The current state of hydrochemical indicators of Lake Kenon—the cooling reservoir of the TPP

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Abstract. A characteristic is given of the current hydrochemical state of the water of Lake Kenon, which is used as a reservoir - a cooler for the Chita TPP. For over 50-years of operation of the station located on its shore, under the conditions of anthropogenic impact, there has been a sharp change in the chemical type of the lake’s water. Currently, the predominant anion is the sulfate ion. Above the MPC standard for water of water bodies of fishery significance are the content of magnesium and sulfates and the trace elements: fluorine, vanadium, strontium, molybdenum, copper, tungsten. The concentrations of boron, lithium, bromine are relatively increased, in some samples - iron, manganese, aluminum and barium.

1. Introduction
The characteristic of the current hydrochemical state of Lake Kenon is given on the basis of the results of hydrochemical testing in 2018–2021. The samples were taken at different times of the year at the same station near the western shore of the lake.

Lake Kenon is a unique natural object, used since 1965 as a cooling reservoir for the Chita TPP, in connection with which there was a transformation of its natural state, including the hydrochemical regime.

Lake Kenon is located in the western part (figure 1) of Chita City between the Ingoda River and its left tributary the Chita River, and in geological and structural terms is confined to the central part of the Chita-Ingodinsky intermountain depression. The length of the reservoir is 5.7 km, the average width is 2.8 km, the maximum depth is 6.8 m, the average depth is 4.4 m, the mirror area is 16 km² [1], the estimated volume of water in the lake at a normal level (absolute elevation 654.8 m) is about 91.5 million m³ [2]. The Kadalinka River flows into the lake from the west and the Ivanovsky Stream from the north. The drainage basin of the lake covers an area of 227 km² [3]; in addition to the depression, it includes the southeastern slopes of the Yablonovy Ridge, within which most of the surface runoff entering the lake is formed.
The main contribution to the formation of the modern hydrochemical regime of the reservoir is made by the TPP located on its shore. Annually, about 500 million m$^3$ [1] is taken from the lake for the technological needs of the station and discharged after using over 490 million m$^3$ of water with changed characteristics. To replenish the water losses and to regulate the level in the lake, less saline water is injected from the Ingoda River, which also affects the formation of the salt composition of the lake water. The filtration waters of the ash dump of the CHP, located 3 km to the north-west above the relief from the station, are discharged into the Kadalinka River and through it into the lake by the flow of groundwater. In addition, there are civil and industrial construction projects, a railway line, roads, pipelines, etc. on the catchment area of the lake.

2. Results and discussion

Before the commissioning of the station, the lake water had a hydrocarbonate sodium-magnesium or magnesium-sodium composition with an average annual salinity in the 1950 – 420 mg / L [4]. According to the Hydrometeorological Service in July-August 1956-1958 the content of HCO$_3$ was 385-445 mg / L, and SO$_4^{2-}$ 7.7–20.5 mg / L, while its share in the sum of anions was 6.5-7.0 % -eq. In terms of weight concentrations, the cations were arranged in the series Na$>$ Mg$>$ Ca, in the percentage-equivalent form, sodium and magnesium had similar values and when naming the type of water they could change places [1]. According to testing data 2018-2021 the lake water is characterized by a three-component composition of cations (Mg$>$ Ca$>$ Na) and a predominance of sulfates in the anionic composition (43–52 % -eq.), the content of which, like magnesium (table 1), exceeds the standards for maximum permissible concentrations of harmful substances in the water of the water bodies fishery value [5].

Table 1. Hydrochemical indicators of the Lake Kenon water (mg / L, except for pH).

| Component | 2018 | 2019 | 2020 | 2021 |
|-----------|------|------|------|------|
|           | June | September | November | June | November | June | September | October | May |
| pH        | 8.60 | 7.80  | 8.20  | 7.80 | 8.00      | 8.20 | 8.40      | 8.20    | 8.20 |
| CO$_2$    | <DL$^a$ | 8.80 | 1.76 | ND$^b$ | ND | 2.29      | ND   | 1.06      | 1.23 |
| HCO$_3$   | 122.0 | 167.8 | 198.3 | 176.6 | 210.5 | 207.9 | 203.5 | 221.5 | 212.6 |
| Component | Value |
|-----------|-------|
| CO$_3^{2-}$ | 9.00 <6.0 <6.0 <6.0 <6.0 <6.0 <6.0 <6.0 |
| SO$_4^{2-}$ | 231.4 188.0 206.4 240.0 216.0 244.0 201.6 204.5 197.8 |
| Cl  | 75.9 56.8 66.8 59.9 65.9 66.5 59.3 63.1 59.7 |
| F | 1.44 1.34 1.31 1.31 1.35 1.28 1.31 1.23 1.27 |
| Ca$^{2+}$ | 49.5 47.5 69.1 65.5 70.2 80.5 56.8 67.4 75.3 |
| Mg$^{2+}$ | 48.4 41.8 48.3 48.6 54.1 41.1 48.2 46.7 52.9 |
| Na$^+$ | 61.0 45.5 41.1 48.5 51.6 50.5 47.8 44.9 51.8 |
| K$^+$ | 4.37 3.72 4.78 3.70 2.39 1.08 0.85 1.04 3.10 |
| Si | <DL 2.07 1.22 0.80 0.85 0.70 2.66 2.43 2.42 |
| NO$_3^-$ | 0.39 2.83 2.42 2.71 1.49 1.27 0.32 0.76 1.28 |
| NO$_2^-$ | 0.014 0.077 0.004 0.27 0.008 <0.003 0.005 0.004 <DL |
| NH$_4^+$ | 0.12 1.99 0.29 <DL 0.35 0.41 <DL <DL <DL |
| P$_{total}$ | 0.060 0.080 0.078 0.060 0.050 0.045 0.040 0.045 0.020 |
| TDS | 604.7 555.4 639.8 648.3 674.8 694.6 622.2 651.2 655.7 |
| Al | 0.028 0.038 0.11 0.036 0.019 0.023 0.010 0.005 0.011 |
| Fe | 0.051 0.017 <DL 0.029 0.021 0.018 0.001 0.003 0.066 |
| Mn | 0.003 0.04 <DL 0.006 0.007 0.006 0.0001 0.0005 0.0048 |
| V | 0.002 ND ND 0.002 0.003 0.002 0.004 0.003 0.002 |
| Cr | 0.001 ND ND 0.001 0.002 0.0002 0.0001 0.0002 0.0001 |
| B | 0.26 ND ND 0.30 0.27 0.38 0.30 0.26 0.21 |
| Ba | 0.081 ND ND 0.080 0.087 0.081 0.091 0.076 0.088 |
| Br | 0.073 ND ND 0.051 0.059 0.060 0.081 0.077 0.089 |
| As | 0.005 ND ND 0.005 0.009 0.007 0.012 0.010 0.003 |
| Sr | 1.12 0.91 1.01 0.93 1.07 1.05 0.87 0.81 1.09 |
| Li | 0.049 ND ND 0.042 0.050 0.036 0.051 0.044 0.051 |
| Mo | 0.010 ND ND 0.009 0.017 0.011 0.015 0.014 0.011 |
| Ni | 0.0015 0.0041 <DL 0.0017 0.0024 0.0016 0.0016 0.0024 0.0014 |
| Co | 0.0002 <DL <DL 0.0001 0.0001 0.00005 0.0002 0.0004 0.00034 |
| Pb | 0.00016 <DL <DL 0.00024 0.00048 0.00028 0.00001 0.00005 0.00015 |
| Cd | 0.00004 <DL <DL 0.00038 0.001 0.0002 0.0003 0.0003 0.0001 |
| Cu | 0.0035 0.0049 0.001 0.0032 0.006 0.0019 0.0013 0.0021 0.0017 |
| Zn | 0.004 ND ND 0.009 0.011 0.003 0.003 0.005 0.004 |
| W | 0.0018 ND ND 0.0014 0.002 0.0012 0.0029 0.0019 0.0009 |

* Detection limit.

The most significant changes took place in the anionic composition of the water – the content of hydrocarbonate decreased almost threefold at the maximum, while the sulfate ion increased more than 10 times. The different directionality of the dynamics of these components is due, on the one hand, to a change in the items of the water balance, and, on the other, new sources that have appeared that are
involved in the formation of the salt balance. In particular, the decrease in the concentration of carbonate components is caused by the injection of river water.

The formation of carbonate minerals due to the saturation of the lake’s water in them, most likely, has some participation in the removal of carbonates from the water, which was noted before the start of the TPP [1]. The increase in sulfate concentrations is due to the influence of the ash dump [1] and the deposition of sulfur oxides on the lake water as part of the gas and smoke emissions from the TPP, as well as the discharges of process water from the chemical water treatment units and after cleaning the boilers, where sulfuric acid is used as one of the main reagents.

Changes in the anionic composition of the lake water also manifested themselves in an increase in the concentration of chlorides - from 5-19 mg / L in the tolerance period to over 90 mg / L in recent years [6], which is also associated with the use of chemical reagents containing them in the technological processes of thermal power plants. In some periods, the chloride content exceeds 20 % - eq. and they become significant in determining the chemical type of water. During the studied period of testing, their content varied in the range of 57–76 mg / L, which in percentage-equivalent form is equal to 17–19 % -eq.

The concentrations of nutrients in the lake water do not exceed the fishery standards, with the exception of ammonium nitrogen in some samples, which indicates an intensification of the processes of organic matter decay [4]. The high content of ammonium forms of nitrogen indicates the ability of the ecosystem to decompose organic matter; there is no further accumulation of them. In dry years, the level of nitrogen and phosphorus in the reservoir depends entirely on the in-water biochemical processes of organic matter decomposition. In high-water years, the input of organic matter from the catchment area of the reservoir increases the concentration of nitrogen and phosphorus [4].

There are no data on the content of fluorine in the lake water in the period before the start of the TPP. In the summer of 1991, the concentration of fluorine throughout the entire water area of the lake was in the range of 3.4–4.3 mg / L, which exceeds the fishery standard of 0.75 mg / L [1]. Its accumulation in the lake water is primarily associated with the filtration of water from the ash dump since there are no other real sources. This is confirmed by high concentrations of fluorine in groundwater located in the zone of its influence [7, 8] and low – outside it. Its content in the water of the ash dump settler for the period of 2018–2020 reached 14.8 mg / L [9]. Previously, we recorded the fluorine content in the settling tank water up to 17 mg / L [8]. Of course, not all filtration losses of the ash disposal area enter the lake, moreover, in the aquifer and, probably, in the aeration zone, part of the fluorine is deposited [10, 11] as a result of the formation of fluorite.

Currently, there is a decrease in the content of fluorine in the lake water to 1.31-1.44 mg / L (table), which in any case exceeds the MPC for water of fishery water bodies. A steady decrease in fluorine concentrations in the lake water, according to the TPP observations, has been going on since 1998.

In the microelement composition of lake water, in addition to fluorine, the standard for the content of strontium, vanadium, molybdenum, copper, tungsten is exceeded, in single samples – aluminium, zinc and manganese; concentrations of boron, lithium, bromine, and iron are close to MPC or increased (table). All of these potentially toxic microelements are most often present in the liquid part of the pulp [12] ash dumps of thermal power plants; their concentrations, as a rule, exceed the maximum permissible values for drinking water. In the sedimentation tank of the Chita TPP, anomalous values [9] of these elements, with the exception of copper, are noted; in the groundwater of the zone of influence of the ash dump, the contents of boron, bromine, manganese and lithium exceed the MPC [7].

3. Conclusions

The results of the hydrochemical testing showed that at present sulfate ion predominates in the anionic composition of the lake water, and magnesium in the cationic composition; the concentrations of elements exceed the MPC. The fluorine content has decreased in comparison with the indicators of previous years, but still exceeds the standard.
The concentrations of strontium, vanadium, molybdenum, tungsten, aluminum, zinc and manganese – components of filtration waters of the ash dump, exceed the MPC in the lake water. The contents of boron, bromine, lithium and iron are increased relative to the MPC.

With an increase in the technogenic load on the reservoir and the non-observance of protective and restorative measures, it may lose its recreational and fishery value.

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