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Public Environmental Monitoring of Drinking Water Quality in Norilsk, Russia

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ABSTRACT

Aims Water quality is understood as the totality of its properties due to the nature and concentration of impurities in the water. Providing quality drinking water to citizens has become one of the most significant social problems and the most important factor of national security. The purpose of this study was to analyze the quality of drinking water in the city of Norilsk.

Materials & Methods During the experiment, a team of researchers took samples of drinking water from the water supply network in various districts of the Norilsk industrial region (without preliminary draining and after 5 minutes of draining) and studied the dependence of the quality characteristics of water on the location and sampling method.

Findings In terms of organoleptic indicators, drinking water in all Norilsk industrial region areas complies with the requirements of Sanitary Rules and Regulations and GOST. Sampling from three control points in the Norilsk industrial region showed that the water is soft, and its salt content is mainly due to hardness salts.

Conclusion The presence of microorganisms in the water supply network of the Norilsk industrial region is not significant, and the permanganate oxidizability indicator does not exceed the requirements of Sanitary Rules and Regulations.

Keywords Ecological Parameter Monitoring; Industry; Water Supply; Public Facilities

CITATION LINKS

[1] Water supply lessons in Russia [2] Computational fluid dynamics modeling alternatives for UV-initiated advanced oxidation processes [3] New approaches in biological wastewater treatment aimed at removal of organic matter and nutrients [4] Flow intake control using dry-weather forecast [5] Evolution of urban black and odorous water: The characteristics of microbial community and driving-factors [6] "Provision of the population of Russia with drinking water" [7] Prelocalization and leak detection in drinking water distribution networks using modeling-based algorithms: A case study for the city of Casablanca (Morocco) [8] Consumption of safe drinking water in Pakistan: Its dimensions and determinants [9] On the state of water supply in populated areas of the Sverdlovsk region [10] Surface-water purification using cellulose paper impregnated with silver nanoparticles [11] Thermal regime of river water as a response to climatic processes in the Upper Don drainage basin [12] Can terminal settling velocity and drag of natural particles in water ever be predicted accurately [13] Aggregated methodology of multicriterion economic and ecological examination of the ecologically oriented investment projects [14] Comparative analysis on the effectiveness of various filtration methods on the potability of water [15] Membrane fouling remediation in ultrafiltration of latex contaminated wastewater [16] Drinking water: Assessing and managing risk [17] Computational fluid dynamics simulation and parametric study of an open channel ultra-violet wastewater disinfection reactor [18] Quality of drinking water for cows and their health [19] Sanitation and food hygiene [20] Improving the quality of soft waters [21] Chemistry and microbiology of water [22] Variability of biological traits and fish capacity groups of three years old Russian sturgeons hatched in ponds [23] Some theoretical and practical issues of medical geographical research [24] Prediction of chameleonic efficiency [25] Development of legal norms on biodiversity protection reflecting EU trends [26] Environmental taxes as a condition of business responsibility in the conditions of sustainable development [27] Study of the salinity of drinking water

Introduction

According to UN estimates, the shortage of safe drinking water can become one of the most acute and pressing problems. The specificity of this problem for Russia is not a shortage of water resources but their pollution and ongoing degradation of water bodies. Water quality is understood as the totality of its properties due to the nature and concentration of impurities in the water. The supply of drinking water with guaranteed quality for Russian citizens has become one of the most socially significant problems and the most important factor in the national security of this country [1, 2]. Over 10 million people in Russia do not have access to quality drinking water, and 60 percent of the country's population drinks from contaminated wells. The poor water quality is due to companies have dumped dangerous chemicals into rivers and lakes, and these pollutants are inevitably absorbed into the human body through water and food. The percentage of purified wastewater from businesses, residences, and public facilities are pretty low, and those facilities constitute 90% of the total pollution sources. [3]. Waterborne illness as a result of such pollution behaviors contributes to the death of more than 3 million people every year – more deaths than those a war cause. Traditional water purification methods include ozonation, chlorination, UV treatment, ultrafiltration, and electrolysis [4]. The use of chlorine and ozone is dangerous because they are poisonous substances, and ultraviolet light is inefficient because it purifies water only near the source [5]. The effectiveness of a country's solutions directly affects citizens' health and determines the degree of environmental safety in several regions of the country, and sometimes contributes to the emergence of social tension in them [6, 7]. Experts predict that if access to quality drinking water does not improve, the demand for water supply by 2025 will exceed more than 50% of the global supply [5]. The effectiveness of a treatment facility can be measured by the ratio of treated effluent to standard quality as a percentage of the total volume of treated water. For Russia as a whole, this Diagram is only 19 percent due to congestion or lack of treatment plants in several federal districts and most constituent entities of the Russian Federation due to low efficiency and deterioration of conditions of treatment facilities [3].

Providing high-quality drinking water to the population in industrial cities is a serious scientific and practical task. On the one hand, the requirements for the quality of drinking water directed to the centralized water supply are stricter than ever, and on the other hand, existing technologies cannot always cope with the task due to various factors: natural, environmental and technological, as well as the state of water supply networks [8]. Operating public utilities shows that the violations of the normal level of water supply and environmental safety of consumers are mainly associated with accidents at pipeline sections - the most functionally significant and vulnerable elements of the life support systems in the regions [9, 10].

Drinking water enters the water supply system - in which the biological, organoleptic, and toxic indicators and chemical substances are within the limits of the drinking water supply [11, 12]. The quality of drinking water supplied by centralized water supply systems must comply with Sanitary Rules and Regulations 2.1.4.1074-01 "Drinking water; Hygienic requirements for water quality of centralized drinking water supply systems; Quality control; Hygienic requirements for ensuring the safety of hot water supply systems" [13-17].

This study aimed to analyze the quality of drinking water in Norilsk as the only tool for monitoring its conditions and properties.

Materials and Methods

In this experimental study, a team of researchers took drinking water samples from the water supply network of various districts of the Norilsk industrial region (without preliminary draining and after 5 minutes of draining) and studied the dependence of the quality characteristics of water on the location and sampling method.

Colour determination: During the experiment, the color of the water was determined photometrically - by comparing samples of the test water with solutions imitating the color of natural water.

Equipment, materials, reagents used for testing: Nalsa Medical Smart Digital Photo Colorimeter instrument with 400-700nm (Nalsa Medical; India); wavelength range filters, digital wavelength 405-630nm, latest LED-based indication, photodiode photocell, 12.5mm round chamber, silicon photodiode detector and a blue filter (413nm); sample cells with a thickness of the light-absorbing layer of 5-10cm; volumetric flasks with a capacity of $1000cm^3$; volumetric pipettes with a capacity of 1, 5, $10cm^3$ with divisions of $0.1cm^3$; potassium dichromate; cobalt sulfate; sulphuric acid, density $1.84g/cm^3$; distilled water; membrane filters

A set of Nessler tubes with a capacity of $100cm^3$ was used to prepare the color scale. In each tube, solutions No. 1 and No. 2 in the ratio indicated on the color scale:

No. 1) Dissolve in distilled water and bring the volume of the solution to $1dm^3$ (0.0875g of potassium dichromate ($K_2Cr_2O_7$), 2g of cobalt sulfate ($CoSO_4 \cdot 7H_2O$), and 1 cm^3 of sulphuric acid (density $1.84g/cm^3$)

No. 2) In a flask with a capacity of $1dm^3$, place $1cm^3$ of concentrated sulfuric acid with a density of $1.84g/cm^3$ and bring it to 1 dm^3 with distilled water.

The solution in each tube corresponds to a certain degree of color. The color scale must be stored in a dark place and replaced every 2-3 months. The calibration graph is built on the color scale. The obtained values of optical densities and the corresponding degrees of color are plotted on the graph. When determining the color with a photocolorimeter, sample cells with a thickness of a light-absorbing layer of 5-10cm were used. The control liquid is distilled water, from which suspended substances were removed by filtration through membrane filters. The optical density of the filtrate of the investigated water sample was measured in the blue part of the spectrum with a light filter at 413nm. The color degree was determined by a calibration chart and expressed in degrees of color.

Determining the pH: There are several methods for determining the pH value of solutions. The pH value is estimated using indicators, accurately measured with a pH meter, or determined analytically by conducting an acid-base titration.

Necessary equipment and reagents: pH meter I-160MI, measuring combined electrode 7MA8500-8FF (LZY027Ch1138), a beaker with a capacity of 50cm^3

An aliquot of the test water and a measuring electrode was placed in a beaker. The readings were taken after 5 minutes.

Salinity determination: The electrometric method for determining the salinity is based on measuring the relative electrical conductivity of water using a special device - a conductometer, which makes it possible to accelerate and increase the determination accuracy compared to other methods. The principle of operation of the conductometer is based on the direct dependence of the electrical conductivity of water (current strength in a constant electric field created by the electrodes of the device) on the number of compounds dissolved in water. A wide range of appropriate equipment now allows measuring the conductivity of almost any water, from ultrapure (very low conductivity) to saturated with chemical compounds (high conductivity) [18].

Equipment and reagents used: TDS hold conductometer, 25cm^3 beaker

To determine the salinity of water, a conductometer was placed in a beaker with a test sample, and the readings were taken after a sound signal.

Determination of the total water hardness: The following equipment and reagents were used to determine the total water hardness: burette with the volume of 25cm^3, stand, ammonium buffer mixture (NH_4OH + NH_4Cl) with pH of 8-9, complexone (Trilon B) with 0.1 N, eriochrome black (sugar mixture 1 g indicator + 99 g sodium chloride), conical flasks with a capacity of 250cm^3, measuring cylinders for 100cm^3, 10cm^3.

A sample of 100cm^3 was placed in a conical flask, then 10cm^3 of an ammonium buffer mixture, 10-20mg of eriochrome black were added, mixed, and titrated with a Trilon B solution until the color of the solution changed from wine red to blue. The total stiffness was calculated using formula (Equation 1):

$$dH = \frac{V \times C \times 1000}{W} mmol - \frac{eq}{dm^3} \quad (1)$$

Where: V – the volume of 0.1 N of Trilon B solution used for titration, C – concentration of Trilon B solution (0.1 N), W – aliquot part of the sample, cm^3.

According to the Sanitary Rules and Regulations, the degree of acid-base indicators, determined by the concentration of hydrogen ions, forms the pH parameters, which are normally 6-9 units for drinking water, according to the Sanitary Rules and Regulations [19-25]. In terms of this indicator, Russian standards are almost the same as the EU directive - 6.50-9.50 and from the US Environmental Protection Agency (USEPA) - 6.50-8.50.

Oxidability: Oxidability is a value that characterizes the content of organic and mineral substances in water, oxidized (under certain conditions) by one of the strong chemical oxidants. This indicator reflects the total concentration of organic matter in the water. The nature of organic substances can be very different - humic acids of soils, complex organic matter of plants, and chemical compounds of anthropogenic origin. Other methods are used to identify specific compounds. Permanganate oxidisability is a measure of the total amount of organic matter in the water. It does not show exactly which substances are present but shows how many are in total.

Permanganate oxidizability in water is based on the oxidation of organic and inorganic substances, present in a water sample, a known amount of potassium permanganate is added into a sulfuric acid medium with boiling for 10 minutes. Not included in the reaction potassium permanganate is reduced with oxalic acid or salt oxalic acid (e.g. potassium oxalate). Excess oxalic acid (oxalate ion) is titrated with a solution of potassium permanganate

The obtained data were statistically processed at p=95%, and the confidence interval was determined as 6.5±0.8.

Findings

The average pH of drinking water in all regions of the NIR was following the Sanitary Rules and Regulations requirements and is equal to 6.5 (Table 1).

The lowest pH value (6.1) was related to the water of the 4th micro-district of the Talnakh district. Slightly higher, the pH was 6.2 in the 3rd micro-district and Rudnaya street of Talnakh district, Metallurgov Square - Tsentralny district. The highest pH value was 6.5, observed in the Oganer and Tsentralny districts. The pH values remained almost unchanged after draining (Diagram 1, a).

Water hardness is caused by positive ions Ca^{2+} and Mg^{2+} and negative bicarbonate ions (HCO_3^-). The average hardness value did not depend on whether the sample was taken immediately or after a 5-minute drain and was equal to 1.47 to 1.68, depending on the area. Since the NIR is located in the permafrost region, the water used for drinking purposes was soft. Differences in this indicator in the NIR districts were 0.3mmol/L.

The harder water in the Tsentralny district and the softer water in the Oganer district, with the average hardness in the Talnakh district. After draining, the hardness indicators changed slightly. These minor fluctuations were associated with different water sources (Diagram 1, b).

The salinity index corresponds to the stiffness index. Before draining, the total salt content was 107mg/L in Talnakh and Oganer districts and 121mg/L in the Tsentralny district. After draining in Talnakh and Oganer districts, the indicator did not change; in the Tsentralny district, it decreased by 2mg/L. Comparing the data on hardness and salt content, it can be concluded that the salt content is mainly conditioned by hardness salts. The highest indicators of salinity were noted in the Tsentralny district (Diagram 1, c).

The values of permanganate oxidisability in tap water were in the range from 2.7 to 6.12mgO/L, depending on the area in which the sample was taken. These values did not exceed the requirements of Sanitary Rules and Regulations. Higher rates were noted in the Tsentralny district: Molodezhny passway (6.12mgO/L and 4.19mgO/L) and in the Talnakh district: Rudnaya street (5.2mgO/L and 4.7mgO/L). This indicates the presence of microorganisms in water pipes due to the long-term operation of water supply systems in apartment buildings. Before draining, water had higher permanganate oxidisability than after. This can be explained by the fact that some of the microorganisms in the water pipes are washed off by the water flow and are also killed by chlorine (Diagram 1, c).

Table 1) Water quality characteristics at the sampling site

Samples	**Hardness** (mmol/L)	**pH**	**Salinity** (mg/L)
Before draining			
Talnakh	1.53	6.5	107
Tsentralny	1.68	6.5	121
Oraner	1.47	6.5	107
After draining			
Talnakh	1.50	6.5	107
Tsentralny	1.68	6.5	119
Oraner	1.50	6.5	107

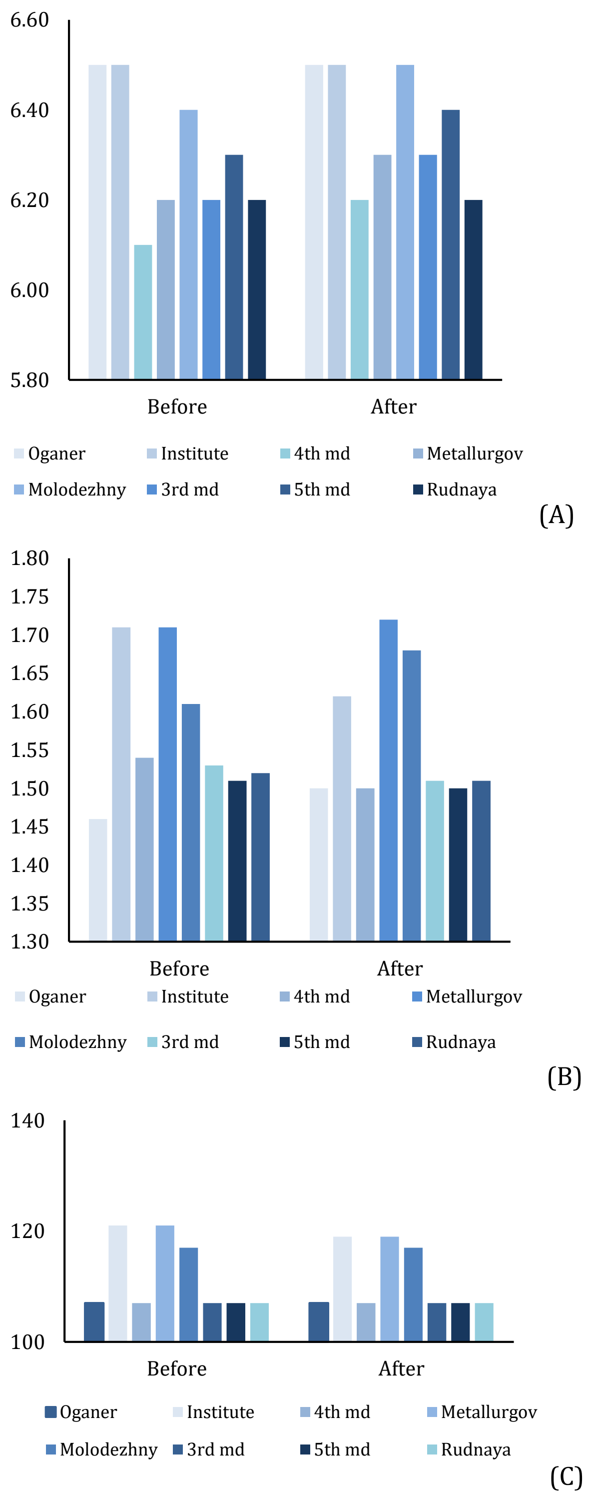

Diagram 1) Dependence of pH (a), Hardness (mmol/L) (b), Salinity (mg/L) (c) of drinking water on the sampling location

Discussion

The following rivers are used to supply drinking water to the city of Norilsk: Norilskaya and Ergalakh for the Central and Oganer districts, Hayerlach for the Talnakh district, and Ambarnaya for the Kayerkan district. Before entering the water supply network, water is treated at the treatment facilities of Norilsk and the Oganer residential area. This study aimed to sample water from three districts of Norilsk: Tsentralny, Talnakh, and Ograner districts. Samples were taken after a five-minute drain and without it. Two samples were taken from one site to prove or disprove the recommendation to drain water before drinking to improve its quality.

Drinking water must have good organoleptic properties, i.e., be transparent, colorless, tasteless, and odorless, at a refreshing temperature, and free of visible impurities [26].

Turbidity is a simple and irrefutable indicator of a change in water quality. A sudden change in turbidity may indicate an additional source of contamination (biological, organic, or inorganic) or signal problems in the water treatment process. An important indicator of the quality of water used for almost any purpose is the presence of mechanical impurities - suspended solids, solid particles of silt, clay, algae, and other microorganisms, and other small particles. The permissible amount of suspended solids, as well as their probable content, are very different. Particulate matter suspended in water interferes with the passage of light through the water sample and creates a quantitative characteristic of the water called turbidity. Turbidity can be viewed as a measure of the relative clarity of water [27].

The data in Table 1 shows that the turbidity of tap water is lower than the normalized indicator (2.6) in all districts of the Norilsk industrial region (hereinafter - NIR). This is because the tests were carried out in the winter. Turbidity of water increases with rains, floods, and melting of glaciers. It should be noted that the intakes in the Norilsk Industrial Zone are organized in such a way that even during the flood period, the water entering the treatment plant has a minimum amount of suspended solids.

Colour degree can be associated with dissolved salts, organic compounds, and iron ions in the water. A high color index (350 on the color scale) indicates high water contamination by foreign impurities and cannot be used for drinking purposes. It can be seen that regardless of sampling, the color of drinking water is 5 points. Visually, water is characterized by the indicator "colorless". This indicates that no contaminants that give color to the water have been found in drinking water. In addition, the presence of iron ions, which appear as a result of corrosion of water supply networks, affects the color of the water. Iron (II) ions can color water greenish, and iron (III) ions give water a brownish tint. The lack of color in drinking water indicates a good condition of the water supply networks in the areas under investigation.

The smell of water can be caused by both natural compounds and chemical ones. For disinfection at water treatment plants, water from the water intake is chlorinated. During the passage of a portion of water from the wastewater treatment plant to the consumer, chlorine must evaporate, and the residual should be zero. It can be seen that drinking water sampled in the Tsentralny district has the odor of chlorine. No chlorine odor was detected in samples taken in other areas of the NIR.

Drinking water should have a pleasant, refreshing taste without any foreign aftertaste. If some kind of aftertaste is present, this may indicate an increased presence of salt and some minerals in the water. In addition, chlorinated water also has its flavor, which vanishes by the weathering of chlorine. The taste of water depends on the mineral composition of the water, its temperature, and dissolved gases.

The temperature regime of cold water in the tap is not regulated by GOST (Gosudarstvennyy Standart); however, these indicators directly depend on the season. This feature is associated with the temperature of the water at the source of the water intake and the temperature indicators of the soil at the level of water conduct. The optimal drinking water temperature for the physiological needs of a person is 8-15°C. Water temperature in all NIR areas is between 15-17°C. Such water quenches thirst well. After 5 minutes of draining the water, the temperature drops by 1°C. Lowering the temperature of drinking water by 1-2°C improves its taste perception. Thus, to improve the organoleptic properties of water, it should be drained from the tap for 5-10 minutes.

The present study is limited due to the number of taking water samples, and the season during which the experiment was carried out. In future studies, the authors suggest widening the seasonal gap and presenting more water samples for the analysis.

Conclusion

In terms of organoleptic indicators, drinking water in all areas of the Norilsk industrial region meets the requirements of Sanitary Rules and Regulations and GOST. By sampling from three NIR control points, it has been proven that the water is soft, and its salt content is mainly due to hard salts. The theory that five-minute drainage of water affects indicators such as pH, hardness, and salt content was also experimentally rejected. In addition, the presence of microorganisms in the NIR water supply network is not significant; the permanganate oxidation index does not exceed the requirements of health laws and regulations.

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