Analytical Chemistry

THE STUDY OF GROUNDWATER QUALITY OF SCIENTIFIC AND PRODUCTION CENTER OF THE SOUTH FORESTRY IN ILMENSKY STATE RESERVE

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The present work deals with the quality of groundwater used for water supply of the scientific and production center of the South forestry in Ilmensky State Reserve. Chemical analyses of water from three wells have been conducted. The relationship of the quality of surface water and groundwater has been investigated. Anthropogenic causes of the variation of drinking water quality from the existing guidelines have been identified.
Keywords: groundwater, drinking water, physicochemical parameters of water quality, water supply, permanganate oxidability, nitrate.

Introduction

Underground sources play an important part in water supply, being the main sources of water supply in small population centers. However, nowadays economic activity inevitably leads to change in the status of groundwater. Significant groundwater intake without compliance with the established mode of operation of water intakes causes the depletion of deposits and pollution in some cases. As the result, the intake of large volumes of water forms extensive depression craters, there is a flow of groundwater from adjacent aquiferous strata and involvement of surface watercourses in groundwater recharge, which affects the quality of produced water.

In the present paper the physicochemical indicators of water quality are determined for the currently existing boreholes in the area of the research and production base of the Ilmensky State Reserve. The antropogenic influence on the chemical composition of water is studied, and the relationship of surface (Ilmensky lake) and groundwater.

Experimental

Investigations were carried out in July 2014 on the area of the scientific center of the Ilmensky State Reserve.

Ilmensky State Reserve, located on the eastern slopes of the Southern Urals, in the Chelyabinsk region, north-east of the Miass city. The reserve was established in order to preserve exceptionally diverse complex of rocks and minerals, as well as the flora and fauna typical of the Southern Urals. Scientific and industrial center of the reserve is located on the eastern shore of the Ilmensky lake.

Every year in summer on the area of the center the research work in field practices is carried out by the research teams of leading universities of the Russian Federation: Moscow State University, Kazan Federal University, National Research South Ural State University. In July, the center can accommodate up to 300 people simultaneously, while in the rest of the year there are only 2-3 staff members. Thus, in the summer period the problem of drinking water quality for the scientific center sharply arises.

Water sampling for the determination of the physicochemical parameters and hydrochemical analysis was carried out in accordance with the requirements of the State standard GOST P 51592-2000.

Chemical analysis of water samples at each point was carried out in the laboratory according to standard procedures (Table 1). For spectrophotometric studies the photocolorimeter KFK-3 was used.

For the potentiometric and conductometric measurements, respectively, the portable IPL Multitest and KSL Multitest were used.

Determination was performed in triplicate. Mathematical processing of the data was performed using standard methods of variation statistics.

Table 1

Chemical parameters of water quality, notation used, and determination methods

Chemical parameters	Method
pH value, **pH**	Potentiometry
Redox potential, **Eh**, mV	Potentiometry
Elecroconductivity, μS/cm	Conductometry
Salinity as NaCl, mg/L	Conductometry
Ammonium, $\mathbf{NH_4^+}$, mg/L	Spectrophotometry with Nessler's reagent at 440 nm according to the State standard GOST P 14.1: 2.1-95
Nitrate, $\mathbf{NO_3^-}$, mg/L	Potentiometry with nitrate-selective electrode
Nitrite, $\mathbf{NO_2^-}$, mg/L	Spectrophotometry with Griess reagent at 520 nm according to the State standard GOST P 14.1: 2.3-95
Orthophosphate phosphorus, $\mathbf{PO_4^{3-}}$, mg/L	Spectrophotometry with ammonium molybdate at 690 nm according to the State standard GOST P 4.1: 2.112-97
Chloride, $\mathbf{Cl^-}$, mg/L	Potentiometry with chloride-selective electrode
Sodium, $\mathbf{Na^+}$, mg/L	Potentiometrically with sodium-selective electrode
Potassium, $\mathbf{K^+}$, mg/L	Potentiometry with potassium-selective electrode
Total hardness, **H**, mmol/L	Titration by Trilon B with Chromogen black according to the State standard GOST P 52407-2005
Hardness as calcium, $\mathbf{Ca^{2+}}$, mg/L	Titration by Trilon B with murexide
Total iron content, $\mathbf{Fe_{total}}$, mg/L	Spectrophotometry with sulfosalicylic acid at 440 nm according to PND F 14.1: 2: 4.50-96
Permanganate oxidability, mg O_2/L	Kubel's method titration by potassium permanganate in acidic medium according to the State standard GOST P 14.1: 2: 4.154-99

Status quo

The water supply of the center proceeds from three wells. Note that the wells are exploited only in summer. In winter the wells are closed up, and the center employees use imported water for household and drinking needs.

The well No. 1 is exploited for more than 30 years. Its depth is 30 meters. Water from the well No. 2 is used in the bath for domestic needs (washing, laundry) and drinking needs of the center employees, constantly residing in the area. The well was bored in 2013, its depth is 40 meters. The well No. 3 is 22 meters deep, it was bored in 2014.

With regard to sewage, the household water on the area of the centre is collected into organized ditches. The sewage treatment is not done.

Results and Discussion

The results of analyses of water from the wells are shown in Table 2.

As can be seen from Table 2, the high content of various forms of nitrogen (ammonium, nitrate, nitrite) is found in water from all wells. Oxidability of water from the well No. 3 exceeds the value of maximum permissible concentration (MPC) and amounts to 9.2 mg O_2/L. The same high values of oxidability (10 mg O_2/L) are recorded in the kitchen-dining room, which is supplied from the well No. 3. Also the content of ammonium is increased up to 1.5 mg/L. Although the standard content of ammonium in drinking water equals 2 mg/L [4], a more rigorous standard is adopted for ammonia in production of bottled drinking water (0.1 mg/L for the first quality category and 0.05 mg/L for the highest quality) [5].

Table 2

Chemical parameters of water quality for the samples, taken from the area of scientific and production center of the Ilmensky State Reserve

Indicator, notation, unit	Sampling point					MPC
	Well No.1	Well No.2	Well No.2 (after boiling)	Well No.3	The kitchen-dining room No.3	
Nitrate, NO_3^-, mg/L	0.5±0.1	49.5±0.2	–	0.4±0.1	0.4±0.1	max 45 [3]
Nitrite, NO_2^-, mg/L	0.105± 0.005	0.020± 0.005	–	0.017± 0.005	0.110± 0.005	3 [4]
Ammonium, NH_4^+, mg/L	0.35± 0.02	0.30±0.02	–	Higher 1.5	0.15± 0.02	2 [4]
Total iron content, Fe_{total}, mg/L	0.10± 0.02	0.05±0.02	Lower 0.01	0.20± 0.02	0.05± 0.02	0.3 [4]
Permanganate oxidability, mg O_2/L	5.6±0.1	4.8±0.1	2.8±0.1	9.2±0.1	10.0±0.1	within 5–7 [3]
Total hardness, H, mmol/L	5.2±0.1	6.5±0.1	–	4.1±0.1	5.5±0.1	within 7 – 10[3]
Salinity as NaCl, mg/L	189.2± 0.1	389.6±0.1	38.0±0.1	152.6± 0.1	178.9± 0.1	within 1000 – 1500 [3]
pH	6.88± 0.05	6.26±0.05	–	6.83 ±0.05	6.78 ±0.05	6–9 [3]
Eh, mV	245.2± 0.1	252.3±0.1	–	255.4± 0.1	332.3± 0.1	–
Hardness as calcium, Ca^{2+}, mg/L	3.5±0.1	5.1±0.1	–	2.9±0.1	5.2±0.1	–
Chloride, Cl^-, mg/L	44.7±0.2	89.5±0.2	–	12.6±0.1	12.6±0.1	max 350 [3]
Sodium, Na^+, mg/L	5.1±0.1	8.2±0.1	–	4.1±0.1	3.6±0.1	200 [4]
Potassium, K^+, mg/L	3.0±0.1	0.9±0.1	–	0.2±0.1	0.2±0.1	–
Orthophosphate phosphorus, PO_4^{3-}, mg/L	Lower 0.01	Lower 0.01	–	0.07±0.02	Lower 0.01	3.5

The well No.3 (22 meters deep) is bored in the first aquiferous stratum. It is poorly insulated from surface water and is prone to anthropogenic pollution. That is why the natural processes, as well as the anthropogenic influence, can be causes of water inadequacy for drinking purposes.

The first reason is related to climatic features of July 2014. In the study we have found the high values of oxidability (28 mg O_2/L) for water of the Ilmensky lake. According to previous research [6–8] and the literature data [9], the Ilmensky lake belongs to mesotrophic type, the high content of organic substances is not characteristic to it. Such abnormally high values of oxidability are associated with the following natural processes, peculiar to July 2014. The southwestern part of the lake is waterlogged, with the quagmires along the coastline, which turns into a swamp. The lake is separated from the swamp by a ridge. As the result of heavy rains in this year the water level of the lake has risen above the ridge, which acts as the watershed, and swamp water has got into the lake. It explains the heightened values of ammonium (up to 0.85 mg/L) in the lake water. Significant deterioration of the Ilmensky lake water quality could lead to significant deterioration of water from the well No. 3. The other reason is the lack of treatment systems for domestic liquid waste. The significantly higher concentration of ammonium in groundwater (exceeding 1.5 mg/L) than in the Ilmensky lake (up to 0.85 mg/L) speaks in favor of the hypothesis.

The amount of nitrate exceeding MPC has been found in water from the well No. 2 (49.5 mg/L). This well is deeper (40 meters). The reason in this case can be the anthropogenic pollution of fecal waste, containing ammonium nitrogen, which is oxidized to nitrate by nitrifying bacteria in reducing conditions of underground water. On the other hand, the significant increase in nitrate can be the feature of groundwater in the given geographical area.

Methemoglobinemia occurs with prolonged use of drinking water, containing significant amount of nitrate. The ability of blood to transport oxygen is reduced, this leads to adverse effects to the organism. Methemoglobinemia can cause cyanosis (blue skin of the extremities and body), weakness and cardiopalmus. Progressive methemoglobinemia leads to depression of the central nervous system, causes headaches, dizziness, chronic fatigue, labored breathing and nausea. The severe form of methemoglobinemia leads to chronic sleepiness, brief loss of consciousness, irregular heartbeat [10, 11].

After boiling the quality of water from the well No. 2 is significantly improved to the desired values (Table 1).

The water from the well No.1 is of the highest quality in the investigated area. The increased values of permanganate oxidability (5.6 mg/L), higher than MPC, have been recorded for this water, but they do not exceed the normal values. This well is the deepest and is not affected by anthropogenic factors and surface water.

Conclusion

Thus, the water in two wells in the scientific and production center does not meet the standard of drinking water according to nitrate and permanganate oxidability value. The ammonium concentration has increased in all three wells.

The water from the well No. 2 can be used for drinking after preliminary boiling. The water from the well No.3 has very bad quality. This is associated with shallow depth of the wells (20 meters), while the artesian water is located at much greater depth in geographical conditions of the scientific and production center of the Ilmensky State Reserve.

The correlation between the quality of water in the Ilmensky lake and groundwater quality has been revealed.

In our opinion, it is necessary to bring sewerage in the area of the scientific and production center into line with the required standards. To this end, we propose to carry out the collection of household water in a special container, as well as to purify it locally in the deep-purification biological treatment plants, which are now widely available on the market. Alternatively, for seasonal work SBR-reactor (sequencing batch reactor) can prove the most suitable for decontamination. Such facilities work particularly well in the systems characterized by low wastewater discharge in certain periods.

We suggest purifying the water from underground wells with the use of the membrane filtration technology systems [12, 13].

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ИССЛЕДОВАНИЕ КАЧЕСТВА ПОДЗЕМНЫХ ВОД НА ТЕРРИТОРИИ НАУЧНО-ПРОИЗВОДСТВЕННОЙ БАЗЫ ЮЖНОГО ЛЕСНИЧЕСТВА ИЛЬМЕНСКОГО ГОСУДАРСТВЕННОГО ЗАПОВЕДНИКА

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Работа посвящена проблеме качества подземных вод, использующихся для водоснабжения научно-производственной базы южного лесничества Ильменского государственного заповедника. Проведен химический анализ воды из трех скважин. Исследована взаимосвязь качества поверхностных и подземных вод. Выявлены антропогенные причины несоответствия подземных вод гигиеническим требованиям к качеству питьевой воды.

Ключевые слова: подземные воды, питьевая вода, физико-химические показатели качества воды, водоподготовка, перманганатная окисляемость, нитраты.

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