The content of heavy metals in the water of Lake Gusinoe (Western Transbaikalia) and its tributaries

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Abstract. Investigation of the transformation of substances in the basin of the Selenga River, the main tributary of Lake Baikal, due to anthropogenic impact under conditions of global climate change, is especially important for Lake Baikal which is a World Natural Heritage Site and the main source of fresh drinking water not only in the region, but also in the world. One of the key research objects in the Selenga River basin, which is subject to significant anthropogenic impact, is the ecosystem of Lake Gusinoe. This study presents the results of analysis of the physical and chemical parameters of the water mass of Gusinoe Lake basin for the period from 2017 to 2020. Thus, the results on hydrochemical indicators for a long-term period of research of the lake show changes in the chemical composition of water and the concentration of main ions. In 2020, the content of almost all metals was higher than in 2017-2020, which may be due to the rise in the level of Lake Gusinoe and groundwater that began in 2019 and continued in 2020, as a result of rain floods that caused flooding of the coastal territories and the entry of pollutants into watercourses and the lake.

1. Introduction

Under conditions of progressive anthropogenic pressure on the environment, the task of preserving unique ecosystems is becoming more and more urgent. The study on the transformation of substances in the water bodies of the Selenga River basin, the main tributary of Lake Baikal, which carries up to 50 % of water runoff and more than 50 % of chemical runoff, as well as on their ecological state due to anthropogenic impact under global climate change, is of special importance for the lake. Baikal is an object of the world natural heritage and the main source of fresh drinking water not only in the region, but also in the world [1, 2].

One of the key research objects in the Selenga River basin is Lake Gusinoe which is the most important reservoir in terms of the intensity of water and fisheries use in the region, while the lake is the only source of economic and drinking water supply for the city of Gusinozersk and adjacent settlements. There is a potential threat that anthropogenic activities on the lake may become the largest source of pollution of the basin and pose a danger to the ecosystem of Lake Baikal [3]. In the vicinity of Lake
Gusinoe and Gusinozersk City, the Gusinozersk industrial complex formed which is one of the largest in the Republic of Buryatia. It includes energy-producing, processing and transport enterprises, most of which, together with the City of Gusinozersk, are located on the northern and northeastern shores of the lake. In the southwestern part of the lake the village of Gusinoe Lake is located with a railway station and a locomotive depot. All these objects consume and pollute a huge amount of water. The largest polluter in this territory is the Gusinozerskaya State District Power Plant (SDPP), which consumes 85.1 % of the total water intake of surface waters of the Republic of Buryatia. The ecological state of the lake is also influenced by the uncultivated overburden piles of the Holboldzhinsky coal mine, located along the entire eastern coast. A great influence on the ecological state of the lake is also exerted by huge masses of atmospheric emissions of SDPP (exceeding 63 thousand tons/year), which are deposited on the lake surface. In the long-term dynamics, there is an increase in the volume of wastewater discharge due to an increase in the volume of water resources abstraction for electricity generation [4].

2. Materials and Methods

2.1. Study area
Lake Gusinoe is the largest freshwater lake in the Transbaikalia territory (Figure 1). The 24.8 km long catchment area with the average width of 8 km covers an area of 924 km², with the water mirror area encompassing 163 km², and its maximum depth is 26 m and an average depth is 15 m. The volume of the water mass is 2.4 km³. The absolute height of the water edge reaches 551 m [3]. The lake belongs to low-flow reservoirs (with a relative water exchange coefficient of 0.0125). The tributaries flowing into it are low-water. Most often, they freeze over in winter, and often do not reach the lake in summer. The hydrographic network is represented by 72 watercourses of a total length of 312 km. The largest tributary by water content is the Tsagan-gol River, which flows from the Temnik River and further flows into the lake in the southwestern part. Having the largest catchment area (382 km²) and length (44 km), the Zagustai River flows into the lake in its northern part, cutting through the Khambinsky Range. One river, namely, the Bain-gol, flows out of the lake in the southeastern part, which flows into the Selenga River after 14 km distance [3, 5].

Figure 1. Lake Baikal basin (Russian part), the basin of Lake Gusinoe
2.2. Methods

From 2017 to 2020, the chemical composition of the surface waters of Lake Gusinoe and their tributaries was determined to study the state of the water bodies of the Lake Baikal basin and to identify the features of the spatial and temporal distribution of indicator indicators (macro- and microelements). The expedition work was carried out using the scientific hospitals of the BIP SB RAS on Lake Gusinoe (we have been conducting comprehensive studies since 2016). Water sampling was carried out 4 times a year in all hydrological seasons.

In the field, the physicochemical parameters of water were measured: temperature, pH, turbidity, and the content of oxygen dissolved in water. The ionic composition of water was determined using the Dionex ICS-1600 ion chromatograph. Water mineralization was calculated as the arithmetic sum of the content of all ions determined by the analysis in mg/dm³. For multi-element ICP analysis, samples were taken in pre-washed 0.5-1 liter PET bottles. To determine the dissolved forms of the elements, the sample was filtered through a membrane filter with a pore diameter of 0.45 microns, and then the samples were fixed with concentrated nitric acid. The multi-element analysis was performed on an atomic emission spectrometer with inductively coupled plasma Profile Plus and an atomic absorption spectrophotometer Solaar M6. For calibration of the device, multi-element standard solutions for ICP IV-STOCK-1 were used. The chemical analysis was performed by methods generally accepted in the hydrochemistry of fresh water [6, 7].

3. Results and Discussion

We quantified the content of Fe, Cu, Zn, Pb, Cd, Ni, Cr, Mn in samples of surface and bottom water. The content of TM in the lake's water area in 2020 in comparison with previous years of research is shown in Figure 2.

![Figure 2. Seasonal dynamics of TM content in the water of Lake Gusinoe in 2017-2020](image)

The analysis of the trace element composition of the water showed that the iron content in the water area of the lake and its tributaries varied widely – from 0.02 to 0.048 mg/l. The manganese content in the lake’s water area was an order of magnitude lower, the maximum values were observed in winter in the northern and southern basins-up to 0.017 mg/l, in other seasons the manganese content was significantly lower. According to the zinc content, the highest values were observed in the subglacial period in the southern basin. High copper content in the water was observed throughout the entire water area, especially in the spring during the flow of meltwater from the catchment area. Pollution of the lake's waters with copper, zinc and occasionally iron was also noted earlier according to the observations.
of Roshydromet [4]. Increase in the water level in the lake Gusinoe, as well as the rise of groundwater in 2019-2020, rain floods led to an increase in the content of manganese and iron in the water.

The content of elements in the water of the tributaries of the lake. Gusinoe and in the Bayan-gol river are shown in Figure 3. In the rivers Zagustai, Tel and Bayan-gol, the average iron content was highest in spring and summer, which is associated with the flushing of pollutants from the adjacent surface and the arrival of polluted meltwater. From the tributaries, the rivers Zagustai and Tel, flowing near the ash dumps of the SDPP, were constantly distinguished by high concentrations of iron and manganese.

![Figure 3. Seasonal dynamics of iron, manganese, zinc and copper in the water of the tributaries of Lake Gusinoe and the Bayan-gol River in 2020; 1 – Bayan-Gol, 2 – Tsagan-Gol, 3 – Tsagan-Gol mouth, 4 – Zagustai, 5 – Tel.](image)

The content of lead, cadmium, nickel and chromium in the water of Lake Gusinoe and its tributaries in 2020 was in the intervals significantly below the MPC of fisheries and often below the detection limits. The highest concentrations of these metals in the water were observed during the spring flood and rain floods, which may be due to the arrival of pollutants from adjacent territories [8]. In general, according to the results of studies conducted in 2020 it is possible to note an increased content of heavy metals in the northern basin of the lake, which is consistent with the data obtained during studies in 2017-2019, as well as in the Tel and Zagustai rivers, which are in the zone of influence of the GRES and discharges of the city of Gusinozzersk.

4. Conclusions

Thus, the analysis of the obtained results showed that in accordance with the ecological classification [9] in 2020, the water quality of Lake Gusinoe corresponded to the category "slightly polluted" in terms of chemical indicators and the content of toxic substances, and in the regions of Zagustayka and Tel varied between "moderately polluted" and "heavily polluted". In 2020, due to an increase in the water level in the Lake Gusinoe, as well as ground water, flooding of the coastal zone, the washing of pollutants during a rain flood from adjacent territories where there are waste dumps of a coal mine, ash dumps of SDPP, areas with saline soils, an increase in the content of sulfates, manganese and iron in the water of the territory contributes to a decrease in water quality, especially due to the influx of heavy
metals. The high level of anthropogenic load in the conditions of changes in the water regime of the lake makes it necessary to constantly monitor the chemical composition and ecotoxins in lake waters.

Acknowledgements
Research was carried out within the framework of the State assignment of Baikal Institute of Nature Management of SB RAS and partial financial support by the Ministry of Science and Higher Education of the Russian Federation, the grant for implementation of large scientific projects on priority areas of scientific and technological development (the project "Fundamentals, methods and technologies for digital monitoring and forecasting of the environmental situation on the Baikal natural territory", No. 13.1902.21.0033).

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