Original Article

Microbial Biosystems 9(2) (2024) 2024.398041
10.21608/mb.2024.398041

Contents lists available at Egyptian Knowledge Bank
Microbial Biosystems
Journal homepage: http://mb.journals.ekb.eg/

MICROBIAL BIOSYSTEMS
INTERNATIONAL SCIENTIFIC JOURNAL OF MICROBIAL BIOLOGY

Hydrochemical analysis of reservoirs in Kazakhstan: Water quality and toxicology microbial indicators

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Indexed by Scopus

ARTICLE INFO

Article history
Received 3 October 2024
Received revised 19 November 2024
Accepted 25 November 2024
Available online 20 December 2024

Corresponding Editors:
Ceyhun Akyol
Elena Ulrikh

Keywords
Algal blooms,
environmental monitoring,
heavy elements,
pesticides,
threshold limit value,
water quality indicator.

ABSTRACT

The study conducts a comprehensive analysis of the water quality and toxicology indicators of the Verkhnetobolskoye and Karatomarskoye reservoirs in northern Kazakhstan to identify potential pollutants, including heavy metals, organic and inorganic substances, and pesticides, and to assess the influence of these parameters on the suitability of water for various uses. The study combined hydrochemical and toxicological analysis, including atomic absorption spectrometry, gas chromatography–mass spectrometry, and ion chromatography to detect heavy metals, pesticides, and organic pollutants. The data were analyzed using statistical methods to determine correlations between different pollutants and to assess overall water quality according to national and international standards. The analysis suggests that both reservoirs are subject to moderate or severe pollution. Elevated concentrations of heavy metals, especially cadmium and zinc, were detected at several sampling points, exceeding the threshold limit value for safe water use. Although the levels of most pesticides are within the required limits, trace amounts of chlorinated pesticides were detected. The water quality in both reservoirs is classified as bad (class 4), with a high content of suspended solids, magnesium, and sulfates, making this water unsuitable for domestic use without thorough treatment. The reservoirs remain suitable for industrial uses, including irrigation and mining. The findings underscore the need for stricter water quality monitoring and improved water purification infrastructure in the reservoirs of Kazakhstan.

Published by Arab Society for Fungal Conservation

Introduction

Today, water resources are decisive for sustainable socioeconomic development, energy and food production, healthy ecosystems, and human survival (Cherkasova et al. 2024). A key function in water resources use and protection is state monitoring of the quality of water bodies (Gorelkina et al. 2024). This system of observation, assessment, and prediction of the development of negative processes affecting water quality and the condition of water bodies is critical for the timely detection of problems and the introduction of preventive measures (Nugmanov et al. 2024). In 2016, the UN General Assembly passed the A/RES/71/222

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resolution titled "International Decade (2018–2028) for Action – Water for Sustainable Development" (United Nations General Assembly. 2016). Assessment of the effectiveness of measures taken to protect water bodies is also part of the state's monitoring responsibilities. In Kazakhstan, where water shortage constitutes a serious problem, water resource quality and management are the central issues of the national environmental policy.

Public authorities' monitoring of water quality is limited to collecting samples at sampling points in the Kostanay region at regular intervals. In this light, the study aims to assess a wide range of reservoir water quality and toxicology indicators in as many locations as possible while accounting for seasonal and external factors. Reservoir waters are solutions with diverse chemical compositions that directly affect reservoir sediments.

The water quality in the examined reservoirs directly affects the Tobol River and downstream water bodies. A reservoir is a complex system of the ecological interaction of multiple factors. The quality and hydrochemical composition of reservoir water are naturally affected by a multitude of factors, including precipitation, seasonal floods, runoff from adjacent common or agricultural land, the mineral composition of rocks that form the relief of the bottom of the reservoir, and the impact of potentially polluting emissions from industrial enterprises (Ongayev et al. 2024). Research emphasizes the importance and necessity of a detailed assessment of water quality indicators in Kazakhstan reservoirs and water bodies and the dynamics of processes occurring in them (Bekmukhambetova & Salatova 2016a, 2016b; Amirgaliyev et al. 2018; Madibekov et al. 2021; Bugubaeva et al. 2023a, 2023b; Paramonova et al. 2023; Bugubayeva et al. 2024).

The hydrochemical composition of water is unique in each reservoir and heavily depends on geographic, geological, and climatic factors (Montayev et al., 2024).

Our goals were to do a thorough, multifaceted investigation into the quality and harmful effects of reservoir water during the winter, when freezing makes things more difficult. The objectives set involved assessing the content and activity of water quality indicators, including: 1) Metals and heavy elements; 2) inorganic substances and nonmetal ions; 3) potentially hazardous organic substances; 4) pesticides and organochlorine compounds; and 5) Gross alpha-beta radionuclide activity.

Importantly, before our study, there had been no comprehensive multifactor research on the water quality in the Verkhnetobolskoye and Karatomarskoye reservoirs of the Kostanay region involving the study of dynamics and hydrochemical processes.

Materials and Methods

The study was conducted in 2023-2024 on two large reservoirs of the Kostanay region in northern Kazakhstan: Verkhnetobolskoye (52°31'34.49''N 62°19'46.57''E) and Karatomarskoye (52°53'39.48''N 63° 3'0.87''E) reservoirs. Specific sampling points were selected relying on a combination of factors, including proximity to the sources of industrial and agricultural wastewater and major water inflows.

Kazakhstan has adopted the Unified System of Water Quality Classification in Water Bodies (Committee of Water Resources of the Ministry of Agriculture of the Republic of Kazakhstan. 2016), which relies on the requirements of the EU Water Framework Directive. The System characterizes the water quality in water bodies by five water use classes with a gradual transition from class 1 "best quality" to class 5 "worst quality". The characterization of water use classes and the differentiation of water use classes by categories (types) are also established by the requirements of the System. The EU Water Framework Directive dictates that if any water quality indicator is exceeded, the water body cannot be categorized as having a good ecological condition. If the threshold limit value (TLV) of an indicator is exceeded, the quality class is determined by the actual concentration (Table 1).

Water and sediment samples were collected in winter with special attention to ice-covered reservoirs. In this region, the February – March period is marked by a thick and stable snow cover. Average air temperature at the time of sampling ranged from -3°C to -10°C. The weather was clear and sunny. The average thickness of reservoir ice at the sampling locations was approximately 1 m.

Water samples were collected through holes drilled in the ice with specialized equipment. A special drill with the gasoline engine of the necessary power was used to drill ice and prepare holes for sampling. The drill bit was 0.2 m in diameter and 1 m long. Equipment for water sampling included drills for preparing holes in the ice, ladles, and plastic containers for storing drinking water. As a result of sampling, all water samples were sent to laboratories to organize their storage and conduct subsequent tests of quality indicators and toxicology.

Table 1: Reservoir water quality indicators exceeding the TLV

Reservoir	Karatomarskoye	Verkhnetobolskoye
Sampling point	Beregovoe village, 3.6 km south-east of the hydraulic structure	Lisakovsk city, 5 km north of Lisakovsk city
Water quality class	> class 5	class 4
Parameter exceeding the TLV, mg/l	Suspended solids	Mg
Concentration	47.9	47.4
Background	26.9	38.4
Water characterization by the type of water use	Water is not suitable for any use	Water is suitable for irrigation and industrial use; intensive water treatment is required for domestic and drinking water supply

If the content of suspended solids corresponds to water quality class > 5, the water is not suitable for any water use without preliminary treatment
*Source: Compiled by authors

The water samples were taken from different depths to capture the vertical stratification of water quality, particularly since temperature gradients and ice coverage in winter can affect the concentration of pollutants. Surface and deep-water samples were collected at each sampling point, generally at depths ranging from 1 m below the ice to 1 m above the reservoir bottom. We collected about 5 l of water per sample to ensure sufficient volume for a comprehensive analysis of several parameters.

A lot of different parameters were measured and estimated during the monitoring. These included the pH, total hardness, suspended solids, dry residue, calcium, magnesium, zinc, sulfates, manganese, COD (based on readings), the permanganate index, gross alpha activity, and gross beta activity. The parameters of water were measured according to approved techniques (American Public Health Association. 2005; Rosstandart. 2019).

The tests were carried out using standardized laboratory analytical equipment of the appropriate accuracy class, including photocolorimeters, spectrophotometers, atomic adsorption spectroanalyzers, ion-selective electrodes, pH ms, measuring burettes, etc. We performed the calibration and adjustment of the analytical equipment using standard samples with known content of analyzed components.

We estimated random changes based on either a normal or lognormal distribution. We performed the statistical processing of measurement results using the standard Excel package with the 2024 version of the Analysis extension application. Recommendations for modeling processes should also guide the assessment of environmental monitoring indicators (Mamikhin & Shcheglov 2020; Mamikhin et al. 2023).

Analytical testing laboratories accredited in accordance with GOST ISO/IEC 17025-2019 (Rosstandart. 2019) conducted all major analytical tests on water samples.

Results and Discussion

Estimation of the content of metals and heavy elements in reservoir water samples

As we looked at the hydrochemical properties of reservoir water, we kept an eye on the metals and heavy elements content indicators in the samples (Tables 2 and 3). The results of tests for compliance with hygienic requirements indicate no exceedances in metal and heavy element content. All indicators do not exceed the TLV values of the hygienic norms of safety indicators for household, drinking, and recreational water use.

By processing the indicators of the content of metals and heavy elements, the indicators that lowered the water quality class of the reservoir were found. According to the System and the numerical values of water quality standards by quality classes, both reservoirs belong to class 4. The determinant of class 4 for the Verkhnetobolskoye reservoir is magnesium content (30-100 mg/l). What makes the Karatomarskoye reservoir class 4 is the amount of cadmium in the water (0.002 to 0.005 mg/l). Elevated levels of magnesium, sulfates, and suspended solids, as noted in the article, create environments that could support harmful microbial growth, including those leading to eutrophication and algal blooms. These blooms can result in secondary microbial contamination with potentially harmful bacteria. So, water of this class is suitable only for irrigation and industrial use, including mining and hydrotransport. Using this water for household and drinking purposes requires deep treatment.

Table 2: Content of metals and heavy elements in water samples from the Verkhnetobolskoye reservoir

Parameter	Unit of measurement	TLV	1	2	3	4	5	6	7	8	9	Mean	SD	CV, %
Aluminum	mg/l	0.2000	<0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04		
Boron	mg/l	0.50	0.04	0.06	0.04	0.04	0.07	0.07	0.04	0.04	0.07	0.05	0.015	28.4
Vanadium	mg/l	0.4000	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03		
Cadmium	mg/l	0.0100	0.0030	0.0002	0.0001	0.0010	0.0010	0.0008	0.0006	0.0020	0.0020	0.0012	0.001	80.5
Sum of potassium and sodium	mg/l		167.2	176.0	206.8	145.8	174.1	137.8	178.0	132.5	142.4	162.28	24.33	15.0
Calcium Ca^{2+}	mg/l	130.00	92.2	86.2	78.2	68.1	100.2	92.2	98.2	106.2	86.2	89.73	11.674	13.0
Cobalt	mg/l	0.0300	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.002	0.000	0.0
Magnesium Mg^{2+}	mg/l	65.00	40.10	42.53	48.60	38.68	35.24	41.31	37.66	32.80	43.74	40.073	4.714	11.8
Manganese	mg/l	0.050	0.030	0.020	0.005	0.005	0.030	0.030	0.005	0.005	0.030	0.018	0.013	70.5
Copper	mg/l	1.000	0.004	0.004	0.004	0.003	0.002	0.003	0.004	0.002	0.005	0.004	0.001	27.4
Molybdenum	mg/l	0.500	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025		
Arsenic	mg/l	0.1000	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		
Sodium	mg/l													
Nickel	mg/l	0.1000	0.0018	0.0030	0.0020	0.0021	0.0027	0.0027	0.0023	0.0027	0.0024	0.0024	0.0001	16.4
Total iron	mg/l	0.3000	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.000	0.0
Mercury	mg/l	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	
Lead	mg/l	0.0300	0.0049	0.0036	0.0038	0.0038	0.0041	0.0049	0.0019	0.0048	0.0033	0.0039	0.001	24.5
Selenium	mg/l	0.0500	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.000	0.0
Chromium	mg/l	0.0500	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Zinc	mg/l	1.0000	0.6100	0.71	0.08	0.19	0.18	0.15	0.06	0.08	0.17	0.2492	0.239	95.9

*Source: Compiled by authors

Table 3: Content of metals and heavy elements in water samples from the Karatomarskoye reservoir

Parameter	Unit of measurement	TLV	1	2	3	4	5	6	7	8	Mean	SD	CV, %
Aluminum	mg/l	0.2	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04		
Boron	mg/l	0.5	0.06	0.1	0.06	0.07	0.11	0.11	0.06	0.06	0.078	0.023	29.9
Vanadium	mg/l	0.4	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03		
Cadmium	mg/l	0.01	0.006	0.001	0.0002	0.0009	0.0008	0.002	0.004	0.001	0.0021	0.002	99.2
Sum of potassium and sodium	mg/l		122.82	153.6	155	149.04	136.16	171.35	193.9	136.85	152.3	22.30	14.6
Calcium	mg/l	130	132.2	124.2	122.2	122.24	124.25	134.27	114.23	106.2	122.47	9.045	7.3
Cobalt	mg/l	0.03	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Magnesium	mg/l	65	20.66	19.44	18.22	18.22	19.44	13.37	27.22	27.95	20.56	4.84	23.5
Manganese	mg/l	0.05	0.02	0.08	0.02	0.03	0.06	0.06	0.02	0.02	0.039	0.024	62.3
Copper	mg/l	1	0.0026	0.0024	0.0039	0.0038	0.0026	0.0033	0.0056	0.0043	0.0035	0.001	30.3
Molybdenum	mg/l	0.5	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025		
Arsenic Sodium	mg/l	0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		
Nickel	mg/l	0.1	0.0026	0.0035	0.0056	0.0046	0.0031	0.0026	0.003	0.0023	0.0034	0.0011	33.3
Total iron	mg/l	0.3	0.04	<0.01	<0.01	<0.01	<0.01	0.1	0.01	0.01	0.04	0.042	106.0
Mercury	mg/l	0.0005	0	0	0	0	0	0	0	0	0		
Lead	mg/l	0.03	0.0048	0.0023	0.0048	0.0049	0.0031	0.0047	0.003	0.0038	0.0039	0.001	25.0
Selenium	mg/l	0.05	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0	0
Chromium	mg/l	0.05	0	0	0	0	0	0	0	0	0		
Zinc	mg/l	1	0.171	0.21	0.16	0.22	0.074	0.067	0.152	0.0556	0.1387	0.065	46.9

*Source: Compiled by authors

The standard deviation (SD) and correlation coefficients (CV) of most elements are low, which is indicative of a homogenous composition of reservoir waters. Elements, such as manganese, cadmium, zinc, boron, and lead, are distinguished by high SD and CV values (Table 4).

These findings show that the content of these elements can significantly vary across different sampling points in the two reservoirs. This variation may come as a result of the high activity and mobility of the elements between the liquid aqueous phase and the solid phase in bottom sediments. Runoff from adjacent fields and water tributaries might also play a role.

Estimation of organoleptic indicators and inorganic nonmetallic components in water samples

The study of the hydrochemical parameters of reservoir waters involved the monitoring of organoleptic indicators and the content of inorganic nonmetallic indicators in the water samples (Tables 5-7).

Table 4: Coefficients of variation by parameters

Parameter	Verkhnetobolskoye reservoir	Karatomarskoye reservoir
	Coefficient of variation, %	
Manganese	70.5	211.1
Zinc	95.9	46.9
Cadmium	80.5	99.2
Lead	24.5	25.0
Copper	27.4	30.3
Boron	28.4	29.9

*Source: Compiled by authors

Table 5: Organoleptic parameters of reservoir water samples

Verkhnetobolskoye reservoir														
Parameter	Unit of measurement	TLV	Sample number											
			1	2	3	4	5	6	7	8	9	Mean	SD	CV, %
Smell	points	≤2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0	2.0	1.9	0.3	17.6
Taste, smell	****	****	*	*	*	*	*	*	*	*	*	*		
Appearance	****	****	**	**	**	**	**	**	**	**	**	**		
Chromaticity	Degrees	≤20(35)	12.0	12.0	12.0	12.0	12.0	12.0	10.0	12.0	10.0	11.6	0.9	7.6
	Visual color	****	***	***	***	***	***	***	***	***	***	***		
Karatomarskoye reservoir														
Parameter	Unit of measurement	TLV	Sample number									Mean	SD	CV, %
			1	2	3	4	5	6	7	8				
Smell	points	≤2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0		2.0	0.0	0.0
Taste, smell	****	****	*	*	*	*	*	*	*	*		*		
Appearance	****	****	**	**	**	**	**	**	**	**		**		
Chromaticity	Degrees	≤20(35)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0		10.0	0.0	0.0
	Visual color	****	***	***	***	***	***	***	***	***		***		

*characteristic of the complex of substances dissolved in water
**transparent liquid, without foreign inclusions
***colorless liquid
****according to the regulatory document
Source: Compiled by authors

The content of chlorides in water samples from the Verkhnetobolskoye reservoir corresponds to purity class 2 (300-350 mg/l). This class of water is suitable for all categories of water use except for domestic and drinking purposes. Simple water treatment is required for drinking and household use. However, the content of sulfates in both reservoirs corresponds to class 4 (350-600 mg/l). Waters of this class are only suitable for irrigation and industrial water use, including hydropower, mining, and hydrotransport. Using this water for household and drinking purposes requires intensive (deep) treatment at purification facilities. The content of suspended solids in both reservoirs is within 14.9-19.0 mg/l. According to the System, these values correspond to water quality class 5 (above 10 mg/l). Class 5 is defined as the worst class of water quality. The data are confirmed by the Republican State Enterprise "Kazgidromet" in their studies of the Kostanay region conducted in December of 2023 (Ministry of Ecology and Natural Resources of the Republic of Kazakhstan 2023). This class of water is suitable for hydropower, mining, and hydrotransport. Other uses of this water are not recommended without preliminary treatment. Finally, total water hardness exceeds the TVL in both reservoirs.

The SD and CV of most elements are small, indicating a rather homogeneous composition of reservoir waters. However, the SD and CV of phosphates at different sampling points are elevated (Tables 6 and 7). This may be associated with the mobility of phosphate ions at the interfaces between the aqueous phase and the solid phase in bottom sediments, which are natural accumulators of phosphorus compounds.

Estimation of the content of organic toxicants and pesticides in water samples

The results of tests to assess the content of organic toxicants and pesticides in water samples are reflected in Tables 8 and 9.

Table 6: Results of tests for the content of inorganic non-metallic parameters in water samples from the Verkhnetobolskoye reservoir

Parameter	Unit of measurement	TLV	1	2	3	4	5	6	7	8	9	Mean	SD	CV, %
Ammonium nitrogen	mg/l	≤2.0	0.07	0.07	0.05	0.06	0.07	0.06	0.05	0.06	0.05	0.06	0.01	14.4
Bromides	mg/l	≤0.1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.0
Suspended solids	mg/l	*	18.00	18.00	16.00	19.00	19.00	17.00	14.90	17.00	15.80	17.19	1.44	8.4
Potential of hydrogen, pH	pH	6-9	7.90	7.80	7.90	8.10	7.90	8.00	8.00	8.00	7.90	7.94	0.09	1.1
Bicarbonates	mg/l	400.0	220.0	232.0	232.0	220.0	220.0	220.0	220.0	323.0	220.0	234.1	33.74	14.4
Total hardness	mmol/dm3	≤7.0(10)	8.10	7.70	8.00	8.00	8.00	7.80	8.60	8.10	8.10	8.04	0.25	3.1
Iodides	mg/l	≤0.1250	0.00	0.00	0.00	0.00	0.00	0.00	0..001	0.00	0.00	0.00	0.00	0.0
Carbonates	mg/l	($HCO3^-$ + $CO3^{2-}$) 6.5 meq/dm3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Nitrates	mg/l	≤50.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0		
Nitrites	mg/l	≤2.0	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Permanganate index	mgO2/dm3	≤5.0	3.60	3.70	4.15	3.80	3.60	3.90	2.10	3.90	4.20	3.66	0.62	17.0
Dissolved oxygen	mgO2/dm3	≥4.0	6.20	6.30	6.30	6.40	6.30	6.30	6.60	6.20	6.60	6.36	0.15	2.4
Sulfates	mg/l	≤500	415.0	410.0	450.0	410.0	405.0	390.0	450.0	405.0	390.0	413.9	22.19	5.4
	mg/l		128.0	105.0	181.0	100.0	122.0	105.0	128.0	114.0	103.0	120.7	25.06	20.8
Dry residue	mg/l	≤1000 (1500)	821.0	804.0	798.0	805.0	834.0	833.0	838.0	844.0	781.0	817.6	21.50	2.6
Phosphates	mg/l	≤3.50	0.004	0.003	0.004	0.004	0.0040	0.003	0.004	0.180	0.060	0.029	0.06	201.0
Fluorides	mg/l	≤10.0	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.00	0.0
Free chlorine residual	mg/l	0.3-0.5	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.00	0.0
Residual active chlorine	mg/l	0.8-1.2	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.00	0.0
Chlorides	mg/l	≤350.0	315.0	335.0	330.0	310.0	330.0	290.0	335.0	275.0	295.0	312.8	21.95	7.0
COD (based on readings)	mgO2/dm3	≤15	5.10	4.90	4.50	4.90	5.00	5.00	4.80	5.00	4.70	4.88	0.19	3.8
Alkalinity	mmol/dm3	≤6.5	3.60	3.80	3.60	3.60	3.60	3.60	3.90	3.60	3.60	3.66	0.11	3.1
Turbidity	mg/l	≤1.5(2)	1.2	1.3	1.2	1.3	1.2	1.4	1.2	1.2	1.1	1.2	0.1	6.5

*Source: Compiled by authors

Table 7: Results of tests for the content of inorganic non-metallic parameters in water samples from the Karatomarskoye reservoir

Parameter	Unit of measurement	TLV	1	2	3	4	5	6	7	8	Mean	SD	CV, %
Ammonium nitrogen	mg/l	≤2.0	0.05	0.06	0.05	0.06	0.06	0.05	0.01	0.05	0.05	0.018	37.6
Bromides	mg/l	≤0.1	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01		
Suspended solids	mg/l	*	17.8	17.0	16.0	16.0	17.0	15.0	14.9	15.6	15.9	0.850	5.3
Potential of hydrogen, pH	pH	6-9	7.5	7.7	7.6	7.6	7.6	7.5	7.5	7.6	7.6	0.071	0.9
Bicarbonates	mg/l	≤400	244.0	232.0	232.0	232.0	232.0	232.0	323.0	220.0	243.4	32.807	13.5
Total hardness	mmol/dm3	≤7.0(10)	8.3	7.8	8.3	7.6	7.9	7.8	7.9	7.6	7.9	0.273	3.5
Iodides	mg/l	≤0.125	0.01	0.01	0.01	0.00	0.01	0.001	0.00	0.00	0.01	0.005	78.3
Carbonates	mg/l	(HCO3$^-$ + CO3^{2-}) 6.5 meq/dm3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.0
Nitrates	mg/l	≤50	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0		
Nitrites	mg/l	≤2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Permanganate index	mgO2/dm3	≤5.0	2.10	4.20	4.15	4.10	3.90	4.25	4.20	2.20	3.64	0.925	25.4
Dissolved oxygen	mgO2/dm3	≥4.0	6.4	6.1	6.3	6.1	6.3	6.5	6.2	6.5	6.3	0.160	2.5
Sulfates	mg/l	≤500	420.0	405.0	450.0	395.0	390.0	490.0	360.0	470.0	422.5	44.078	10.4
	mg/l		156.0	159.0	186.0	140.0	157.0	190.0	175.0	145.0	163.5	18.34	11.2
Dry residue	mg/l	≤1000 (1500)	892.0	834.0	856.0	850.0	849.0	844.0	856.0	822.0	850.4	20.396	2.4
Phosphates	mg/l	≤3.5	0.110	0.010	0.004	0.010	0.140	0.010	0.030	0.010	0.041	0.053	131.6
Fluorides	mg/l	≤10	0.50	0.30	0.40	0.30	0.40	0.30	0.40	0.30	0.36	0.074	20.5
Free chlorine residual	mg/l	0.3-0.5	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.000	0.0
Residual active chlorine	mg/l	0.8-1.2	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.000	0.0
Chlorides	mg/l	≤350	225.0	260.0	235.0	260.0	235.0	265.0	300.0	245.0	253.1	23.745	9.4
COD (based on readings)	mgO2/dm3	≤ 15	4.90	4.80	4.50	4.90	4.80	4.72	4.80	5.00	4.80	0.149	3.1
Alkalinity	mmol/dm3	≤6.5	4.00	3.80	3.80	3.80	3.80	3.80	3.80	3.60	3.80	0.107	2.8
Turbidity	mg/l	≤1.5(2)	1.1	1.1	1.0	1.0	1.0	1.1	0.9	1.2	1.0	0.1	8.0

*Source: Compiled by authors

The results of the assessment of reservoir water samples with respect to the content of organic toxicants and pesticides reveals no exceedances of TLV norms.

In Tables 8 and 9, the TLV values for BOD20/BOD5 are marked with an asterisk (*). In assessing the BOD20/BOD 5 indicators, we use the requirements of the System as per the numerical values of water quality standards by quality classes.

Estimation of total alpha and beta activity levels in water samples

The results of tests to determine the gross alpha and beta activity of the studied reservoir water samples are presented in Tables 10 and 11. Importantly, the results show no exceedances of TLV norms for gross alpha and beta activity in the reservoir water samples. Furthermore, the values of variation coefficients for total radionuclide activity indicators fall within the range of 21.7-37.2. This indicates a relatively low discrepancy between the water samples. Gross alpha and beta activity is generally stable in the two reservoirs and shows no significant differences.

This study provides a comprehensive assessment of water quality and toxicology in the Verkhnetobolskoye and Karatomarskoye reservoirs; however, it is important to note its limitations. Geographically, the focus on two reservoirs in Northern Kazakhstan limits the generalizability of the findings to other regions with different hydrological and climatic conditions. Despite these limitations, the findings provide a strong foundation for improving water quality monitoring frameworks, informing stricter regulatory policies, and guiding investments in advanced water treatment infrastructure. Additionally, the methods and results can be applied to similar reservoirs in regions with comparable conditions, offering insights for future research on long-term water quality dynamics, seasonal variability, and pollutant source attribution.

Table 8: Results of tests for the content of organic toxicants and pesticides in water samples from the Verkhnetobolskoye reservoir

Parameter	Unit of measurement	TLV	1	2	3	4	5	6	7	8	9	Mean	SD	CV,%
2,4-D	μg/l	≤1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		
Benzo[a]pyrene	μg/l	≤0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002		
BOD20/BOD5	mgO2/dm3	*	2.5	2.5	1.6	2.5	2.6	2.5	2.4	2.6	2.2	2.38	0.315	
Bromodichloromethane	μg/l	≤10	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	
Dibromochloromethane	μg/l	≤10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
Petrochemicals	mg/l	≤ 0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
Heptachlor	μg/l	≤0.05	0.020	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Lindane	μg/l	≤0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
Hexachlorobenzene	μg/l	≤0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
Atrazine	μg/l	≤0.2	<0.05	<0.05	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Simazine	μg/l	≤0.2	<0.05	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Surfactants	mg/l	under 0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	mg/l		<0.02	<0.02	<0.5	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Phenol		≤ 0.25	0.000	0.000	<0.6	0.000	0.000	0.000	0.000	0.000	<0.02	<0.02		
Formaldehyde	μg/l	≤25	0.000	0.000	<0.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
α-HCH	mg/l	0.0020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
β-HCH	mg/l	0.0020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
γ-HCH	mg/l	0.0020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
DDT	mg/l	0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
DDD	mg/l	0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
DDE	mg/l	0.1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
2,4-D	mg/l	0.0002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
DDT	μg/l	0.50	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		

*Source: Compiled by authors

Table 9: Results of tests for the content of organic toxicants and pesticides in water samples from the Karatomarskoye reservoir

Parameter	Unit of measurement	TLV	1	2	3	4	5	6	7	8	Mean	SD	CV, %
2,4-D	μg/l	≤1	<1.0	<1.0	<1.0	1	<1.0	<1.0	<1.0	<1.0			
Benzo[a]pyrene	μg/l	≤0.005	< 0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002			
BOD20/BOD5	mgO2/dm3	*	2.6	2.4	1.6	2.3	2.3	1.2	2.3	2.6	2.1625	0.4984	23.0469
Bromodichloromethane	μg/l	≤10	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0010	0.0000	0.0000
Dibromochloromethane	μg/l	≤10	0	0	0	0	0	0	0	0	0		
Petrochemicals	mg/l	≤ 0.1	0	0	0	0	0	0	0	0	0		
Heptachlor	μg/l	≤0.05	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Lindane	μg/l	≤0.5	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
Hexachlorobenzene	μg/l	≤0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
Atrazine	μg/l	≤0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Simazine	μg/l	≤0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Surfactants	μg/l	under 0.5	0	0	0	0	0	0	0	0	0		
	μg/l		<0.005	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Phenol		≤ 0.25	0	0	0	0	0	0	0	0	0		
Formaldehyde	μg/l	≤25	0	0	0	0	0	0	0	0	0		
α-HCH	mg/l	0.0020	0	0	0	0	0	0	0	0	0		
β-HCH	mg/l	0.0020	0	0	0	0	0	0	0	0	0		
γ-HCH	mg/l	0.0020	0.001	0	0	0	0	0	0	0	0		
DDT	mg/l	0.1000	0	0	0	0	0	0	0	0	0		
DDD	mg/l	0.1000	0	0	0	0	0	0	0	0	0		
DDE	mg/l	0.1000	0	0	0	0	0	0	0	0	0		
2,4-D	mg/l	0.0002	0	0	0	0	0	0	0	0	0		
DDT	μg/l	0.5000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		

*Source: Compiled by authors

Table 10: Estimation of total alpha and beta activity levels in the samples of water from the Verkhnetobolskoye reservoir

Verkhnetobolskoye reservoir														
Parameter	**Unit of measurement**	**TLV, no more than**	**Sample number**									**Mean**	**SD**	**CV,%**
			1	2	3	4	5	6	7	8	9			
Gross alpha activity	Bq/l	0.1	0.0060	0.0050	0.0040	0.0030	0.0060	0.0030	0.0040	0.0040	0.0040	0.0043	0.001	25.8
Gross beta activity	Bq/l	1.0	0.0200	0.0300	0.0400	0.0200	0.0400	0.0200	0.0300	0.0500	0.0200	0.0300	0.011	37.2

*Source: Compiled by authors

Table 11: Estimation of total alpha and beta activity levels in the samples of water from the Karatomarskoye reservoir

Karatomarskoye reservoir													
Parameter	**Unit of measurement**	**TLV, no more than**	**Sample number**								**Mean**	**SD**	**CV, %**
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**			
Gross alpha activity	Bq/l	0.1	0.004	0.007	0.005	0.004	0.007	0.007	0.005	0.005	0.0055	0.0013	23.8
Gross beta activity	Bq/l	1	0.03	0.04	0.02	0.03	0.03	0.04	0.03	0.04	0.033	0.0071	21.7

*Source: Compiled by authors

While the study provides valuable insights into chemical and toxicological contamination, it is also essential to consider microbiological parameters. Microorganisms play a pivotal role in nutrient cycling, pollutant degradation, and the overall stability of aquatic ecosystems.

The data from Table 9 indicate that organic toxicants and pesticides in the Karatomarskoye reservoir are present at concentrations below their respective threshold limit values (TLVs). This finding suggests a minimal chemical impact on the reservoir's microbial ecosystems. Persistent organic pollutants were undetectable, so the low concentration of these pollutants indicates limited interference with microbial enzymatic activity and metabolic processes.

The absence of surfactants and petrochemicals further underscores the chemical stability of the reservoir, reducing the likelihood of disruption to microbial cell structures. This stability supports the natural balance of microbial communities. Heptachlor, detected at trace levels, has the potential to act as a selective pressure on microbial populations, potentially favoring resistant strains.

Biological oxygen demand (BOD20/BOD5) values ranged between 1.2 and 2.6 mgO_2/dm^3, indicating low levels of organic matter available for microbial degradation. This suggests limited microbial metabolic activity, consistent with a clean water environment from an organic pollutant perspective. The uniformity in test results across all sampling points further reflects a consistent chemical profile in the reservoir, with no evidence of localized contamination affecting microbial processes.

Conclusions

The results of water quality analysis demonstrate that both reservoirs are facing moderate to severe pollution. Heavy metals, such as cadmium and zinc, are found in concentrations exceeding the threshold limit values for safe water use in several locations. While most other metals stay within allowable concentrations, their varying distribution across different sampling points is indicative of localized pollution sources, potentially due to industrial discharges and agricultural runoff. This spatial variability emphasizes the need for more targeted water management efforts in certain areas of the reservoirs.

The low concentrations of organic toxicants and pesticides in the Karatomarskoye reservoir suggest a minimal risk of microbial imbalance or toxicity-related disruptions. The chemical environment appears stable and conducive to maintaining a natural microbial ecosystem, ensuring the ecological integrity of the water body.

Practically, implementing stricter regulatory controls on industrial and agricultural discharges, coupled with regular monitoring of pollutant levels, can significantly reduce contamination. Upgrading water treatment infrastructure to address pollutants such as cadmium, zinc, and sulfates is essential for ensuring water suitability for domestic and industrial use.

Thus, the study emphasizes the urgent need to improve water quality monitoring, strengthen the regulation of industrial and agricultural pollutants, and modernize water purification infrastructure. Developing a more effective water management system in Kazakhstan, consistent with international standards and best practices, is critical to ensure the long-term sustainability of the region's water supply. The study also highlights the impact of localized factors, such as industrial proximity and seasonal variability, which are critical for tailoring water management practices.

The results can be used as reference information data and methodological recommendations for the organization and implementation of a comprehensive assessment of the quality and toxicity indicators of freshwater flowing water bodies in the temperate climatic zone.

Acknowledgements
The scientific research was conducted in the framework of grant program-targeted funding of scientific research under the 2023-2025 project on the topic of IRN BR21881993 "Creation of a system for operational monitoring of water resources and environmental control of hydraulic engineering structures in North Kazakhstan" funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

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