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Integrated use of lake-type basin-coolers for recreational purposes

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Abstract. At present the bulk of all water bodies in the Russian Federation and the Republic of Tatarstan in particular is experiencing significant anthropogenic impact. One of the types of impact is thermal. The article shows the positive effects of thermal contamination on lake-type basin-cooler such as increasing of the concentration of dissolved oxygen in the water in winter, improving the state of bottom sediments as a result of the water circulation, and expanding the possibilities of aquaculture. The possibilities of integrated use of lake-type coolers for recreational purposes are shown (combining the technical use of lake water with recreational purposes through the implementation of sporting events and the creation of a park and observation zone on the lake).

Introduction

Since ancient times people have settled near water bodies that played an important role in their life. In this regard, water resources should be given special attention as one of the most important elements of economic development, taking into account its social and environmental advantages [1]. The rapid growth of urbanization has a negative impact on intra-urban water bodies. Rivers, water passages and reservoirs are basin-coolers of thermal power stations, sewage receivers, these negatively affect the quality of water and bottom sediments, the life of hydrobionts, aquatic vegetation and the coastal zone. However, if rivers have a flow and are capable of carrying pollutants, the lakes accumulate them and as a result they are most susceptible to various kinds of pollution. Due to this, it becomes urgent to assess the ecological status of water bodies especially those that serve multi-purpose use.

One of the main physical and chemical indicators for determining the state of water bodies is temperature. The thermal regime of water bodies determines the rates of organic substances' circulation and their involvement in food chains. Contemporary research gives much data on the negative impact of thermal pollution on the lake's aquatic ecosystem: the oppression of most species of hydrobionts, prerequisites for eutrophication and silting of the bottom, increased evaporation and, as a result, increased water hardness, incremented pathogenic microflora and macrophyte production. However, most of the described consequences can be avoided with the rational management of the aquatic ecosystem and the selection of ways to improve the condition of water bodies.

In addition, as shown in the current article the thermal pollution does not always lead to the degradation of aquatic ecosystems and may prove useful to humans. For example, prospects for the development of aquaculture are expanding. Spawning season of fish is shifted to earlier periods, the period of feeding of young fish is extended. A new warm-water biotope with a longer vegetation



period is created, which has a significant impact on both the composition of the fauna of fish and the change in the biological indices of individual species.

The identification of the features of the aquatic ecosystems formation in the urban environment allows to combine the interests of different economy sectors with the integrated use of lakes in the urbanized area. It also provides the necessary quality of the ecosystems state for completing the main task.

Kazan, is an industrialized city with a million population, has a system of Kaban lakes (Figure 1). One of its lakes – the Lake Sredniy Kaban is a basin-cooler of Kazan CHPP-1 and, therefore, its main task is to provide the uninterrupted supply of water to cool the turbogenerators. In addition to using the Lake Sredniy Kaban as a cooling pond, it receives sewage from 7 industrial enterprises, stormwater sewage and surface runoff from municipal lands, private households and urban garden associations. Since 2013 the Lake Sredniy Kaban is also a sports venue of international level which annually hosts competitions in rowing sports of different levels.

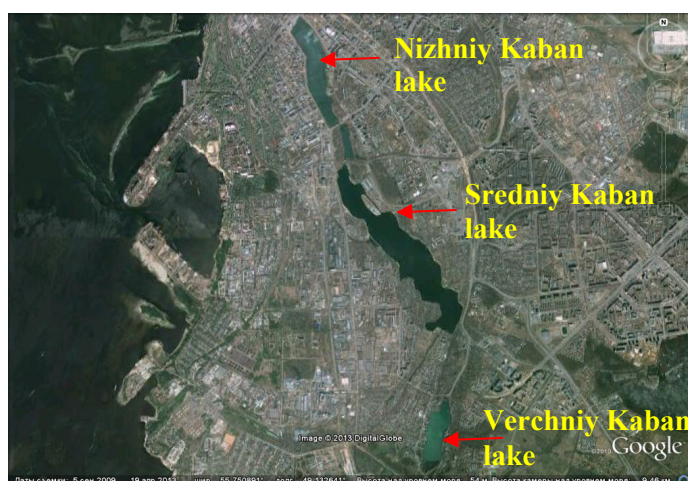


Figure 1. The Kaban Lake system (view from the space).

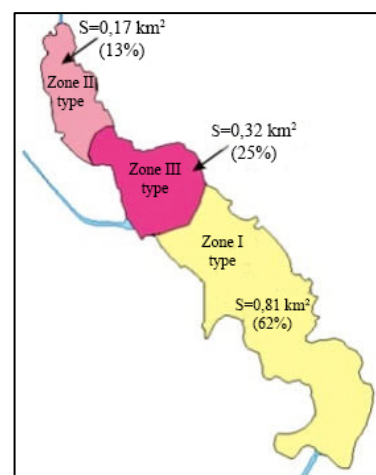


Figure 2. Zoning of the Lake Sredniy Kaban.

To create a rational approach to the integrated use of the natural cooler for recreational purposes, it is necessary to obtain a comprehensive assessment of the ecological state of the lake.

Features of the Lake Sredniy Kaban as a result of the activities of Kazan CHPP-1

The long-term studies (from 2010 to 2018) of abiotic factors of the environment made it possible to identify 3 zones [2] of the lake with industrial, thermal pollution (Figure 2).

Zone of the I type shows industrial pollution. This zone is characterized by a lack of thermal impact on the reservoir, resulting in 6 periods in the temperature regime: summer and winter stagnation; a partial summer and winter, full autumn and spring circulation. The lake temperature in the surface layer of water varies from 0.3 to 31.1 °C during the year, from 1.9 to 15.4 °C in the bottom. The average annual concentration of oxygen in water is 6.3 ± 0.9 mg/l. The presence of open water patch, as a result of thermal action, leads to an increase in the oxygen concentration in the winter period to 6.2 ± 0.9 mg/l in the neighboring zone (zone of III type), while in a lake with a minimum anthropogenic impact the concentration is 4.4 ± 0.9 mg/l. Ph reaction of the environment during the year with the exception of July is alkaline (10.03), it is caused by the massive development of phytoplankton.

Zone of the II type is the upstream of the lake, here water circulation is observed as a result of Kazan CHPP-1 work. The zone shows higher average seasonal water temperature in spring and autumn in comparison with the zone of I type: an increase of 65.7% and 8.1%, respectively; the number of temperature periods is 6. Reverse stratification and ice cover are observed in the

temperature regime in winter. Higher concentrations of dissolved oxygen in water in spring (in the surface layer of water by 39%, in the bottom layer by 13.3%) are noted in comparison with the zone of I type. The pH values shift to a weakly alkaline but do not exceed the limits of the established standards of 6.5-8.5 with the exception of summer (11.1).

Zone of the III type is specified by industrial and thermal pollution. This zone is characterized by the absence of periods of complete autumn circulation and partial winter circulation, winter stagnation. The absence of the ice cover leads to a direct stratification of the water temperature. The average seasonal values of water temperature are maximum (in winter – 6.1 ± 1.2 °C, in spring – 7 ± 1.2 °C, in summer – 26.8 ± 1.2 °C, in autumn – 15.1 ± 1.2 °C). Despite a significant temperature increase in the summer, the values of dissolved oxygen in the surface are similar to a lake with a natural temperature regime, in winter it increases by 81% as a result of the intake of oxygenated waters from the open discharge channel of the CHPP and the absence of ice cover.

A detailed analysis of the physical and chemical parameters of the Lake Sredniy Kaban allowed to develop a water quality index (I_{QW}) [3] which makes it possible to assess the quality of water by the contamination degree based on the use of a prospective complex indicator-total antioxidant activity [4]. This index is derived from the balance equation of the values of antioxidant activity (mg.rutin/l) and abiotic factors of the environment: surface water temperature (°C), dissolved oxygen (mg/l), pH, Eh (mV) (formula 1).

$$I_{WQ} = \frac{-18,96 - 0,32 \cdot T_s - 0,33 \cdot Co_2 + 4,26 \cdot pH + 0,19 \cdot Eh}{TAOA}, \quad (1)$$

where TAOA - total antioxidant activity (mg.rutin/l); t - temperature of the surface water layer (°C); Co_2 is the concentration of dissolved oxygen in water (mg/l); pH is the pH of the environment; Eh is the redox potential of the environment (mV).

The reliability of the predicted model is confirmed by a standard error of 0.09 and a determination index of 99.32%. If the index values are in the range from -1 to +1, the waters are classified as clean (oligosaprobic according to the data of the parallel microbiological analysis). If it is in the intervals from +1 to +2 and from -1 to -2, then it is α -mesosaprobic zone, if from +2 to +3 and -2 to -3, then it is β -mesosaprobic zone. At values of the index in the range $-3 < I_{QW} < 3$, contaminated water is polysaprobic. The water quality in zone II is characterized as the lowest (in the summer, the I_{QW} reaches -3.2). Zone III is characterized by the maximum variability of the I_{QW} (from -2.5 to +2.4, $V = 909.4\%$). At different times water quality is characterized as oligo-, β -mesosaprobic

Integrated assessment of the Lake Sredniy Kaban

In order to map out the ways of rehabilitation of the lake in conditions of high anthropogenic load when the lakes are located within the industrial developed urban environment and are used for multi-diversity purposes, it is necessary to identify the most important parameters that can be used to upgrading the condition of the lakes. As a result of the realized investigations [10] the integrated assessment (Figure 3) was carried out on 14 indicators (dissolved oxygen, pH, TAOA, water temperature, Eh, saprophytic microorganisms quantity, number and biomass of phyto-, zooplankton, zoobentos, ikhtyomass), described in 6 methods of water quality evaluation [2, 5-7]. Since in the methods considered, the degree of water pollution and trophicity of lakes is represented by a different number of water quality categories, we have made the translation of these methods into a scoring assessment, where each category of water quality was assigned 1 point [3]. The water quality decreases as the number of points increase. The minimum score is 33, the maximum is 208.

The results of the integrated assessment (Figure 3) indicate that during the summer and winter periods, the lowest water quality is observed compared to the spring and autumn periods. Herewith, in the summer period the maximum proportion of pollution of type zones II and III is contributed by the physicochemical indicators (50% and 62% of the maximum number of scores respectively), and in I type zone is contributed by the microbiological indicators (52% and 53% respectively). In winter

period physicochemical indices make the maximum contribution to the contamination (from 56% to 60% of the maximum number of points).

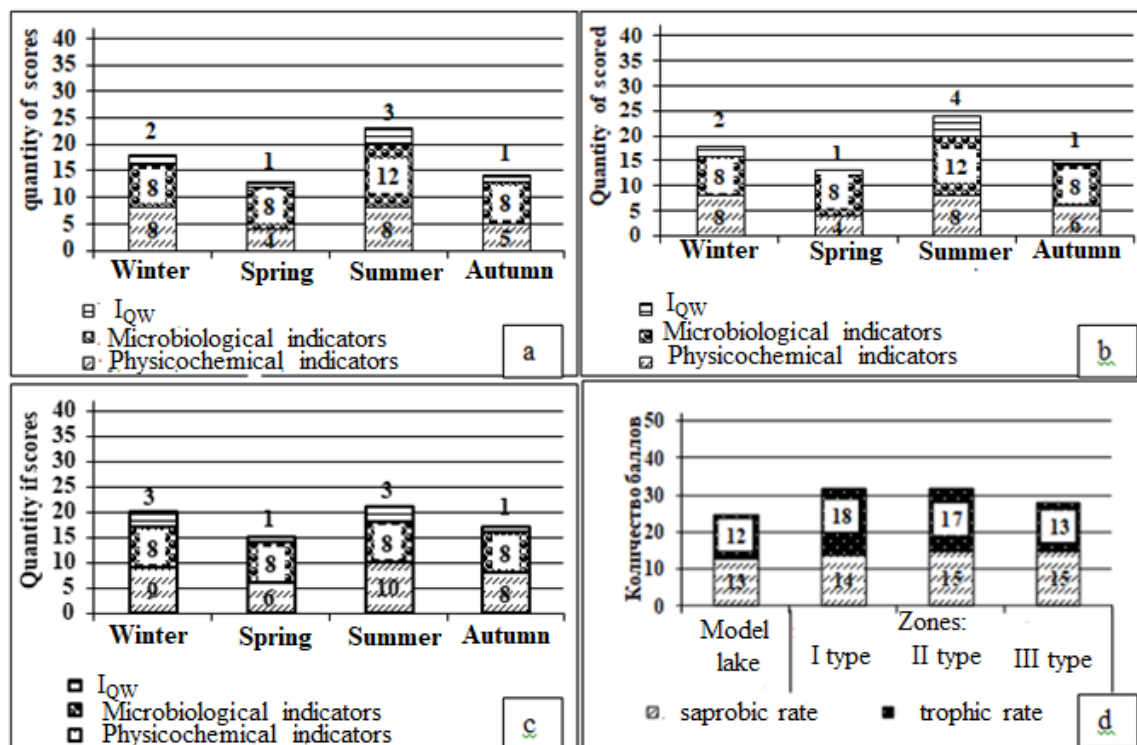


Figure 3. Integrated assessment of the pollution degree of Lake Sredniy Kaban: a – I type zone; b – II type zone; c – III type zone; d – integrated assessment of biota.

A water quality assessment based on biota characteristics (Figure 3 d) revealed the worst state of the aquatic ecosystem in I and II type zones (32 points each), which are characterized by a complex anthropogenic impact. In general, an integrated scoring assessment of the pollution degree and trophicity indicates the average level of pollution (mesotrophy) of the lake with industrial pollution.

Thus, the complex analysis of the state of the lake ecosystem allows us to rationally select the integrated use of the basin-cooler for recreational purposes.

Recreational zone design on the base of basin-cooler of energy facility

The realized integrated assessment of the ecosystem state of the Lake Sredniy Kaban allowed composing the scheme for the improvement of condition of the lake (figure 4).

In connection with the increasing anthropogenic pressure on the lake and the availability of a center for rowing sports on the shore of the lake, the realization of recreational potential is proposed. This will solve the issue of pollution of the lake by storm sewage in the I type zone (18 out of 21), which cause maximum damage. This event is possible through the formation of a rational and promising system of recreational facilities (a zoo and a well-equipped embankment) and engineering infrastructure (the creation of a drainage system for storm water drainage). The general layout of the territory after the construction of the recreational zone is shown on Figure 5.

Due to the fact that the modern zoo is under construction at the moment, the center of rowing sports was built for the Universiade 2013, we offer to landscape the territory creating:

- Forest park zone (№ 5 on the Figure 5, green color);
- Upgrading in small forms (№ 4 on the Figure 5, sand color). Creation of comfortable recreation areas on the water body and the possibility of monitoring the competitions in rowing sports

from any angle and distance. Achieved by equipping the area with benches, pedestrian and bicycle paths, flowerbeds, pergolas, retaining walls;

- Hanging terraces above the water area (№ 6 on the Figure 5, light blue color). The hanging terraces allow more detailed observation of the water environment of the lake and its hydrobionts.

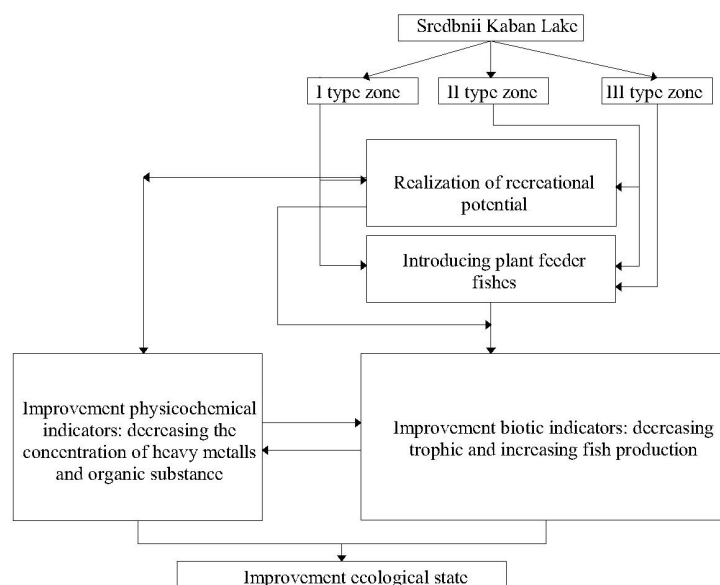


Figure 4. Scheme for the improvement of condition of the Lake Sredniy Kaban.

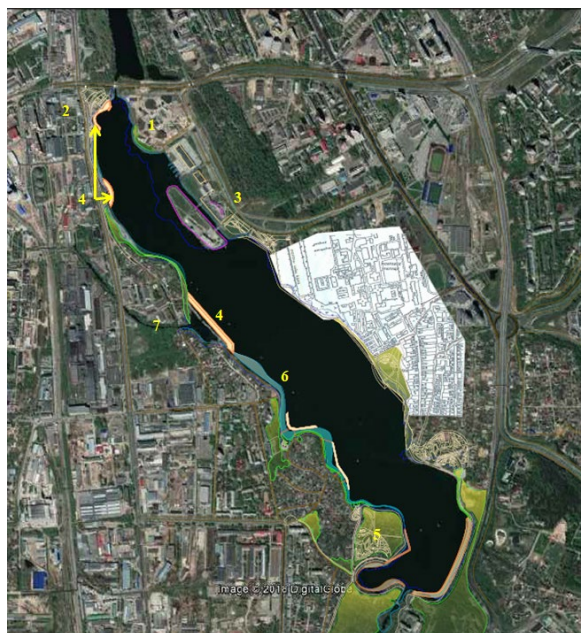


Figure 5. General layout after the creation of recreational zone: 1 – zoo; 2 – Kazan CHPP-1; 3 – center of rowing sports; 4 – Upgrading in small forms; 5 – forest park zone; 6 – hanging terraces above the water area; 7 – open offtake.

Due to the fact that recently the number of floating higher aquatic plants in the Lake Sredniy Kaban increases, it is advisable to stock the reservoir with herbivorous fish. This will also reduce the level of

overgrowth of the lake. From the calculations carried out for the fodder base for the Lake Sredniy Kaban, it is generally recommended that *Ctenopharyngodon idella* Val introduced with a density of planting of 705 pcs/ha, which will ensure an annual seizure of the highest aquatic vegetation with an area of 5.2 hectares and the possibility of catching fish products in the volume of 1505 kg with an annual stocking by yearlings with a density of planting of 705 pcs/ha.

All planned events will reap the appearance of the cooling pond located in the city boundary, make the lake more attractive for the residents of Kazan in connection with the possibility of using it as a park and sports zone, and improve the physicochemical and biotic indicators of the lake.

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