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FEAUTERES OF THE GROUNDWATERS CHEMICAL COMPOSITION ON THE NATIONAL CONSERVATION AREA “ST. SOPHIA OF KYIV” TERRITORY

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Abstract

The article analyses the monitoring data of the groundwater chemical composition in nine observation wells on the territory of the St. Sophia Cathedral ensemble, obtained during 2012-2024. The results of the groundwaters chemical composition analysis of the Reserve's territory revealed exceedances of the standard indicators (total mineralization, chlorides, ammonium, sodium and potassium, pH) in the waters of a number of wells. It was found that the water from the wells located in the northern and western parts of the Reserve's territory has either a weakly expressed trend towards an increase in the concentration of groundwater chemical composition components and total mineralization, or no such trend at all, while the water from the wells located in the eastern, southern and central parts of the Reserve's territory has a significant trend towards an increase in the concentration of both individual components and total mineralization. The facts of exceeding the established standards in the waters of a number of wells in the Reserve by various indicators may have natural and technogenic causes, while the trends towards a constant, significant increase in a number of water components and overall mineralization have technogenic causes. It was determined that the groundwater of the reserve territory is divided into two groups by its composition: mixed type (with a slight predominance of hydrocarbonate ions) and calcium chloride.

Key words: *groundwaters, chemical composition, monitoring, National Conservation Area «St. Sophia of Kyiv», mineralization.*

Introduction. In accordance with the monument protection requirements of Ukraine and UNESCO's requirements for the protection of the world's cultural and natural heritage, the National Conservation Area “St. Sophia of Kyiv” carries out ongoing comprehensive monitoring of the technical conditions of the monuments and the surrounding area of the Sophia Cathedral. A necessary

component of such monitoring is hydrogeological monitoring, including analysis of the chemical composition of groundwater, its level and temperature.

The aim of the work was to determine the mechanisms and technogenic impact on the formation of the chemical composition of groundwater in the territory of the National Conservation Area “St. Sophia of Kyiv”.

Methods. Sampling was carried out using a funnel after complete manual pumping of the wells. Sampling was carried out from nine observation wells - No. 5', 6, 7', 9', 10, 11, 12, 13, 14 - located on the territory of the National Conservation Area “St. Sophia of Kyiv” in the summer-autumn (late August - early September) and autumn-winter (late November - early December) periods. The chemical composition of the water samples was determined in the hydrochemical laboratory. The work was carried out at the Institute of Geological Sciences of the National Academy of Sciences of Ukraine in accordance with the agreement with the National Conservation Area “St. Sophia of Kyiv” [1]. Historical data on the chemical composition of water for previous years were used from the references [2, 3].



**Fig. 1. General plan of the National Conservation Area “St. Sophia of Kyiv”
with hydrogeological monitoring wells [2]**

Potentiometric method for determination of the pH and the concentration of Ca^{2+} , Cl^- , NO_3^- , NH_4^+ ions of water samples by the using a DL AI-125 ionometer and a set of glass and ion-selective electrodes. By **flame spectrometry** was determined the concentration of Na^+ and K^+ cations using an Elico CL 22D flame photometer. By the **titrimetric method** with phenolphthalein and methylorange indicators the concentrations of CO_3^{2-} and HCO_3^- anions were determined respectively. The **gravimetric method** was used to determine the concentration of SO_4^{2-} by precipitation with a 10% barium chloride solution and using an Ohaus Adventure analytical balance. The total Fe concentration

was determined by the *photocolorimetric method* with rhodanide using a KFK-2MP photoelectrocolorimeter.

Results

The total salinity of the water in most wells is up to 1 g/dm³ (fresh water) or 1.5 g/dm³ (conditionally fresh water). Thus, the waters of wells No. 5', 6, 7', 11, 12, 14 can be classified as fresh and conditionally fresh waters. The water of wells No. 10 and 13 can be considered brackish, where the salinity exceeds 1.5 g/dm³ in both summer and winter periods. Also, a slight excess (1.6 g/dm³) of salt content was recorded in the summer in the waters of well No. 9' (Table 1),.

According to the chemical composition of the water, the water quality standards [4] were exceeded in a number of wells (Table 1) and the possible factors that could have caused the exceedance of the standards were considered.

Table 1 Wells with exceedances of water quality standards in accordance with the Sanitary and Epidemiological Standards (ДСанПіН 2.2.4-171-10) [4]

Normative indicator	Wells with violation of norms	Data	Concentration, mg/dm ³ (pH – units)	Maximum permissible concentration, mg/dm ³	Possible factors of violation of norms
TDS	9'	08.2024	1599.22	≤ 1500	Natural: features of the water-bearing rock; Technogenic: sewage leaks into the ground
	10	08.2024	1917.22		
		11.2024	1549.39		
	13	08.2024	2126.82		
		11.2024	2106.55		
Cl ⁻	9'	08.2024	470.9	≤ 350	Technogenic: sewage leaks into the ground, soil salinization due to salt sprinkling on streets in winters, etc.
	10	08.2024	968.5		
		11.2024	429.6		
	13	08.2024	975.8		
		11.2024	833.9		
Fe ²⁺ + Fe ³⁺	5'	08.2024	7.3	≤ 1.0	Natural: peculiarities of the water-bearing rock (elevated iron levels are quite common in waters of the Quaternary aquifer); Technogenic: use of steel casing in wells
	6	08.2024	25.6		
		11.2024	9.9		
	9'	08.2024	9.4		
		11.2024	3.5		
	10	08.2024	10.1		
		11.2024	5.4		
	11	08.2024	23		
		11.2024	4.2		
	12	08.2024	27.9		
		11.2024	10.3		
	13	08.2024	3.2		
		11.2024	4.3		
NH ₄ ⁺	11	08.2024	9.9	≤ 2.6	

Normative indicator	Wells with violation of norms	Data	Concentration, mg/dm ³ (pH – units)	Maximum permissible concentration, mg/dm ³	Possible factors of violation of norms
		11.2024	5.1		Technogenic: unorganized sewage leaks into the ground
	12	08.2024	10.1		
		11.2024	5		
Na ⁺ + K ⁺	13	08.2024	230	≤ 200	Gets into water with chlorides
		11.2024	330		
pH	11	11.2024	6,28	6,5 - 8,5 units	Natural: features of the water-bearing rock; Technogenic: sewage leaks into the ground

Having analyzed the change in the concentration of the main components of the chemical composition of groundwater and its total salinity (Fig. 4) over time, the studied observation wells can be divided into three groups:

1. No increase in the concentration of the main components and total mineralization was observed in wells No. 6 and 9;

2. A slight increase in the concentration of some of the main components (mainly chloride ions) and total mineralization - holes No. 10, 11, 13. The exception here is hole No. 13, where, despite a minimal increase in total mineralization and other components, a 4-fold increase in Cl⁻ concentration was found;

3. Significant (2 or more times) increase in concentrations of the main components and total mineralization - wells No. 5', 7', 12, 14.

Thus, the water of the wells located in the northern and western parts of the Reserve's territory has either a weakly expressed trend towards an increase in the concentrations of groundwater chemical composition components and total mineralization, or no such trend at all. The water from the wells located in the eastern, southern and central (near the Cathedral) parts of the Reserve's territory has a noticeable upward trend in the concentrations of both individual components and total mineralization.

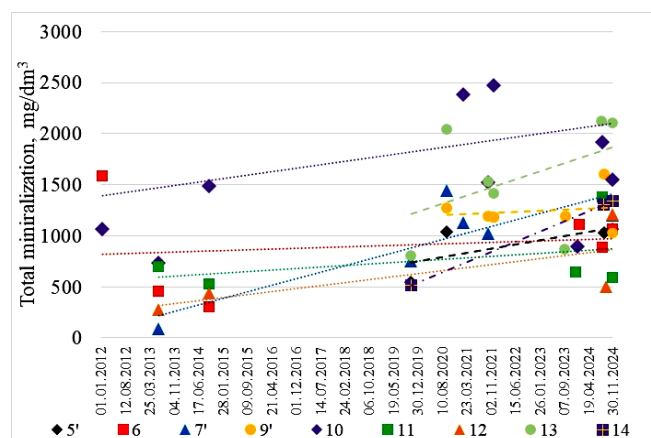


Fig. 2. Changes of total mineralization in well water during the observation period

The Piper diagram was used to determine the type of groundwater on the territory of the St Sophia of Kyiv National Conservation Area (Fig. 4). Ca^{2+} , Na^+ , and K^+ prevail among the cations. Among the anions are hydrocarbonates, chlorides and sulphates. Thus, the groundwater of the Reserve can be divided into two groups by anionic composition: mixed type with a certain slight predominance of hydrocarbonate ions (wells No. 5', 6, 7', 9', 10, 14) and chloride water (wells No. 11, 12, 13). The cationic composition of the water is of mixed type with a slight predominance of calcium ions and a significant proportion of sodium ions. Thus, the well water is divided into:

1. Mixed type (with a slight predominance of hydrocarbonates) - water from wells No. 5', 6, 7', 9', 10, 14;
2. Calcium chloride - water from wells No. 11 and 12 and calcium-sodium-potassium chloride - water from well No. 13.

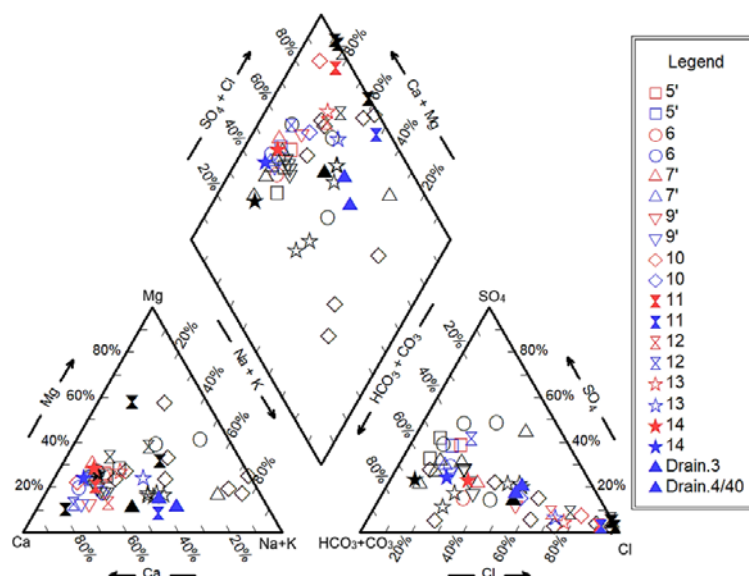


Fig. 4. Piper diagram of groundwaters of the territory of Reserve Area

Conclusions

1. Exceedances of the drinking water quality standards established by Sanitary and Epidemiological Norms (ДСанПіН 2.2.4-171-10) were recorded in the water of a number of wells in at least one of the seasons during which the following indicators were studied: chlorides - wells 9', 10, 13; total iron - wells 5', 6, 9', 10, 11, 12, 13, 14; ammonium - wells 11, 12; total sodium + potassium - well 13; pH - well 11; total mineralization - wells 9', 10, 13.

2. It was established that the waters of the wells located in the eastern, southern and central (near the Cathedral) parts of the Reserve (wells No. 5', 7', 12, 14) have a significant trend towards an increase (by 2 or more times) in the concentrations of individual components and total mineralization, which may be the result of the active expansion of the impact of technogenic waters from the urban area around the Reserve, as well as the use of sand and salt topping on the paths in winter.

3. Episodic exceedances of the established standards in the waters of a number of wells by various indicators can be explained by both natural (peculiarities of the composition of the water-bearing rock of moraine sediments) and technological factors (unorganized leaks of sewage, heat supply communications, use of table salt for sprinkling streets in winter). Trends towards a constant, significant increase in a number of water components and total salinity during the monitoring period in the waters of some wells are explained by anthropogenic factors.

4. The water of the Reserve's wells is divided into groups: mixed type (water of wells No. 5', 6, 7', 9', 10, 14); calcium chloride (No. 11, 12); calcium-sodium-potassium chloride (No. 13).

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**ОСОБЛИВОСТІ ХІМІЧНОГО СКЛАДУ ПІДЗЕМНИХ ВОД НА ТЕРИТОРІЇ
НАЦІОНАЛЬНОГО ЗАПОВІДНИКА «СОФІЯ КИЇВСЬКА»**

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Анотація

В статті проаналізовано моніторингові дані щодо хімічного складу ґрунтових вод, в дев'яти спостережних свердловинах на території ансамблю споруд Софійського собору, отримані протягом 2012 - 2024 років. За результатами визначення хімічного складу ґрунтових вод території Заповідника зафіксовані перевищення нормативних показників (загальної мінералізації, хлоридів, амонію, натрію та калію, величини рН) у водах ряду свердловин. Встановлено, що води свердловин, розташованих в північній та західній частині території заповідника мають або слабо виражений тренд на підвищення концентрацій компонентів хімічного складу ґрунтових вод та загальної мінералізації, або такий тренд взагалі відсутній, а води свердловин, які розміщені в східній, південній та центральній частині території заповідника мають суттєвий тренд до підвищення концентрацій як окремих компонентів, так і загальної мінералізації. Факти перевищення встановлених норм в водах ряду свердловин заповідника за різними показниками можуть мати природні та техногенні причини, натомість тренди до постійного, суттєвого підвищення ряду компонентів вод та загальної мінералізації мають саме техногенні причини. Визначено, що ґрунтові води території заповідника за своїм складом діляться на дві групи: змішаного типу (з незначним переважанням гідрокарбонат-іонів) та хлоридно-кальцієві.

Ключові слова: ґрунтові води, хімічний склад, моніторинг, Національний заповідник «Софія Київська», мінералізація.