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Assessment of the Open Water State in Water Use Point of the Population the Murmansk Region

Marina Litvinova[1], Ekaterina Obukhova[2], and Anna Malaeva[3]

[1]Department of Microbiology and Biochemistry, Murmansk State Technical University, Murmansk, Russian Federation
[2]MUE Murmanskvodokanal, Russian Federation
[3]Department of Foreign Languages, Murmansk State Technical University, Murmansk, Russian Federation

Abstract

The study of the ecological situation in lake basins, including the assessment of water pollution, has become relevant recently, since the quality of drinking water depends on the quality of surface water bodies. The paper reflects the main results of water quality assessment of Lower Vaengskoye Lake in the Murmansk Region in the period 2016--2017. Hydro-chemical studies included the following indicators: biochemical consumption of oxygen, mass content of ammonium, nitrites, nitrates, sulfates, iron, coloration and hardness of water, permanganate oxidation. Natural factors are decisive contributors to the chemical composition of water. The sanitary status of the lake was assessed using the methods of microbiological analysis of water from the surface sources of water use. According to the microbiological indicators in the studies, water meets the requirements of hygienic standards. According to sanitary-chemical indicators, there is a variance with the requirements of hygienic standards in 10% of all the studies conducted, namely in terms of coloration, permanganate oxidation, and iron. On the whole, the quality of the lake's water during the period of the study was assessed by the value of the integral hydro-chemical index as ``pure'' water (by the value of WPI). The results of the tests make it possible to conclude that the degree of the anthropogenic burden on the reservoir studied is insignificant.

Keywords: open water bodies, microorganisms, monitoring, water pollution index.

Corresponding Author:
Marina Litvinova
mlit1@rambler.ru

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1. Introduction

Nowadays the deterioration of the quality of natural water and the state of water systems resulted from the increased anthropogenic activity is an urgent problem. The accumulation and dispersal of substances of human-induced nature throughout the planet have also affected freshwater ecosystems, significantly changing the water quality over the past decades [1]. The Murmansk region possesses vast reserves of water resources; however, the existing problems of the sanitary condition of drinking water

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supply sources are still urgent. Regular monitoring of the chemical and microbiological composition of water masses will allow assessing the state of the reservoir and the intensity of its self-cleaning processes. The objective of the study is to assess the sanitary-hygienic condition of the lake based on microbiological and hydro-chemical indicators. Only a comprehensive analysis of the condition of water bodies will reliably assess their state and design the approaches to their restoration.

2. Methods and Equipment

2.1. Methods

The object of the study is Lower Vaengskoye Lake. It belongs to the basin of the Kola Peninsula Rivers flowing into the Barents Sea, the lake flows into the Vaenga River; the area ofthe reservoir is 1.6 km ^{2}. It has a predominantly elongated shape in the meridian direction. The lake of tectonic origin lies in the basin has a complex configuration of the coastline and an elongated shape, uneven bottom topography [2]. Complete usually sets in October; Ice breakup occurs in mid-May. The lake water is clean, has a low degree of mineralization and a low content of nutrients. The lake belongs to surface water bodies of general usage, they are utilized for drinking and municipal water supply [3].

The monitoring of sanitary and microbiological indicators of lake water repeated monthly from 2016 to 2017, the samples of the surface water were collected in sterile containers, volume 500 ml [4]. Microbiological tests were done in the laboratory immediately after sampling. The water quality of the lake was assessed according to the sanitary-microbiological parameters: total coliform bacteria (TCB), thermotolerant coliform bacteria (THTCB), total microbial count (TMC), records of coliphages, guided by methodology guidelines 4.2.1884-04 and Sanitary Regulations and Norms- SanPiN 2.1.5.980-00 [5, 6].The determination of the quantity of saprophytic bacteria is a very valuable indicator in the assessment of self-cleaning processes, it supplements and specifies the sanitary characteristics of the reservoir. The number of TCB and THTCB were determined in the tests applying the membrane filtration method. The results are presented in table 1.

Hydro-chemical tests consisted of the following indicators: biochemical consumption of oxygen, mass content of ammonium, nitrite, nitrate, sulphate, iron (III), coloration and hardness of water, permanganate oxidation [7--14].

Hydro-chemical index of water pollution (WPI) was determined. Hydro-chemical WPI is an additive indicator and is the average proportion of excess MPC for a limited number of individual ingredients and is calculated by the equation (1):

$$WPI = \frac{1}{n} \cdot \sum_{i=1}^{n} \frac{Ci}{MPCi} = \frac{1}{6} \cdot \sum_{i=1}^{6} \frac{Ci}{MPCi} \qquad (1)$$

where n - the number of indicators used to calculate the index; Ci - concentration of a chemical substance in water, mg / l; MPCi - the maximum permissible concentration of a substance in water, mg / l.

When determining the WPI for water bodies of municipal-drinking and cultural- public water uses, the calculation is carried out according to the maximum permissible concentration for six components, they necessarily include Biological Oxygen Demand (BOD_5), as well as the values of 4 more indicators that are the most unfavorable for this water body, or which have the largest concentration (ratio ci / MPCi) [15].

3. Results and Discussion

Two-year hydro-chemical observations showed that in the lake the level of permanganate oxidation fluctuated within small limits and there was an excess of MPC in the summer months (Table 1).

The coloration of the water increased in late April, early May and in the summer months, since humus substances enter the lakes with melt water and rain. In December, salt concentration and mineralization increases, it also intensifies the coloration. During the two years of the research the coloration in the lake water exceeded MPC.

The concentration of iron (III) increased in late April, early May and in the summer months with the running of meltwater and rainwater into the open water body.

In the process of biochemical oxidation of organic substances in water, a decrease in the concentration of dissolved oxygen occurs, and this decrease is an indirect measure of the organic substances content in water. In the period of the research, the level of oxygen fluctuated within small limits and was insignificant; it did not violate the established values. Minimumal values of indicators were recorded from March to April and from September to October, which indicates an increase in eutrophication in these periods.

The content of suspended solids depends on the time of the year. During floods and rains, organic and inorganic substances are washed off the soil, large amounts of suspended solids run into an open reservoir. In winter water is cleaned, salts are concentrated. Throughout the period of the research, the values of the suspended solids index were within MPC.

Concentrations of ammonia and ammonium ions, nitrites, nitrates, sulfates in the water met the hygienic standards and according to these indexes water is suitable for household and drinking usage.

In the course of the research, the number of mesophilic aerobes and facultative anaerobes capable of forming colonies on nutrient agar were determined. The criterion is used to speculate of the organic pollution of an object, based on the assumption that the more organic compounds an object contains, the more microorganisms are found. In the present study, when analyzing water samples, it was found that TMC meets sanitary standards.

The results of calculating the number of TCB in the lake under study are presented in Table 1.

TABLE 1: Physico-chemical and sanitary-microbiological characteristics of the water of Lower Vaengskoye Lake 2016-2017 years.

Indicator	Month/	January	February	March	April	May	June	July	August	September	October	November	December
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Color, degree of color	2016	22	24	22	21	26	26	24	28	24	29	28	26
	2017	25	24	24	22	25	28	29	23	25	26	28	26
Permanganate oxidation, mgO_2 / dm^3	2016	3,67	4,3	4,2	3,5	4,7	3,4	4,2	2,9	4,5	5,3	6,2	5,5
	2017	4,4	3,5	4,1	4,1	4	5,2	3,1	4,4	5,9	5,4	5,1	4,6
BOD_5, mgO_2 / dm^3	2016	1,2	0,5	0,65	0,52	1,2	0,66	0,72	0,81	0,5	0,55	0,5	0,5
	2017	0,52	1,3	0,5	0,65	1,2	0,5	0,9	0,5	0,67	0,5	0,72	0,96
Hardness, °H	2016	0,35	0,46	0,42	0,48	0,42	0,44	0,39	0,39	0,46	0,4	0,41	0,42
	2017	0,46	0,4	0,46	0,45	0,38	0,39	0,44	0,38	0,4	0,38	0,34	0,42
Iron (total), mg / dm^3	2016	0,27	0,3	0,28	0,26	0,28	0,3	0,27	0,28	0,27	0,3	0,37	0,26
	2017	0,24	0,29	0,16	0,21	0,23	0,28	0,26	0,21	0,36	0,4	0,27	0,21
Sulfate ion, mg / dm^3	2016	3,64	8,6	8,2	6,4	8,2	7,5	7,8	7,6	7,2	11,4	10,4	9,5
	2017	7,3	4,5	6,5	6,8	2	2,4	4,7	2,4	2	3,3	4	4,2

Indicator	Month/	January	February	March	April	May	June	July	August	September	October	November	December
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ammonium ion, mg / dm^3	2016	0,23	0,19	0,18	0,14	1,4	0,17	0,46	1,1	0,23	0,14	0,37	0,13
	2017	0,43	0,274	0,24	0,23	0,93	0,44	0,37	0,19	0,57	0,52	0,32	0,59
Nitrite ion, mg / dm^3	2016	0,004	0,003	0,003	0,003	0,004	0,003	0,003	0,003	0,003	0,003	0,004	0,07
	2017	0,013	0,003	0,003	0,003	0,003	0,011	0,003	0,004	0,008	0,003	0,003	0,008
Nitrate ion, mg / dm^3	2016	0,18	0,144	0,1	0,22	0,1	0,1	0,21	0,151	0,175	0,138	0,1	0,168
	2017	0,1	0,1	0,1	0,1	0,43	0,1	0,21	0,26	0,1	0,132	0,26	0,1
Total Microbial Count (TMC), CFU/ cm^3	2016	2	8	2	7	14	10	12	4	3	3	3	3
	2017	5	3	10	5	7	3	6	5	3	6	2	5
Total coliform bacteria (TCB), CFU / 100 ml	2016	24	26	32	62	68	50	86	94	24	52	6	6
	2017	6	12	10	34	52	20	26	24	30	30	10	16
Thermotolerant coliform bacteria (THTCB), CFU / 100 ml	2016	24	26	35	62	68	34	86	94	71	52	0	0
	2017	0	12	2	5	52	10	26	24	30	30	2	16

Throughout the period of the research, the microbiological indicators of TCB gradually increased from the minimum values in winter to the maximum in summer, but within the normal range. An increase in the number of TCB in the spring and autumn hydrological seasons can be explained by the fact that with the beginning of the spring period, the water temperature in the lake gradually increases, ice and snow begin to melt, and allochthonous organic substances enter the lake naturally with flood waters, it creates favorable conditions for the reproduction and multiplying bacteria, and this, therefore, leads to an increase in their number. And in the autumn hydrological season, the abundance of rains is observed, as a result, allochthonous substances get into the water bodies. It was noted that the lake water contains an acceptable amount of TCB and THTCB and meets the standards and is suitable for drinking and household use according to these indicators. Coliphages were not detected throughout the period of study.

The correlation analysis of the links between the values of physico-chemical and microbiological parameters in the water of the lake showed that significant direct links between the parameters of coloration, permanganate oxidation and iron (Table 2). The existence of a relationship between coloration and the concentration of iron in water was revealed using the correlation analysis. The calculated value of the correlation coefficient proved to be equal to 0,81. It indicates a direct and strong dependence, i.e., the higher the iron content, the higher the coloration of water. A similar pattern was observed in such indicators as permanganate oxidation and coloration of water. The calculated value of the correlation coefficient was 0,62. The interrelation between the permanganate oxidation and coloration of water is statistically significant. The correlation coefficient equals 0.60, which indicates direct and average dependence, i.e., the higher the values of permanganate oxidation, the higher the coloration of water. No significant correlations were revealed between the concentrations of the other physico-chemical and microbiological parameters (Table 2).

Table 2: Significant coefficients of correlation for microbiological and physico-chemical indicators in the waters of the lakes.

Indicators	Permanganate oxidation, mgO_2/dm^3	Iron (total), mg/dm^3	Sulphate-ion, mg/dm^3	Nitrate-ion, mg/dm^3
Coloration, degrees of coloration	**0,617**	**0,813**	0,187	0,076
Permanganate oxidation, mgO2 / dm3	-	**0,603**	0,263	0,120
Suspended matter, mg / dm3	-	0,109	-0,027	-0,062
Iron (total), mg / dm3	-	-	0,259	0,087
Total coliform bacteria (TCB), CFU / 100 ml	-0,030	0,041	0,301	0,238
Thermo-tolerant coliform bacteria (THTCB), CFU / 100 ml	-0,025	0,053	0,305	0,273

In order to assess the quality of the waters of the Lower Vaengskoye Lake for the period of 2016-2018 an integral index of water quality was calculated: WPI (water pollution index). The results are presented in table 3. Classification of water quality according to the values of WPI, allows dividing the surface water into 7 classes depending on the degree of contamination (Table 3).

According to the value of WPI index in 2016--2017, the quality of the lake's water is assessed as ``clean'', characterized by the 2nd class of water quality.

TABLE 3: WPI value, water quality class.

Year	WPI	Quality of water	Water quality class
2016	0,899	clean	2
2017	0,663	clean	2

4. Conclusion

Thus, as a result of the research carried out on sanitary-chemical indicators 10% of all tests show the violation of the requirements of hygienic standards, namely, on the following indicators: permanganate oxidation, iron and water coloration while meeting the requirements of hygienic standards on microbiological indicators is observed in all tests. The water of lakes for the two-year period (2016 - 2017) is characterized by clean water pollution index and refers to the 2nd class of water quality.

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