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RESEARCH ARTICLE

THE ENVIRONMENTAL CONDITION OF LAKE BILIKOL AFTER ANTHROPOGENIC POLLUTION FROM THE ASA RIVER, KAZAKHSTAN

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ABSTRACT

The ecological condition of Lake Bilikol under conditions of anthropogenic pollution from the Asa River has been recently documented. Major pollution events occurred in 1983-1984 and 1988 after the accidental release of industrial effluents from the Zhambyl Phosphorus Factory into the Asa River. This also became the starting point of environmental deterioration. In subsequent years, the flora and fauna of the lake were partially self-restored, but because of the impact of pollutants, the lake is still in the stage of severe degradation. This article examines changes in the ecological condition of Lake Bilikol under anthropogenic pollution inputs from the Asa River, which is the main source to the lake. This article also includes a description of the geographical location, information on lake fauna (fish stocks, water, and water birds), and hydrography and anthropogenic impacts. The level of anthropogenic impact and its duration over time, which multiplied after the accidental release of industrial wastewater from the Zhambyl phosphorus plant into the Asa riverbed in 1983-84 and 1988, is the starting point of ecological degradation of the lake and is reviewed in more detail. Chemical analysis results of water and soils of the lakebed, which are mainly polluted by phosphates and fluorides, and their transformation during the last 30 years are presented in methodical terms. In certain years, there was a partial self-restoration of the lake ecosystem (water quality, fauna, and flora). Nevertheless, the lake is currently experiencing severe ecological degradation because of the long-term influence of chemical pollutants. In the future, environmental protection measures are needed to plan practical measures for the rehabilitation of the lake using methods both for the acceleration of biological self-remediation and for hydro-mechanical cleaning of the lakebed and lake water.

KEYWORDS

lake, river, tributary, pollution, pollution area, maximum allowable concentration.

1. INTRODUCTION

Zhambyl Province, a territory in the Republic of Kazakhstan, receives water from transboundary Shu, Talas and Asa rivers with sources in the Kyrgyz Alatau mountains. The volume of transboundary flow is more than 70%, which requires grassroots water users to take a careful approach in matters related to the use of water resources (Environmental Information Bulletin of the Republic of Kazakhstan, 2014). One of the key tasks is to keep water bodies (reservoirs, ponds and lakes) clean, conduct treatment, and ensure environmental releases. In the oblast, the most polluted water body is Lake Bilikol, which is located in the lower reaches of the Asa River. Lake pollution is assessed using the water pollution index and is considered "very dirty." Until 1983, the rest zone for local residents and a children's camp were located on the lake shore (Archival documents of Zhambly Natural Resources Pollution Monitoring Laboratory for 1972-2013). At that time, Lake Bilikol was considered a natural "pearl" of the area. In 1983 and 1988 (twice within 5 years), and as a result of a breach of the tailings dam of the phosphorus plants located on the right bank of the Asa River, tailings were discharged through the Asa River into the lake. Within approximately 5 years, all fish species disappeared, and the lake is now classified as a heavily polluted body of water.

The most problematic aspect is the composition of bottom sediments of the lake, which are still contaminated by phosphorus production wastes and organic compounds. Bottom sediments are a "time bomb," as they can cause secondary pollution as a result of wind drift because the area is exposed to strong winds and also as a result of underwater springs. This is demonstrated by dynamics of BOD5 analyses when values rose sharply in 2012-2013 as a result of a windstorm that lifted contaminants from the seabed. In 2014, and at the request of the Zhambyl branch of the Republican State Enterprise Kazgidromet, specialists from the RK Institute of Nuclear Physics investigated the lake's radiation indicators and noted elevated levels of heavy metals and radioactive elements in bottom sediments. A high concentration of various biogens caused the development of blue algae and a so-called lake bloom; this process is detrimental to the environment (Skypnyk, 2015). Due to these changes in the chemistry of the lake, the entire shoreline along the perimeter began to overgrow with reeds. The content of dissolved oxygen in the water sharply decreased and its biochemical consumption increased. Part of the

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dissolved oxygen is consumed for biochemical oxidation, which creates a shortage of oxygen for other organisms. In addition, valuable fish species have disappeared.

In 1987-89, there was a temporary improvement in water quality in the lake due to increased flow from the Asa River. Thereafter and until 2016, water inflows from the Asa River steadily decreased. Currently, the lake's biodiversity is unstable and continues to deteriorate. Specialists of the Kazakh Research Institute of Water Management have been systematically conducting scientific research since the accidental release to the Asa River channel. Specifically, they have been assessing the degree of pollution and the condition of the lake and developing recommendations to reduce the negative consequences of the accident (Karlykhanov et al., 2008; Nabiollina et al., 2020). In 2014, based on laboratory analyses of water samples and bottom sediments, statistical characteristics and dynamics of transformation of the main pollutants of the lake's water resources were determined. As a result, resource-recovery measures were proposed such as the following: "It is necessary to exclude pollutants from entering the main tributary of the lake, the Asa River, as it is alarming that the fluoride content in the river water increased in 2015 compared to 2014 and exceeded the maximum permissible concentration by 1.8 times" (Environmental Information Bulletin of the Republic of Kazakhstan, 2014).

It was previously determined that the "Filtration area of Taraz city wastewater does not accommodate the volume of incoming waste, the dams are dilapidated. Design capacity of filtration fields is 43.1 thousand cubic meters of wastewater per day, but actually twice as much comes in every day. The fields are both physically and morally obsolete. Residents of settlements close to the filtration fields suffer from penetration of sewage into groundwater" (Sereda and Varnikov, 2002). Therefore, the construction of modern municipal sewage treatment plants is necessary (Environmental Information Bulletin of the Republic of Kazakhstan, 2014; World Health Organization, 1984; Hoek et al., 1995). Based on the current situation of the hydro-ecological state of Lake Bilikol, a detailed analysis of the pollution of water and bottom sediments of the lake was conducted and this information was generalized to take preventive measures to restore the lake's ecological stability against the influence of external influences.

1.1 Baseline information

Geographic location. Lake Bilikol is located in the foothill valley of the Karatau system and in the lower reaches of the Asa River and is a water body for fishery purposes (Figure 1). The geographical features of the lake form an irregular shape. Specifically, it is divided into two notional parts, namely, a small bowl and a large bowl. These bowls are connected by a narrow isthmus. The Asa River flows along the isthmus into the lake. There may be references to the Asa River in a number of ancient legends. For example, its water resembled a human footprint. The depth of the lake in those times was approximately 20 m.

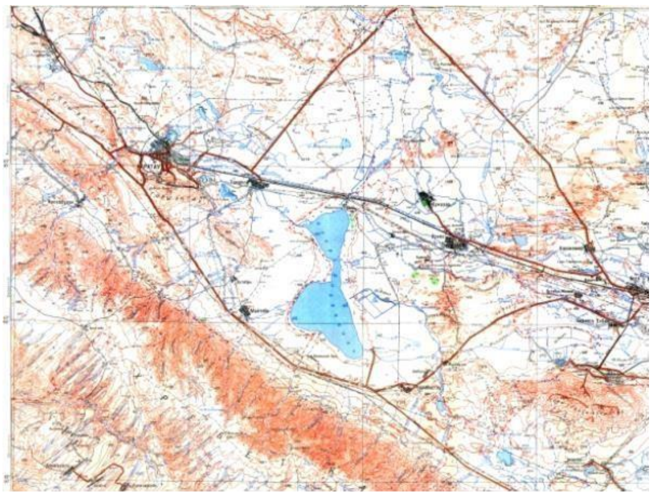

Figure 1: Geographic location of Lake Bilikol

Generally, the area of the lake is approximately 5800 m^2, its length is 3200 m, and its width is 1800 m. The current maximum depth of the lake is approximately 8 m and the average depth is approximately 3 m. The water surface of the lake continually fluctuates, and its intensity depends on the volume of water that enters the lake from the Asa and Berikkara rivers. Other factors do not have much influence on peculiarities of the lake. The structure of the bottom of the lake is undulating with depressions and bluffs up to 5 m wide and 1.5 m deep. The ground in the lake consists of clay and sand with an impressive layer of black, muddy sediment on top. Closer to the shore, remains of rotted reeds can be found. When the water becomes turbid, there is an unpleasant smell of hydrogen sulfide. There is aquatic vegetation around most of the perimeter of the lake. Reeds dominate, but cattails can also be found. Reeds can be up to 5-6 m high here and 2 m of which is a root system located within the water part of the lake.

The climatic conditions in the area are sharply continental. The lake freezes over very often, especially when there is severe frost. The ice formed in this case reaches a thickness of half a meter. At any time of the year, except during the summer, there are high gusts of wind on the lake, which are referred to by the locals as Berikkara.

1.1.1 Hydrography. The Asa River only transports water into the lake for 7-8 months per year.

There are slight gradients at the outlet of the lake into the river, which results in the swamping of some areas. Swamps form in such areas, which are then covered with reeds. The hollow near the lake is shallow and the banks are silty. The silt can occur up to one meter high and is mostly black, but there are also some grey masses that smell of hydrogen sulfide. The southern shoreline is composed entirely of overgrown reeds. The aquatic vegetation is very well developed and particularly concentrated in areas that are protected by reeds from gusts of wind.

1.1.2 Fauna of the lake. Fish stock. Lake Bilikol was previously famous for its fish stock.

Until 1970, Lake Bilikol was capable of supplying all of the population living on the territory of Zhambyl Region with fish. The ichthyofauna of Lake Bilikol is represented by 30 species of different fish. According to older local inhabitants, the lake was home to large catfish, white amur, bighead carp, bilikol carp, pikeperch, carp and others [4]. The catch was good until 1983 when approximately 1,500 t/year of fish were caught. Currently, the lake's fish stocks are visibly impoverished. Pollution and low water levels have resulted in the death of fish. The fish catch, according to recent studies, has decreased by up to 30 times compared to 1972, and species composition has also decreased. Catfish, grass carp and silver carp are no longer found and pikeperch and other species have become rare.

1.1.3 Aquatic and semiaquatic birds.

The network of steppe lakes, consisting of Bilikol, Taskol, Akkol, Darbaza and Ters-Ashibulak, form a rather pleasant environment for birds, which was observed until 1982. Throughout this system of lakes, there are many migratory bird pathways and that is why this system is of high importance, because birds can make a stopover and rest in this location. Locals previously noted large numbers of birds resting on site during their migrations. Unfortunately, birds now don't stay here very often, which is because the lake is heavily polluted. It is this pollution that prevents the formation of a positive environment for birds in the area. Furthermore, other places have become more preferable for birds. However, it is worth noting that in the reed area, waterfowl, such as duck or bittern, can still be spotted and seagulls sometimes fly over the lake. During springtime flooding, it is common to also spot white heron.

1.2 Anthropogenic impacts

In 1983-84 and 1988, as a result of a breach of the tailings dam of phosphorus plants located on the right bank of the Asa River, tailings were discharged through the Asa River into the lake. Within a short period of time, all the fish disappeared, and the lake was classified as a heavily polluted body of water. One of the main problems is the composition of sediments located on the bottom of the lake. These sediments mainly contain phosphorus compounds that are pollutants. In addition, organic waste can be found in the sediments. In 2014, a study was conducted on the lake's radiation levels. In addition, research was requested by the Zhambyl branch of RSE Kazgidromet. During the analysis, we found that lake sediments had a high index of radiation substances (Achival documents of Zhambly Natural Resources Pollution Monitoring Laboratory for 1972-2013).

High concentrations of various biogens cause the development of blue algae and lake bloom. This process is detrimental to the environment

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(Skypnyk, 2015). With this background of changes in the chemistry of the lake, the entire shoreline along the perimeter began to overgrow with reeds. Furthermore, the content of dissolved oxygen in the water has sharply decreased and its biochemical consumption has increased. Part of the dissolved oxygen is consumed for biochemical oxidation, which creates a shortage of oxygen for other organisms. Because of this, valuable fish species have disappeared. In 1987-89, there was a temporary improvement in lake water quality due to increased flow from the Asa River. Thereafter and until 2016, water inflows from the Asa River steadily decreased. Currently, the lake's biodiversity is unstable and continues to deteriorate.

Specialists of the Kazakh Research Institute of Water Management have been systematically conducting scientific research since the accidental release to the Asa River channel and assessing the degree of pollution and the condition of the lake and developing recommendations to reduce the negative impacts. The following aspects were substantiated such as a) releases along the Asa River and cleaning measures of the lakebed, b) rehabilitation measures based on examples of other water bodies, and c) rational use of melt and flood waters in low-water years to maintain the lake level (Karlykhanov et al., 2008; Nabiollina et al., 2020; Sereda and Varnikov, 2002; World Health Organization, 1984; Hoek et al., 1995).

2. Methods

An analysis to determine the degree of chemical pollution of water and bottom sediments of Lake Bilikol was conducted in accordance with the instructions (Report on R&D work, 2015; Karlykhanov et al., 2014a). Water samples for chemical analysis were collected from a boat in a zig-zag pattern for full coverage of the water surface (Figure 2), and analyses were then conducted according to standard methods (Karlykhanov et al., 2014b; Karlykhanov et al., 2014c; Karlykhanov et al., 2018).

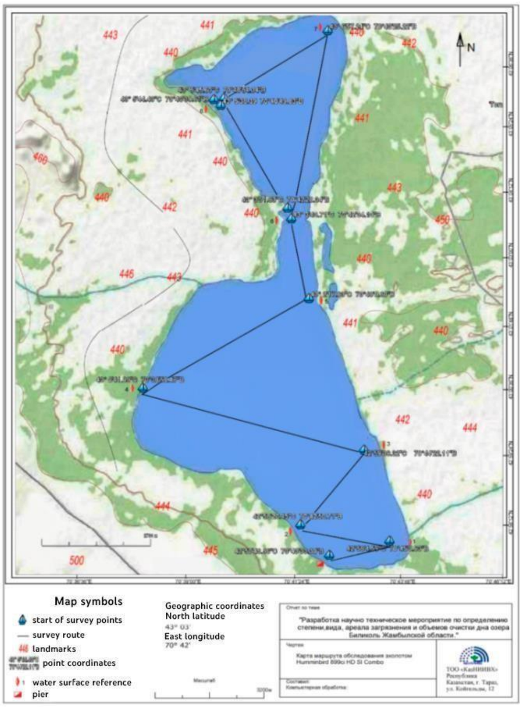


Figure 2: Schematic of sampling from Lake Bilikol

2.1 Methodology for determining the specific conductivity.

The main indicator of ions in water is the specific electrical conductivity and reflects the overall salt composition of the aquatic environment. It is worth noting that even small amounts of impurities can significantly increase the electrical conductivity, which is why it is an important characteristic of water. Samples were collected using a special unit, the conductivity meter 340i, and then immediately tested. The basic unit of measurement is Siemens per meter. The total salt content of the water body corresponds to the total salinity, which is measured in milligrams per square decimeter.

2.2 Methods to determine pH.

The pH of a water body is based on the concentration of hydrogen ions and is measured with the Ionometer 360i.

2.3 Methods to determine fluorides.

The fluoride content in water is analyzed using a colorimetric method of examination. This method is based on a color change so that the concentration of the desired component can be determined. If the solution has acquired a yellow color, then a high concentration of fluorides can be determined. However, if the color remains the same (i.e., crimson), then fluorides in the water are low. Distilled water, which is colored crimson in the analysis, is used as a reference. During the analysis, the water was yellow, which indicates a high concentration of fluorides in the lake. To calculate this concentration more accurately, a Genway-6300 FEC instrument is used.

2.4 Methods to determine phosphorus compounds.

Phosphorus compounds were determined by analytical testing, namely, by reacting with molybdate in an acidic medium. The reaction produces phosphor molybdenum acid. When phosphorus compounds are present in the water, the solution turns a light blue and the presence o phosphate in the water can be visually detected. The exact concentration of phosphorus compounds is determined with the Spekol-1500 device and based on the colorimetric method of analysis. During the test, a sample of lake water is poured into a 100 ml flask with a graduated cylinder. Then, 10 ml of reagent is added to the sample and the reaction mass is intensively stirred. The solution turns blue, which indicates phosphate in the water. After 15 minutes, the optical density is measured on the FEC for future calculations of the exact concentration of phosphorus compounds.

2.5 Methods to determine biochemical oxygen demand - BOD_5.

BOD_5 is the amount of oxygen dissolved in the aquatic environment that is expended in the oxidation processes of organic compounds in water. Microorganisms that are present in the aquatic environment also play a significant role in this process. This study determined the amount of oxygen expended in the oxidation of organic compounds located in one volume of lake water. The analysis was conducted at room temperature for five days. The amount of oxygen in the water marks the oxygen regime of the water body and is essential for allowing hydrobionts to breathe. Oxygen is also involved in the cleaning processes of the pond as it oxidizes decomposition products of organisms that have died. A slight decrease in the amount of oxygen provides an indication of changes in the bioprocess in the reservoir and of water pollution by organic compounds.

Dissolved oxygen concentration BOD_5 is calculated using the formula (Report on R&D Work, 2015):

$$C_1 = \frac{8 \times C_м \times V_т \times V \times 1000}{V - V1},$$

C_1- the concentration of dissolved oxygen; 8- equivalent mass of atomic oxygen; C_m- concentration of titrated standard solution of thiosulfate, m/l; V_t- total volume of sodium thiosulfate solution; V- volume of sample taken for determination; and V_1- volume of displaced sample due to the addition of magnesium sulfate and potassium iodide solutions.

3. Results and Discussion

Sampling of water and soil from the bottom of the lake for analysis was conducted after a preliminary study of the water composition using 20 indicators and after exclusion of some ingredients due to their absence or insignificant content in the water composition. Table 1 shows the results of the chemical analysis of 15 ingredients. A comparative analysis of statistical data on the dynamics of main indicators of water pollution in the lake by total mineralization and sulfates, phosphates and fluorides, BOD_5, and dissolved oxygen for the last 40 years is shown in Figure 3.

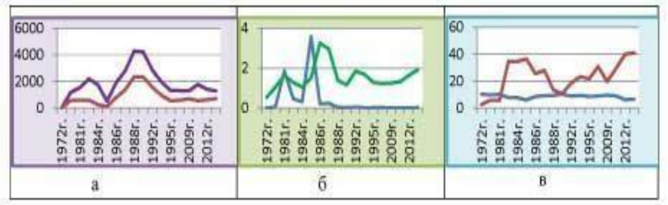


Figure 3: Dynamics of a) Total water salinity (mg/dm³) and sulfate content (mg/dm³), b) Phosphate content (mg/dm³) and fluoride content (mg/dm³), and c) BOD_5 and dissolved oxygen content over the last 40 years

LOC for total water salinity is 1000 mg/dm3. The values for 1972 were obtained before the start of the first salvo of chemical plants. The highest salt concentration was observed in 1988-89 when it reached 4289 and 4208 mg/dm3, respectively, and exceeded the LOC by 4.3 times. The highest sulfate content observed occurred in 1989 when it was 2377 mg/dm3.

Table 1: Results of the chemical analysis of Lake Bilikol water (sampling date 08.10.2015)

Number of sampling points	Defined components in mg/dm³														
	BOD, mgO2/l	COD, mg/l	pH	Ammoniumsulfate, mg/l	Hardness, mgeq/l	Calcium, mg/l	Magnesium, mg/l	Fluoride, mg/l	Hydro carbonate, mg/l	Mineralization, mg/l	Chlorides, mg/l	Total iron, mg/l	Phenols, mg/l	Manganese, mg/l	Phosphates, mg/l
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
LOC*	6	30	6,5-8,5	100		180	40	0,05	100	1000	300	0,3	0,001	0,01	0,05
01	7	35	8,4	504	9	66	74	1,56	284	1193	66	0,8	0,001	0,02	0,07
02	6	31	8,6	510	12	66	110	1,52	281	1154	65	0,8	0,002	0,02	0,10
03	6	34	7,7	505	10	*59*	81	1,52	278	1179	66	0,8	0,001	0,03	0,08
04	6	33	7,6	498	10	63	83	1,52	281	1173	67	0,5	0,001	0,07	0,06
05	6	33	7,9	620	12	33	108	1,80	284	1353	79	0,5	0,002	0,03	0,05
06	11	54	7,3	530	11	79	81	1,60	324	1278	67	1,3	0,003	0,02	0,21
07	17	68	7,1	511	9	59	66	1,60	278	1199	66	0,3	0,002	0,04	0,10
08	12	73	7,4	500	10	56	88	1,45	294	1182	67	0,9	0,002	0,03	0,20
09	5	40	8,3	632	10	63	88	1,54'	294	1410	83	0,7	0,001	0,02	0,09
10	6	50	8,2	636	11	67	91	1,56	205	1278	78	0,5	0,001	0,02	0,07
11	8	50	7,9	562	11	**59**	93	1,57	291	1285	78	0,5	0,001	0,02	0,20
12	6	43	8,3	683	11	71	93	1,77	297	1482	83	0,5	0,001	0,02	0,09
13	3	42	7,4	632	11	67	93	1,57	294	1401	82	0,5	0,001	0,02	0,08
13	10	43	7,3	677	11	71	93	1,89	306	1490	85	0,5	0,001	0,01	0,07
14	4	44	7,7	644	11	59	93	1,62	294	1413	78	0,5	0,001	0,03	0,06
15	4	45	8,3	624	11	71	88	1,57	291	1388	82	0,6	0,001	0,01	0,05
16	5	45	8,0	668	11	**47**	106	1,36	291	1437	78	0,6	0,002	0,01	0,07
17	4	35	8,4	692	12	67	108	0,96	300	1478	78	0,6	0,001	0,01	0,05
18	4	43	8,4	630	11	71	96	1,49	297	1397	82	0,8	0,001	0,02	0,06
19	8	51	8,4	655	11	63	96	1,16	297	1439	83	0,5	0,001	0,03	0,11
20	5	43	7,4	606	11	75	93	1,96	297	1359	80	0,7	0,001	0,03	0,12
21	5	45	8,3	663	12	71	105	1,62	297	1443	85	0,6	0,001	0,08	0,14
22	6	49	8,4	682	11	71	93	1,91	294	1477	83	0,7	0,001	0,08	0,12

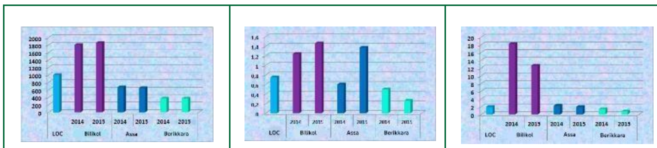
*LOC for water bodies with important fisheries (Order of the Federal Agency for Fisheries No. 20 of 18.01.2010)

The highest phosphate content was observed in 1981 and 1985. In 1985, the level was 3.582 mg/dm3, which slightly exceeded the LOC value of 3.5 mg/dm3 for phosphate by a factor of 1.02. Since 1989, the phosphate content has been maintained at a stable and low level. The maximum fluoride content occurred in 1986. A level of 3.25 mg/dm3 with a maximum permissible fluoride content of 0.75 mg/dm3 has remained high for all years and exceeded the maximum permissible concentration by 4 on three occurrences. The same is true for BOD5. LOC for BOD5 should not exceed 1 mg/dm3. The maximum BOD5 content was recorded from 1982 to 1985 and from 2010 to 2013. After the emergency escape, BOD5 passed LOC 34 times. Biochemical oxygen demand levels in 2012 reached the level of 1983 when the discharge occurred into the lake. In 2013, BOD exceeded LOC by 40 times, which indicated a decomposition processes of organic matter and blue-green algae development.

Since the resumption of regular observations, the condition of the lake has not improved. his can be observed by comparing data on BOD5, hardness, and sum of ions for January-August months of 2014-15 where BOD_5 exceedances are 5-8 times greater and the sum of ions increased up to 1.5 times. Table 2 and Figure 4 show results of the comparative analysis of water purity of the lake and its tributaries, i.e., the Asa and Berikkara rivers by pH, total mineralization, fluorides, phosphates and BOD_5.

Table 2: Summary table of indicators for 2014-15

Indicators	LOC	Lake Bilikol	Asa	Berikkara
pH		8,4-8,5	7,9	8,2
Total mineralization, mg/l	1000	1859	672	372
Fluorides, mg/l	0,05	1,46	0,05	0,05
Phosphates, mg/l	0,05	0,13-0,08	0,01	0,01
BOD_5, mg/l	6	18-12	2	1



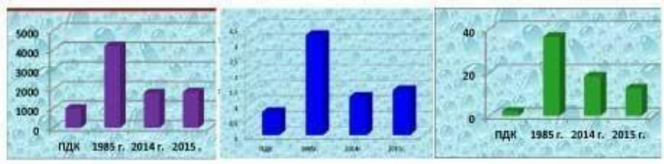
a b c

Figure 4: A comparative chart of water analyses of Lake Bilikol and Asa and Berikkara tributaries: a) total mineralization, b) fluoride, and c) BOD_5

The total water salinity in Lake Bilikol is in exceedance by 1.8 times, while in the Asa and Berikkara rivers it is normal. Fluorides in the lake exceed LOC by 1.6-1.9 times, while in they are normal within the Asa and Berikkara rivers. BOD5 in the lake exceeded LOC by 9 times in 2014, by 6.3 times in 2015, while it was normal in the Asa and Berikkara rivers (Karlykhananov et al., 2020a; Karlykhananov et al., 2020b). A comparative analysis of results obtained for the water indicators in the lake in 2014-15 is provided, and a maximum pollution of the lake occurred in 1985-89. A indicator relative to LOC are shown in Table 3 and Figure 5.

Table 3: Summary table of pollutant indicators

Indicators	BOD mg/dm³	Maximum	2014	2015
Total mineralization	1000	4289	1805	1859
Fluorides	0,05	3,25	1,4	1,4
Phosphates	0,05	3,6	0,13	0,08
BOD5	6	40	18	12



a b c

Figure 5: A comparative diagram for a) total water salinity, b) fluoride content, and c) biochemical oxygen demand BOD_5

3.1 Recommendations

Suggestions for lake rehabilitation. Every water body is a complex ecosystem of bacteria, algae and higher plants and their combined activity ensures the self-purification of the water. Self-purification factors are manifold but they can be divided into 3 groups: physical, biological and mechanical (Ivanova and Shpigun, 1999; Scheiner, 1976). Among the physical factors of self-purification of water bodies, dilution, dissolution, and mixing of incoming pollutants in water is of primary importance. Under a year-round flow of clean river water from the Asa River into Lake Bilikol, this condition is met if a limited environmental flow through the river is ensured. Biological self-purification factors include saprophytic bacteria, fungi, actinomycetes, and algae for which the main source of energy is the consumption of non-living organic material. This overall activity ensures the self-purification of water bodies (Semenov, 1977; Pehlivanoglu-Mantas and Sedlak, 2006). Excessive pollution of a water body undermines self-renewal processes and beneficial microflora is suppressed, which is what happened in Lake Bilikol. To help the reservoir cope with pollution, additional cleaning of the reservoir from organic matter, removal of bottom sediments, and water dilution by inflow of clean water is required. Based on the above, a comprehensive approach for lake rehabilitation to clean the lake is proposed (Table 4). The next necessary measure for rehabilitation of the lake is to exclude the flow of pollutants into the main tributary of the lake, i.e., the Asa River.

Table 4: Lake Bilikol rehabilitation action plan

Physical treatment (improving the hydrological regime)	Biological methods for water and sediment treatment	Mechanical methods of treatment
1. To increase flow along the Asa River it is necessary to ensure rational use of water resources. To save water for irrigation it is necessary to utilize drip irrigation 2. To provide water flow on the Berikkara river, construction of a dam on the river should not be allowed 3. "Water Flushing" and recharge of the lake with groundwater by drilling wells along the lake shore	1. The usage of water hyacinth (Eichorna) to clean water and bottom sediments from harmful substances including heavy metals and radionuclides 2. Purification of water and bottom sediments using strains of natural aerobic and facultative microorganisms for which organic matter and nitrogen and phosphorus are the main sources of energy 3. Planting sea buckthorn bushes along the bank	Mechanical cleaning of the riparian zone from excessive bulrush using special machinery

Despite efforts, the fluoride content in the river water increased in 2015 compared to 2014 and exceeded the maximum permissible concentration by a factor of 1.8. Therefore, it is necessary to do the following:

1. Recommend that enterprises whose effluents enter the Asa River switch to a closed cycle of water use in production.

2. Exclude entry of pollutants into the waters of the Asa River from the city's wastewater filtration fields. The Asa River runs close to these fields and they can enter the river through groundwater transfer.

4. Conclusion

A water analysis of Lake Bilikol in 2015 shows a stable chemical composition for limited ingredients and these include lead, cadmium, total chromium, and phosphates. In early studies, phosphates were well above the LOC by 1.5 to 10 times and higher. Other indicators of water chemistry (mineralization, odor, sulfates, and BOD5) were also significantly higher than normal. A generalization of studies conducted earlier to determine the degree of pollution of the lake since the phosphorus plant sewage in 1983-84 and a preliminary study of the lake in 2015 showed that the lake is still categorized as a heavily polluted water body. However, waters of the Asa and Berikkara tributary waters are much cleaner by all indicators. Therefore, pollution of the lake mainly has a residual character after anthropogenic discharges of industrial wastewater from the phosphorus plant in the 1980s.

The pollution of Lake Bilikol remains high for nearly all parameters. According to the water pollution index, the lake is characterized as a "very polluted" water body. It should be noted that water resources of Lake Bilikol are in a stage of severe eutrophication. Self-purification processes in the lake are also very slow. Under these conditions, an increase of water through the Asa and Berikkara rivers and use of melt and flood waters will contribute to purification of the lake. The continuous implementation of conservation measures is advised. When planning practical measures for rehabilitation of the lake, it is necessary to use an integrated method of both biological self-remediation and hydromechanical treatment as they complement each other and the automated water-metering system. Simultaneously, introduction of an automated system of water accounting and water allocation according to modern technologies is necessary.

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