Chemical composition of surface water in the main tributaries of Lake Baikal – the Selenga and the Barguzin Rivers

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Abstract. Lake Baikal is one of the oldest fresh water bodies on the planet, where the largest available water reserves are concentrated. River runoff plays an important role in the overall balance of substances entering the Lake. The Selenga River is the main tributary of Lake Baikal, in the basin of which, unlike other tributaries, a large number of industrial, agricultural, processing enterprises, settlements and cities are concentrated. The Barguzin River is the third largest river flowing into Lake Baikal, is the basin where intensive development in agriculture and forestry has undertaken. This paper presents the results of the analysis of surface water samples of the Selenga and Barguzin rivers collected during 2015-2016. In 2015, the water level for the Selenga and Barguzin rivers was characterized by extremely low water content, which caused an increase in the concentrations of major ions and trace elements in surface waters. The more favorable water regime in 2016 caused a significant decrease in ion concentrations. Maximum concentrations of iron and manganese are observed in winter and during flooding in the spring. In conditions of low water content, increased copper and zinc contents were also observed in the surface water of the Lake tributaries.

1. Introduction
In the conditions of progressive anthropogenic impacts on the environment, the task of preserving unique ecosystems becomes more urgent. Lake Baikal is one of the oldest freshwater bodies on the planet, where the largest reserves of fresh water are available for use on the most densely populated continent. River runoff plays an important role in the overall balance of substances entering the Lake, as it is the main element of the chemical balance of this unique Lake. Of the more than 300 watercourses flowing into the Lake, only the Selenga River brings almost half the volume of water mass [1].

The Selenga River is the main tributary of Lake Baikal, in the basin of which, unlike other tributaries, a large number of industrial, agricultural, processing enterprises, settlements and cities are concentrated. As Selenga carries up to 50% of water and more than 50% of chemical runoff, it is considered as a key factor in the stability of Lake Baikal ecosystem [2].

Selenga River flows through the territory of two neighboring countries – Mongolia and Russia. The length of the river is 1024 km, of which 409 km is within Russia. Since the end of the twentieth century, there is a decrease in the quality of the Selenga River in Mongolia, caused by an increase in anthropogenic impacts on the catchment area [3].
Gold mining in Mongolia over the last 10 years increased 17 times (the number of deposits where gold is mined by the hydraulic method, the use of cyanide and mercury [4]. The observed intensification of economic activity in the Northern regions of Mongolia occurs accompanied by climate change. Thereby a decrease in precipitation in the Selenga River basin and its water content is observed [5]. In conditions of reduced water content of the river reduced dilution capacity, while increasing revenues to the river of pollutants leads to a deterioration of water quality. The data of long-term studies of the Selenga River Delta showed that the change in hydrological conditions largely determines the dynamics of the concentrations of chemical components in the river and its delta ducts [6].

The Barguzin River is the third largest river flowing into Lake Baikal, in the basin of which the most intensive development agriculture and forestry has undertaken, has a well-developed river network. As a result of intensive use of water resources of the Barguzin River basin, there was a noticeable trend of changing the natural composition of water and reducing their quality [7]. In the dynamics of economic development of the Barguzin basin the greatest intensity is characteristic of the second half of the twentieth century. At the beginning of this period, actively carried out logging and plowing of land during 1961-1985 the area of forests decreased by 250 thousand hectares (20%), arable lands and pastures increased by 27 thousand hectares. The area of irrigated lands reached 16 thousand hectares. Changes in the catchment area caused such changes in the formation of surface runoff resources due to irretrievable losses in irrigation and reduced runoff as a result of logging. Due to the decline in agriculture in the 2000s, water abstraction for irrigated agriculture decreased from 17.8 million m³ in 1991 to 7.3 million m³ in 2000. However, logging and forest fires, especially extensive in 2015-2017, continue to have a negative impact.

2. Models and Methods

Sampling of surface water of the Selenga River was conducted during the summer low water (July) 2015 and 2016 from the border with Mongolia (the urban-type settlement of Naushki) to the village of Kabansk and its major tributaries the Rivers Dzhida, Temnik, Chikoy. In the Barguzin River, sampling was carried out in all hydrological seasons of 2016 – from the village of Kurumkan to the confluence of Lake Baikal and on the tributaries of the Argada and Ina rivers. pH and temperature values were determined by the portable pH meter IT-1101. The dissolved oxygen content was determined using a portable oximeter HI 9147 (HANNA). The chemical analysis was performed by methods generally accepted in hydrochemistry of fresh water [8]. Determination of cations and anions was performed on the ionic chromatograph ICS 1600. The content of Al, Fe, Mn, Cu, Zn, Pb, Cd, Cr, Ni was determined by atomic emission method on Profile Plus spectrometer (Teledyne, USA).

3. Results and Discussion

The average annual flow of the Selenga River is 30 km³, in 2015 and 2016 the annual flow of the Selenga River was 15.4 and 25.3 km³. In general, according to the results of studies, the gas regime was in favorable limits for aquatic organisms. The content of dissolved oxygen in the Selenga River and its tributaries Dzhida, Temnik and Chikoy was 8.5–10.5 mg/dm³ (7.3-8.0 mg/dm³ in 2015) with the highest values near the urban-type settlement of Naushki. The pH of the water varied from 6.80 to 8.44 (6.91–8.69 in 2015), with maximum in the Selenga River near the village of Kabansk and the village of Novoselenginsk and minima in the rivers Temnik and Chikoy. The composition of ions of the Selenga River water and its tributaries belongs to the hydrocarbonate class of calcium group. The amount of ions of the Selenga waters varied from 245 mg/l in 2015 and 200 mg/l in 2016 near the village of Naushki to 157 mg/l in the area of the village of Kabansk. In 2015, the water salinity was higher, as well as the content of the main ions, due to the reduced water content of the River in this period and a more favorable water regime in 2016. The amount of ions increased on the border with Mongolia and decreased to the mouth (Kabansk) in process of dilution by less mineralized waters of tributaries of the Selenga River. The strongest dilution is observed after the confluence of the largest tributary is the Chikoy River. From the tributaries of the Dzhida River had a salinity higher than that of the Selenga River.
In the long-term aspect the relative composition of ions in river waters remains quite stable. The data obtained confirm the tendency to increase the content of sulphates in waters coming from the territory of Mongolia, which is especially pronounced in low-water periods (2015) [9]. Mineralization of water and the concentration of major ions in water of the Selenga River and its tributaries did not exceed the standards for fishery water bodies.

Total iron content in 2016 was 31.56 µg/dm³ (10.42 µg/dm³ in 2015), an increase compared to 2015 was due to flooding. Relatively high iron content is typical for the Temnik and Chikoy rivers due to high natural background values. The concentration of manganese in the surface waters of the Selenga River and its tributaries in 2016, as well as in 2015, was significantly lower (up to 1 µg/dm³) compared to 2012. The Maximum value up to 60 µg/dm³ was recorded near the village of Kabansk. In July 2016, the concentration of zinc in the Selenga River and its tributaries did not exceed 1 µg/dm³, while in 2015 increased values were observed in almost all studied samples. The maximum concentrations were observed in the Dzhida River (22.9 µg/dm³), the Temnik River (22.8 µg/dm³) and in the Selenga River below Ulan-Ude city (18.6 µg/dm³). The content of Pb, Cd, Ni, Co and Cu in the surface waters of the Selenga River and its tributaries in 2015-2016 was below the detection limit.

For the Barguzin River, the average annual water consumption is 130 m³/s (4.1 km³/year). 2015 and 2016 were low-water for the Barguzin River – according to Rosgidromet of Russia, the annual flow amounted to 2.13 and 2.47 km³/year, respectively. According to the results of studies, the pH of water in the Barguzin River and its tributaries was 7.1-8.7. The gas regime was favorable: the content of dissolved oxygen was 7.1-18.6 mg/dm³ with highs in spring and autumn, and a minimum in summer. By season 2016, the sum of ions in the waters was changed within the range of mg/dm³: the Barguzin River – 118-190, the Argada River – 115-259, the Ina River – 82-127, with highs during the winter low water, minimum – during high water and rain floods. Downstream mineralization of surface waters of the Barguzin River is reduced due to dilution of the Argada and Ina rivers. The chemical composition of the water of the Barguzin River and its tributaries belongs to the hydrocarbonate class, calcium group. The content of hydrocarbons in the course of the year changed in the water of the Barguzin River in the range 73-128 mg/dm³, the Argada River – 77-193 mg/ dm³, the Ina River – 81-47 mg/dm³. The content of sulfate and chloride ions in 2016 in the water of rivers Barguzin, Argada and Ina was low: 10.0-14.7; 5.3-7.6; 13.2-14.5 mg/dm³ of sulphates and chlorides 0.3-0.6 mg/dm³, 0.2-0.3 and 0.2-0.5 mg/dm³, respectively. Calcium content was in the water Barguzin River 22.3-39.4 mg/dm³; the Argada River – 19.5-45.3 mg/dm³; the Ina River – 14.3-20.8 mg/dm³. Magnesium content is about an order of magnitude lower than calcium, which is typical for the water of these rivers. The concentration of the main ions and their total content in the water of the Barguzin River and its tributaries in 2016 in the long-term aspect are comparable with the data of 2011 [9].

According to the results of the determination of metals, high iron content (up to 130 µg/dm³) in spring in the water of the Barguzin River should be noted, in other periods the concentration was lower - 36 - 120 µg/dm³. The copper content reaching 11.9 µg/dm³ was observed in winter at the mouth of the Barguzin River, in other seasons the copper concentration decreased to minimum values. Copper content at the level of 1.6-17.2 µg/dm³ was determined in all seasons in the Ina River with a maximum in winter and a minimum in autumn, in the Argada River ranged from 1.8 (summer) to 13 µg/dm³ (winter). The content of lead in water of the Barguzin River maximum was in the spring (up to 10 µg/dm³), in other seasons – much lower – 1-3 µg/dm³. According to the content of manganese in the water of rivers, the maximum concentrations were in the spring in the Barguzin River. In the Argada River in winter there were very high concentrations of iron (up to 850 µg/dm³) and manganese (up to 2400 µg/dm³), due to the underground power of the River due to its almost complete freezing. However, despite the high amount of ions and elements in winter, the Argada River, due to the very low flow, has virtually no effect on the composition of the Barguzin River waters. In the interannual aspect the content of heavy metal was increased relative to 2011 [10], which is explained by the low water content of the Barguzin River in 2015-2016.
4. Conclusion
The microelement composition of surface waters was determined by changes in the water content of rivers flowing into Lake Baikal. Results show that the 2015 was characterized by extremely low water content for the Selenga and the Barguzin rivers, which caused an increase in the concentrations of major ions and trace elements in surface waters to the maximum values characteristic of low-water periods, due to an increase in the proportion of groundwater flow in the Rivers' nutrition. A more favorable water regime in 2016 caused a significant decrease in the concentrations of the components, while the relative composition of the main ions remained stable at all times. The microelement composition of surface waters was determined by changes in the water content of rivers, the maximum concentrations of iron and manganese are observed in winter and during the spring flood. Increased copper and zinc content are fixed in conditions of low water content.

Acknowledgements
The study was carried out as part of the state assignment of Baikal Institute of Nature Management, SB RAS and with partial financial support from the Russian Foundation for Basic Research in the framework of the scientific project No. 17-29-05085.

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