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Sanitary-microbiological characteristics of the coastal zone of Lake Baikal during the seasonal change in the lake level in 2022

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ABSTRACT. The paper presents the results of the study of water quality by sanitary-microbiological characteristics in the littoral zone of Lake Baikal and its tributaries in July and September 2022. It was found that the number of studied bacteria does not correlate with the level of the lake, but is caused by the seasonal anthropogenic load. Exceedances of the standards in the summer period were detected in the area of Kultuk settlement, Baikalsk town, Listvyanka settlement, Bolshie Koty settlement, in the bays of Maloe More, Chivyrkuisky and Barguzinsky bays, and in the rivers Medlyanka, Pokhabikha, Pereyomnaya, Kuchelga, Turka, Barguzin, and in the hydrotherm of Zmeinaya Bay. In autumn, the quality of the surface water did not meet the norm near the settlement of Bolshoe Goloustnoe, in Aya Bay, in the bays Zagli and Chivyrkuisky, and in the mouths of the rivers Medlyanka, Pokhabikha, Slyudyanka, and Mysovka. In the tributaries where wastewater is discharged (Medlyanka, Pokhabikha and Mysovka), the number of sanitary-indicatory bacteria remains high both in the summer and autumn seasons.

Keywords: Lake Baikal, coliform bacteria, enterococci, *E. coli*, water level

1. Introduction

It is well known that the coastal zone of the water body is an ecological barrier to pollutants coming from the shore. Here, as a result of physico-chemical and biological processes, they are transformed that helps to reduce the negative impact on the lake as a whole. Over the last decade serious changes are observed in the coastal zone of Lake Baikal, which are characterized as a crisis (Kravtsova et al., 2014; Timoshkin et al., 2014; 2016; Belykh et al., 2016). The coast of the lake is under high recreational load – the growing number of tourists causes numerous tent camping, uncontrolled construction of recreation centers that have no wastewater facilities, and an increase in the number of ships (Evstropyeva et al., 2021). These circumstances have led to a multiple increase in compounds of nitrogen and phosphorus in the coastal zone (Khodzher et al., 2017) and opportunistic microorganisms (Shtykova et al., 2018).

Increase of the river flow in 2019-2021 enriched with significant amounts of biogenic elements and organic matter has resulted in additional nutrients entering the shallow water zone of Lake Baikal, increasing trophicity and decreasing coastal water quality. The high lake level during this period caused an increased abrasion and waterlogging of low parts of the coastal zone, which probably worsened the ecological situation in the coastal zone of Lake Baikal, especially in areas under anthropogenic load.

The paper is aimed to assess the impact of changes in the level of Lake Baikal on the quality of coastal waters in terms of sanitary-bacteriological characteristics in 2022.

2. Materials and methods

Expeditionary works were carried out in July and September 2022. Surface water samples were taken according to GOST 31942-2012 in the mouths of 16 tributaries (rivers: Medlyanka, Kultuchnaya, Pokhabikha, Slyudyanka, Utulik, Solzan, B. Osinovka, Snezhnaya, Pereyomnaya, Mysovka, Turka, Kika, Selenga, Barguzin, Buguldeika, Goloustnaya) and in 24 areas of the coastal zone of the lake (Listvyanka settlement, Bolshie Koty settlement, Bolshoye Goloustnoye settlement, Aya Bay, Bays of Maloe More, Chivyrkuisky and Barguzinsky Bays, Posolsky sor,

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areas of Kultuk settlement, Slyudyanka town, Utulik settlement, Baikalsk town, Vydrino settlement, Tankhoi settlement, Babushkin town, Gremyachinsk settlement) (Fig. 1). In July and September, the water level of Lake Baikal was 456.72 and 456.85 m, respectively (http://www.rushydro.ru/hydrology/informer/). A total of 300 samples were taken and analyzed, the research was conducted according to MUK 4.2.1884-04 and GOST 24849-2014. At all stations, water quality is assessed for the main sanitary- microbiological indicators according to SanPiN 1.2.3685-21. Defined indicators: coliform bacteria (CB), enterococci and *E. coli*, the number of which must not exceed 500 CFU/100 cm^3, 10 CFU/100 cm^3, 100 CFU/100 cm^3 respectively. We also determined allochthonous organotrophic microorganisms (total microbial count - TMC, 37°C).

3. Results and discussion

In July 2022, there were determined the exceedances of the standards of SanPiN 1.2.3685-21 (2021) in the area of Kultuk settlement, Baikalsk town, Listvyanka settlement, B. Koty settlement, Bazarnaya Bay, in the bays Tutaysky, Zagli, Khul, Mukhor, Irkutskaya Bay, Khuzhirsky, Chivyrkuisky, Barguzinsky, in the rivers Medlyanka, Pokhabikha, Pereyomnaya, Kuchelga, Turka, Barguzin and in the hydrotherm of Zmeinaya Bay. Significant exceedances of sanitary-bacteriological indicators were detected in the area of B. Koty settlement (CB in 1.8 times, *E.coli* in 9 times, enterococci in 35 times), Bazarnaya bay (CB in 4.5 times, enterococci in 7.8 times), Khuzhirsky bay (CB in 4 times, enterococci in 2.6 times), Monakhovo settlement (CB in 6.5 times, enterococci in 12 times), Zmeinaya bay (CB in 2 times, enterococci in 44 times) and Kultuk settlement (CB in 3.2 times, enterococci in 5 times). The rivers Pokhabikha and Medlyanka have the lowest water quality, exceeding CB values in 23 and 8.6 times, E. coli in 104 and 4.6 times, and enterococci in 185 and 40 times, correspondingly.

In September 2022, surface water quality did not meet the norm near the settlement of B. Goloustnoe, in Aya Bay, Zagli and Chivyrkuisky bays, and in the mouths of the rivers Medlyanka, Pokhabikha, Slyudyanka and Mysovka. Significant exceedances of sanitary-bacteriological indicators were detected in the waters of the rivers Medlyanka, Pokhabikha, and Mysovka. At the mouth of the Medlyanka River CB exceeded the normative values in 1.8 times (880 CFU/100 cm^3), enterococci in 7 times (70 CFU/100 cm^3); at the mouth of the Pokhabikha River CB were 27 times higher than the norm (13 600 CFU/100 cm^3), *E. coli* in 96 times (9600 CFU/100 cm^3), enterococci in 232 times (2320 CFU/100 cm^3) and in the mouth of the Mysovka river, CB – in 20 times (9850 CFU/100 cm^3), *E. coli* in 83.5 times (8350 CFU/100 cm^3), enterococci in 1700 times (1650 CFU/100 cm^3). Obviously, the poor water quality of these rivers relates to the discharge of domestic wastewater from nearby towns.

A comparative analysis of the results of the study of the coastal waters of Lake Baikal found that the number of allochthonous organotrophic microorganisms in July ranged from 0 to 197 CFU/cm^3, in September from 0 to 42 CFU/100 cm^3 (Fig. 2A, $p = 0.006$); coliform bacteria from 0 to 3500 CFU/100 cm^3 and from 0 to 88 CFU/100 cm^3 (Fig. 2A, $p = 0.012$); enterococci from 0 to 587 CFU/100 cm^3 and from 0 to 268 CFU/100 cm^3 (Fig. 2A, $p = 0.0006$) correspondently. The presence of high numbers of opportunistic bacteria in the summer period is caused by the obvious anthropogenic load. Significant excess of the standards was revealed in the places of active recreation of tourists - the bays of

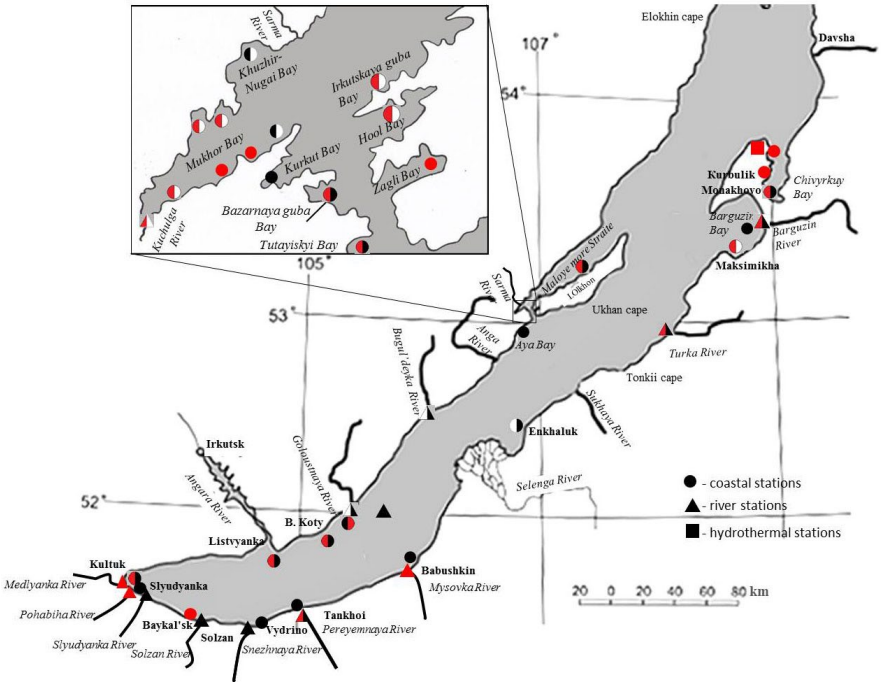

Fig.1. Sampling scheme in July (left side of marker) and in September (right side of marker) 2022. Red color – exceedance of the standards, black color - no exceedance of the standards, white color - there was no sampling.

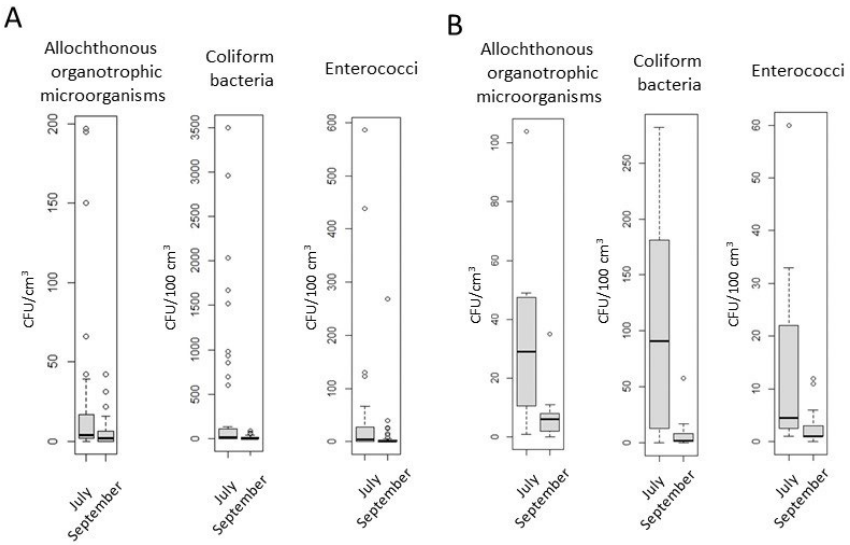

Fig.2. Abundance of bacteria in water of the coastal zone (A) and tributaries (B) in July and September 2022. Note. The comparative analysis does not use the data on the quality of rivers, in which wastewater is discharged.

Maloe More, Chivyrkuisky Bay (Monakhovo, Zmeinaya Bay) and Aya Bay. Maximum CB values of 2960 and 3500 CFU/100 cm^3 were detected in Monakhovo settlement of Chivyrkuisky Bay. It should also be noted that during active tourist visits to the thermal springs, the number of CB reaches up to 2420 CFU/100 cm^3 and enterococci up to 316 CFU/100 cm^3, by September the level of CB decreases to 20 CFU/100 cm^3, and the number of enterococci does not decrease and is 324 CFU/100 cm^3. Perhaps, this pattern correlates to the ability of bacteria of the genus *Enterococcus* to persist in the environment for a longer time due to morphological and physiological features (Kravchenko, 2009).

Comparative analysis of the results of the river water quality showed that the number of opportunistic bacteria was significantly higher in July. Thus, the number of TMC in July ranged from 1 to 600 CFU/cm^3, in September from 0 to 80 CFU/cm^3 (Fig. 2B, $p = 0.01$); CB from 0 to 282 CFU/100 cm^3 and from 0 to 58 CFU/100 cm^3 (Fig. 2B, $p = 0.016$); enterococci from 1 to 60 CFU/100 cm^3 and from 0 to 6 CFU/100 cm^3 (Fig. 2B, $p = 0.05$) correspondently. The level of fecal pollution in river waters is primarily related to the anthropogenic load, which increases in the summer season. In rivers where wastewater is discharged, the number of opportunistic microorganisms remains consistently high, both in the summer and autumn seasons.

In the coastal waters of the lake during the summer, when the water level was 456.72 m, the number of sanitary-bacteriological indicataros was much higher in comparison with the autumn season, when the annual level was maximum high – 456.85 m. Thus, an increase in the level does not result in an increase in the number of opportunistic bacteria. We compared the data obtained in August 2016 (Shtykova et al., 2018), when the water level in the lake was significantly low and was 456.2 m with the data we obtained at a higher lake level in July 2022, and they showed no significant differences in CB and enterococci abundance ($p > 0.05$) confirming the influence of seasonal occurrence rather than water level. Earlier it was also reported that the number of fecal bacteria in the waters of Listvenichny Bay is not related to the water level and temperature, but varies depending on the season and the level of anthropogenic load. The spatial distribution of opportunistic bacteria in the coastal zone of Listvyanka settlement is non-homogeneous; their higher abundance was noted at stations where untreated wastewaters flow into Lake Baikal (Podlesnaya et al., 2022).

4. Conclusions

Based on the analysis of the 2022 data, we can conclude that the abundance of opportunistic bacteria does not depend on the level of the lake, but correlates primarily to the season. Exceedances of the standards were detected in the coastal areas and tributaries under anthropogenic load in the summer. In rivers where wastewater is discharged, the number of opportunistic microorganisms remains consistently high, both in the summer and autumn seasons.

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Conflict of interest

The authors declare no conflict of interest.

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