Ecological and chemical characteristics of well water in the Tobolsk district, Tyumen region

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Abstract. The paper presents the results of comprehensive research on wells in the Tobolsk District, Tyumen Region, Russia. The chemical composition of water consumed by the population was analyzed. Two indicators were found to exceed the limits established by hygienic standards: total ammonia (sum of free ammonia and ammonium ions) and total iron. The content of total ammonia in groundwater on the studied area is high, ranging from 2.01 to 2.58 (MAC = 1.5) mg/l. According to the tests, the water from most of the wells is ferruginous, since the MAC is exceeded in almost all water samples. The iron content varies from 0.12 to 1.25 (MAC = 0.3) mg/l. The water from the underground water supply generally meets hygienic requirements.

1 Introduction

The problem of drinking water quality has affected many aspects of human society throughout its history. In current conditions, water consumption is rising due to such factors as population growth, increasing industrial production, and the emergence of large urban areas. Consequently, fresh water is becoming a scarce natural resource at a fast pace. In addition to supplying a sufficient amount of water, it is particularly important to ensure environmental safety in the water management sector and protect sources of fresh water by limiting their chemical and microbiological pollution. In recent years, the composition of not only surface water, but also groundwater has changed significantly. In this regard, monitoring the quality of water at these socially significant facilities has become an urgent issue [1, 2].

The group of anthropogenic pollutants includes various chemicals. Some of them have a harmful effect on the human body, while others allow indirect assessment of water pollution with organic substances and thereby determine the degree of epidemiological risk of water [3].

The Tyumen Region has huge reserves of drinking water and groundwater, which are sufficiently protected from anthropogenic pollution. In terms of water supply, the Tobolsk District belongs to districts with sufficient fresh surface water reserves. However, due to the low quality of surface water, underground waters serve as the primary source for drinking and domestic needs [4].

According to the hydrogeological zoning map, the Tobolsk Region belongs to the West Siberian Hydrogeological Region and is confined to three hydrogeological structures of

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Order III: Eastern Cis-Ural (western and northern parts of the district to the Tobol River), Vasyugan-Kulunda (northeast of the region, north of the Irtysh River) and Ishim (southeast). All hydrogeological structures feature the development of artesian basins, in which formation waters are often confined to marine and terrigenous formations of different ages [5].

At present, the quality of water in the Irtysh River is classified as Category IV (polluted). The quality of water in the Tobol River at its confluence with the Irtysh River is classified as Category V (highly polluted). The level of water pollution in the Irtysh River is high due to the continuous discharge of untreated industrial and domestic wastewater in the territory of Kazakhstan, as well as regular and emergency discharges from treatment facilities in Omsk. The level of water pollution in the Tobol River is very high due to wastewater discharges from machine-building and metallurgical plants in Sverdlovsk, Chelyabinsk, and Kurgan regions, as well as the city of Tyumen [6].

There are about 700 water wells in the Tyumen Region. Some of the wells are self-flowing. All this leads to unhindered access of pollutants to groundwater.

According to numerous studies, the quality of drinking water in many areas of the Tobolsk District is unsatisfactory in terms of sanitary and chemical indicators. Worn-out water supply networks, unfavorable natural microelement composition of water sources, and insufficient water treatment contribute to this problem. Groundwater in the region was found to have high levels of Fe – from 1,400 to 6,500 μg/l.

The studies were conducted to check the compliance of drinking water from underground sources supplied through centralized cold water supply systems to settlements of the Tobolsk District with the current requirements [7].

2 Material and methods

Currently, most rural settlements of the Tobolsk District use underground water. Water samples were collected in the autumn season of 2022 according to general requirements.

Before taking samples from a well, water was drained for a long time. On average, three liters of water were drained for every ten meters of well depth. Before collecting water, a bottle was thoroughly rinsed several times with the test water. The bottle was filled to the brim. The quantitative chemical analysis of water was performed using methods described in [8].

3 Results

The Tobolsk District has 118 settlements grouped into 22 rural municipalities. The quality of drinking water was tested in 19 settlements. All sampling sites were located in the Tobolsk District, Tyumen Region, Russia: site No. 1 (N 57.402136, E 69.051715) the village of Belaya; No. 2 (N 58.340595, E 68.14434) the village of Korikova; No. 3 (N 58.942958, E 69.124922) the village of Usharova; No. 4 (N 58.200631, E 68.673029) the village of Zagvazdina; No. 5 (58.415708, 68.400100) the village of Malaya Zorkaltseva; No. 6 (57.495364, 69.214754) the village of Medyanki Tatarskie; No. 7 (57.655110, 69.155824) the village of Irtyshatskie Yurty; No. 8 (58.309925, 68.498630) the village of Chukmanka; No. 9 (58.016441, 68.152124) the village of Karachino; No. 10 (58.268643, 68.749459) the village of Oktyabrsky; No. 11 (57.834724, 67.978979) the village of Maslova; No. 12 (58.244369, 68.219193) the village of Savinsky Zaton; No. 13 (58.246030, 68.040034) the village of Usoltseva; No. 14 (57.772928, 67.842044) the village of Preobrazhenka; No. 15 (58.350131, 68.662810) the village of Rostosh; No. 16 (58.092958, 68.725531) the village of Epanchina; No. 17 (58.757312, 68.785845) the village of Nizhnie Aremzyany; No. 18

(58.291368, 68.079033) the village of Ovsyannikova; No. 19 (57.782405, 67.831240) the village of Sannikova (Fig. 1).

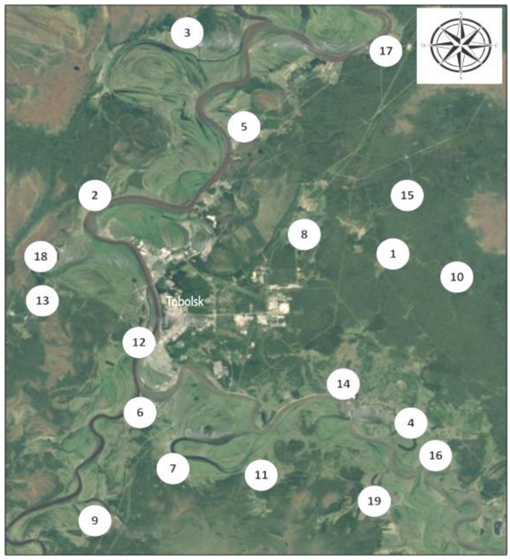

Fig. 1. Map - scheme of the studied areas (wells)

At all the sites, the water supply is sourced from wells. Their depth varies from 112 to 250 meters. The well water enters a storage tank and then, without additional treatment, it is supplied directly to the water supply network and reaches the consumers.

The following indicators were evaluated: total ammonia (sum of free ammonia and ammonium ions), and total iron.

Total ammonia in the well water is not allowed to exceed 1.5 mg/l. Total ammonia in groundwater on the studied area was found in high concentrations – 2.01-2.58 mg/l (the limit established by hygienic standards was exceeded by 8.6 times) The maximum values were observed for groundwater in the village of Chukmanka. Relatively high levels were noted at sites 17 < 11 < 15 < 3, 13 < 16 < 10. The concentrations at the sites were 1.54, 1.60, 1.62, 1.63, 1.64, and 1.79 mg/l, accordingly.

According to the experimental data, the concentration of ammonium ions in other areas ranges from 1.54 to 1.79 mg/l. Total ammonia does not exceed the limit at sites 8 < 2 < 5 < 14 < 1 < 18 < 12 < 9. The concentrations at the sites were 0.16, 0.36, 1.03, 1.28, 1.30, and 1.33, 1.40 mg/l, accordingly.

Ammonium compounds enter underground sources by themselves, without direct participation person, or rather with his indirect participation. Dissolved ammonia (ammonium ion) enters water bodies with surface and underground runoff, atmospheric precipitation, and wastewater. In water bodies, ammonia is also formed during the decomposition of nitrogen-containing organic substances.

Iron is one of the elements found in the highest concentrations in the well water of the Tobolsk District. Iron causes significant inconvenience to the population of the region both when using water for drinking and for industrial purposes. Thus, most of the tested wells feature a high content of iron, which greatly deteriorates their quality.

According to the tests, the water from most of the wells is ferruginous, since the MAC is exceeded in almost all water samples (MAC = 0.3 mg/l). The iron content varies from 0.12 to 1.25 mg/l. The established limit was found to be exceeded at 15 sampling points.

The largest values of the excess over the maximum allowable concentration for total iron in groundwater was found in the following settlements: the village of Sannikova (up to 1.25

mg/l), 4.17-fold excess; the village of Rostosh (up to 1.15 mg/l), 3.83-fold excess; the village of Epanchina (up to 0.89 mg/l), 2.97-fold excess; the village of Rostosh (up to 1.15 mg/l), 3.83-fold excess; the village of Ovsyannikova (up to 0.82 mg/l), 2.73-fold excess. In the villages of Medyanki Tatarskie, Maslova, Chukmanka, and Usharova, the concentration varies from 0.60 to 0.69 mg/l. Concentrations of 0.40 to 0.48 mg/l were recorded in the villages of Zagvazdina, Nizhnie Aremzyany, Irtyshatskie Yurty, Karachino, and Savinsky Zaton. No exceedance was detected in the villages of Belaya, Korikova, Malaya Zorkaltseva, and Preobrazhenka (from 0.12 to 0.29 mg/l). Iron migrates intensively in the groundwater of the Irtysh and Tobol rivers in concentrations exceeding the acceptable levels (Fig. 2).

These results are explained by the high content of humic substances of marsh and soil origin in the water of the Irtysh-Tobolsk basin. The high iron content is a common feature of wells in the Region. The sources of iron are swamp and peat bog waters, which form the basis of small rivers and streams in the studied area. Due to the fact that rivers are fed partly by underground runoff, chemical elements partly come from groundwater.

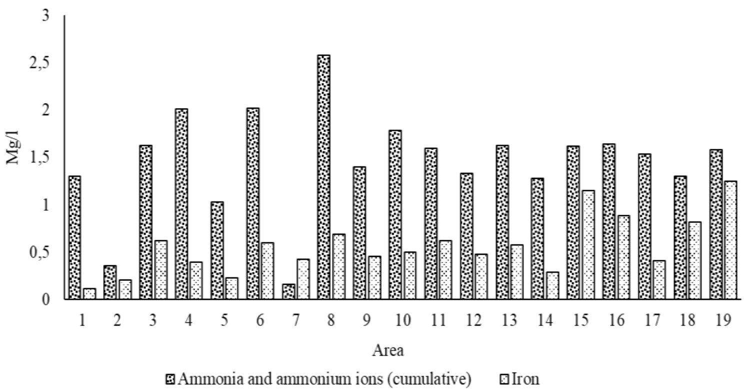

Fig. 2. Quantitative chemical analysis of underground water sources for domestic and drinking water supply at sites 1-19 (mg/l).

Total ammonia and total iron are unevenly distributed in the wells of the Tobolsk District. To assess the distribution of chemical components in the studied area, we constructed maps with isolines. The isoline is a contour line on a geographic map that determines a constant value for each point of the measured quantity. The distribution of isolines shows how values change across the surface. Isolines are lines that connect locations with equal values in a set of raster data which represents a continuous phenomenon, such as temperature or, in our case, the concentration of chemicals in wells. The distribution of isolines shows how the concentration of elements changes across the studied area. We used MapInfo (software for dealing with the Earth's surface). Concentrations of total ammonia and total iron are attached to each selected point on the map.

Total ammonia and total iron have similar distribution patterns, indicating that they are companion elements. Intense coloring was noted in areas with the maximum distribution of concentrations of ammonia and total iron, while slightly colored areas on the map indicate the minimum distribution of ammonia and iron concentrations. Isoline maps can be used to determine the expected concentrations of the studied compounds throughout the studied area and neighboring areas that were not included in the analysis (Fig. 3).

Elevated concentrations of iron, caused by various reasons, require new water treatment methods and techniques.

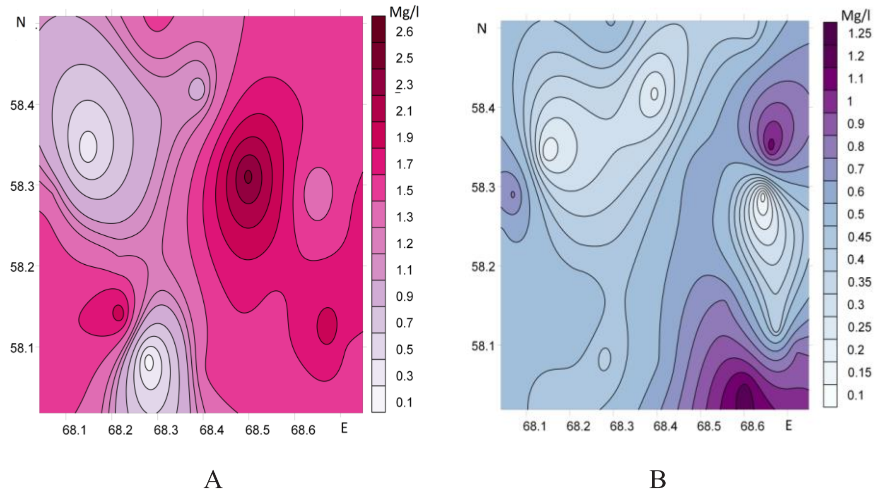

Fig. 3. Distribution of Total Ammonia (A) and Total Iron (B) in the studied areas.

4 Discussion

In terms of water supply, the Tobolsk District belongs to districts with sufficient surface freshwater reserves.

However, due to the low quality of surface water, underground waters serve as the primary source for drinking and domestic needs. According to literature data, groundwater is highly susceptible to domestic pollution due to runoff from residential areas, infiltration of polluted runoff, and leakage of sewage [10-12].

Elevated concentrations of iron have been established for many settlements in Tobolsk and Tobolsk District.

Many researchers have noted that the content of total iron in groundwater increases [13-18].

The average values in the southern taiga and subtaiga regions are 5.25 mg/l, while the maximum values can reach 12.56 mg/l. When the iron concentration exceeds 0.3 mg/l, water causes rusty streaks on plumbing fixtures and stains on laundry. When the iron content exceeds 1 mg/l, water becomes cloudy, turns yellow and brown, and acquires a specific metallic taste. All this makes such water practically unsuitable for domestic and drinking purposes.

5 Conclusion

The chemical composition of water consumed by the population was analyzed. Two indicators were found to exceed the limits established by hygienic standards: total ammonia and total iron.

Considering these factors, the distribution of chemical components on the studied area can be predicted using isolines. Key markers of pollutants should be given special attention. Annual monitoring of the groundwater status should be conducted.

In view of the above factors, a methodological approach should be developed to address the protection of groundwater. A groundwater treatment system with modular drinking water treatment plants should be set up to treat water to drinking quality.

The next objective is to purify well water using a variety of treatment methods and conduct a comprehensive analysis of water in specialized laboratories.

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