ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2523-5664 (Print)
ISSN: 2523-5672 (Online)
CODEN: WCMABD

Water Conservation and Management (WCM)

DOI: http://doi.org/10.26480/wcm.02.2021.108.113

RESEARCH ARTICLE

ASSESSMENT OF HYDROPHYSICAL AND HYDROCHEMICAL FEATURES OF WATER BODIES: A CASE STUDY OF LAKE IMANTAU, KAZAKHSTAN

Zhumay Yerlan[a] , Khussainov Abilzhan[a], Kurmanbayeva Aigul[a*], Skipin Leonid[b], Onerkhan Gulzhaina[c]

[a] Sh. Ualikhanov Kokshetau State University, Kazakhstan
[b] Tyumen Industrial University, Russia
[c] Kazakh University of Technology and Business, Kazakhstan
**Corresponding Author Email: aygul6868@mail.ru*

ARTICLE DETAILS

Article History:

Received 02 October 2021
Accepted 10 November 2021
Available online 23 November 2021

ABSTRACT

The lakes of "Kokshetau" State National Natural Park (SNNP) are scanty and have a mosaic, fragmented character due to the present ecological state. In current work, the chemistry and degree of pollution in this lake is studied. The present research aimed to analyse the hydrophysical and hydrochemical parameters of lake Imantau of "Kokshetau" SNNP. This assessment includes dynamics of the hydrochemical water composition and benthal deposits, heavy metals content, and morphometric indicators of the lake using Earth's remote sensing technique. This technique is based on Earth's retrospective multichannel satellite images Landsat. Ionic water composition, total mineralization, hydrogen index, gas regime, and nutrient content (nitrates, nitrites) are determined. To assess the geochemical state of benthal deposits, the parameters like concentration coefficient (Cc), maximum allowable concentration (MAC) of pollutants in the soil, and total pollution index (Zc) are calculated. The results of this work is measured in terms of changes takes place in lake depth, water mass volume, water hardness, chemical concentrations.

KEYWORDS

Ecological state, hydro-physical and morphometric indicators, hydro-chemical features, benthal deposits, pollution index, lake Imantau.

1. INTRODUCTION

The lakes of specially protected natural areas are unique and are widely used for recreational and balneological purposes; thus, they are under the close attention of scientists (Jasenka et al., 2012). Authors monitored the lakes of National Park in central Croatia based on data analysis and recommended sustainable management and reduced the negative impact of tourism on water pollution and benthal deposits (Horvatinčić et al., 2006). Background content of heavy metals in environment components and the modernization process in monitoring systems in Russia have also been reported (Chepelev, 2007; Dzhenyuk, 2002; Chizhova, 2006; Buyvolov et al., 2019). The North Kazakhstan region (NKR) has a significant number (3500 lakes with a total area of 3410 km^2) of various lakes located on its territory. The total reserves of fresh and brackish water in the lakes of the North Kazakhstan region are estimated at 4 billion m^3 (Bezmaternykh, 2011).

However, small lakes are unique natural complexes that ensure ecosystem sustainability. Pollution in small lakes due to an annually increasing recreational load leads to several factors: a change in the chemical composition of water, an increase in the concentration of heavy metals, a tendency to dry out, an increase in anthropogenic eutrophication of lakes, and complete degradation. Reservoirs of Northern Kazakhstan have long been objects of research by scientists. The first hydrological information about the lakes dates back to the end of the 19th century (Kolomin, 2006). From the mid-60s of the 20th century, more detailed studies of hydrology, hydrochemistry, and biodiversity of lakes have been started, associated with the development of virgin and fallow lands. Later, to preserve and restore unique forest and lake ecosystems in 1996, "Kokshetau" State National Natural Park (SNNP), Republic of Kazakhstan, was created.

Modern scientific research on the lakes of "Kokshetau" SNNP is fragmented and splintery; thus, it is necessary to conduct a comprehensive survey of the territory and generalize state monitoring data to improve its organization and maintenance (Khusainov et al., 2019; Kazabekov and Sagadiev, 2002; Kolomin, 2000; Yakovlev, 2006; Zhumangalieva, 2013). Notably, an annual increase in the recreational load leads to water bodies contamination, necessitating continuous environmental monitoring. Based on the Nature Records Program, the existing monitoring system in "Kokshetau" SNNP has got several issues: it does not provide a long series of quantitative data; does not assess ecosystem dynamics, and identify dominant factors of influence; irregularly in data, which depend on subjective factors; does not study zones with different anthropogenic loads; does not predict further process development course in making management decisions (Zhumai et al., 2020).

Data on this present ecological state of the lakes of "Kokshetau" SNNP are scanty and have a mosaic, fragmented character. The chemistry and pollution degree of lakes are insufficiently studied, although the chemical composition of benthal deposits is not being studied. Furthermore, there is not enough literature to study the dynamics of ecological state of lakes. Thus, we have embarked on a program in assessing the environmental condition of lake Imantau (of "Kokshetau" State National Natural Park) based on hydrophysical and hydrochemical analyses of long-term data. A comprehensive assessment includes dynamics of the hydrochemical water composition and benthal deposits, the content of heavy metals, and

Quick Response Code	Access this article online	
	Website: https://www.watconman.org/	**DOI:** 10.26480/wcm.02.2021.108.113

Cite the Article: Zhumay Yerlan, Khussainov Abilzhan, Kurmanbayeva Aigul, Skipin Leonid, Onerkhan Gulzhaina (2021). Assessment of Hydrophysical and Hydrochemical Features of Water Bodies: A Case Study of Lake Imantau, Kazakhstan. *Water Conservation and Management, 5(2): 108-113.*

morphometric indicators of the lake were studied using Earth's remote sensing techniques based on Earth's retrospective multichannel satellite images Landsat.

2. Geographical Background

The reservoir of lake Imantau is located on the territory of the North Kazakhstan region near the village Imantau, Aiyrtau district, North Kazakhstan region, in a specially protected area of "Kokshetau" State National Natural Park. Geographic coordinates of the lake location: north latitude 53000/32.55//, east longitude 68016/59.90//, absolute height above sea level is 321 m (St. Petersburg, 2017 and St. Petersburg, 2018). The total catchment area is 483 km^2, represented by a hilly, partially plowed (15%) plain. On the southern side, the catchment area is bounded by the Imantau Mountains, and on the north by the Aiyrtau Mountains, where the slopes are covered with pine and birch forests (20% of forest cover). The lake is nourished by atmospheric precipitation; the inflow of small rivers and streams flow into the lake from the southeast and northeast. The lake basin is located at the bottom of the hills. In the southwestern part, an island exists 800 m long and 500 m wide. The southwest coast is steep, rocky, high, and cliffy. The rest of the banks is gentle, as shown in figure 1.

Figure 1: Space image of lake Imantau received from the Yandex server through the SAS Planet program.

3. Analysis and Assessment

Water samples were collected following the interstate standard GOST 31861 - 2012 Water. Sampling of benthal deposits was conducted according to the international standard ISO 5667 - 12 - 1995 using a Petersen graph. Hydrophysical water parameters were determined: odour according to GOST 3351-74 using the organoleptic method; colouration according to GOST 31868-2012; visual determination method of colouration (method A); turbidity according to GOST 3351-74 p.5 using the photometric method. Chemical indicators in samples were determined by GOST 26449: pH of the medium by electrometric method; carbon dioxide, potassium, sodium, nitrates by potentiometric titration method; dissolved oxygen, dry residue mineralization, permanganate oxidizability, hydrocarbonates, carbonates, chlorides by titrimetric method; sulfates, calcium, magnesium, total hardness by complexometric method; chromium (III) by the Photocolorimetric method; nitrites by fluorimetric method; heavy metals content by flameless atomic absorption spectrometry using spectrometer MGA-915.

Morphometric parameters study of lake Imantau was performed by remote sensing of the Earth's remote sensing technique based on Earth's retrospective multichannel satellite images Landsat, based on STO GGI 52.08.40-2017 and P 52.08.874-2018 (St. Petersburg, 2017 and St. Petersburg, 2018). ArcGIS tools were used to assess the present ecological state of lake Imantau. Kurlov's formulas were used to prepare the Scholler diagram and calculate the water pollution index to determine complex indicators to assess water quality (The Republic of Kazakhstan, 2016; Gagarina, 2012). To assess the geochemical state of benthal deposits, the concentration coefficient (Cc) was calculated using the equation (1).

$$K_k = \frac{C_s}{C_b} \qquad (1)$$

Where C_s and C_b refer to pollutant concentration at studied and background sites, respectively.

[The confusion of symbol C_c and K_K as concentration coefficient, is faced at many places.]

To calculate the concentration coefficient, the maximum allowable concentration (MAC) of pollutants in the soil was used as background values using the following formula (Saet, 1981):

$$C_c = \frac{K_i}{MAC} = \frac{Cu}{MAC} + \frac{As}{MAC} + \frac{Hg}{MAC} + \frac{Ni}{MAC} + \frac{Pb}{MAC} + \frac{Zn}{MAC}$$

[(Saet, 1981) this reference is not found in reference list.]

Total pollution measure (Z_c) was taken as a criterion to assess the technogenic impact on benthal deposits, as calculated using the following formula:

$$Z_c = \sum_{i=1}^{N} K_k - (n-1) = 2.491 - (6 - 1) = -2.509$$

Where C_c is the concentration coefficient; n is the number of elements counted.

Index computation of reservoir conservation value was conducted using standard ArcGIS tools. Data processing was performed by classical methods using information packages. Laboratory studies were carried out in a licensed laboratory on certified equipment with chemical analyser error of ± 0.001.

4. Results and Discussions

4.1 Morphological characteristics of Lake Imantau

Morphological features of lakes are important, as they reflect the functioning processes of the lake ecosystem (Potakhin, 2011). Attention is drawn because lakes been have dried off in the last 100–200 years, associated with a general decrease in moisture content. Mikhailov and Dobrovolskiy found cyclical fluctuations in the level of lakes and moisture content in about 1850 ysears (Mikhailov and Dobrovolskiy, 2007). Disturbance on lakes, particularly small ones, has several features associated with the limited size of the reservoir and shallow depths. A group researcher showed that the total surface area of the lakes of Burabay National Park reduced by 7% between 1986 and 2016 due to a decrease in area of the three main lakes (Yapiyev et al., 2020). In contrast, the surface area increased in some smaller lakes. Furthermore, the authors found a decrease in the area and volume of Burabay National Park lakes with prolonged water balance deficits when evaporation from the lake surface exceeded the amount of precipitation. However, in recent years (2013–2016), the precipitation amount has increased and stabilized the water levels in the lakes of Burabay National Park.

[It is suggested to move above two paragraphs in literature review.]

We have established a similar pattern on Lake Imantau. Table 1 presents all the parameters relevant to the present analysis. The lake belongs to the class of deep lakes in terms of depth. The steepness of waves on the lakes is, on average, about 0.1 m. The lake basin has a tectonic origin.

Table 1: Morphometric indicators of lake Imantau

Indicators	1956	2010	2014	2019
Surface area, km^2	53.10	53.32	54.95	53.70
Maximum depth, m	11.5	10.4	10.6	10.5
Average depth, m	6.7	5.8	6.0	5.9
Water mass volume, m^3	355	315.5	315.7	315.6

4.2 Hydrophysical and hydrochemical indicators of Lake Imantau

The current work showed that hydrophysical properties of water in lake Imantau correspond to the permissible standards like there is no odour and the temperature of water was 32–38°C. The turbidity varied in the range of 4.6–5.4 mg/dm^3. Table 2 presents a decrease in temperature and turbidity of water over the last 3 years. The water temperature in the surface horizons of the lake was 22.6–23.7 °C in summer and 17.4–20.0 °C in autumn.

Table 2: Hydrophysical indicators of lake Imantau

Indicators	2015	2016	2017	2018	2019	Norm
Odour (point)	no	no	no	no	no	Not more than 2
Temperature (^{0}C)	40	37	38	35	32	Not defined
Turbidity (mg/dm^3)	5.7	5.5	5.4	4.9	4.6	Not defined

Cite the Article: Zhumay Yerlan, Khussainov Abilzhan, Kurmanbayeva Aigul, Skipin Leonid, Onerkhan Gulzhaina (2021). Assessment of Hydrophysical and Hydrochemical Features of Water Bodies: A Case Study of Lake Imantau, Kazakhstan. *Water Conservation and Management, 5(2): 108-113.*

The pH and total content of dissolved solids in most tectonic lakes on the Tibetan Plateau significantly exceeded national standards for surface water quality due to the geographical environment, climatic background, and chemical characteristics of water (Yan et al., 2018). Besides, the pH value in lake Imantau ranged from 7.6 to 8.6, leading to a slightly alkaline environment, which does not exceed regulatory requirements. Biochemical oxygen consumption indicators from 2014 to 2017 exceeded the norm by 1.18 to 1.31 times. Table 3 presents the hydrochemical indicators during 2018–2019.

Table 3: Hydrochemical indicators of Lake Imantau

Indicators	Actual concentrations by year						USWQCRK* 1st class
	2014	2015	2016	2017	2018	2019	
pH	8.04	8.0	7.66	8.61	8.10	7.90	6.5–8.5
BOD5 (mg/dm^3 of O_2)	3.58	3.86	3.94	3.54	1.47	1.00	3
Total water hardness (eqv. mg/dm^3)	6.20	5.70	3.03	3.86	4.,10	4.30	
Dissolved oxygen (mg/dm^3 of O_2)	9.80	9.40	8.20	8.59	6.20	6.40	
Hydrocarbonate mg/dm^3	34.7	31.7	40.0	34.2	36.2	35,0	
Carbonate (mg/dm^3)	0.89	0.61	0.68	0.56	< 8	< 8	
Chloride (mg/dm^3)	176.0	65.8	26.3	25.1	28.0	32.0	300
Sulphate (mg/dm^3)	357	641	532	538	540	505	250
Calcium (mg/dm^3)	44.1	6.0	6.0	5.2	4.8	4.6	180
Magnesium (mg/dm^3)	48.6	64,8	36,0	43,2	41,0	43,0	20
Sodium (mg/dm^3)	19.5	18.8	16.4	18.8	21.0	29.0	
Potassium (mg/dm^3)	238	188	172	160	157	162	
Nitrate (mg/dm^3)	0	0	0.05	0.25	3.60	4.20	40
Nitrite (mg/dm^3)	0.04	0.05	0.05	1.95	1.54	1.62	0.1
Total Ferrum (mg/dm^3)	0.002	0	0	0	0.160	0.130	< 0.2
Ammonium nitrogen (mg/dm^3)	0.07	0.09	1.50	0.25	2.90	2.70	< 0.5
Dry residue mineralization (mg/dm^3)	950	998	800	830	847	985	1000

[What is USWQCR?]

The total water hardness was determined by the sum of $Ca^{2+}$and Mg^{2+}ions in mg-equ/L. Studies have shown that there was a decrease in total hardness in 2014, and the indicator was 6.2 mg-equ/l for hard water, whereas the indicator was 4.3 mg-equ/l in 2019 with moderate hardness, indicating a decrease in the content of $Ca^{2+}$and Mg^{2+}ions. A decrease in dissolved oxygen was observed from 9.8 mgO_2/dm^3 in 2014 to 6.4 mgO_2/dm^3 in 2019. These concentrations exceeded the maximum allowable concentration (MAC) for fishery and cultural water from 1.55 to 2.2 times.

The concentration of hydrocarbons from 2014 to 2019 varied slightly, ranging from 34.2 mg/dm^3 to 40 mg/dm^3. Carbonate concentration was < 8 mg/dm^3 over the years of research. Chloride ions content was 175.9 mg/dm^3 in 2014, and chloride concentration dropped sharply from 2.7 to 7 times in subsequent years within the permissible concentration.

Sulphates content in the water exceeded the norm from 1.4 to 2.6 times in all years of research. The concentration of calcium ions decreased significantly from 44.1 mg/dm^3 (in 2014) to 4.6 mg/dm^3 (in 2019) within the normal range. Also, there was a decrease in magnesium ions from 48.6 mg/dm^3 (in 2014) to 43.0 mg/dm^3 (in 2019). The magnesium concentration exceeded the permissible norm from 1.8 to 3.2 times. Besides, the amount of sodium, potassium, and total iron ions varied slightly and did not exceed permissible limits.

In recent years, there has been a sharp increase in the concentration of nitrates from 0.05 mg/dm^3 (in 2016) to 4.2 mg/dm^3 (in 2019), increasing by 84 times. Although nitrate content does not exceed the norm, a significant increase in their amount raises concerns. A similar increase in nitrite concentration from 0.035 mg/dm^3 to 1.62 mg/dm^3 was also observed during this period. Thus, the excess allowable concentration for this indicator in 2019 amounted to 16 MAC. Also, there has been an increase in ammonium nitrogen concentration, which was 0.07 mg/dm^{3}in 2014 and increased to 2.7 mg/dm^3 in 2019, exceeding permissible norms by 5.4 times.

The chemical composition of natural waters is inextricably linked with the composition and structure of the soil, which, in turn, was formed during the long evolution of the earth's crust under climate influence. Natural waters have various qualitative and quantitative chemical compositions. The basis for systematization in existing classifications is the mineralization degree, the predominant component or group, the ratio between different values of various ions concentrations, and increased amounts of any specific elements of gas and salt regimes (Aubakirova et al., 2020). Water mineralization was determined by the total amount of ions contained in the natural waters of the lake, including hydrocarbonates, carbonates, chlorides, sulphates, calcium, magnesium, sodium, and potassium (Katanaeva, 2004). From less arid to more arid regions, the mineralization of lake water increases. 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 sulphate and chloride and from the calcium group to magnesium and sodium. HCO_3 and Ca^{2+} ions prevail in the lakes of the forest zone whereas, in lakes of the steppe zone, SO_4^{2-}, HCO_3^-, Na^+ and K^+ can be obtained (Mikhailov and Dobrovolskiy, 2007).

According to the calculations, the water in lake Imantau is fresh. A chemical analysis was carried out in summer, which did not show an excess of 800–998 mg/l. in terms of ions amount. However, samples collected in winter showed mineralization 1652 mg/l, exceeding permissible norms by 0.6 times. As a result, according to Alekin's (1970) classification of waters based on the nature of the ionic composition, the water of lake Imantau had chloride, sulphate, and sodium ions in fresh water in 2014, sulphate, magnesium, sodium ions in 2015, sulphate, magnesium, and sodium ions in slightly fresh water in 2016–2019, as shown in figure 2.

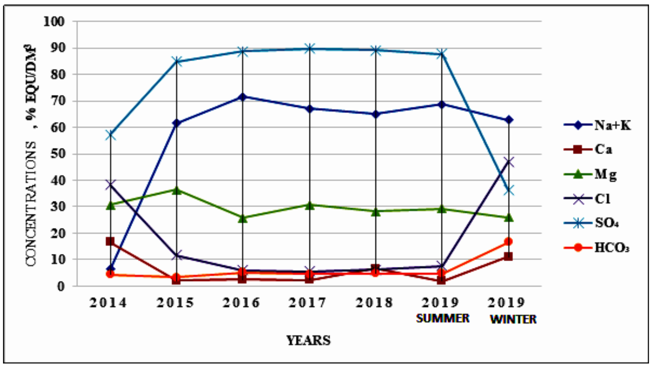

Figure 2: Ionic-salt water composition of Lake Imantau.

4.3 Heavy metal content

Results of water surface study of lake Imantau for the period 2014–2019 showed that the content of zinc, lead, copper, cobalt, manganese, molybdenum, nickel, chromium (III), and strontium do not exceed permissible limits, but an increase in the tendency of concentration of these pollutants was observed, as shown in Table 4.

Table 4: Concentration of heavy metals in the water of Lake Imantau

Indicator/year	Actual concentration by years, mg/dm³						MAC c.g.	MAC r.g.
	2014	2015	2016	2017	2018	2019		
Zinc	0.002	0.001	0.001	0.011	0.120	0.140	0.010	1
Lead	0.0025	0.0250	0.0025	0.0025	0.0070	0.0008	0.0060	0.03
Cadmium	0.0010	0.0010	0.0030	0.0010	<0.0001	<0.0001	0.0010	0.001
Cooper	0.0004	0.0004	0.0014	0.0050	0.0080	0.0900	0.0010	1
Cobalt	0.005	0.001	0.001	0.003	0.001	0.001	0.1	0.1
Manganese	0.0006	0.0006	0.0006	0.0006	0.0050	0.0050	0.0100	0.1
Molybdenum	0.003	0.003	0.003	0.003	<0.001	<0.001	0.25	0.25
Nickel	0.0008	0.0008	-	-	0.0070	0.0060	0.0100	0.1
Chrome (III)	0.012	0.012	0.014	0.012	<0.001	<0.001	0.001	0.1
Argentum	0.350	0.350	0.070	0.0035	<0.0050	<0.0050	0.050	0.05
Strontium	0.028	0.0014	-	-	<0.001	<0.001	-	-
Beryllium	0.002	0.002	-	-	<0.0001	<0.0001	0.0002	0.0002

Cadmium (C_d) content in 2016 exceeded MAC three times; however, the amount of C_d was within the normal range in 2019. It enters the water through discharge of C_d-containing industrial wastewater, precipitation of atmospheric C_d dust, and soil erosion by rainfall. C_d is also a highly toxic substance that accumulates in the environment and can cause teratogenic and carcinogenic effects (Kharina and Aleshina, 2020). During the years of research 2014–2019, the range of C_d concentrations was 0.0001–0.0030 mg/l. In 2014 and 2015, there was a high content of silver ions of 7 MAC and beryllium ions of 10 MAC. Subsequently, their concentration decreased and corresponded to sanitary standards. The study of complex water pollution index showed an annual deterioration of the ecological state of water from "moderately polluted" (CWPI = 1.6) in 2014 to "polluted" in 2019 (CWPI = 5.56) whereas water quality class was decreased from 3 to 5 levels, as shown in Table 5.

Table 5: Complex water pollution index of Lake Imantau.

Ingredients/ years	CWIP calculation of Lake Imantau					
	2014	2015	2016	2017	2018	2019
pH	8.04	8.10	7.66	8.61	8.10	7.90
Dissolved oxygen, mg/l	9.8	9.4	8.2	8.35	6.2	6.4
BOD full, mg /l O_2	3.58	3.86	3.94	3.54	1.47	1.00
Zink, mg/l	0.002	0.0007	0.0007	0.011	0.120	0.140
Lead, mg/l	0.0025	0.025	0.0025	0.0025	0.007	0.008
Cooper, mg/l	0.0004	0.0004	0.0014	0.005	0.008	0.009
Cobalt, mg/l	0.005	0.001	0.001	0.0003	0.0009	0.0008
Result of Σ Ci / MACi	9.52	12.73	9.98	14.81	30.25	33.41
CWIP	1.60	2.12	1.66	2.46	5.04	5.56
	moderately polluted	polluted	moderately polluted	polluted	highly polluted	highly polluted
Water quality class	3	4	3	4	5	5

Figure 3 presents an analysis of data, showing that an increase in the number of visits to the territory of "Kokshetau" SNNP has a negative impact on the water pollution index of lake Imantau. Furthermore, an increase in water pollution in the lake is observed with an increase in the number of tourists over the years. Thus, a close correlation has been established between water pollution indices of lake Imantau and tourist numbers by years, with the correlation coefficient of 0.89 and determination coefficients (R^2) of 0.79 (Kolpakova et al., 2019).

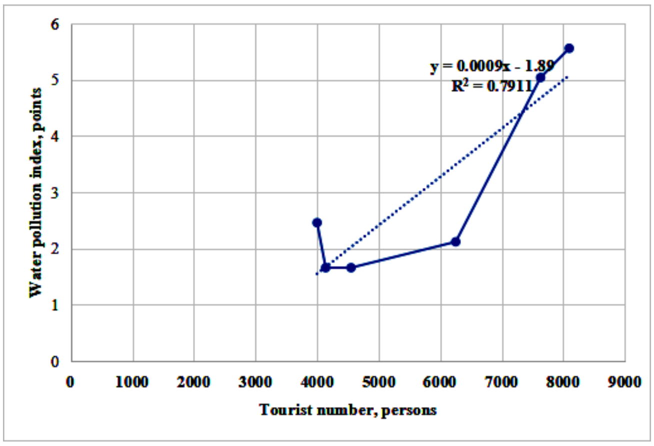

Figure 3: Complex water pollution index and tourists number at lake Imantau.

Most of the water basins are insufficiently surveyed and have not developed areas for recreation. Recreation areas are situated locally, and basins shores are heavily loaded in summer, leading to the degradation of vegetation cover, pollution, and reconsolidation of soil, the emergence of unauthorized dumps, an increase in load on water areas, and risk of infectious and skin diseases (Chekmareva, 2020). This situation is typical for lake Imantau as well. There are two tourist complexes, one children's health centre, two recreation centres, and more than 200 courtyards of private houses on the shore. They are located 20–35 m away from the water's edge. All recreation institutions have local sewerage that pollutes the lake and groundwater. Another source of pollution is the poultry farm located 500 m away from the lake.

4.4 Benthal deposits

The geochemical structure of benthal deposits is determined by material and dynamic factors. The first group of factors determines the regional geochemical background of heavy metals. Dynamic factors affect the geochemical differentiation of matter during the sedimentation-accumulation period through the mechanisms of hydrodynamic, physicochemical, and biogeochemical processes (Vinogradov, 2020). So far, the Republic of Kazakhstan has not developed a unified methodology to assess the quality of benthal deposits of natural water bodies. Therefore, researchers use various methodological approaches to assess their condition. In this regard, as a priority task, we set the determination of the average concentrations and geochemical background of metals in benthal deposits of the lakes at "Kokshetau" SNNP.

Figure 4 depicts the presence of heavy metals in the benthal deposits of lake Imantau. The diversity of the excess of toxicants relative to background values was calculated to assess the geochemical state of benthal deposits. The MAC of soils was used as background indicators. Also, the total pollution index for lake Imantau was calculated.
Yu.E. Saeta (Saet, 1981).

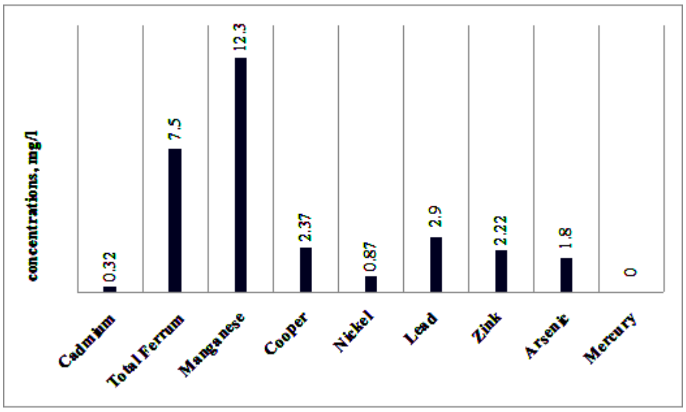

Figure 4: Heavy metals concentration in benthal deposits of Lake Imantau, mg/kg.

[Yu.E. Saeta (Saet, 1981) reference is not found in reference list.]

The results obtained from the present research showed that the level of benthal deposit pollution of lake Imantau is weak (K_k=2.491) and based on an approximate scale to assess water system pollution by Yu.E. Saeta (Saet, 1981), the content relative to the background is found as Z_c = - 2.509.

5. CONCLUSION

The results showed that the lake Imantau belongs to the middle class in terms of water surface area with a maximum depth. The lake basin is of tectonic origin. The pH value of the aquatic environment is slightly alkaline (7.6–8.6), and it does not exceed the normative requirements. The excess of MAC is established according to the following indicators. i) Biochemical oxygen consumption increased by 1.18–1.31 times and the amount of dissolved oxygen by 1.55–2.2 times. Also sulphates content increased by 1.4–2.6 times while ions magnesium by 1.8–3.2 times. The content of nitrite by 16 times while ammonium nitrogen by 5.4 times. The total mineralization is found to be 1652 mg/l, which exceeded the permissible norms by 60%. Still the composition of sulphate, magnesium, and sodium ions is found in freshwater.

The excess of MAC is found among heavy metals due to three times cadmium content, silver ions by seven times, and beryllium ions by ten times. The ecological state of water is found to deteriorate annually, from moderately polluted (CWPI = 1.6) in 2014 to highly polluted (CWPI = 5.56) in 2019. Whereas the water quality decreased from 3 to 5 levels. A close correlation was established between the number of visitors to the park and the dynamics of the water pollution index in the lake, with a correlation coefficient of 0.89. In the benthal deposits, the concentration coefficient is 2.491, and the total pollution index is 2.509. It refers to a weak pollution equation in which the content of toxic elements in water is slightly increased relative to the background, according to the scale used to assess water system pollution based on an indicator of benthal deposits.

REFERENCES

Alekin, O.A., 1970. Fundamentals of Hydrochemistry. Hydrometeorological publishing house.

Aubakirova, G., Adilbekov, Z., Narbayev, S., 2020. Influence of water mineralization on zooplankton productivity in reservoirs of Akmola region. Periodico Tche Quimica, 17 (34), Pp. 520–527.

Bezmaternykh, D.M., 2011. Water and biological resources of lakes in North Kazakhstan region: state, use and ways of restoration. Fish Breeding and Fish Farming, 3 (201), Pp. 9–12.

Buyvolov, Yu. A., Ivanova, N.V., Shashkov, M.P., 2019. Data digitization from naturer records and scientific biological collections of specially protected natural areas. Educational Guidance, FSBI Prioksko-Terrasny Nature Biosphere Reserve, (127).

Chekmareva, E., 2020. Geoecological research of water bodies of the Central Federal District of different recreational availability. In conference of E3S Web of Conferences, Vinogradov Conference on Hydrology: from Learning to Worldview, vol. 163.

Chepelev, O.A., 2007. System improvement of soil-ecological monitoring of anthropogenically transformed landscapes. (Unpublished dissertation).

Chizhova, V.P., 2006. Program development for recreational monitoring of a protected natural area. Tourism and recreation: fundamental and applied research. In Proceedings of the International Scientific and Practical Conferences, 118, pp 392-396.

Dzhenyuk, S.L., 2002. Methodology for information support of environmental monitoring: (Unpublished doctoral dissertation).

Gagarina, O.V., 2012. Assessment and regulation of natural waters quality: criteria, methods, existing problems. Izhevsk: Publishing House.

Horvatincic, N. Brianso, J.L., Obelic, B., Baresic, J., Krajcar-Bronic, I., 2006. Study of Pollution of the Plitvice Lakes by Water and Sediment Analyses. Water Air and Soil Pollution, 6, Pp. 111–121.

Jasenka, S., Srecko, B., Izidora, M., 2012. Lakes National Park (Central Croatia)" – More Than 50 Years of Continuous Monitoring of Natural and Human Influence // (13).

Katanaeva, V.G., 2004. Features of the hydrochemical regime of subtaiga Priishimye lakes. V.G. Katanaeva, S.I. Larin, N.S. Larina, T.V. Sheveleva // Vestnik of Tymen State University – Tymen: TSU, Pp. 175–183.

Kazabekov, A., Sagadiev, K., 2002. State National Natural Park "Kokshetau". Publishing House "Kokshe-Poligraphia", 258.

Kharina, G.V., Aleshina, L.V., 2020. Харина Г.В., Алёшина Л.В. Evaluation of heavy metal contamination of drinking water in Sverdlovsk region. Water industry of Russia, No. 1, Pp. 124–134.

Khusainov, A.T., Memeshov, S.K., Durmekbaeva, S.N., Makhanova, S.K., Fakhrudenova, I.B., Kurmanbayeva, A.S., Khusainova, R.K., 2019. Current ecological state of Burabay National Park, measures to improve it. Kokshetau, Mir Pechati, 324.

Kolomin, Y.M., 2000. 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, Kazakhstan.

Kolomin, Y.M., 2006. History of Fisheries Research in Northern Kazakhstan. Fisheries research in the Republic of Kazakhstan: history and modern state. Bastau, Almaty, Pp. 193–203.

Kolpakova, M.N., Gaskova, O.L., Naymushina, O.S., Karpov, A.V., Vladimirov, A.G., Krivonogov, S.K., 2019. Saline lakes of Northern Kazakhstan: Geochemical correlations of elements and controls on their accumulation in water and bottom sediments. Applied Geochemistry, 107, Pp. 8–18.

Mikhailov, V.N., Dobrovolskiy, A.D., 2007. Textbook for universities. – 2nd Ed. cor. - M.: Vysshaya Shkola, 463.

Potakhin, M.S., 2011. Morphological features of water bodies in Petrozavodsk. http://resources.krc.karelia.ru/water/doc/papers/Water_envir_2011_180-183.pdf.

Vinogradov, V., 2020. Benthal deposits of Republic of Tatarstan lakes. (Unpublished dissertation). Saint-Petersburg University Saint-Petersburg; Russian Federation.

Yakovlev, V.A., 2006. General and specific assessments of ecosystems in Kazakhstan. Book: Landscape and biological diversity of the Republic of Kazakhstan. Almaty: UNDP. «OST-XXI century», Pp. 145–149.

Yakovlev, V.A., 2006. General and specific assessments of ecosystems in Kazakhstan. // Book: Landscape and biological diversity of the Republic of Kazakhstan. Almaty: UNDP. «OST-XXI century», Pp. 145–149.

Yan, L., Sun, M., Yao, X., Gong, N., Li, X., Qi, M., 2018. Lake water in the Tibet Plateau: Quality change and current status evaluation. Huanjing Kexue Xuebao/Acta Scientiae Circumstantiae, 38 (3), Pp. 900–910.

Yapiyev, V., Skrzypek, G., Verhoef, A., Macdonald, D., Sagintayev, Z., 2020. Between boreal Siberia and arid Central Asia – Stable isotope hydrology and water budget of Burabay National Nature Park ecotone (Northern Kazakhstan). Journal of Hydrology: Regional Studies, 27.

Zhumai, E., Kurmanbayeva, A.S., Khusainov, A.T., Agaidarova, A.A., Bayazitova, Z.E., 2020. Ecological state assessment of Lake Beloe (Akkul) of Kokshetau State National Natural Park. Vestnik of KazNITU, Almaty, 4 (140), Pp. 15 – 21.

Zhumangalieva, Z., 2013. Water resources of Kazakhstan: the lakes' fund / 1st Eurasian Multidisciplinary Forum, EMF - Tbilisi, European Scientific institute ESI, (2), Pp. 35–38.