sustainability

MDPI

Article

Assessment of the Hydrophysical and Hydrochemical Characteristics of Lake Burabay (Akmola Region, North Kazakhstan)

Kyzzhibek Shulembayeva [1], Javier Rodrigo-Ilarri [2,*], María-Elena Rodrigo-Clavero [2], Abilzhan Khussainov [1], Anuarbek Kakabayev [1] and Razya Khussainova [1]

[1] Department of Mining, Construction, and Ecology, Sh. Ualikhanov Kokshetau University, Abai Str., 76, Kokshetau 020000, Kazakhstan; sh.zhibek@mail.ru (K.S.); abilzhan.khusainov@mail.ru (A.K.); anuarka@mail.ru (A.K.); bizhamal55@bk.ru (R.K.)

[2] Instituto de Ingeniería del Agua y del Medio Ambiente (IIAMA), Universitat Politècnica de València, 46022 Valencia, Spain; marodcla@upv.es

* Correspondence: jrodrigo@upv.es

Abstract: This paper shows the results of a study on the morphometric, hydrophysical, and hydrochemical indicators of Lake Burabay, North Kazakhstan. The Burabay Protected Area, also known as Burabay National Park or Kokshetau National Park, is a protected natural area located in the north of Kazakhstan. It encompasses a diverse landscape characterized by lakes, forests, and unique rock formations. This analysis includes an eco-toxicological assessment of the hydrochemical composition of waters and benthal deposits by studying the content of metals. The degree of mineralization, ionic composition of water, hydrogen index, pollution index, and water quality class were also determined. Reductions in the area and depth of the lake were identified. The pollution index is 1.5–1.7, which belongs to class 3—moderately polluted. Relatively high concentrations of cadmium, nickel, copper, and arsenic were found in the lake sediments. Therefore, Lake Burabay and its surrounding ecosystem face certain environmental risks and potential water pollution. Although the increase in the number of tourists did not have a significant impact on the water pollution index in Lake Burabay, some of the common threats that impact the area are induced by touristic development, agricultural practices and industrial pollution. Significant efforts should be made to reduce these risks using the environmental indicators as a reference for control environmental quality.

Keywords: ecological state; morphometric; hydrophysical and hydrochemical indicators; pollution index; benthal deposits; Lake Burabay

Citation: Shulembayeva, K.; Rodrigo-Ilarri, J.; Rodrigo-Clavero, M.-E.; Khussainov, A.; Kakabayev, A.; Khussainova, R. Assessment of the Hydrophysical and Hydrochemical Characteristics of Lake Burabay (Akmola Region, North Kazakhstan). *Sustainability* **2023**, *15*, 11788. https://doi.org/10.3390/su151511788

Academic Editors: Joao M. Neto and Paula Carvalho

Received: 21 June 2023
Revised: 24 July 2023
Accepted: 26 July 2023
Published: 31 July 2023

1. Introduction

Global environmental problems include the pollution and desiccation of surface waters, which pose a threat to the environment [1,2]. Water scarcity hinders our ability to provide populations with water for drinking, recreation and economic purposes. This problem is both global and local, and it exists even in economically developed countries [3]. Among the post-Soviet states, Kazakhstan belongs to the lowest water-resource-rich republic. According to official data, water shortages in Kazakhstan by 2030 will reduce the amount of usable water to 40% of the total demand [4]. Due to water scarcity and pollution, the problem of the rational use, protection and restoration of lake resources is of particular importance. Lakes in specially protected natural areas are unique and widely used for recreational and balneological purposes. They are under the constant supervision of scientists [5]. Based on data analysis, recommendations have been developed for sustainable management and for the reduction in the negative impact of tourism on water and sediment pollution [6].

Performing environmental analysis using indicators in Kazakhstan is a necessary tool to ensure sustainability and ecological integrity. Kazakhstan is a vast and diverse country with significant natural resources, including diverse ecosystems, rich biodiversity and essential water bodies such as lakes and rivers. To effectively manage and protect these resources, it is crucial to have a systematic and data-driven approach. Environmental indicators provide a quantitative and standardized way to assess the state of the environment, track changes over time and identify emerging risks and issues. By utilizing indicators related to air and water quality, biodiversity, land use and pollution levels, decision makers can make informed policy decisions, prioritize conservation efforts and implement targeted interventions. This analysis helps to identify key areas of concern, set achievable environmental goals and monitor progress towards sustainable development. Moreover, it promotes transparency, accountability and effective communication among stakeholders, enabling them to work collaboratively towards preserving the natural heritage of Kazakhstan for future generations. By embracing environmental analysis with indicators, Kazakhstan can ensure the long-term sustainability and ecological integrity of its natural resources while fostering a balanced approach to economic growth and environmental protection. These kinds of analysis have seldom been performed so far in North Kazakhstan and, specifically, in the Lake Burabay area.

The lakes of northern Kazakhstan are a source of fresh water, recreation areas and habitats for waterfowl and fish [7,8]. In the northern part of Kazakhstan, there are 3500 lakes with a total area of 3410 km^2, with a water reserve of 4 billion m^3 [9]. These lakes are also subject to drying and pollution, which are associated with the decrease in soil fertility that started with the mass development of virgin and fallow lands in 1953–1955 and that continues to the present [10]. As a result of wind erosion, "dust storms" drove the fertile soil layer into the lakes. This led to the pollution of the lakes and the overgrowth of reeds within them [10].

The hydrochemical composition of surface waters depends on the geochemical background of the region, the natural and climatic conditions, and anthropogenic pollution sources [11]. The change in climatic conditions affects biochemical processes in lake waters, modifying solute concentration and primary production [12]. Recent studies have suggested that lakes are good indicators of global climate change because they are sensitive to environmental changes and can integrate changes in the surrounding landscape and atmosphere [13,14]. Climate variability affects not only the quantity of water but also the quality, increasing, for example, salinity as a result of evaporation and the concentration of dissolved ions [15].

Under the influence of anthropogenic factors, the hydrological regime, the volume of runoff, and the dynamics of the hydrochemical properties of surface waters change. As a result of the ingress of pollutants, the salt composition changes, and the content of suspended substances in the water increases, which leads to a violation of the natural processes of self-purification in lakes and the deterioration of the vital activity of hydrobionts [16].

A thorough knowledge of the hydrochemical characteristics of surface waters plays a vital role in the evaluation of water quality and its suitability for various purposes. Chemical studies on these waters provide information on environmental changes, which help determine the hydrological functions of the basins when combined with isotopic tracers [17].

Lakes in the arid areas of Central Asia are particularly vulnerable to climate change, and their water levels are declining [18,19]. Reservoirs in northern Kazakhstan have been studied by several authors, who have provided insight into the factors influencing lake level fluctuations over the past 100 years [20,21]. The first hydrological studies of these lakes date back to the end of the 19th century [16].

Since the mid-1960s, more detailed studies on the hydrology, hydrochemistry, and biodiversity of the lake related to the development of virgin and fallow lands have been initiated. Special attention has been paid to specially protected natural areas. In order to preserve and restore unique forest and lake ecosystems, the "Burabay" State National Nature Park (hereinafter—NP Burabay) was established in 2000. At the 34th session of the International Coordinating Council of the UNESCO Program "Man and the Biosphere"

(MAB) on 15 June 2022, a decision was made to include NP Burabay in the UNESCO global network of biosphere reserves [22]. This makes it particularly necessary to monitor the ecosystems of this territory.

The annual increase in the recreational load may lead to reservoir pollution, making it necessary to conduct systematic environmental monitoring. The ecological state of NP Burabay lakes has been studied by several authors [23–27], but the data on the current ecological state of NP Burabay lakes are of a mosaic, fragmentary nature.

In this work, a comprehensive assessment of the dynamics of the hydrochemical composition of water and benthal deposits is given, focusing on the content of heavy metals. The morphometric indicators of Lake Burabay have also been studied using remote sensing techniques based on retrospective multichannel satellite images of the Earth by Landsat.

2. Materials and Methods

Lake Burabay is located in the Akmola Region of northern Kazakhstan near the village of Burabay, on the specially protected territory of NP Burabay (Figure 1). The geographical coordinates of the lake are 53°04′30″ N, 70°16′30″ E, and its absolute altitude is 320.6 m above sea level [28].

Figure 1. Location of Lake Burabay inside the Akmola Region in northern Kazakhstan.

The total area of the basin is 164 km^2. The water is clear; the water surface of the lake is open; and, only along the western and northwestern coasts, there are thickets of reeds. The bottom of the lake is flat, with a slope to the north; sandy and rocky near the coast; and muddy in the middle. The lake has several small bays. In the northwestern bay there is a rocky island (Zhumbaktas), rising 20 m above the water level. On the shore of this bay lies the Okzhetpes mountain, about 300 m high.

Figure 2 shows a space image of Lake Burabay received from the Yandex server via the SAS Planet program.

In this work, the Russian national GOST standards were used. The Russian Gosstandart (GOST) standards cover more than 20 industrial branches including the petroleum and chemical industry as well as mining and mineral sources, power and electrical equipment, and oil and gas products. The GOST organization, which was originally established during the Soviet Union era, was appointed to develop and put into practice state policy in the field of standardization. This institution was adopted by the Commonwealth of Independent States (CIS), and it is administrated by the Euro-Asian Council for Standardization, Metrology and Certification (EASC).

Figure 2. Space image of Lake Burabay received from the Yandex server via the SAS Planet program.

Water samples were taken in accordance with GOST 31861-2012 [29]. Water samples were taken four times in a year: in winter (January), spring (April), summer (July) and autumn (October) during the 2018–2022 period. Water sampling was carried out at 3 points from a lake depth of 0.5 m: in the south, in the center and in the north of the lake. Benthal deposit sampling at 2 points—to the south and to the north of the places where water was sampled—were taken in summer, according to the international standard ISO 5667-12-1995 [30] (Figure 3). Water samples were filtered before laboratory analysis. Hydrophysical parameters of water were determined: odor according to GOST 3351-74 [31] by the organoleptic method; color according to GOST 31868-2012 [32] by the visual method; turbidity according to GOST 3351-74 [31] by the photometric method. Chemical parameters were determined according to GOST 26449 [33]: pH of the medium by the electrometric method; carbon dioxide, potassium, sodium and nitrates by the potentiometric method; dissolved oxygen, dry residue mineralization, permanganate oxidizability, bicarbonates, carbonates and chlorides by the titration method; sulfates, calcium, magnesium and total hardness by the complexometric method; nitrites by the fluorometric method; heavy metal content by the flameless atomic absorption spectrometer on the MGA-915 spectrometer.

A morphometric parameters study of Lake Burabay was performed by remote sensing using retrospective multichannel satellite images from Landsat, based on STO GGI 52.08.40-2017 [34] and R 52.08.874-2018 [35].

According to Kurlo's formulas, the Scholler diagram was prepared, and the water pollution index was calculated to determine complex indicators to assess water quality using Equation (1) [36]:

$$\mathrm{WPI} = \sum_{i=1}^{n} \frac{C_i}{\mathrm{MPC}_i} \quad (1)$$

where n is a strictly limited number of indicators (for surface waters, n = 6); C_i is the concentration of the i-th pollutant in water; MPC_i is the maximum allowable concentration of the i-th pollutant.

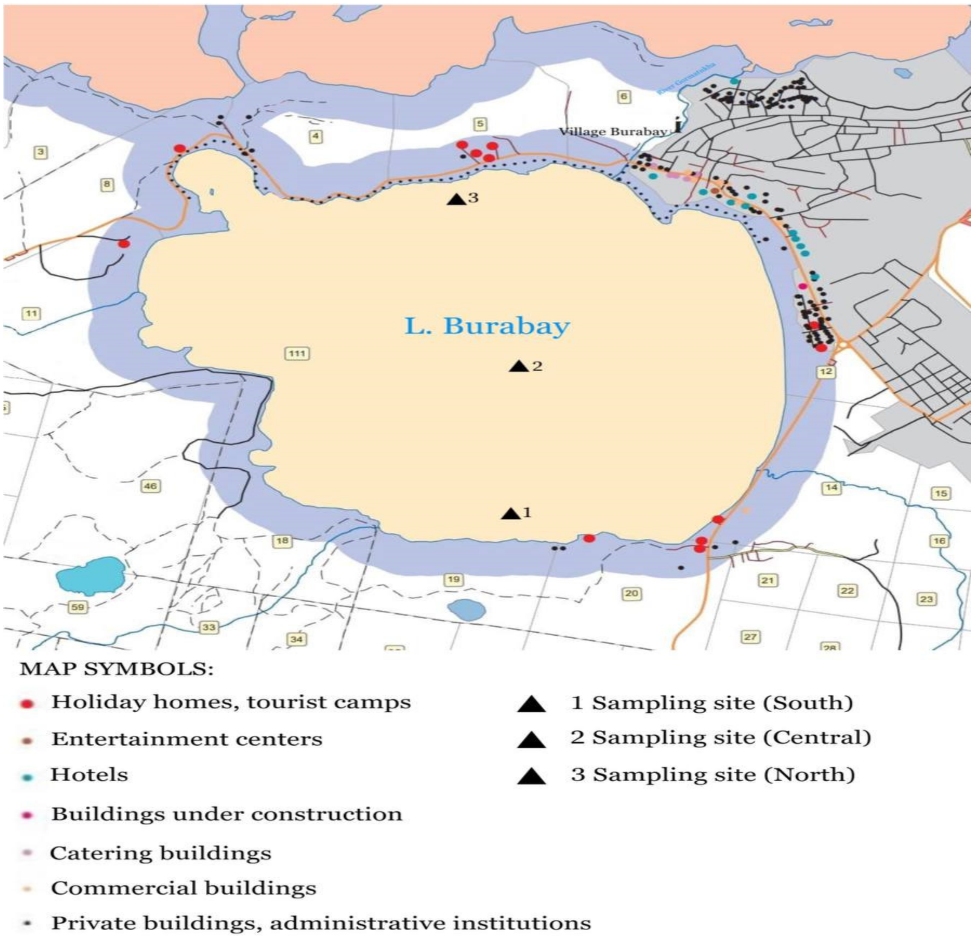

Figure 3. Location of the water samples inside Lake Burabay (marked as 1, 2, 3).

The chemical concentration coefficient (Cc) of pollutants in benthal disposal was calculated using Equation (2) [37]:

$$Cc = C_i / C_{\phi i} \tag{2}$$

where C_i and $C_{\phi i}$ refer to pollutant concentration at studied and background sites, respectively.

To indicate the summary index (Z_c), the maximum permissible concentrations (MPC) of pollutants in the soil were used as background values according to Equation (3) [38]:

$$Z_c = \sum_{i=1}^{n} C_c = \frac{C_1}{MPC_1} + \frac{C_2}{MPC_2} + \ldots + \frac{C_n}{MPC_n} \tag{3}$$

To assess the technogenic impact on benthal deposits, we used the summary index (Z_c) as calculated using Equation (4):

$$Z_c = \sum_{i=1}^{n} Cc - (n-1) \tag{4}$$

The calculation of the environmental value index of the lake was carried out using the ArcGIS program. Data processing was carried out by conventional methods using information systems. The studies were carried out in a licensed laboratory on certified equipment with an accuracy of ±0.001.

3. Results and Discussion

3.1. Morphometric Characteristics

The morphological features of lakes reflect the processes of the functioning of the lake ecosystem [39]. Mikhailov and Dobrovolsky [40] noted that, over the past 100–200 years, lakes have been drying up, and they found cyclical fluctuations in lake levels and precipitation occurring since 1850. Yapiyev et al. found that the total area of four large lakes of NP Burabay (Lake Burabay, Lake Bolshoe Chabachye, Lake Shchuchye and Lake Maloe Chabachye) decreased by 7% in the period from 1986 to 2016 [19]. The authors explain the decrease in the area and volume of the lakes of NP Burabay by a long-term deficit of the water balance, when evaporation from the lake surface exceeds the amount of precipitation. However, in recent years (2013–2016), precipitation has increased and stabilized the water level in the lakes of Burabay National Park.

According to Uryvaeva, in 1958 the area of the water surface was 10.5 km^2. The maximum length is 4.6 km, and the maximum width is 3.2 km [41]. Our observations have shown that the area of the reservoir has decreased by 0.4–0.6 km^2. The maximum depth of the lake decreased from 5.7 m in 1956 to 5.3 m in 2022; the average depth decreased from 3.4 to 3.0 m during the same years (Table 1).

Table 1. Morphometric indicators of Lake Burabay.

Indicators	1956	2010	2017	2022
Surface area (km^2)	10.5	9.9	10.0	10.1
Maximum depth (m)	5.7	5.6	5.3	5.3
Average depth (m)	3.4	3.1	3.1	3.0

The main feeding of the lake is carried out by the Sary-Bulak River and three streams originating from the marshes. The streams and the Sary-Bulak River have a well-defined swampy floodplain, so they carry iron-rich water into the lake. The lake also receives water from underground springs. The bottom of Lake Burabay is flat and heavily silted in the southern part. The thickness of silt deposits in some places reaches 1–1.5 m. In the northern and eastern parts of the lake, the bottom is sandy.

The reduction in the surface area of the reservoir is associated with the silting of underground springs and the drying up of swamps due to global climate change. Also, until 2013, the water in Lake Burabay was used to supply the population with drinking water and household needs. In 2014, a water supply system was put into operation from the Sergeevskoye reservoir, known as the Yesil water reservoir, which drastically reduced the water intake from the lake.

3.2. Hydrophysical Characteristics

The hydrophysical properties of the water of Lake Burabay during the years of research (2018–2022) corresponded to acceptable standards.Smells were not detected. Under the conditions of a sharply continental climate, the water temperature in Lake Burabay fluctuated widely; amounted to 0 °C in January; and varied from 3.8 to 21.6 °C in April, from 12.8 to 26.4 °C in July and from 0 to 12.4 °C in October. The average annual water temperature varied from 16.8 to 20 °C. The color of the water was between 20.0 and 33.3 °K in winter, between 10.0 and 40.0 °K in spring, between 15 and 23.8 °K in summer and between 15.0 and 25.0 °K in autumn, and the average for the year was between 24 and 25 °K. In 2021–2022. Overall, there was a decrease in temperature and water color (Table 2).

Table 2. Hydrophysical indicators of Lake Burabay.

Indicators	2018	2019	2020	2021	2022	Norm
Smell (point)	-	-	-	-	-	No more than 2
Temperature (°C)	19	19.2	20	17.2	16.8	Not defined
Color (°K)	25	25	25	24	24	Not defined

3.3. Hydrochemical Characteristics

The pH value and other hydrochemical indicators in most tectonic lakes of the Tibetan Plateau were shown to significantly exceed national surface water quality standards due to geographical conditions, climatic background and chemical characteristics of the water [42]. The values of the hydrochemical indicators and benthal deposites of Lake Burabay during the 2018–2022 are provided as Supplementary Materials (Tables S1–S10).

Table 3 and Figure 4 show the hydrochemical indicators of Lake Burabay during the 2018–2022 period. The results of the chemical analysis showed that the pH value in the lake ranged from slightly alkaline, 7.5, to alkaline, 8.9, which generally does not exceed regulatory requirements. The exception was in 2022, when pH increased to 8.9, while the maximum permissible concentration is between 6.5 and 8.5.

Table 3. Hydrochemical indicators of Lake Burabay.

Indicators	Actual Indicators by Year					Average for 5 Years	MPC *
	2018	2019	2020	2021	2022		
pH	8.0	7.5	7.9	8.3	8.9	8.14	6.5–8.5
BOD_5 (mg/L)	1.22	1.6	3.28	0.86	2.48	1.9	4.0
Total water hardness (equ. mg/L)	1.95	2.01	2.33	2.56	4.15	2.6	-
Dissolved oxygen (mg/L)	8.59	9.07	9.16	8.09	8.59	8.7	6 (**)
Hydrocarbonate (mg/L)	117.4	154.7	136.8	126.6	177.8	142.66	-
Chloride (mg/L)	11.9	12.9	10.9	15.4	22.1	14.5	350.
Sulphate (mg/L)	178	182	199	209	252	204	500.0
Calcium (mg/L)	32.1	38.6	27.7	36.1	44.6	35.8	3.5
Magnesium (mg/L)	7.2	8.6	6.8	9.2	10.9	8.5	20.0
Sodium (mg/L) Potassium (mg/L)	23.1	18.9	16.5	9.4	57.1	25.01	200.0
Nitrates (mg/L)	1.07	1.06	1.08	0.18	2.3	1.14	45.0
Nitrites (mg/L)	0.006	0.008	0.007	0.009	0.008	0.031	3.3
Total Iron(mg/L)	0.08	0.01	0.06	0.057	0.005	0.06	
Ammonium nitrogen, mg/L	0.99	1.01	0.142	0.147	0.057	0.47	2.0
Mineralization, mg/L	160	192	247	193	321	223	1000 (1500)

* MPC: Maximum permissible concentration. ** Critical lower oxygen concentration value.

According to Kazhydromet, most of the freshwater lakes of the Kazakh uplands have alkaline and slightly alkaline reactions within their aquatic environments, which refers to an abiotic factor; that is, the alkalinity is of natural origin.

The concentration of bicarbonates in water averaged 142.7 mg/L. It increased from 117.4 mg/L in 2018 to 177.8 mg/L in 2022. This explains the increase in the alkalinity of the aquatic environment to 8.9 in 2022.

There was an increase in the total hardness of water from 1.95 ppm in 2018 to 4.15 ppm in 2022, which is associated with an increase in the concentration of bicarbonates in water; its average value was 2.6 ppm, which is 2.7 times lower than the MPC (MPC 7.0). The increase in the alkalinity of the aquatic environment is explained by the increase in the concentration of bicarbonates and the general hardness of the water.

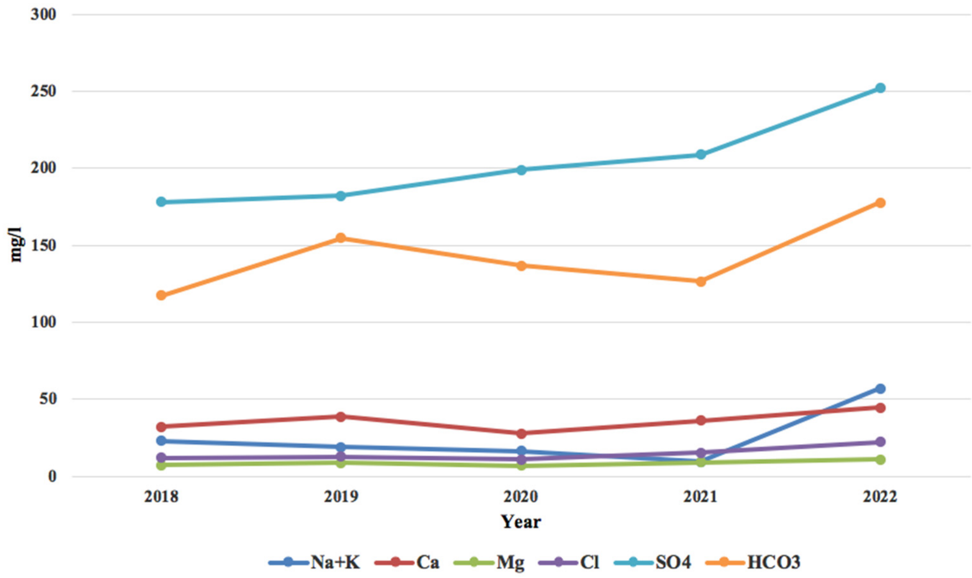

Figure 4. Ionic-saline composition of the water of Lake Burabay, mg/L.

According to the anionic composition, the salinity chemistry is sulfate-hydrocarbonate-chloride. The average content of sulfates was 204 mg/L (MPC 500), the average content of hydrocarbonates was 143 mg/L (MPC 400), and the average content of chlorides was 14.5 mg/L (MPC 350). For the cationic composition, calcium–sodium–magnesium, the average content was, for each respective element, 35.8 mg/L (MPC 3.5), 25.0 mg/L (MPC 200.0) and 8.5 mg/L (MPC 20.0). This salinity chemistry is too dry for most lakes of the Eurasian continent.

Biochemical oxygen consumption fluctuated significantly over the years from 0.86 mg/L in 2021 to 3.28 mg/L in 2020 and averaged 1.9 mg/L, which is almost 2 times lower than the MPC (MPC 4.0).

Studies have shown a high content of soluble oxygen in water, 8.7 g/L, which is 2.2 times higher than the MPC (MPC 6 mg/L). This is a positive moment in terms of ensuring the active life of hydrobionts. It should be noted that the minimum content of soluble oxygen, 8.09 mg/L, was set in 2021, and the maximum, 9.16 mg/L, was set in 2020. These indicators are closely correlated with the minimum oxygen consumption in 2021 and the maximum consumption in 2020.

The concentrations of total iron and ammonium nitrogen are not significant at 0.006 mg/L and 0.047 mg/L, respectively. The degree of water mineralization is also not high; it averaged 223 mg/L, with MPC values of 1000 mg/L. The content of anionic surfactants (surfactants) and synthetic surfactants (surfactants) is very low: 0.019 at an MPC of 0.5. The content of nitrates and nitrites also did not exceed the MPC and amounted to 1.14 mg/L and 0.03 mg/L, respectively. This does not pose an environmental hazard.

Biochemical oxygen consumption averaged 1.9 mg/L, which is almost 2 times lower than the MPC. However, there was an increase in the total water hardness from 1.95 mg/L in 2018 to 4.15 mg/L in 2022. Its average value was 2.6 mg/L, which is 2.7 times lower than the MPC (MPC 7.0). A high content of soluble oxygen was found, 8.7 mg/L, which is 2.2 times higher than the MPC (MPC 4 mg/L). The concentration of bicarbonates in water averaged 142.7 mg/L. According to the anionic composition, the salinity chemistry is sulphate. The average content of sulfates was 204 mg/L at a maximum concentration of 500 mg/L, and the content of chlorides was only 14.5 mg/L at a maximum concentration of 350 mg/L.

For the cationic composition, calcium–sodium, the content of each respective element was 35.8 mg/L and 25.0 mg/L, which does not exceed the MPC value. The magnesium content averaged 8.5 mg/L, with an MPC of 20 mg/L. The content of nitrates and nitrites also did not exceed the MPC and amounted to 1.14 mg/L and 0.03 mg/L, respectively. The concentration of total iron and ammonium nitrogen is not significant at 0.006 mg/L and 0.047 mg/L, respectively. The degree of mineralization of the water is also not high; it averaged 223 mg/L, with an MPC value of 1000 mg/L. The content of AS and SS is very low: 0.019 at an MPC of 0.5.

The chemical composition of natural waters is inextricably linked to the composition and structure of the soil, which, in turn, was formed during the long evolution of the Earth's crust under the influence of climate.

The basis for systematization in existing classifications is the degree of mineralization, the predominant component or group, the ratio between different values of concentrations of various ions and increased amounts of certain specific elements of gas and salt regimes [43]. Water mineralization was determined by the total number of ions contained in the natural waters of the lake, including bicarbonates, carbonates, chlorides, sulfates, calcium, magnesium, sodium and potassium [44]. From less arid to more arid areas, the mineralization of lake water increases. The transformation of the elemental chemical composition of water (the content of anions and cations) occurs in the same direction: water from the carbonate class passes into sulfate and chloride and, from the calcium group, into magnesium and sodium. In the lakes of the forest zone, HCO_3^- and Ca^{2+} ions predominate, whereas, in the lakes of the steppe zone, SO_4^{2-}, HCO_3^-, Na^+ and K^+ can be obtained [41].

According to the classification of Alekin [45], the water in Lake Burabay is fresh, and the degree of mineralization averaged 223 mg/L over 5 years. However, the degree of mineralization increased from 160 mg/L in 2018 to 321 mg/L in 2022. The anionic composition of the water was dominated by sulfate ions, the concentration of which increased in the 2018–2022 period from 178 to 252 mg/L. The content of hydrocarbonates averaged 143 mg/L over 5 years; their concentration increased from 117 to 178 mg/L over the years of the study. The chloride content in the water is insignificant. On average it was 14 mg/L, and the concentration also increased from 12 to 22 mg/L. Among the cations, calcium predominates (on average, 36 mg/L), followed by sodium (25 mg/L). The magnesium content is insignificant (8 mg/L). It should be noted that the concentration of these cations during the study years increased from 32 to 45 mg/L for calcium, from 23 to 57 mg/L for sodium and from 7 to 11 mg/L for magnesium (Figure 4).

3.4. Content of Heavy Metals

The content of heavy metals (zinc, lead, cadmium, cobalt, copper and manganese) over the years of the study did not exceed the maximum permissible concentrations (Table 4).

Table 4. Concentration of heavy metals in the water of Lake Burabay, mg/L.

Indicators	Actuals Indicators by Year					Average for 5 Years	MPC *
	2018	2019	2020	2021	2022		
Zinc	0.005	0.007	0.008	0.005	0.004	0.006	1.0
Lead	0.0025	0.0009	0.0012	0.0010	0.0007	0.0012	0.03
Cadmium	0.0005	0.0004	0.0006	0.0009	0.0010	0.0007	0.001
Cobalt	0.004	0.001	0.001	0.002	0.001	0.0018	0.1
Manganese	0.036	0.025	0.018	0.009	0.020	0.021	0.1
Copper	0.0017	0.0015	0.0012	0.001	0.0025	0.0016	1.0

* MPC: Maximum permissible concentration.

The calculations of the water pollution index in Lake Burabay showed that, for all elements, their indicators do not exceed the MPCs. According to the degree of pollution, the water, on average, belongs to class 3, with a pollution index of 1.5–1.7: the water is moderately polluted (Table 5).

Table 5. Complex index of water pollution in Lake Burabay, mg/L.

Indicators	2018	2019	2020	2021	2022	r
pH	8	7.5	7.9	8.34	8.95	0.79
Dissolved oxygen (mg/L)	8.59	9.07	9.16	8.09	8.59	−0.37
BOD_5 (mg/L)	1.22	1.6	3.28	0.86	2.48	0.30
Zinc (mg/L)	0.005	0.007	0.008	0.005	0.006	0
Lead (mg/L)	0.0025	0.0009	0.0012	0.0010	0.0007	−0.77
Copper (mg/L)	0.0005	0.0004	0.0006	0.0009	0.0010	0.91
Cobalt (mg/L)	0.004	0.001	0.001	0.002	0.001	−0.60
Results of $\sum$ Cc/MPC	10.16	9.8	9.02	9.56	9.7	−0.44
Water pollution index	1.7	1.6	1.5	1.6	1.6	−0.44
Water quality class	III	III	III	III	III	

r: Correlation coefficient.

The calculations showed a different correlation dependence of the indicators of the water pollution index over the years of the study: a direct close correlation was established between the years of the study with the pH value (r = 0.79); a very close correlation was established with the copper content (r = 0.91); a moderate association was established with BOD (r = 0.30); an inverse close correlation was established with the lead content (r = −0.77); an inverse medium relationship was established with the cobalt content (r = −0.60); and a moderate inverse relationship was established with the content of soluble oxygen in water (r = −0.37). According to the sum of concentrations of pollutants and the water pollution index, an inverse moderate correlation was established with the years of the study (r = −0.44).

The number of tourists visiting the territory of NP Burabay has been increasing year by year. So, if in 2018 there were 618,632 people, then in 2022 their number increased to 693,267 people, but in 2020 the number of tourists decreased to 481,714 people, which was associated with the pandemic. It should be noted that the increase in the number of tourists had a significant impact on the index of water pollution in Lake Burabay. The calculations showed an average correlation between the water pollution index in Lake Burabay and the number of tourists; the correlation coefficient was 0.63 (Figure 5).

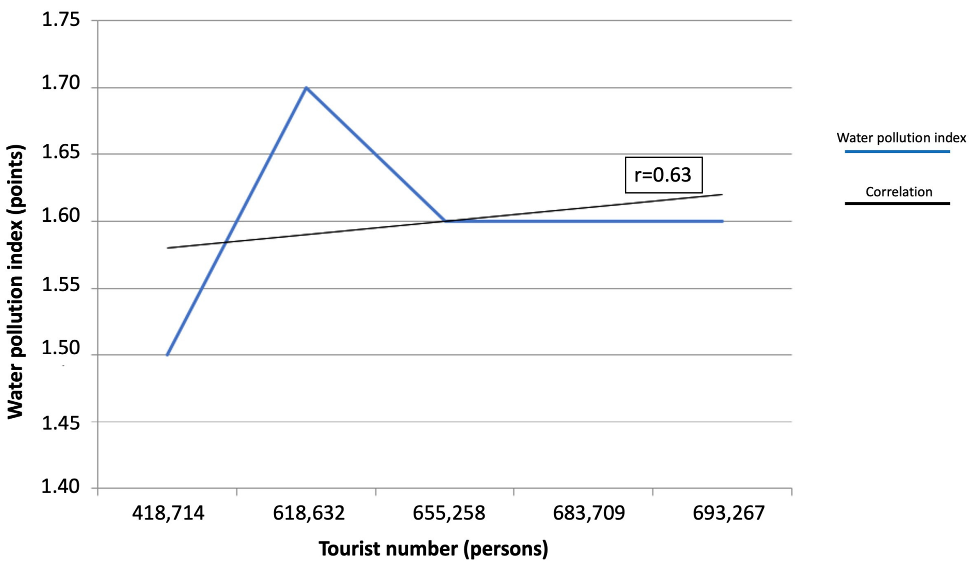

Figure 5. Correlation between the index of water pollution in Lake Burabay and the number of tourists for 2018–2022.

It should be noted that the number of tourists has an indirect impact on the water pollution index. The coastal zone of Lake Burabay includes the village of Burabay, and there are many sanatoriums, recreation centers, entertainment centers and health centers. All of these sites have individual septic tanks, most of which do not have bottom waterproofing. For this reason, wastewater enters Lake Burabay via groundwater. The increase in the number of tourists is accompanied by an increase in the volume of wastewater.

To eliminate this source of pollution, a sewerage system was built in the village of Burabay. Currently, the construction of treatment facilities is underway. The commissioning of this facility will reduce the level of water pollution in Lake Burabay and the dependence of water pollution on the number of tourists.

Lake Burabay is located on the territory of the UNESCO Biosphere Reserve, so there are no industrial enterprises, which stops the lake from being polluted by industrial wastewater.

3.5. Benthal Deposits

The chemical composition of benthal deposits primarily depends on the geochemical conditions of the region, as well as on geochemical differentiation due to hydrodynamic physicochemical and biochemical processes in a certain landscape [46]. A unified methodology for assessing the quality of the benthal deposits of surface reservoirs has not been developed in the Republic of Kazakhstan yet. Therefore, as standards for the maximum permissible concentrations of pollutants in bottom sediments, we recorded their values in the soil.

The results of laboratory studies showed that the average cadmium content in benthal deposits for 2018–2022 was 0.83 mg/kg, which is 1.66 times higher than the MPC (MPC 0.5 mg/kg). It was also found that the maximum permissible norms of nickel, copper and arsenic content were exceeded by 5.7, 3.26 and 1.9 times, respectively. The content of other heavy metals was significantly lower than the maximum permissible concentrations: lead, 0.35 times; chromium, 0.77 times; manganese, 0.02 times. It should be noted that, in the bottom sediments, a decrease in the contents of cadmium, lead, copper and chromium was noted over the years (Table 6).

Table 6. Dynamics of the contents and concentration coefficients of heavy metals in the benthal deposits of Lake Burabay by year, mg/kg.

Heavy Metals	2018	2019	2020	2021	2022	Average for 5 Years	r
Cadmium	$\frac{0.58}{1.16}$	$\frac{1.40}{2.90}$	$\frac{1.45}{2.84}$	$\frac{0.35}{0.70}$	$\frac{0.34}{0.68}$	$\frac{0.83}{1.66}$	−0.44
Nickel	$\frac{19.56}{4.89}$	$\frac{14.85}{9.71}$	$\frac{25.59}{6.40}$	$\frac{27.02}{6.76}$	$\frac{27.02}{6.76}$	$\frac{22.80}{5.70}$	−0.54
Lead	$\frac{8.45}{0.26}$	$\frac{12.01}{0.38}$	$\frac{14.20}{0.44}$	$\frac{13.38}{0.42}$	$\frac{7.47}{0.23}$	$\frac{11.10}{0.35}$	−0.03
Copper	$\frac{10.86}{3.62}$	$\frac{15.94}{5.31}$	$\frac{13.78}{4.60}$	$\frac{5.36}{1.79}$	$\frac{2.96}{0.99}$	$\frac{9.78}{3.26}$	−0.76
Chrome	$\frac{6.75}{1.12}$	$\frac{4.00}{0.67}$	$\frac{4.97}{0.83}$	$\frac{4.46}{0.78}$	$\frac{2.60}{0.43}$	$\frac{4.60}{0.77}$	−0.80
Arsenic	$\frac{4.36}{2.18}$	$\frac{2.90}{1.45}$	$\frac{2.78}{1.39}$	$\frac{4.46}{2.23}$	$\frac{4.75}{2.38}$	$\frac{3.85}{1.90}$	0.39
Manganese	$\frac{23.72}{0.01}$	$\frac{29.36}{0.02}$	$\frac{23.23}{0.02}$	$\frac{23.78}{0.02}$	$\frac{23.78}{0.02}$	$\frac{24.80}{0.02}$	0.70
$\sum$	13.24	14.62	16.52	12.7	11.49	13.71	−0.44

Note: The numerator is the actual concentration of heavy metals, and the denominator is the concentration coefficient of heavy metals. r, Correlation coefficient.

The calculations showed that the manganese concentration coefficient increased from 0.01 in 2018 to 0.02 in 2022; a direct close correlation was established between its content and the years of study (r = 0.70). For arsenic, a direct moderate relationship was established (r = 0.39). On the positive side, the concentration coefficients of chromium, copper, nickel and cadmium were reduced. A close inverse relationship was established with the concentration of chromium (r = −0.80) and copper (r = −0.76), and an inverse average relationship was established with the concentrations of nickel (r = −0.54) and cadmium (r = −0.40). The total concentration of heavy metals had an inverse average correlation with the years of the study (r = −0.44).

The total concentration coefficient of heavy metals in the benthal deposits varied from 11.5 to 16.5 over the years and averaged 13.7. The level of pollution of the benthal deposits of Lake Burabay on the water pollution index showed systemic weakness, its value relative to the background ranging from 5.5 to 10.5 and averaging 7.7 [38].

There was a decreasing tendency in the level of pollution of the benthal deposits with heavy metals over the years: the total indicators of pollution of the benthal deposits with heavy metals amounted to 7.24 in 2018, to 10.52 in 2020 and to 5.49 in 2022 relative to the background (Figure 6).

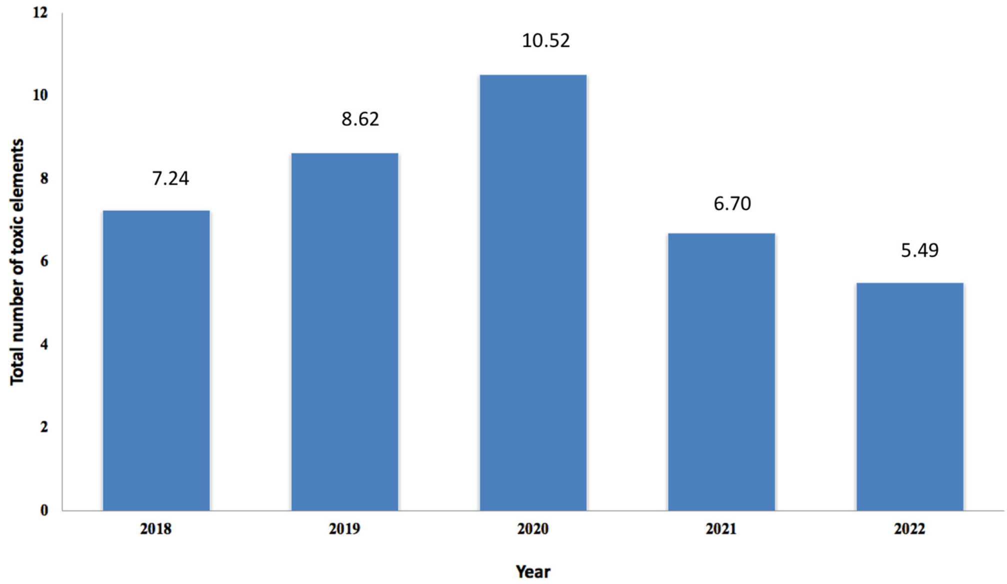

Figure 6. Total indicators of pollution of bottom sediments with heavy metals of Lake Burabay.

In general, benthal deposits have a negative impact on water quality and the recreational value of Lake Burabay. Therefore, it is necessary to clean the lake of bottom sediments. According to Kazhydromet, the content of heavy metals is noted in recreational and other lakes.

The results show that the area of the water surface of Lake Burabay has decreased from 0.4 to 0.6 km^2 and that the average depth decreased from 3.4 to 3.0 m. The pH value in the lake ranged from slightly alkaline, 7.5, to alkaline, 8.9, which generally does not exceed regulatory requirements. The salinity chemistry is sulphate in anionic composition, and calcium–sodium in cationic composition. According to the degree of mineralization, the lake is fresh. The content of heavy metals (zinc, lead, cadmium, cobalt, copper and manganese) over the years of the study did not exceed the maximum permissible concentrations. According to the degree of pollution, the water belongs to class 3, moderately polluted, and the pollution index was 1.5–1.7. The increase in the number of tourists did not have a significant impact on the water pollution index in Lake Burabay.

In benthal deposits, the cadmium content averaged 0.83 mg/kg in 2018–2022, which is 1.66 times higher than the MPC. It was also found that the maximum permissible norms of nickel, copper and arsenic content were exceeded by 5.7, 3.26 and 1.9 times, respectively. The total concentration coefficient of polluting elements in bottom sediments averaged 13.7 and was weak, at 7.7, according to the scale of assessment of the level of pollution of the water system. An inverse moderate correlation was established between the level of pollution with toxic elements and the years of study: the correlation coefficient was 0.44.

4. Conclusions

The results of the study showed that Lake Burabay and its surrounding ecosystem face certain environmental risks and potential water pollution. Some of the common threats that impact the area include the following:

1. Touristic development: rapid urbanization and infrastructure development in the vicinity of the lake lead to increased pollution and habitat destruction.
2. Agricultural practices: intensive agricultural activities can result in runoff into the lake, leading to water pollution.
3. Industrial pollution: industrial activities in the region, such as manufacturing and mining, may generate pollutants that can enter the lake via runoff or direct discharge.

To effectively reduce environmental risks in the Lake Burabay protected area, a comprehensive approach utilizing environmental indicators is crucial. Firstly, regularly monitoring water quality indicators (such as pH levels, dissolved oxygen and nutrient concentrations) and the presence of pollutants can help identify potential threats and guide appropriate interventions. Additionally, tracking biodiversity indicators, including species richness and abundance, can provide insights into the health and resilience of the ecosystem. Implementing measures to preserve and restore critical habitats, such as wetlands and riparian zones, is essential for maintaining water quality and supporting diverse flora and fauna. Promoting sustainable land use practices in the surrounding areas, such as by minimizing the use of fertilizers and pesticides, controlling erosion and managing wastewater, can mitigate pollution inputs. The effective governance and enforcement of regulations are crucial for preventing unauthorized activities, such as illegal fishing or pollution discharge, within the protected areas. Finally, fostering public awareness and engagement via education and outreach programs can enhance the understanding of the importance of Lake Burabay, while promoting responsible behavior towards its conservation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su151511788/s1, Table S1: Hydrochemical indicators of Lake Burabay, 2018; Table S2: Benthal deposite of Lake Burabay, 2018; Table S3: Hydrochemical indicators of Lake Burabay, 2019; Table S4: Benthal deposite of Lake Burabay, 2019; Table S5: Hydrochemical indicators of Lake Burabay, 2020; Table S6: Benthal deposite of Lake Burabay, 2020; Table S7: Hydrochemical indicators of Lake Burabay, 2021; Table S8: Benthal deposite of Lake Burabay, 2021; Table S9: Hydrochemical indicators of Lake Burabay, 2022; Table S10: Benthal deposite of Lake Burabay, 2022.

Author Contributions: Conceptualization, K.S. and A.K. (Abilzhan Khussainov); methodology, K.S.; software, K.S. and A.K. (Abilzhan Khussainov); validation, J.R.-I. and M.-E.R.-C.; formal analysis, J.R.-I.; investigation, K.S. and M.-E.R.-C.; resources, A.K. (Abilzhan Khussainov) and A.K. (Anuarbek Kakabayev); data curation, K.S. and R.K.; writing—original draft preparation, J.R.-I. and M.-E.R.-C.; writing—review and editing, J.R.-I. and M.-E.R.-C.; visualization, K.S. and R.K.; supervision, J.R.-I.; project administration, A.K. (Anuarbek Kakabayev); funding acquisition, J.R.-I. and A.K. (Anuarbek Kakabayev). All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. De Baat, M.L.; Van der Oost, R.; Van de Lee, G.H.; Wieringa, N.; Hamers, T.; Verdonschot, P.F.M.; De Voogt, P.; Kraak, M.H.S. Advancements in effect-based surface water quality assessment. *Water Res.* **2020**, *183*, 116017. [CrossRef] [PubMed]
2. Bernhardt, E.S.; Rosi, E.J.; Gessner, M.O. Synthetic chemicals as agents of global change. *Front. Ecol. Environ.* **2017**, *15*, 84–90. [CrossRef]
3. Thotagamuwa, H.T.B.N.; Weerasinghe, V.P.A. Surface water quality assessment for the management of hydrological regimes: Kalu Oya and Mudun Ela catchment in Sri Lanka. *Environ. Nanotechnol. Monit. Manag.* **2021**, *15*, 100402. [CrossRef]
4. Kazakhstan Govern. Kazakhstan 2030' Strategy and Its Economic Priority, 1997. 23 October 1997. Available online: https://www.akorda.kz/upload/content_files/doc/Gos_programi/%D0%A1%D1%82%D1%80%D0%B0%D1%82%D0%B5%D0%B3%D0%B8%D1%8F%202030%20%28%D0%B0%D0%BD%D0%B3%D0%BB%29.doc (accessed on 24 July 2023).

5. Jasenka, S.; SrećkoSrecko, B.; Izidora, M. Plitvice Lakes National Park (Central Croatia)—More Than 50 Years of Continuous Monitoring of Natural and Human Influence. *Eur. Geol.* **2011**, *34*, 12–16.
6. Horvatincic, N.; Brianso, J.L.; Obelic, B.; Baresic, J.; Krajcar-Bronic, I. Study of Pollution of the Plitvice Lakes by Water and Sediment Analyses. *Water Air Soil Pollut.* **2006**, *6*, 475–485. [CrossRef]
7. Khussainov, A.T.; Shulembayeva, K.M.; Sindireva, A.V.; Zandybay, A.; Kakabayev, A.A. Dynamics of hydrochemical indicators and water quality of Lake Maloe Chabachye. *Eurasian J. Ecol.* **2021**, *69*, 13–22. [CrossRef]
8. Jashenko, R.; Maltseva, E.; Ilina, V. The conservation of ecosystem and biological diversity in Alakol Biosphere Reserve (East Kazakhstan). *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *298*, 012022. [CrossRef]
9. Bezmaternykh, D.M. Water and biological resources of lakes in the North Kazakhstan province: Current state, use and restoration. *Fish Farming Fish.* **2011**, *3*, 9–12. (In Russian)
10. Mukhanbet, A.K.; Khusainov, A.T.; Elubayev, S.Z.; Balgabayev, A.M.; Khusainova, R.K. The Effect of Fly Ash Application at Cultivation of Spring Wheat on Chernozem Soils of Northern Kazakhstan. *Biosci. Biotechnol. Res. Asia* **2016**, *13*, 1007. [CrossRef]
11. Batheria, R.; Jain, D. Water quality assessment of lake water: A review. *Sustain. Water Resour. Manag.* **2016**, *2*, 161–173. [CrossRef]
12. Han, F.; Liu, T.; Huang, Y.; Zan, C.; Pan, X.; Xu, Z. Response of water quality to climate warming and atmospheric deposition in an alpine lake of Tianshan Mountains, Central Asia. *Ecol. Indic.* **2023**, *147*, 109949. [CrossRef]
13. Haddout, S.; Priya, K.L.; Boko, H. Thermal response of Moroccan lakes to climatic warming: First results. *Ann. Limnol. Int. J. Limnol.* **2018**, *54*, 2. [CrossRef]
14. Paudyal, R.; Kang, S.; Sharma, C.M.; Tripathee, L.; Huang, J.; Rupakheti, D.; Sillanpää, M. Major ions and trace elements of two selected rivers near Everest region, southern Himalayas, Nepal. *Environ. Earth Sci.* **2015**, *75*, 46. [CrossRef]
15. Shen, B.; Wu, J.; Zhan, S.; Jin, M.; Saparov, A.S.; Abuduwaili, J. Spatial variations and controls on the hydrochemistry of surface waters across the Ili-Balkhash Basin, arid Central Asia. *J. Hydrol.* **2021**, *600*, 126565. [CrossRef]
16. Kolomin, Y.M. *History of Fisheries Research in Northern Kazakhstan. Fisheries Research in the Republic of Kazakhstan: History and Modern State*; Bastau: Almaty, Kazakhstan, 2006; pp. 193–203.
17. Wu, H.; Wu, J.; Li, J.; Fu, C. Spatial variations of hydrochemistry and stable isotopes in mountainous river water from the Central Asian headwaters of the Tajikistan Pamirs. *Catena* **2020**, *193*, 104639. [CrossRef]
18. Yapiyev, V.; Sagintayev, Z.; Inglezakis, V.J.; Samarkhanov, K.; Verhoef, A. Essentials of Endorheic Basins and Lakes: A Review in the Context of Current and Future Water Resource Management and Mitigation Activities in Central Asia. *Water* **2017**, *9*, 798. [CrossRef]
19. Yapiyev, V.; Skrzypek, G.; Verhoef, A.; Macdonald, D.; Sagintayev, Z. Between boreal Siberia and arid Central Asia—Stable isotope hydrology and water budget of Burabay National Nature Park ecotone (Northern Kazakhstan). *J. Hydrol. Reg. Stud.* **2020**, *27*, 100644. [CrossRef]
20. Yapiyev, V.; Samarkhanov, K.; Tulegenova, N.; Jumassultanova, S.; Verhoef, A.; Saidaliyeva, Z.; Umirov, N.; Sagintayev, Z.; Namazbayeva, A.; Zhumabayev, D.; et al. Estimation of áter storage changes in small endorheic lakes in Northern Kazakhstan. *J. Arid Environ.* **2019**, *160*, 42–55. [CrossRef]
21. Yapiyev, V.; Sagintayev, Z.; Verhoef, A.; Kassymbekova, A.; Baigaliyeva, M.; Zhumabayev, D.; Malgazhdar, D.; Abudanash, D.; Ongdas, N.; Jumassultanova, S. The changing water cycle: Burabay National Nature Park, Northern Kazakhstan. *Wiley Interdiscip. Rev. Water* **2017**, *4*, e1227. [CrossRef]
22. UNESCO International Coordinating Council of the Programme on Man and the Biosphere, 34th, Paris, 2022. SC-22/CONF.234/16. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000382865.locale=en (accessed on 24 July 2023).
23. Ramazanova, M.; Bulai, M.; Ursu, A.; DeyaTortella, B.; Kakabayev, A. Effects of tourism development on surface area of main lakes of Shchuchinsk-Burabay resort area, Kazakhstan. *Eur. J. Tour. Res.* **2019**, *21*, 69–86. [CrossRef]
24. Salikova, N.S.; Rodrigo-Ilarri, J.; Alimova, K.K.; Rodrigo-Clavero, M.-E. Analysis of the Water Quality of the Ishim River within the Akmola Region (Kazakhstan) Using Hydrochemical Indicators. *Water* **2021**, *13*, 1243. [CrossRef]
25. Kolomin, Y.M. *Inspection of Lakes of the State National Natural Park Kokshetau and Development of Recommendations for Their Fishery Use*; Research Report of North Kazakhstan State University; North Kazakhstan State University: Petropavl, Kazakhstan, 2000.
26. Krupa, E.; Romanova, S.; Berkinbaev, G.; Yakovleva, N.; Sadvakasov, E. Zooplankton as indicator of the ecological state of protected aquatic ecosystems (Lake Borovoe, Burabay National Nature Park, Northern Kazakhstan). *Water* **2020**, *12*, 2580. [CrossRef]
27. Maikanov, B.S.; Auteleyeva, L.T.; Ismagulova, G.T.; Wiśniewski, J.; Bełkot, Z.; Anusz, K. Quality and safety of fish products in the Shuchinsk-Burabay Resort Zone. *Med. Weter.* **2020**, *76*, 585–588. [CrossRef]
28. Ministry of Natural Resources and Environment—Russian Federation; Russian Federal Service for Hydrometeorology and Environmental Monitoring and Environmental Monitoring (RosHydroMet). *Hydrographic Characterization. Characteristics by Cartographic Method*; Ministry of Natural Resources and the Environment of the Russian Federation: Saint Petersburg, Russia, 2018.
29. *GOST 31861-2012*; Water. General Requirements for Sampling. Federal Agency for Technical Regulation and Metrology: Moscow, Russia, 2012.
30. *ISO 5667-12-1995*; Water Quality—Sampling—Part 12: Guidance on Sampling of Bottom Sediments. International Organization for Standardization: Geneva, Switzerland, 1995.
31. *GOST 3351-74*; Drinking Water. Methods for Determination of Odor, Taste, Color and Turbidity. State Committee of Standards of the Council of Ministers of the USSR: Moscow, Russia, 1974.

32. *GOST 31868-2012*; Water. Methods for Determination of Colour. Federal Agency for Technical Regulation and Metrology: Moscow, Russia, 2012.
33. *GOST 26449.1-85*; Stationary Distillation Desalting Units. Methods of Saline Water Chemical Analysis. Federal Agency for Technical Regulation and Metrology: Moscow, Russia, 1985.
34. *STO GGI 52.08.40-2017*; Determination of the Morphometric Characteristics of Land Water Bodies and Their Watersheds Using the Technology of Geographical Information Systems Using Digital Maps of the Russian Federation and Satellite Images. Federal Agency for Technical Regulation and Metrology: Moscow, Russia, 2017.
35. *R 52.08.874-2018*; Determination of hydrographic characteristics by cartographic method. Roshydromet: Moscow, Russia, 2018.
36. Gagarina, O.V. *Assessment and Regulation of Natural Waters Quality: Criteria, Methods, Existing Problems*; Publishing House: Izhevsk, Russia, 2012.
37. Vodyanitsky, Y.N. Formulas for estimating total soil contamination with heavy metals and metalloids. *Soil Sci.* **2010**, *10*, 1276–1280.
38. Saet, Y.E. Geochemical principles of identification of zones of impact of industrial emissions in urban agglomerations. In *Landscape-Geochemical Zoning and Environmental Protection*; Saet, Y.E., Smirnova, R.S., Eds.; Mysl: Moscow, Russia, 1983.
39. Potakhin, M.S. Morphological Features of Water Bodies in Petrozavodsk. 2011. Available online: http://resources.krc.karelia.ru/water/doc/papers/Water_envir_2011_180-183.pdf (accessed on 20 July 2023).
40. Mikhailov, V.N.; Dobrovolskiy, A.D. *Textbook for Universities*, 2nd ed.; Vysshaya Shkola: Moscow, Russia, 2007; p. 463.
41. Uryvaeva, V.A. *Surface Water Resources of Virgin and Fallow Lands Development Areas. Akmola Region of the Kazakh SSR*; Hydrometeorological Publishing House: Leningrad, Russia, 1958; pp. 28–29.
42. Yan, L.; Sun, M.; Yao, X.; Gong, N.; Li, X.; Qi, M. Lake water in the Tibet Plateau: Quality change and current status evaluation. *Acta Sci. Circumstantiae* **2018**, *38*, 900–910.
43. Aubakirova, G.; Adilbekov, Z.; Narbayev, S. Influence of water mineralization on zooplankton productivity in reservoirs of Akmola region. *Period. Tche Quim.* **2020**, *17*, 520. [CrossRef]
44. Katanayeva, V.G. *Features of the Hydrochemical Regime of Subtaiga Priishimye Lakes*; Katanaeva, V.G., Larin, S.I., Larina, N.S., Sheveleva, T.V., Eds.; Vestnik of Tymen State University: Tyumen, Russia, 2004; pp. 175–183.
45. Alekin, O.A. *Fundamentals of Hydrochemistry*; Hydrometeorological Publishing House: Moscow, Russia, 1970.
46. Vinogradov, V. Benthal Deposits of Republic of Tatarstan Lakes. Ph.D. Dissertation, Saint-Petersburg University, Saint Petersburg, Russia, 2020.