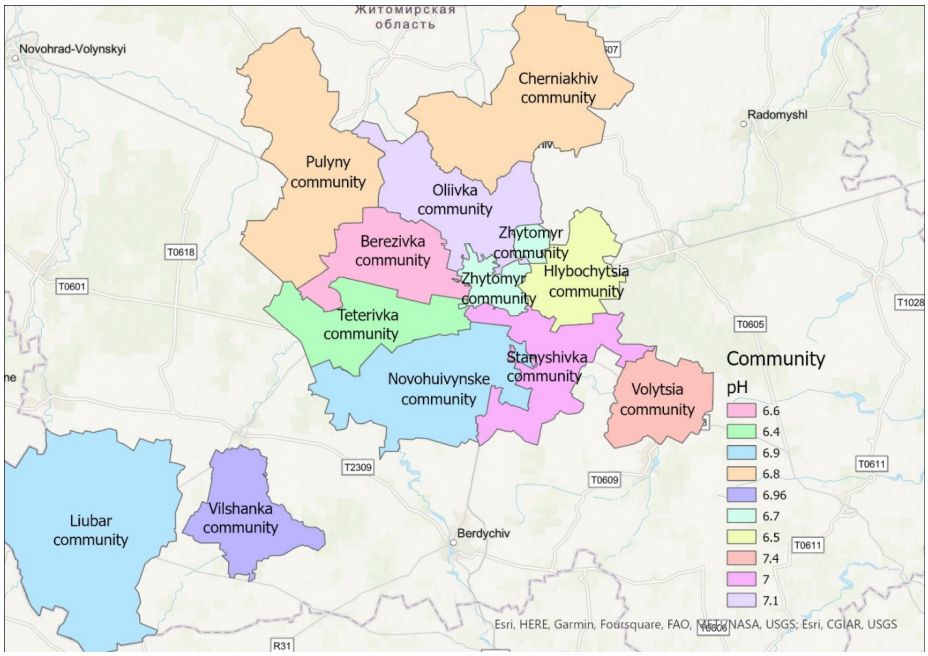

Fig. 1. Level of pH indicator in drinking water from non-centralized water supply sources in the studied communities, pH units

Source: own research.

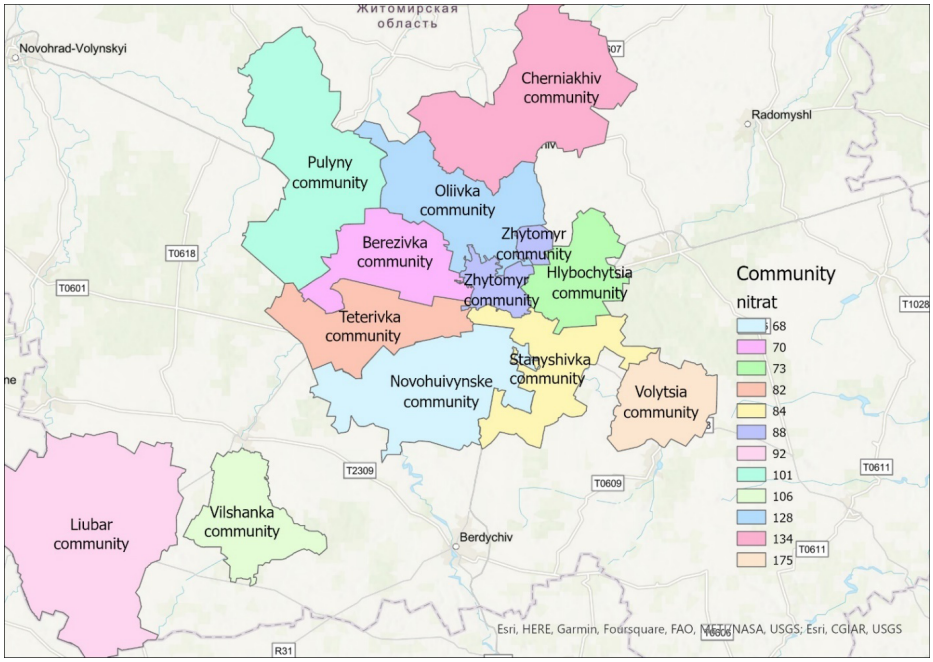

Fig. 2. Nitrate content in drinking water from non-centralized water supply sources in the studied communities, mg/dm^3

Source: own research.

been established that an excess of nitrate content by 1.1 to 2 times was recorded in seven communities, and an excess of the MAC by more than two times was detected in five communities (Table 1).

The average content of total iron in drinking water from non-centralized water supply sources in territorial communities ranged from 0.17–1.89 mg/dm^3. Exceedance of the standard, on average, was recorded only in rural settlements of the Liubar community, which amounted to 1.9 times (Fig. 3).

Through water intake and surveys in the area of wells, interviews with local residents, and inspections of rural settlements, it was found that the water quality of non-centralized water supply sources is not ideal, which is associated with specific sources of pollution. The environmental and cultural level of local residents is low. The chaotic development of household plots, disregard for the requirements of sanitary legislation, the application of nitrogen fertilizers in violation of sanitation standards, combined with inadequate maintenance, are the reasons for the deterioration of water quality in modern non-centralized water supply systems [19].

The responsibility for managing the water resources of non-centralized water supply sources lies with their owners, who often have illusions about their control and water quality, and as a result underestimate the risks of pollution. The perception of water quality in non-centralized water supply sources is important for making decisions and taking measures to improve it and prevent pollution. However, such decisions and measures should be implemented not only at the individual level, but also at the level of village and town councils and united territorial communities.

Having assessed the state of non-centralized drinking water supply in the studied communities of Zhytomyr district, it was proved that the quality of drinking water in many cases does not meet the standard, and its constant consumption can negatively affect the health of local residents, especially children. Therefore, there is a need to develop practical recommendations for local governments to improve the environmental safety of drinking water supply [20–24].

In view of this, it became necessary to develop a Plan to improve the state of drinking water supply within the community. The strategic objective of this document is

Table 1

Grouping of UTCs by the indicator of exceeding the average nitrate content in drinking water

Exceedance of standard	UTCs
1,1–2,0 MAC	Zhytomyr, Liubar, Novohuivynske, Berezivka, Hlybochytsia, Stanyshivka, Teterivka
2,1–5,0 MAC	Pulyny, Cherniakhiv, Vilshanka, Volytsia, Oliivka

Source: own research.

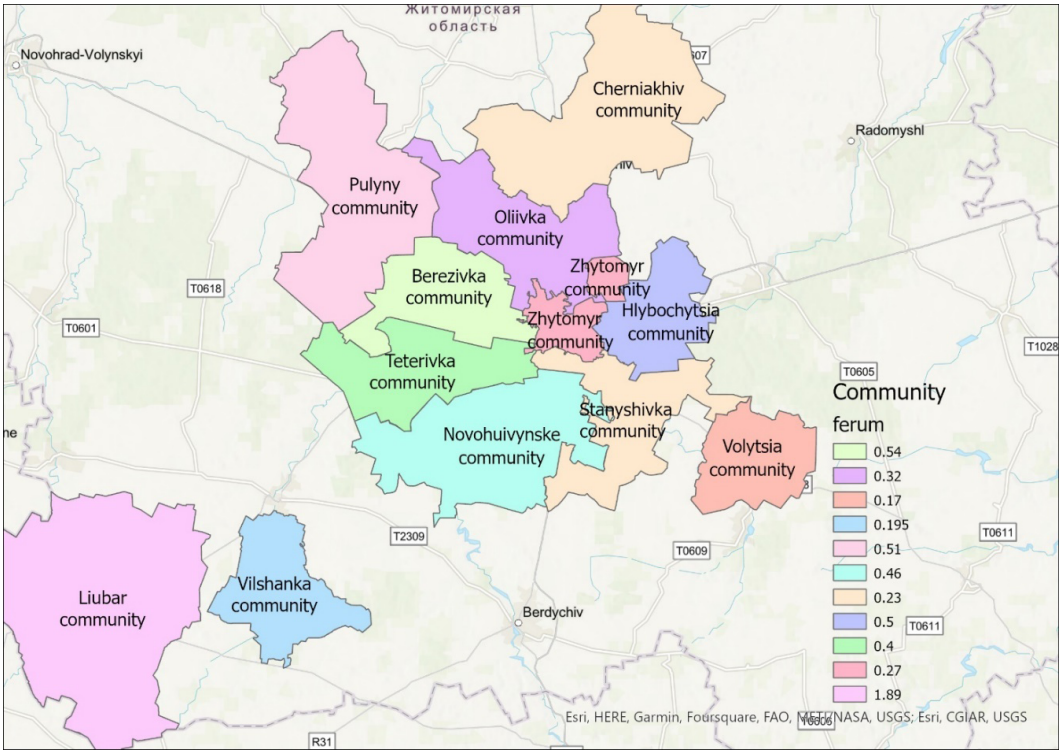

Fig. 3. Total iron content in drinking water of the studied communities, mg/m^3

Source: own research.

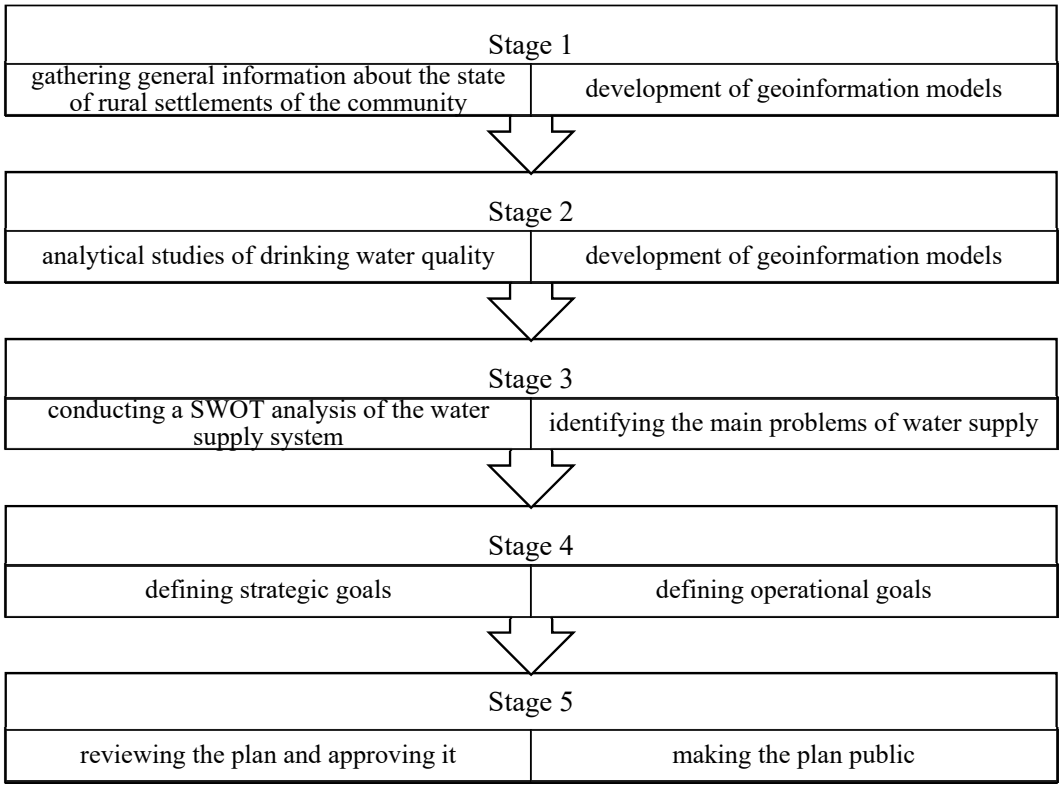

Fig. 4. Key stages of developing a plan for improving the state of community drinking water supply

to achieve a safe level of water supply and drinking water quality in the community through the interaction of the governing body and village residents. The development of the Plan must take into account public opinion, comments and suggestions. Before starting the development of the plan for improving the state of community drinking water supply, it is necessary to conduct a survey of the local population to determine the level of their interest and awareness in the field of safe water supply.

The development of the Plan should be based on the sequential implementation of 5 mandatory stages (Figure 4), the number of which may be increased depending on certain conditions. The development team should include representatives of all settlements in the community, representatives of the governing body, heads of utility companies, village elders, members of the public, and engaged experts and scientists from certain institutions. In order to inform the population, the progress of the plan development process should be covered on the community website and in social media.

Conclusions. In order to improve the environmental safety of drinking water supply, it is necessary to develop a plan for improving the condition of drinking water supply within a particular community, which should be based on the joint efforts of the management staff and residents of rural settlements; also, when developing the plan, it is mandatory to use GIS technologies with a territorial reference to map and identify the causes of the negative state of drinking water.

Thus, the use of geo-information systems and the creation of geo-information models of the state of potable underground water in rural settlement areas with their help make it possible to obtain effective management decisions regarding the creation and improvement of the level of safe water supply of united territorial communities. Therefore, further research should involve the creation of similar models for all communities of Zhytomyr region.

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