Spatial differentiation of bottom waters in the geosystem of the Chita TPP-1 cooling reservoir

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Abstract. The aim of the study was to identify the spatial differentiation of the hydrophysical parameters of the bottom waters of the Chita TPP-1 cooling reservoir. On October 24 2022 hydrophysical parameters were studied using the YSI EXO 2 instrument: temperature, oxygen concentration in water, specific electrical conductivity, hydrogen index, redox potential and turbidity at the research stations. It was found that all indicators for the lake research stations are homogeneous, with the exception of temperature. Based on the data obtained, three clusters are identified: 1 – the main part of the cooling reservoir with the same hydrophysical parameters; 2 – the thermal part of the cooling reservoir with high temperature and relatively low oxygen content; 3 - the coastal zone of the cooling reservoir with increased turbidity.

1 Introduction

Under the influence of human needs and anthropogenic factors, the transformation of natural geosystems into natural and technical ones is realized, which results in an almost complete restructuring of the characteristics and conditions that initially developed in the natural system [20]. In cooling reservoirs, the hydrophysical parameters of the aquatic environment change in this way, which determine the peculiarities of the functioning of aquatic geosystems and influence the biogeochemical processes occurring in them [6-7].

Kenon Lake is a natural reservoir located in urban development, used as a cooler for Chita TPP-1, which is: a favorite vacation spot for the urban population; the most important object of water, heat and electricity supply to the administrative center of the Trans-Baikal Territory – Chita city [2]; as well as carrying considerable fisheries importance [13].

After the commissioning of the Chita thermal power plant in 1965, there was a violation of the natural thermal and hydrological regime of the lake, which undoubtedly affected the water quality, changed the hydrochemical and hydrophysical parameters of the cooling reservoir [5].

Comprehensive studies of the hydrochemical regime of the Chita TPP-1 cooling reservoir were conducted in 1966-1967 according to a short program by the ichthyological expedition of the Chita Pedagogical Institute [5]; 1969-1971 by the Trans-Baikal complex

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expedition of the Limnological Institute of the SB Academy of Sciences of the USSR [15]; in 2018, the research was conducted by the Laboratory of Aquatic Ecosystems of INREC SB RAS together with PJSC "TGK-14" in order to further develop recommendations for reducing the thermal load on the reservoir. The Federal Service for Hydrometeorology and Environmental Monitoring carries out studies of the surface waters of Lake Kenon at a limited number of monitoring stations. Detailed studies of the spatial differentiation hydrophysical parameters of the bottom subsystem are few. The purpose of this study was to identify the spatial differentiation of the hydrophysical parameters of the bottom waters of the Chita TPP-1 cooling reservoir.

2 Materials and methods

Kenon Lake is located on the territory of the Trans-Baikal Territory, Russia. The lake is located on the northwestern outskirts of Chita city (52.03915°N, 113.38446°E). The lake area is 15.2 km^2, length 5.6 km, width (average) 2.9 km. The average depth is 4.8 m, the maximum is 6.2 m. The lake basin, like the Chita-Ingodinskaya basin as a whole, belongs to areas of insufficient moisture. Summers are hot and dry, and winters are cold and long. Kenon Lake belongs to drainless reservoirs, however, during wet periods, at high water levels, a small surface runoff is recorded in the Ingoda River [10]. After the commissioning of Chita TPP-1 and the formation of a "thermal" non-freezing area on the lake, water is pumped from the Ingoda River. The study area is dominated by westerly and northwesterly winds.

Measurements of bottom water indicators were carried out at Kenon Lake on October 24, 2022, before the onset of the ice period. 32 monitoring stations were evenly distributed over the entire area of the reservoir (Figure 1). The measurements were performed using an EXO 2 multiparameter device for environmental monitoring (YSI Inc, USA).

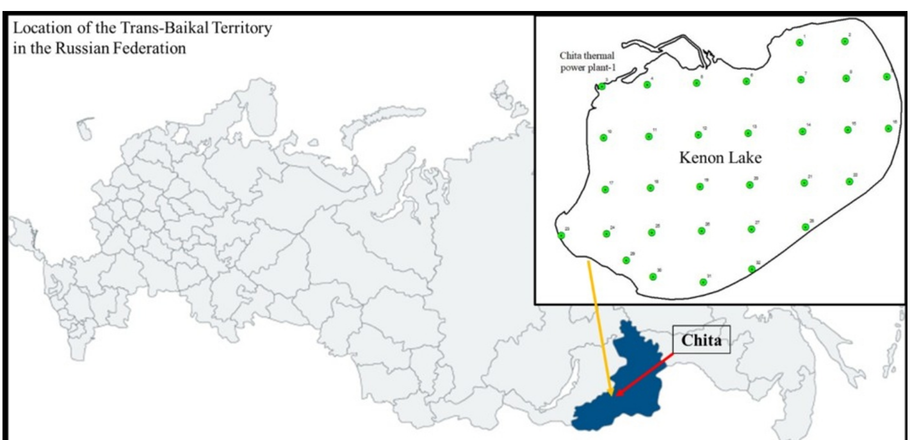

Fig. 1. Monitoring stations for the study of bottom water indicators on the lake Kenon in 2022.

The depth of the stations was determined by a hydrographic lot. The multiparameter device "EXO 2" was submerge in accordance with the measured depth within 0.5-1.0 m from the surface of the bottom sediments. The following parameters were measured using the device: temperature, oxygen concentration in water, specific electrical conductivity, hydrogen index, redox potential and turbidity.

The obtained values of the parameters of the aquatic environment are normalized and statistically processed in the program Microsoft Excel and ExcelStat. The values of the turbidity index for stations No. 1 (121.42) and No. 4 (683.46) were excluded from the statistical analysis because they did not correspond to the high transparency at station No. 4 (at least 4.5 m) and the presence of vegetation at station No. 1 at a depth of 3.5 m. The average turbidity values of nearby points are taken as the turbidity values at these stations. For station number 1, the average values for stations 2, 7 and 6 were used. For station number 4, the average values for station 3, 5 and 11 were used.

The mapping of the bottom temperature distribution is performed in the program ArcGIS (ArcMap) 10.8.

3 Results and Discussion

In general, measurements of hydrophysical parameters are stable or they are slightly changeable. These indicators include: pH, ORP, SPC and DO. The values of turbidity and especially temperature varied over a larger range. The oxygen content in water plays an important role in the biogeochemical cycle, the evolution of the structure and functions of ecosystems [22], vital activity of hydrobionts [17], as well as characterizing the hydrophysical state of the reservoir. Low oxygen content in water worsens water quality and habitat of aquatic organisms [11]. With a lack of oxygen, hypoxia and anoxia develop, which can lead to mass death of fish [14]. The range from 6.7 to 10.8 mgO_2/dm^3 is considered to be a favorable value of oxygen content for hydrobionts [17]. For example, in the cooling reservoirs of the Kalinin NPP, the oxygen content in the water throughout the year is in the range of 6.7-10.8 mgO_2/dm^3, which corresponds to a sufficiently favorable oxygen regime for hydrobionts [17]. In Kenon Lake, the oxygen content in October 2022 amounted to 9.8-12.7 mgO_2/dm^3 at the stations, which corresponds to the favorable oxygen regime of the Chita TPP-1 cooling reservoir at that time.

The redox potential (Eh) is an environmental indicator of the condition of the research objects. In natural waters, eH values generally range from 400 to 700 mV relative to a saturated silver chloride electrode [19]. In the lower and upper layers of bottom sediments of reservoirs, the change in the value of eH varies from +40 to -130 mV [19]. In Kenon Lake, ORP values in the bottom water layer varied from 77 mV to 94.1 mV at stations, which corresponds to a slightly oxidizing environment.

Electrical conductivity is an approximate characteristic of the concentration of inorganic electrolytes in water. The indicator depends mainly on the mineralization of natural waters. and usually ranges from 50 to 10,000 microns/cm. pH and electrical conductivity measurements are carried out to solve important tasks of chemical control of the water regime of the main circuit and auxiliary systems of the thermal power plant power unit [1, 21]. In the cooling reservoir of the Chita TPP-1, the values of specific electrical conductivity varied from 978 to 983 mcm/cm at the research stations. The obtained values of specific electrical conductivity correspond to the mineralization of 626 – 629 mg/l at monitoring stations. According to the WHO document [12] such mineralization indicators correspond to good and acceptable waters.

The hydrogen index, as well as the specific electrical conductivity, is one of the important indicators that has a significant impact on hydrochemical processes, the composition of water, the degree of decomposition of organic substances, as well as the activity of hydrobionts [17]. In the period 1977-1989 in October, the pH value at the TPP-1 water intake was 8.4, and the average annual values varied from 8.1 to 8.9 [10]. On October 24, 2022, in Kenon Lake, the pH value at the stations varied from 8.5 to 8.7, and its value was 8.5±0.5, which corresponds to a slightly alkaline aquatic environment. In general, the data obtained in 2022 are comparable with the results of studies in the 70s and 90s.

The value of the bottom temperature, based on the data obtained, is the most heterogeneous hydrophysical indicator compared to all others. As a result of the study, it was found that the increased bottom temperature was spread mainly along the western shore of Kenon Lake (Figure 2), which corresponds to the results of the 1971 research [15]. The highest temperature value (8.0 °C) was noted at station No. 3, which was located directly in the discharge zone from Chita TPP-1, and in the area of the supply channel the minimum bottom temperature of the lake waters (2.9 °C) was noted. Water temperature is an important environmental factor affecting the rate of biological and physico-chemical processes in reservoirs [3]. In cooling reservoirs of thermal power plants, nuclear power plants, etc., special attention is directed to the influence of thermal load on them, since the discharge of warm water from power plants leads to a shift in the natural temperature balance of the reservoir, which affects the processes of production and destruction, and can lead to their imbalance [4].

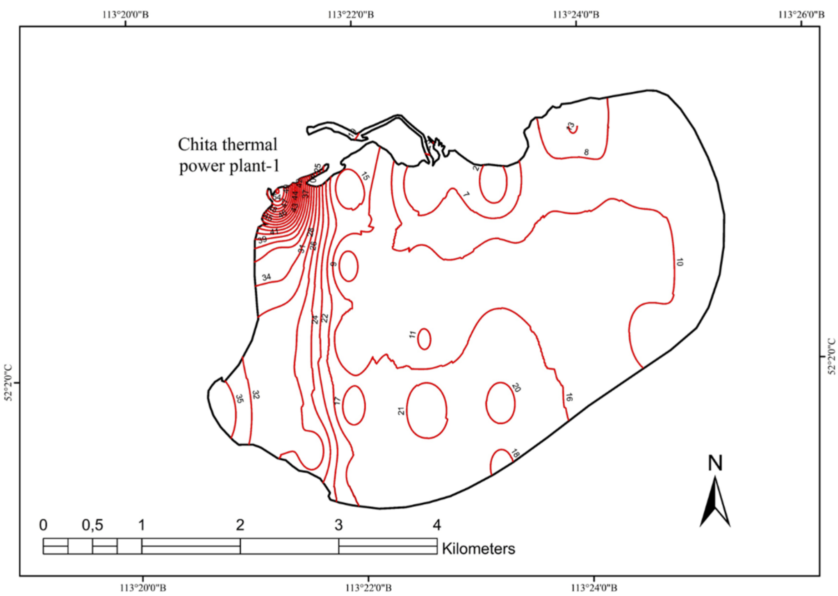

Fig. 2. The spread of bottom temperatures across Kenon Lake.

The temperature regime of the reservoir has a direct effect on the intensity of eutrophication [4]; biological productivity [9], water quality [16], dynamics, and in general, features of the functioning of the aquatic geoecosystem [8].

The turbidity index in the cooling reservoir of the Chita TPP-1 varied from 0.6 to 9.7 FNU at the research stations. The values obtained correspond to SEDIMENT-Related Criteria for Surface Water Quality (EPA, USA) [18], where the value of critical turbidity is taken as 25 N.T.U (FNU).

Cluster processing of the data obtained made it possible to identify three sections of the Chita TPP-1 cooling reservoir (Figure 3, Table 1). Cluster 1 is the main zone of the lake with little changing indicators; cluster 2 is the thermal zone of the reservoir; cluster 3 – Kenon Lake Coastal area.

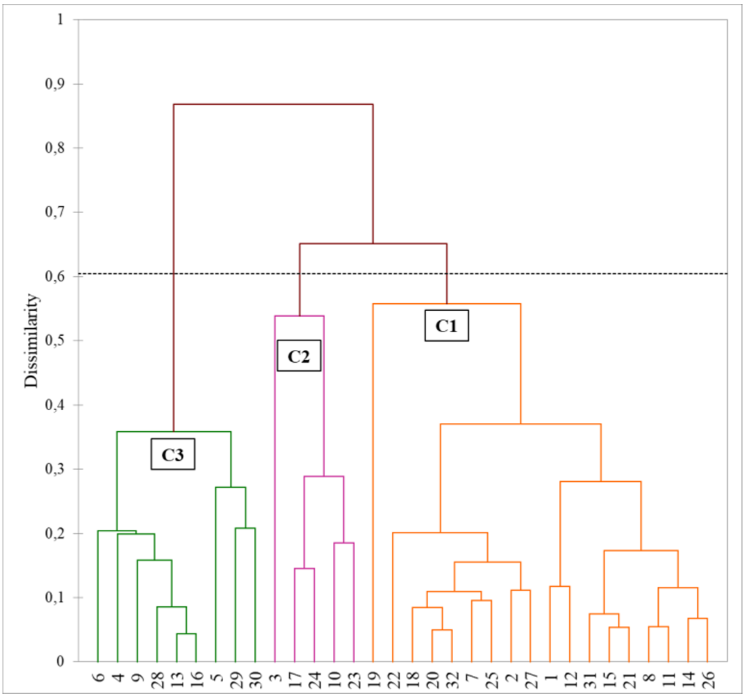

Fig. 3. Distribution of monitoring stations on Kenon Lake by clusters.

Table 1. Selected clusters in the lake based on the results of the data obtained.

Parameters	Cluster 1	Cluster 2	Cluster 3	The average value for the lake
T°C	3.5±0.2	5.4±1.5	3.5±0.5	3.8±0.9
DO mg/L	12.1±0.3	11.4±1	12.3±0.4	12±0.5
SPC µS/cm	980±0.5	980±2	980±1.4	980±1
pH	8.6±0.03	8.5±0.02	8.6±0.04	8.6±0.04
ORP mV	86±3.2	82.1±3.1	88±3.5	86±3.6
FNU	1.04±0.3	1.9±0.5	5±2.1	2.3±2.1

4 Conclusion

The performed studies allow us to assert that the hydrophysical indicators of the state of the bottom waters of the Chita TPP-1 cooling reservoir - Kenon Lake in October 2022 – are generally homogeneous, with the exception of temperature. The temperature values of the bottom waters along the western part of the reservoir are at a relatively high level, compared with the central and eastern parts of the lake. More than 50 years later, in the cooling reservoir of the Chita TPP-1, the features of the distribution of elevated temperature and hydrogen index remain comparable with the known results of previous studies. It can be assumed that the western and eastern parts of the bottom subsystem differ in the features of functioning (the rate of production and destruction).

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