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SPATIAL ANALYSIS OF WATER QUALITY INDICATORS IN DROHOBYCH DISTRICT

Abstract. Water quality is one of the important indicators of the well-being in the region. While the sources of decentralized water supply are relatively protected and under constant control, the quality of water in the sources of decentralized water supply needs additional attention. At the same time, water quality indicators of decentralized water supply sources make it possible to assess the quality of natural waters in the region. The development of spatial analysis methods in the assessment of water quality allows to determine the influence of environmental factors on water quality and to determine areas and settlements with the most and least safe conditions for decentralized water supply. The article presents the results of a spatial analysis that permitted to assess the water quality of the sources of decentralized water supply in the Drohobych district. The conducted analysis made it possible to establish the territories with the highest water quality in the district. The proposed method can be used in monitoring studies and for assessing the quality of natural resources in the region.
Key words: Drohobych district, monitoring, water quality, spatial analysis.

INTRODUCTION

A decentralized water supply system is the system where water is sourced, and distributed locally, and not being supplied by a centralized system [12]. This can be done in a variety of ways, including stormwater collection, groundwater recharge, and small-scale well water use. Decentralized systems offer a number of advantages over centralized systems, including increased resilience, lower costs and greater community participation in water management. But their use can also be subject to regulatory restrictions. In addition, such sources require ongoing monitoring. Decentralised water systems can be an effective means of ensuring access to safe and reliable water in regions where centralised systems are neither feasible nor desirable [10].

Water quality testing is an important monitoring instrument to ensure that the water is safe for human consumption, aquatic life and other uses. The reasons for the significance of water quality testing are [2]:

1. Protecting human health: Water is a vital resource for humans, and contaminated water can cause many health problems, including diarrhoea, cholera, typhoid and other waterborne diseases.
2. Environmental Protection: Water quality testing helps to monitor the health of aquatic ecosystems and protect them from pollution.

3. Regulatory Compliance: Governments and regulatory bodies have established water quality standards, and water quality testing helps to ensure those standards are met.

4. Economic Benefits: Safe drinking water is critical to agriculture, industry and tourism. Water quality testing ensures that water is adequate for these activities and can contribute to economic growth.

Water quality monitoring surveys include the chemical analysis of various indicators. Such studies provide updated information on water quality at a certain point in time. At the same time, spatial analysis can also be used to assess the quality of water resources of the territories. Mapping the results of chemical analyzes of water allows identifying regions with unsatisfactory conditions, assessing the spread of pollution, and determining the impact of related factors on water quality [19].

Spatial analysis is the process of reviewing and interpreting geographical location information. It involves using a variety of techniques and tools to analyze spatial data, such as maps, satellite imagery and geographical information systems (GIS) [6, 7]. Spatial analysis may be used to determine trends, relationships and trends in geography-related data, such as population density, land use and environmental factors. It is widely used in urbanism, environmental sciences and epidemiology [1].

Spatial analysis can also be used to model the dispersion of pollutants in the environment, taking into consideration factors such as winds, terrain and land cover. This can assist in predicting the potential impact of pollution on neighboring communities and ecosystems [20].

Spatial analysis of pollution sources involves the use of geographic information systems (GIS) to identify and map the location of pollution sources, such as factories, power plants, transportation routes, place of wastewater discharges and landfills [21]. This information can then be used to assess the potential impact of these sources on human health and the environment, as well as to develop strategies for mitigating their effects [5].

GIS technology allows the integration of various data sources, such as satellite imagery, air quality monitoring data, and demographic information, to create detailed maps of pollution sources and their surrounding areas. This can help identify trends in pollution levels and areas that are especially vulnerable to pollution [13].

Apart from GIS technologies, the instruments in Excel and similar products may be used for spatial analysis. For spatial analysis in Excel, geographical data in a format that Excel can read, such as CSV, TXT or Excel files are used. Excels built-in mapping and analysis tools, such as the “Map Chart” and “Data Analysis” features help to analyze and visualize the data [14].

Some common spatial analysis techniques performed in Excel include [8]:

1. Mapping: Create maps to visualise spatial models and relationships in data.
2. Spatial statistics: Calculate distance, area, proximity and other spatial statistics for data analysis.
3. Spatial Interpolation: Estimate values of locations where data are missing or incomplete through interpolation techniques.
4. Cluster analysis: Identify groups or clusters of data points which have similar spatial features.
5. Spatial regression: Analyze the relationship between spatial and other non-spatial variables by means of a regression analysis.

Excel can be a useful tool for basic spatial analysis, but more sophisticated analyses may require specialized GIS software.

Another applied software, Tableau, can be also used for data processing and spatial analysis. Special instruments in this software are used for creating digital maps. Spatial analysis in Tableau involves the use of geographic data to build maps and analyze site-based data. In Tableau, the user can log on to various spatial data sources, such as shape files, KML files, Excel files and spatial databases, and view the data on a map. Users can also create custom maps by importing their own map images or by creating maps through the mapping tools in Tableau [19].

The spatial analysis in Tableau includes various characteristics, such as geo-coding, spatial connections and spatial calculations. Geocoding is the process of converting addresses or place names into geographical coordinates that can be used to trace data on a map. Spatial connections make it possible to combine spatial data with non-spatial data, such as demographic and sales data. Mapping visualization also helps to find hidden information or insights. Spatial calculations enable users to make calculations based on geographical data, such as measuring distances or creating buffers around points [11]. Spatial analysis in Tableau allows users to gain insights into their data based on location, which can be useful for a variety of applications, such as market analysis, urban planning, and environmental monitoring [16].

MATERIALS AND METHODS

The studies of the water quality indicators and further spatial analysis were performed in the Drohobych district. Drohobych district is located in the Lviv Oblast of Ukraine and is known for its diverse landscape, including forests, mountains, and rivers. The district is situated in the Precarpathians, the region has a temperate climate, with mild summers and cold winters [15]. The main industries in the district are agriculture, machine building, recreation, forestry. The district is also home to several protected natural areas, including the Carpathian Biosphere Reserve and the Skole Beskids National Nature Park, which are important for biodiversity conservation [3].

Fig. 1. Map of Drohobych district

Water resources of the region are represented by rivers that enter the Dniester basin, reservoirs, streams, and underground waters. The cities of the district, Drohobych, Stebnyk, Boryslav, and Truskavets, have a centralized water supply [17]. One of the main suppliers of drinking water is the utility company "Drohobychvodokanal". At the same time, in many inhabited points in rural areas, the population uses sources of decentralized water supply, in particular, water from wells. The quality of water in these settlements needs to be monitored and evaluated.

To assess the quality of water in the Drohobych District, water samples were taken in 17 settlements (Table 1). Samples were taken and analyzed in 2021. The analysis was carried out according to 13 indicators: ammonium content, chlorides, sulfates, iron content, hardness, total mineralization, content of nitrates, nitrites, fluorides, manganese, odor, total mineralization and hydrogen index. Analyzes were performed in accordance with standard methods for assessing the quality of drinking water [4, 18]. A data file was generated based on the results.

Table 1

Settlements, where water samples were taken and their geographical coordinates

No.	Settlement	Latitude	Longitude
1	Lishnia	49,37361	23,45417
2	Uniatychi	49,37361	23,41583
3	Nahujevychi	49,361945	23,320557
4	Stupnytsia	49,431389	23,3225
5	Verkhni Hai	49,313334	23,656112
6	Medvezha	49,407778	23,381944
7	Ranevychi	49,345278	23,556389
8	Bystyrtsia	49,471111	23,445
9	Navoshychi	49,475556	23,450278
10	Luszok	49,449722	23,369444
11	Pochaievychi	49,360557	23,575557
12	Rykhtychi	49,39139	23,541945
13	Dobrivliany	49,435278	23,566111
14	Mykhailevychi	49,375835	23,600558
15	Nyzhni Hai	49,3476	23,676668
16	Derezhychi	49,334722	23,455833
17	Drohobych (district center)	49,35	23,5

At the next stage, the geographic coordinates of the sampling points were added to the received data file. The file prepared in this way was further processed in the Tableau software. A separate map was compiled for each indicator of water quality [9]. The parameters for distinguishing indicators were used - the size of the marker and its color. The darker color of the settlement marker and its larger size corresponded to a higher value of the quality indicator. A lighter color and smaller marker size corresponded to a smaller indicator value.

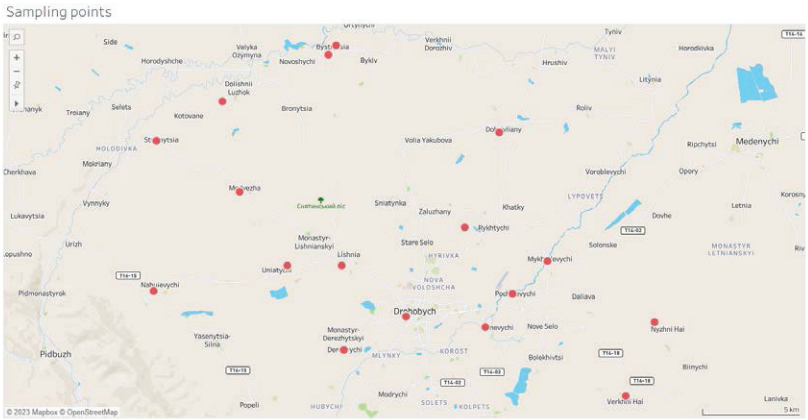

Fig. 2. Map of the sampling points

RESULTS

The results of the spatial analysis are presented in the form of a set of maps from the display of values for the corresponding indicator. The ammonium content (Fig. 3) of the water samples of the studied settlements differs slightly. The lowest values are observed for the southeastern part and the northwestern part of the district. The highest value for this indicator was recorded for the northeastern part (the village of Dobrivlyany).

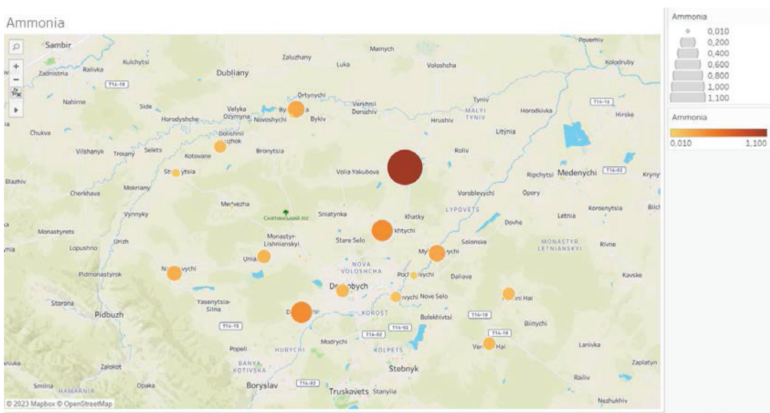

Fig. 3. Map of ammonia content

According to the content of chlorides (Fig. 4), the territory of the district can be divided into two parts. The eastern and southeastern part of the district is characterized by a lower content of chlorine ions. In the eastern and especially in the northeastern part, this indicator has higher values. As for the content of fluorides (Fig. 5), it is possible to single out only the part of the district with the lowest content of them. The lowest value is observed for the southern and southeastern parts of the district. In the rest of the territory, the value of this indicator is approximately 5 times higher.

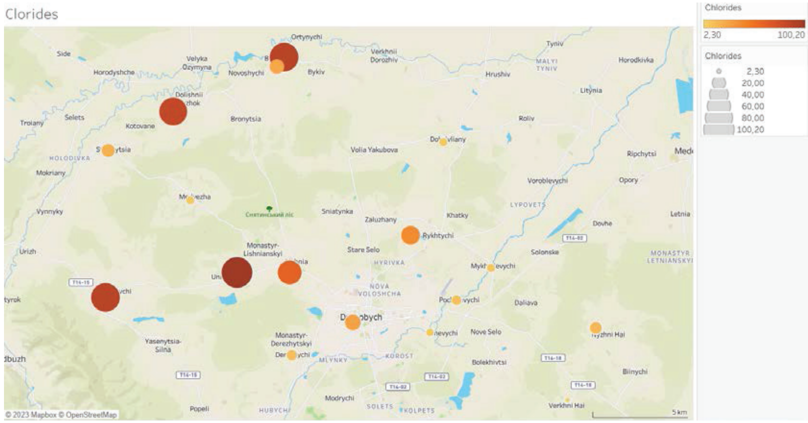

Fig. 4. Map of chlorides content

Fig. 5. Map of fluorides content

Regarding water hardness, the smallest and largest values differ by more than 5 times. The highest indicators of hardness are recorded in the northern and northeastern parts of the district. The lowest value of this parameter is observed for the southeastern part of the district (Fig. 6). The lowest value of iron content in water is also observed in the southeastern part of the district (Fig. 7). In the rest of the territory, the values of this indicator were 4-5 times higher. The highest value was observed for one settlement - the village of Dobrivlyany.

The content of manganese in the water of all studied objects is approximately the same. The absence of special differences can be seen on the corresponding map (Fig. 8). Analysis of the nitrate content shows the presence of differences depending on the location of the research object (Fig. 9). The highest values are observed in the northwestern part of Drohobych district. The lowest content of nitrates in water is recorded in the southeastern part of the district.

The content of nitrites in the studied water differs significantly only for two settlements in the north and south of the district (Fig. 10). In the rest of the studied area, the nitrite content in the water is about 5-7 times lower. For the southeastern part of the district, this indicator is almost 10 times lower. The evaluation of the smell of water (Fig. 11) shows that this parameter is the same for most settlements in the studied area. Much higher values of this indicator are recorded in three settlements located in the northeastern part of the studied district.

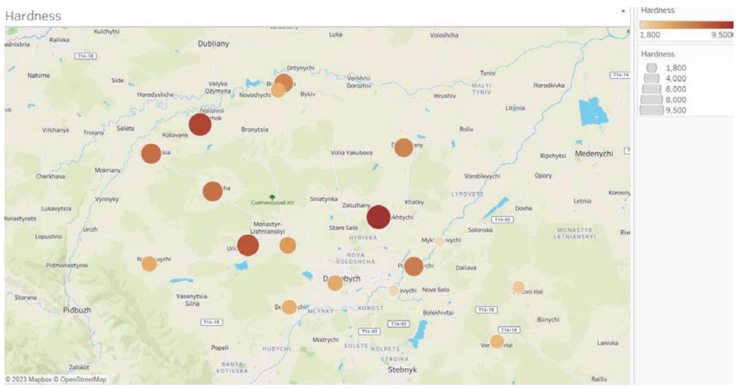

Fig. 6. Map of water hardness

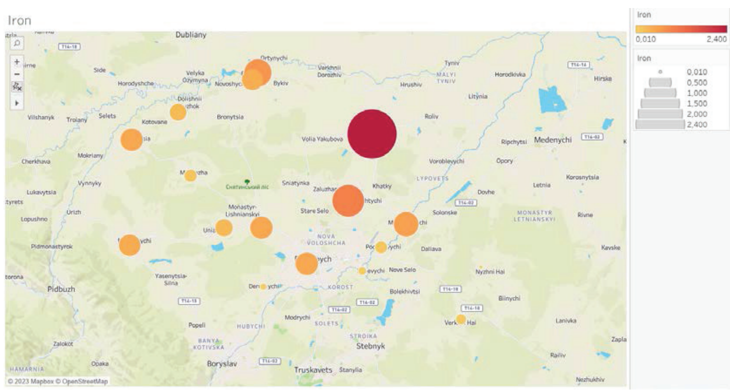

Fig. 7. Map of iron content

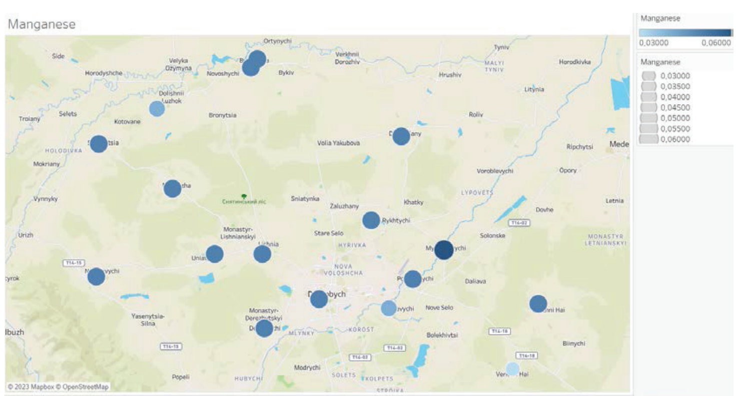

Fig. 8. Map of manganese content

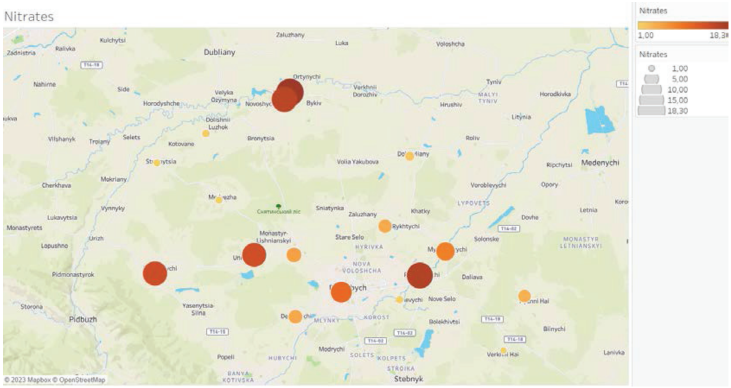

Fig. 9. Map of nitrates content

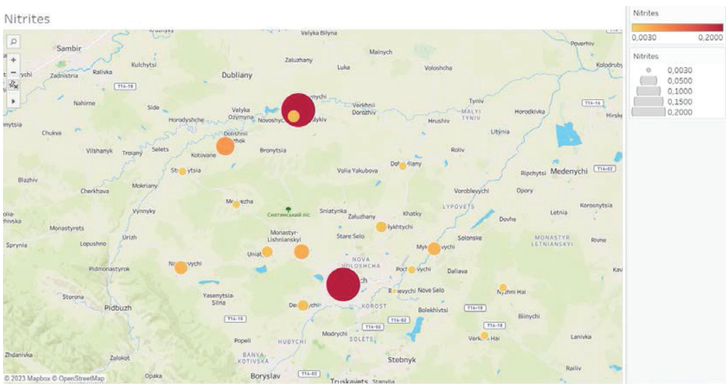

Fig. 10. Map of nitrites content

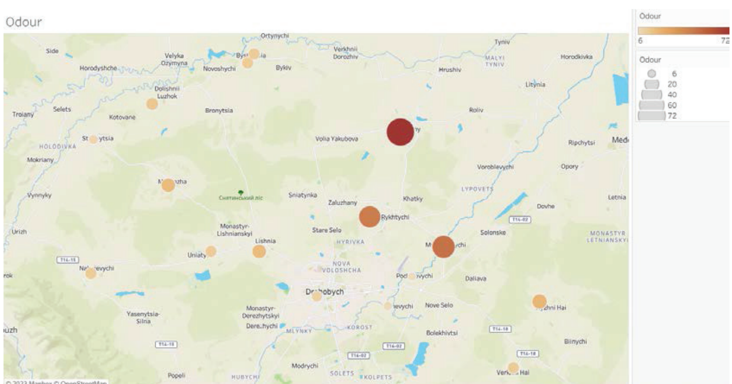

Fig. 11. Map of odor in studied area

Regarding the content of sulfate ions in water, the territory of the studied area is divided into two parts (Fig. 12). The highest values of this indicator are observed for the northwestern part. Further, the value of the sulfate content decreases towards the southeast. In the southeastern part of the district, the content of sulfates is the lowest. A similar pattern is observed for general mineralization (Fig. 13). In the direction of movement from the north-west to the south-east, the value of this indicator also decreases and reaches the minimum value in the south-eastern part of the district.

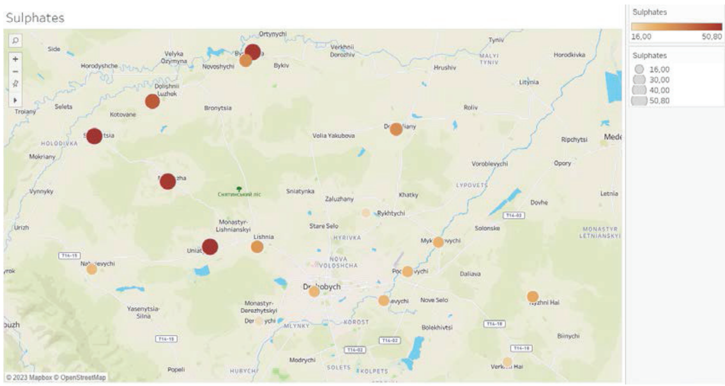

Fig. 12. Map of sulfates content

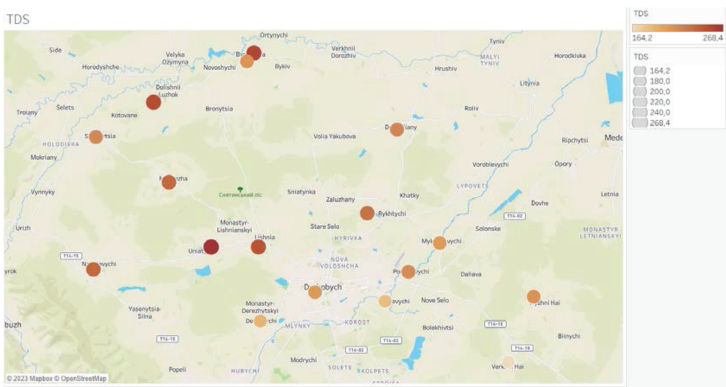

Fig. 13. Map of TDS in studied area

Regarding the content of sulfate ions in water, the territory of the studied area is divided into two parts (Fig. 12). The highest values of this indicator are observed for the northwestern part. Further, the value of the sulfate content decreases towards the southeast. In the southeastern part of the district, the content of sulfates is the lowest. A similar pattern is observed for total mineralization (Fig. 13). In the direction of movement from the north-west to the south-east, the value of this indicator also decreases and reaches the minimum value in the south-eastern part of the district.

Thus, the spatial analysis shows that the investigated indicators can be divided into two groups - those that depend on the place of sampling, and those that do not. Parameters of manganese content, smell, pH, nitrite and iron content. They do not depend on the place of sampling. For the rest of the parameters, the results of the analysis are influenced by the place where the sample was taken. For these indicators, it can be concluded that the highest indicators of quality and water are characteristic of the southeastern part of the district. It is in this part that the lowest content of nitrates, chlorides, and sulfates, as well as the lowest total mineralization and turbidity, is recorded in water samples.

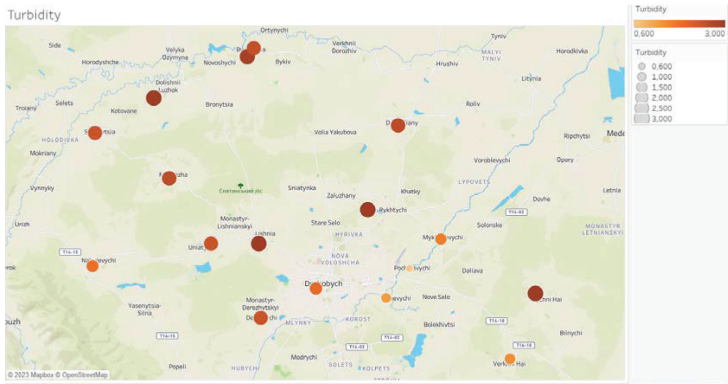

Fig. 14. Map of turbidity in studied area

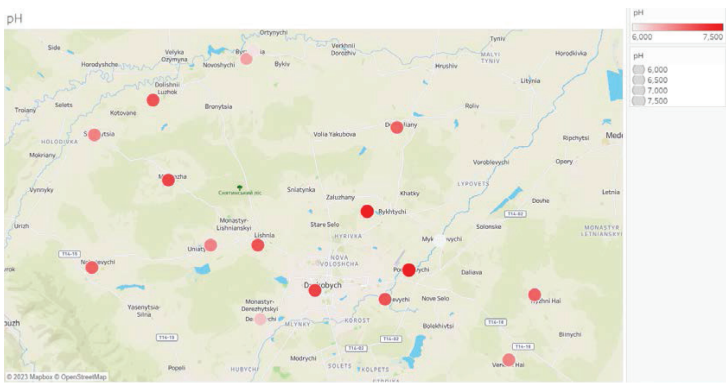

Fig. 15. Map of pH in studied area

CONCLUSIONS

Decentralized water supply sources continue to be an additional, and in some regions, the main source of water supply. Their monitoring is important not only from the point of view of water supply security, but also as a source of information about water quality in the region. In addition to the typical chemical analysis of water, the monitoring methodology can be accompanied by the use of spatial analysis. Both geographic information systems and a number of applied software products can be used to solve spatial data analysis tasks. The carried out spatial analysis of water quality indicators in the Drohobych district made it possible to create a number of maps for water quality assessment. The conducted analysis showed that the quality parameters were divided into two groups - parameters that depend and do not depend on the place of sampling for analysis. According to the water quality indicators, which depend on the place of sampling, it was possible to establish that the water in the south-eastern part of the Drohobych district has the best quality indicators. In the rest of the territory, the water may have a higher content of pollutants. The conducted analysis can be used to create a monitoring system, as well as to analyze the impact of environmental factors and human economic activity on water quality.

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АНОТАЦІЯ

ПРОСТРОВА ОЦІНКА ПОКАЗНИКІВ ЯКОСТІ ВОДИ У ДРОГОБИЦЬКОМУ РАЙОНІ

Джерела децентралізованого водопостачання продовжують посідати важливе місце забезпеченні водою цілого ряду регіонів. Попри те, що централізоване водопостачання є надійнішим, децентралізоване водопостачання можна розглядати як резерв. Крім того, інформація про якість води джерел децентралізованого водопостачання дозволяє додатково оцінити стан водних ресурсів у регіоні.

Моніторингові дослідження якості води зазвичай передбачають відбір проб, їх хімічний аналіз та формування бази даних про якість води. Разом з тим у практику починає впроваджуватися просторовий аналіз розташування джерел забруднення або джерел з чистою водою. Такий аналіз дозволяє виявити райони забруднень, визначити вплив факторів довкілля та антропогенних факторів на якість води. Просторовий аналіз передбачає використання геоінформаційних (ГІС) та складання електронних та інтерактивних карт. Допоміжними інструментами для просторового аналізу можуть служити інші програмні продукти, наприклад Excel або Tableau. У них можуть створюватися файли даних, а нові можливості цих додатків дозволяють також створювати тематичні карти.

Об’єктом проведеного дослідження були води джерел децентралізованого водопостачання у Дрогобицькому районі. До водних ресурсів на території входять притоки Дністра, ряд водосховищ, вода підземних джерел. Водопостачання міст району здійснюється за рахунок джерел централізованого водопостачання, у той час, як у сільській місцевості використовуються також джерела децентралізованого водопостачання. Для дослідження було відібрано проби води у 17 населених пунктах району. Аналізувалися 13 показників якості води. Дані аналізу прив’язувалися до координат населеного пункту, у якому відбиралися проби води. На основі отриманих даних складися електронні карти.

Проведений аналіз показників якості води показав, що умовно їх можна розділити на дві групи. До першої групи належать показники, що не залежать від місця відбору проби та є практично однаковими для всіх населених пунктів. Це pH, запах, вміст нітритів, магнію. Другу групу складають показники, що відрізняються залежно від місця відбору проби. До таких належать вміст хлоридів та сульфатів, вміст заліза, загальна твердість, вміст фторидів та нітратів. Значення цих показників є найменшим для об’єктів дослідження, розташованих у південно-східній частині району. Таким чином, можна зробити висновок, що саме у південно-східній частині району вода джерел децентралізованого водопостачання характеризується найвищими показниками якості. Слід зазначити, що у всіх досліджуваних пробах показники якості не перевищували допустимого значення, проте саме у південно-східній частині району якість води є найвищою. Виконання просторового аналізу є додатковим інструментом моніторингу якості води. З його допомогою можна складати інтерактивні карти, оцінювати вплив факторів на якість води, розробляти управлінські рішення у межах району.

Ключові слова: Дрогобицький район, моніторинг, якість води, просторовий аналіз.