Assessment of the quality of spring waters in Novgorod region and the risk of its use

I A Kuzmina and I V Letenkova

Yaroslav-the-Wise Novgorod State University, 41, ul. B. St. Peterburgskaya, Veliky Novgorod, Russian Federation

E-mail: irina-nov@mail.ru

Abstract. The article analyzes the quality of spring water in Novgorod region. There is a difference in water quality by district, in some areas there is a discrepancy with sanitary and hygienic indicators in terms of color, hardness, permanganate oxidizability and manganese content.

1. Introduction

The springs are unique natural hydrological objects of scientific, cultural and historical value, are natural monuments. It is widely believed that water in springs, subject to natural filtration, is potable. However, at present, the quality of groundwater, including springs, is deteriorating due to anthropogenic impact on the environment [1–8].

Until recently, water was considered an inexhaustible natural resource. It was believed that it was possible to use water from any sources and in any volume. However, a shortage of fresh water is currently observed all over the planet. The tense situation in supplying people with fresh water is not so much a shortage of water resources as a powerful increase in their pollution in the course of human activities.

For water supply of settlements, surface and underground sources are used. The share of groundwater in the water supply of the population of the Russian Federation is 43% [9]. In Novgorod region, the share of underground sources in the total balance of water consumption varies widely from 9 to 51%. In more than half of the districts, only groundwater is the source of drinking water.

In four districts (Demyansky, Soletsky, Khvoyninsky and Shimsky) the contribution of underground sources to the consumption of drinking water is 95-98% [10].

The rural population mainly uses water from non-centralized water supply sources (wells and springs) for drinking purposes. However, in 2018 in Novgorod region, 35.4% of water samples taken from sources in this category did not meet the requirements of hygienic standards for chemical composition [11].

Information on the ecological state of the springs in Novgorod region is very scattered, so the subject of the study is the generalization and analysis of the quality of water from the sources of Batetsky, Malovishersky, Soletsky, Starorussky, Khvoyninsky and Shimsky districts of Novgorod region according to chemical indicators.

The purpose of this work is to assess the quality of spring waters in Novgorod region and the risk of its use for drinking water supply based on chemical analysis data.
2. Objects and methods of research
At the Department of Chemistry and the Department of Ecology and Nature Management of NovSU, studies of the ecological state of spring waters of the region have been carried out for two years. At the moment, the sources of six districts are examined – Batetskiy, Starorussky, Soletsky, Shimsky, and Khvoininsky. In this paper, we analyze the chemical indicators of water quality of the examined sources.

3. Results and discussion
According to the organoleptic indicators of spring water, Batetsky and Malovishersky districts stand out from the other districts: in almost all springs, the color exceeds the MPC. This may be due to infiltration water recharge or external arrangement of the source.

![Graph](image)

**Figure 1.** Groundwater color values.

Groundwater color values are not exceeded in the spring waters of Soletsky, Starorussky, Khvoininsky and Shimsky districts [12].

The smell of groundwater in the studied areas is very weak or completely absent.

In the studied areas, according to hydrochemical indicators, spring water meets the requirements of sanitary and hygienic standards, with the exception of groundwater in Batetsky district, where the hardness exceeds the maximum permissible concentration.

From figure 2 it follows that in Batetsky district spring waters are hard (hardness> 8.0 mmol-equiv/dm³ and exceeds the permissible value equal to 7.0 mmol-equiv/dm³ [12]). In Malovishersky, Soletsky, Starorussky and Shimsky districts, the water of the examined sources is characterized by medium hardness (4.0-7.0 mmol-equiv/dm³), which can be explained by the occurrence of groundwater in limestone deposits. The spring waters of Khvoininsky region belong to soft waters (hardness is 1.5-4 mmol-equiv/dm³).

The waters of all the examined springs have a reaction close to neutral: the pH varies from 7.28 to 8.17.
By the value of mineralization, the underground waters of Batetsky, Starorussky, Khvoyninsky, Shimsky and Malovishersky districts can be attributed to fresh water with a salinity of up to 1.0 g/dm$^3$ and suitable for drinking [12]. Such weakly mineralized waters are used for medicinal and drinking purposes. In Soletsky district (figure 3), in almost all sources, water is not suitable for drinking, since mineralization values exceed the established norm. Such waters are called brackish, with a salinity of 1.0 to 10.0 g/dm$^3$.

In accordance with regulatory documents, the permanganate oxidation of spring waters, which characterizes the content of dissolved organic substances, is within normal limits in all districts except Shimsky.

Figure 4 shows that permanganate oxidation was exceeded by 3.52 times in the spring waters of Shimsky district [12]. This can be explained by the fact that groundwater in this area is located in a lowland where rainfall and water accumulate during floods.
Groundwater is more prone to nitrate contamination than surface water due to the lack of microorganisms that can use them as a substrate [13]. From Figure 5 it follows that in Shimsky district the concentration of nitrate ions is higher, which may indicate a long-term pollution of sources with nitrogen-containing substances and the complete oxidation of these substances. However, in none of the districts do the concentrations of nitrate ions in the waters of the examined sources exceed the MPC [12].

Concentrations of heavy metal ions in spring waters, in general, do not exceed permissible norms, with the exception of manganese compounds. The concentration of copper (Cu\(^{2+}\)), lead (Pb\(^{2+}\)) and cadmium (Cd\(^{2+}\)) in most springs is below the detection limit.

Of heavy metals, a common indicator for comparing the degree of pollution of spring waters of six regions is the content of manganese compounds (Mn\(_{\text{total}}\)). From Figure 6, we can conclude that the concentration of manganese in groundwater is high in Soletsky and Shimsky districts. Moreover, in Shimsky district, the concentration of manganese compounds exceeds the permissible norms [12]. The increased content of manganese compounds in drinking water has a negative effect on the central nervous system, blood formation organs, and excretory system [14].
To assess the degree of groundwater pollution, the pollution index was calculated:

\[ I = \frac{\sum_{i=1}^{n} C_i}{MPC_i}, \]

where \( C_i \) is the concentration of pollutants; 
\( MPC_i \) - maximum permissible concentration of pollutants.

Based on the results obtained, a gradation of groundwater pollution was created:

I degree of pollution: water having a degree of pollution \( I < 4 \), is recommended for use; II degree of pollution: water having a degree of pollution \( I = 5 - 7 \), satisfactory; III degree of pollution: water having a degree of pollution \( I > 7 \), is not recommended for use.

| District   | Pollutant index | Pollution degree |
|------------|-----------------|-----------------|
| Batetsky   | 5.58            | II              |
| Malovishersky | 3.9            | I               |
| Starorussky | 3.86           | I               |
| Soletsy   | 6.92            | II              |
| Shimsky   | 7.80            | III             |
| Khvoininsky | 2.06           | I               |

Based on the assessment of the degree of pollution of underground spring water, a map was compiled characterizing the degree of pollution of groundwater in Novgorod region by hydrochemical indicators.

To assess the risk of drinking test water, the \( HQ \) hazard index (from the words Hazard Quotient) was determined, which shows how many times the average daily dose of a toxicant exceeds the threshold dose rate. Hazard index was calculated by the formula [15, 16]:

\[ HQ = \frac{m}{H_D} \]

where \( H_D \) is the threshold dose rate, the value of which for Mn is 0.14 [15]; \( m \) is the average daily dose of the toxicant.

A health threat exists if the hazard index assumes a value greater than \( HQ > 1 \), and the health hazard is all the more significant the more the \( HQ \) index exceeds one.
The daily average dose of the toxicant was calculated using the equation [15]:

\[ m = \frac{C \times v \times f \times T_p}{P \times T} \]

where \( C \) is the concentration of the toxicant in drinking water, mg/dm\(^3\); \( v \) is the rate of flow of water into the human body, dm\(^3\)/day; \( f \) is the number of days in a year during which a toxicant is exposed; \( T_p \) is the number of years during which the tested drinking water is consumed; \( P \) is the average mass of an adult, kg; \( T \) is the average exposure time of a toxicant (or the average duration of a possible exposure to a toxicant over a person’s life).

In the calculation, it was assumed that an adult consumes 2 dm\(^3\) of water per day. Average life expectancy in Novgorod region is 70.5 years, the average duration of the expected exposure to the toxicant is 30 years (10,950 days).

We will carry out an assessment based on data on average concentrations of manganese compounds, since their content is the main indicator in excess of the MPC.

**Table 2.** Hazard index for the districts of Novgorod region.

| Districts     | Batetsky | Malovishersky | Soletsky | Starorussky | Khvoininsky | Shimsky |
|---------------|----------|---------------|----------|-------------|-------------|---------|
| C(Mn), mg/dm\(^3\) | 0.0046   | 0.05982       | 0.0964   | 0.0501      | 0.0206      | 0.1035  |
| m             | 0.00030  | 0.00402       | 0.00647  | 0.00336     | 0.00138     | 0.00695 |
| HQ            | 0.00220  | 0.02869       | 0.04623  | 0.02403     | 0.00990     | 0.04964 |

Thus, in the spring waters of Batetsky, Malovishersky, Soletsky and Shimsky districts, color, hardness, mineralization, permanganate oxidizability and concentration of manganese compounds in some cases exceeded the established norms.
A technique was applied, thanks to which groundwater was ranked by degree of pollution. Based on the data obtained, a map of the gradation of the districts according to the degree of pollution of underground (spring) waters in Novgorod region was created.

There are three districts in the territory of which the examined sources had the least pollution: Malovishersky, Starorussky and Khvoininsky.

Even with the use of spring water with a high content of manganese compounds throughout life, there is no risk to health.

References
[1] Kon’shina L G 2016 Assessment of water quality of sources of decentralized water supply of Yekaterinburg and its environs Hygiene and Sanitation 95 (5) 413–16
[2] Akhmedenov K M 2015 Complex characteristics of the springs of Western Kazakhstan Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences 2 69–83
[3] Lukashevich O D and Chernyshova N A 2018 Water safety in the springs of the city of Tomsk XXI century Technosphere Safety 3 2 (10) 81–95 DOI: 10.21285/2500-1582-2018-2-81-97
[4] Alekseev S V, Alekseeva L P, Sholokhov P A, Orgilyanov A I and Kononov A M 2018 Groundwater and surface water quality in the area of the village Listvyanka (south-west coast of Lake Baikal) Geography and Natural Resources 4 105–114
[5] Shershnov O V 2017 Technogenic hydrogeochemical anomalies within the influence area of industrial chemical dumps Journal of the Belarusian State University. Geography and Geology 1 130–36
[6] Ahmad S, Singh N and Mazhar S 2020 Hydrochemical characteristics of the groundwater in Trans-Yamuna Alluvial aquifer, Palwal District, Haryana, India Applied Water Science 10 75 DOI: 10.1007/s13201-020-1150-2
[7] Kumari M and Rai S C 2020 Hydrogeochemical evaluation of groundwater quality for drinking and irrigation purposes using water quality index in semiarid region of India Journal of Geological Society of India 95 159–68 DOI: 10.1007/ s12594-020-1407-4
[8] Madhav S, Ahmad A, Kumar A, Kushawaha J, Singh P and Mishra P K 2018 Geochemical assessment of groundwater quality for its suitability for drinking and irrigation purpose in rural areas of Sant Ravidas Nagar (Bhadoli) Geology, Ecology, and Landscapes 2 127–36
[9] Modern Groundwater and Surface Water Resources of the European Part of Russia: Formation, Distribution, Use 2015 ed R G Dzhamalov and N L Frolova (Moscow: GEOS) p 320
[10] Ostroumova S A and Vasina G G 2010 Informational bulletin on the state of subsurface resources in Novgorod Region of the Russian Federation for 2009 Archive of the State Unitary Enterprise PKGE MPR RF (St. Petersburg) 15 p 60
[11] Overview of the state and environmental protection of Novgorod region in 2018 2019 Reference publication (Veliky Novgorod)
[12] Hygienic requirements for water quality of non-centralized water supply. Sanitary protection of sources. Sanitary and epidemiological rules and regulations of SanPiN 2.1.4.1175-02 2003 (Moscow)
[13] Kuznetsova T A 2016 The influence of spring water on the state of public health (on the example of the Baryshsky district of the Ulyanovsk region) Ulyanovsk Medical and Biological Journal 1 158–67
[14] Mazunina D L 2015 Negative effects of manganese in chronic intake with drinking water Human Ecology 3 25–31
[15] Kammen D M, Hassenzahl D M 1999 Should We Risk It? Exploring Environmental, Health, and Technological Problem Solving (Princeton: Princeton University Press)
[16] Akoto O, Teku J A and Gasinu D 2019 Chemical characteristics and health hazards of heavy metals in shallow groundwater: case study Anloga community, Volta Region, Ghana *Applied Water Science* 9 36 DOI: 10.1007/s13201-019-0914-z