

Scientific article

CHANGES IN WATER POLLUTION IN THE KARATAL RIVER DURING GLACIER SHRINKAGE IN THE SHYZHY AND KORA RIVER BASINS

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KEY WORDS

Shyzhy River, Kora River, Glaciers, Zhetysu Alatau (Dzungarian Alatau), glacier degradation, heavy metals, river runoff, anthropogenic pollution, Karatal River basin

ABSTRACT

This study examines the spatial and seasonal variability of water quality in glacier-fed river systems within the Karatal River basin, located in the north-western sector of the Zhetysu Alatau (Kazakhstan). The investigation focused on the Kora and Shyzhy rivers, which play a key role in forming the hydrological regime of the Karatal River. Fieldwork was carried out in 2025 and included two sampling campaigns (July and September), during which a total of 30 water samples were collected from the upper, middle, and lower river reaches. Hydrochemical analyses identified the presence of major ions, nutrients, and a range of trace elements (Pb, Cd, Zn, Cu, Cr, Mn, Sb, Sr, Se, Ni, Al, Mo). The results indicate that water chemistry in the headwater zones is primarily governed by natural processes, including lithological weathering, interactions between meltwater and glacial–moraine deposits, and atmospheric deposition of aerosols onto snow and ice surfaces. Along the downstream gradient, a dual trend is observed: the reduction of certain constituents due to sorption and sedimentation, alongside localized increases associated with anthropogenic pressures. Measured concentrations of chemical constituents remained within the permissible limits established by the sanitary regulations of the Republic of Kazakhstan. Nevertheless, ongoing glacier retreat may intensify the mobilization of previously accumulated contaminants during periods of enhanced ablation. The findings highlight the importance of integrated monitoring approaches for glacier-fed river systems in order to ensure reliable water quality assessment and to minimize emerging environmental risks.

1. INTRODUCTION

Mountain glaciers of the Zhetysu (Dzungarian) Alatau constitute a critical component of the water resources of the Balkhash–Alakol basin and play a fundamental role in regulating the runoff of the Karatal, Koksus, Lepsy and other tributaries draining into Lake Balkhash. Their current condition is shaped by both large-scale climatic transformations and regional natural and anthropogenic influences [1...3].

Systematic glaciological investigations in the region have been conducted since the mid-twentieth century. According to the Catalogue of Glaciers of the USSR and subsequent studies, the Karatal River basin contained 356 glaciers in the mid-twentieth century, covering a total area of approximately 206 km² [4...5]. Further research by Cherkasov, Severskiy, Blagoveshchensky, Vilesov and other scholars has consistently demonstrated a persistent trend of glacier retreat across the region [6... 9].

Remote sensing data indicate that the glaciated area of the north-western Zhetysu Alatau declined from 215.0 km² in 1956 to 113.6 km² in 2015, while the total number of glaciers decreased from 356 to 206 [9...10]. These changes are accompanied by reductions in glacier length and alterations in accumulation and ablation regimes, which in turn exert a significant influence on river runoff formation [11] (Figure 1).

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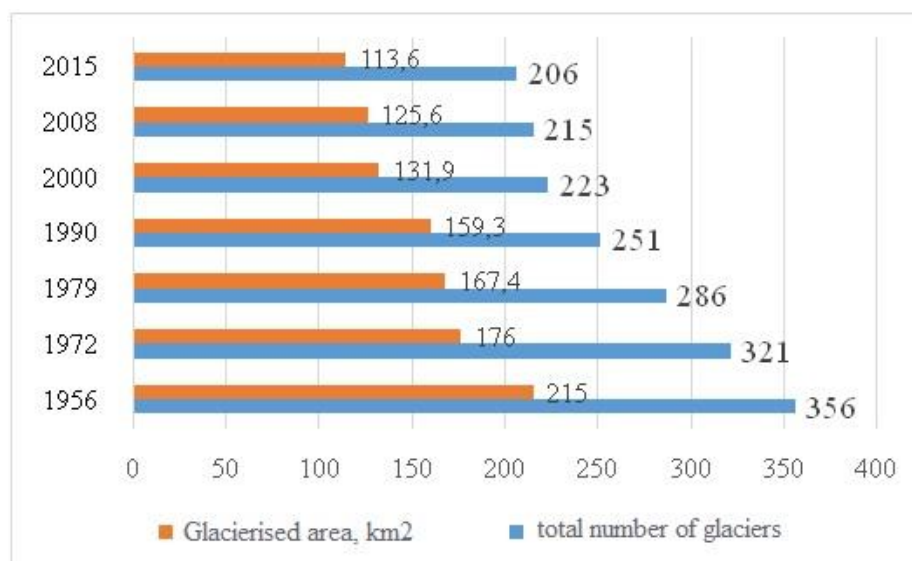


Figure 1. Temporal changes in glacier mass and glacierised area in the Karatal River basin (1956...2015) [9...10]

In addition to climatic drivers, the role of anthropogenic influence is becoming increasingly significant. Recent studies have documented the accumulation of heavy metals within components of mountain ecosystems in the Zhetysu Alatau [12...14], indicating that pollution processes exhibit both regional [3] and transboundary characteristics [15].

At the same time, the spatial variability of the chemical composition of waters formed by glacier melt and tributary inflows remains insufficiently explored [16]. In particular, the contribution of anthropogenic factors to water quality across different segments of the river network has not been comprehensively assessed [17...18].

The aim of the study is to determine the specific features of changes in the chemical composition and pollution of the Karatal River water under the conditions of glacier retreat in the Shyzhy and Kora river basins.

2. MATERIALS AND METHODS

The study was conducted in the north-western sector of the Zhetysu (Dzungarian) Alatau within the Karatal River basin. The research focused on the watercourses of the Kora, Shyzhy and Karatal rivers, examining their upper, middle and lower reaches, which are largely sustained by glacier-fed runoff.

The study was based on long-term hydrometeorological records obtained from the Kosagash, Taubulak, Tekeli and Taldykorgan meteorological stations (RSE “Kazhydromet”), as well as data from Kazselezashchita, cartographic sources [19...20], and previously published research on regional glaciation [9].

Field investigations were carried out in 2025 and were supported by both field-based and laboratory analyses conducted in collaboration with researchers from the Department of Natural Sciences at Zhetysu University named after I. Zhansugurov and the Institute of High Mountain Biology of the University of Žilina (Slovakia).

The fieldwork encompassed glacier zones and the upper, middle and lower reaches of the Kora and Shyzhy rivers, which represent key tributaries of the Karatal River and are fed by glaciers such as Satpayev, Bessonov, Tronov (Mukan) and Kaskabulak (Figure 2).



Figure 2. *Inspection of the Kaskabulak Glacier at the source of the Kaskabulak River, a right-bank tributary of the Kora River. Photograph taken by the authors*

Water sampling was undertaken during two field campaigns, from 16 to 27 July and from 13 to 22 September 2025. In total, 30 water samples were collected from different segments of the hydrographic network, including the headwaters, middle and lower reaches of the Kora and Shyzhy rivers, as well as the upper course of the Karatal River.

Sampling locations were selected with consideration of altitudinal zonation and the characteristics of glacier-fed runoff formation. Samples were collected at the mouth of the Kaskabulak River (7.2 km from the glacier terminus, 2450 m a.s.l.), in the middle (2170 m) and lower (1028 m) reaches of the Kora River, as well as in the upper (2660 m), middle (2358 m) and lower (1027 m) reaches of the Shyzhy River. Additional sampling was conducted in the upper reach of the Karatal River (822 m a.s.l.) in the vicinity of Tekeli.

This spatial distribution of sampling sites enabled the assessment of hydrochemical changes along the flow path from glacier sources to downstream, more urbanised areas.

Water samples were collected in pre-cleaned, chemically resistant glass containers. Prior to sampling, all containers were rinsed with distilled water and subsequently with the sampled water. Each sample was labelled with information on location, date and time of collection.

Laboratory analyses were carried out in accredited laboratories of the Department of Sanitary and Epidemiological Control of the Zhetysu Region. The analytical programme included the determination of physicochemical, organoleptic and microbiological parameters. The elemental composition of the samples was analysed using instrumental analytical techniques.

Water quality assessment was conducted in accordance with the sanitary standards established by Order No. 26 of the Minister of Health of the Republic of Kazakhstan dated 20 February 2023 [21].

Data processing followed a comparative approach and involved the analysis of spatial variations in hydrochemical indicators across different river sections, with the obtained values evaluated against the established regulatory thresholds.

3. RESULTS AND DISCUSSION

The Karatal River basin is situated in the north-western part of the Zhetysu (Dzungarian) Alatau [5] and represents one of the principal centres of contemporary glaciation in the region [13...14]. River runoff formation in this area is governed by the complex interplay of orographic, climatic and glaciological factors (Figure 3).

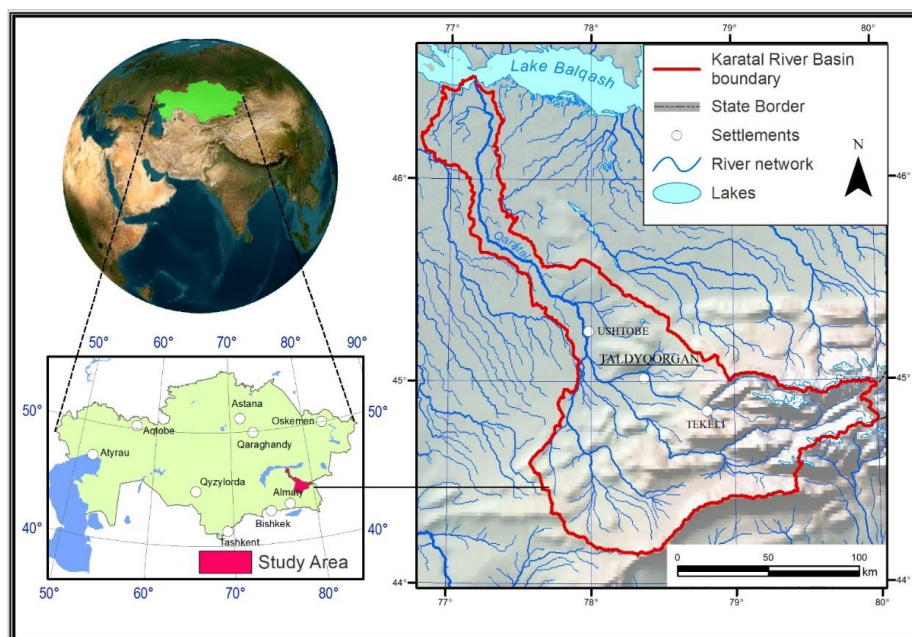


Figure 3. Map of the Karatal River Basin as a Center of Contemporary Glaciation

The boundaries of the basin are associated with the North-Central ridge of the Zhetysu Alatau (Zhamankol, Arasan, Koitas) and the chains of the South-Central ridges (Toksanbay, Satylu, Koyandy-Tau, Altyn-Emel), which are integrated within the Konuroba mountain system. This orographic configuration determines a pronounced altitudinal zonation, aspect-controlled differentiation of snow accumulation, and the formation of zones of solid precipitation accumulation.

According to glaciological studies [9], the extent of contemporary glaciation reaches approximately 84 km along the North-Central ridge and about 60 km along the South-Central ridge [22], which is consistent with field observations and the spatial distribution of glacial landforms in the headwater valleys.

The hydrographic network of the basin is characterised by the interaction of several subsystems. A key role is played by the right-bank tributaries, the Kora and Shyzhy rivers, which are fed by numerous glaciers [23]. The confluence of the Kora, Shyzhy and Koksus rivers within the Taldykorgan intermontane depression leads to the formation of the unified channel of the Karatal River, ensuring the sustained hydrological functioning of the basin [1].

Morphometric characteristics of the most significant glaciers contributing to runoff formation are presented in Table 1. The data provided in the table are for informational purposes.

Table 1

Morphometric Characteristics of the largest glaciers in the Karatal River Basin (2013) [2]

Glaciers	River Basin	Elevation Above Sea Level of the lower part of the glacier	Area, km ²	Length, km	Volume, km ³
Assubay	Kora	3250	16.7	8	1.83
Satbayev	Kora	3330	13.2	10.9	1.1
Bessonov	Shyzhy	2903	12.6	6	1.21
Tronov (Mukan)	Kora	3500	11.86	5.4	1.13
Ayussay	Shyzhy	3120	11.2	6	1.01
Kazan	Koksus	3120	10.9	5.8	0.80
Y.Altynsarin	Kora	3450	1.0	1.8	0.9

Abolina	Kora	3540	1.7	4.7	1.2
Kara Aryk	Koksu	3957	1.24	1.8	0.98
Demikpe	Koksu	3953	3.62	3.35	1.38

Analysis of the data presented in Table 1, together with long-term hydrological observations [8], indicates that contemporary glaciation plays [11] a decisive role in regulating the runoff of the Kora and Shyzhy rivers [20]. The linkage between glacier systems and the hydrological regime is reflected in the presence of valley glaciers at the river headwaters and in the pronounced seasonal variability of discharge.

The seasonal pattern of river flow in glacier- and snow-fed systems is characterized by a distinct peak during the period from May to August. This phase corresponds to intensified melting of seasonal snow cover and glacier bodies [8], including the Tronov, Bessonov, Altynsarin, Satpayev and Assubay glaciers, which leads to a marked increase in mean monthly discharge in the Kora and Shyzhy rivers [23].

Monitoring data from 2022...2025, combined with glaciological information [6], indicate that during this period the glaciers Tronov, Bessonov, Altynsarin, Demikpe, Kara-Aryk, Kazan, Satpaev, and Asubai experience the most intensive melting, resulting in an increase in the mean monthly discharge of the Kora, Shyzhy, and Koksu rivers [20...21].

Thus, the Karatal River basin constitutes a complex natural system in which the formation of river runoff is governed by the interplay of glacial feeding, orographic conditions, and the seasonal dynamics of hydrological processes [1...2]. This combination creates the prerequisites for the spatial differentiation of hydrochemical parameters of water [23].

The results of field expeditions and laboratory investigations have made it possible to characterize the hydrochemical state of the Kora, Shyzhy, and Karatal rivers, which are formed under conditions of glacial feeding in the north-western part of the Zhetysu Alatau. It has been established that the spatial differentiation of the chemical composition of water is determined by the combined influence of natural factors (glacial alimentation, lithology, and altitudinal zonation) and anthropogenic impacts, which intensify downstream [12...14].

The results of laboratory analysis of water samples collected in July 2025 are presented in Table 2.

Table 2
Results of laboratory analysis of water samples (16...17 July and 25...26 July 2025)

Chemical substances	Detected chemical substances, mg/dm ³							
	Maximum permissible concentration (MPC), mg/dm ³	Kaskabulak River, flowing into the Kora River (h = 2,414 m; 44°53'57" N, 79°18'14" E; 16 July 2025)	Middle course of the Kora River (h = 2,170 m; 44°59'52" N, 79°18'14" E; 17 July 2025)	Lower course of the Kora River (Tekeli) (h = 1,028 m; 44°51'33" N, 78°46'04" E; 17 July 2025)	Upper course of the Shyzhy River (h = 2,660 m; 44°57'06" N, 79°08'37" E; 25 July 2025)	Middle course of the Shyzhy River (h = 2,358 m; 44°53'57" N, 79°07'50" E; 26 July 2025)	Lower course of the Shyzhy River (Tekeli) (h = 1,027 m; 44°51'33" N, 78°46'04" E; 26 July 2025)	Source of the Karatal River (Tekeli) (h = 822 m; 45°02'22" N, 78°14'22" E; 26 July 2025)
Cation								
Cu	1.0	0.003	0.001	0.001	0.001	0.002	0.0023	0.21
Pb	0.03	0.005	0.001	0.002	0.001	0.0024	0.0026	0.003
Zn	1.0	0.02	0.03	0.01	0.025	0.01	0.01	0.38
Cr	0.05	0.005	0.001	0.001	0.001	0.001	0.002	0.024
Cd	0.001	0.0006	0.0001	0.0003	0.0001	0.0003	0.0004	0.005
Mn	1.0	0.02	0.01	0.01	0.01	0.01	0.025	0.031
Li	0.1	0.0004	0.0002	0.0001	0.0002	0.0001	0.0002	0.016
Sb	0.05	0.002	0.001	0.002	0.001	0.002	0.002	0.003
Ba	0.1	0.002	0.002	0.001	0.002	0.001	0.002	0.026

Sr	7.0	1.26	2.17	2.03	2.17	2.03	2.05	1.53
Bi	0.1	0.006	0.002	0.003	0.002	0.003	0.005	0.039
Co	0.1	0.005	0.001	0.001	0.001	0.001	0.003	0.002
Na	200	9.26	11.18	10.1	11.18	10.1	10.4	14.33
As	0.05	0.004	0.002	-	0.002	0.004	0.006	0.003
Se	0.01	0.001	0.002	0.002	0.002	0.002	0.002	0.005
Ni	0.1	0.002	0.001	0.001	0.001	0.001	0.002	0.001
Al	0.5	0.003	0.001	0.002	0.001	0.002	0.004	0.003
Mo	0.25	0.003	0.001	0.001	0.001	0.001	0.002	0.005
Anion								
Chlorides	350	37.2	34.9	37.2	35.0	36.3	37.3	37.4
Sulfates	500	44.0	44.11	44.0	50.2	44.0	44.3	42.03
Ammonia	2.0	0.01	0.08	0.1	0.07	0.07	0.09	0.06
Nitrates	3.3	0.018	0.024	0.01	0.031	0.028	0.032	0.018
Nitrites	45.0	0.03	0.09	1.23	0.006	0.032	0.053	1.022
pH		7.5	7.7	7.8	7.4	7.5	7.7	7.8
COD	15...30	17.4	17.8	18.0	15.3	17.4	17.9	17.4

During the summer period, characterized by the maximum intensity of glacial feeding [16], the hydrochemical regime of the studied rivers is distinguished by relative stability [23]. The reaction of the aquatic environment at all observation sites falls within neutral to slightly alkaline values (pH 7.4...7.8), indicating a balanced acid–base state. Chemical oxygen demand values range from 15.3 to 18.0 mg/dm³, reflecting a moderate content of organic matter.

The ionic composition of the water is predominantly of the sulphate–chloride type [16]. Sulphate concentrations range from 44.0 to 50.2 mg/dm³, while chloride concentrations vary between 34.9 and 37.4 mg/dm³. Sodium content ranges from 9.26 to 14.33 mg/dm³ and demonstrates an increasing trend downstream, which is attributable to both lithogenic processes and anthropogenic influences [23].

Concentrations of heavy metals and trace elements generally do not exceed the maximum permissible limits [24]; however, they exhibit pronounced spatial heterogeneity [12...14]. Minimal values are recorded in the upper reaches of the rivers (Cu 0.001...0.003 mg/dm³; Zn 0.01...0.02 mg/dm³), whereas an increase is observed in the lower reaches, particularly in the Karatal River. The most significant rise is noted for copper (up to 0.21 mg/dm³) and zinc (up to 0.38 mg/dm³), indicating localised anthropogenic impact within urbanised areas.

Concentrations of biogenic substances remain generally low, although variability is observed at certain sites. Elevated nitrite levels have been recorded in the lower reaches of the Kora and Shyzhy rivers (up to 1.23 and 1.02 mg/dm³, respectively), which may be associated with episodic pollutant inputs and intensified nitrogen transformation processes.

Thus, during the summer period, a relatively stable hydrochemical regime is established, albeit with the presence of local anomalies caused by anthropogenic impact

The data obtained in September 2025 are presented in Table 3.

Table 3

Results of laboratory analysis of water samples (13...14 September and 20...21 September 2025)

Chemical substances	Detected chemical substances, mg/dm ³							
	Maximum permissible concentration (MPC), mg/dm ³	Kaskabulak River, flowing into the Kora River (h = 2,414 m; 44°53'57" N, 79°18'14" E; 13 September 2025)	Middle course of the Kora River (h = 2,170 m; 44°59'52" N, 79°18'14" E; 14 September 2025)	Lower course of the Kora River (Tekeli) (h = 1,028 m; 44°51'33" N, 78°46'04" E; 14 September 2025)	Upper course of the Shyzhy River (h = 2,660 m; 44°57'06" N, 79°08'37" E; 20 September 2025)	Middle course of the Shyzhy River (h = 2,358 m; 44°53'57" N, 79°07'50" E; 21 September 2025)	Lower course of the Shyzhy River (Tekeli) (h = 1,027 m; 44°51'33" N, 78°46'04" E; 21 September 2025)	Source of the Karatal River (Tekeli) (h = 822 m; 45°02'22" N, 78°14'22" E; 21 September 2025)
Cation								
Cu	1.0	0.003	0.001	0.002	0.001	0.002	0.0023	0.0021
Pb	0.03	0.004	0.002	0.003	0.001	0.0024	0.0026	0.003

Zn	1.0	0.02	0.03	0.041	0.033	0.018	0.021	0.31
Cr	0.05	0.003	0.001	0.004	0.001	0.003	0.005	0.026
Cd	0.001	0.0005	0.0002	0.0004	0.0002	0.0003	0.0005	0.0004
Mn	1.0	0.01	0.03	0.05	0.02	0.02	0.03	0.033
Li	0.1	0.0004	0.0003	0.0005	0.0002	0.0003	0.0004	0.016
Sb	0.05	0.002	0.002	0.004	0.001	0.002	0.002	0.0022
Ba	0.1	0.002	0.002	0.004	0.001	0.003	0.005	0.004
Sr	7.0	1.20	2.27	2.33	2.17	2.23	2.25	2.24
Bi	0.1	0.003	0.004	0.006	0.002	0.005	0.006	0.007
Co	0.1	0.002	0.003	0.007	0.001	0.004	0.006	0.005
Na	200	9.23	11.11	12.3	11.12	12.1	12.18	11.45
As	0.05	0.003	0.003	0.004	0.002	0.004	0.004	0.003
Se	0.01	0.001	0.002	0.003	0.001	0.002	0.003	0.003
Ni	0.1	0.002	0.003	0.005	0.001	0.002	0.003	0.006
Al	0.5	0.001	0.001	0.004	0.002	0.004	0.004	0.005
Mo	0.25	0.001	0.003	0.005	0.001	0.004	0.003	0.003
Anion								
Chlorides	350	38.4	38.9	39.2	36.0	37.5	38.2	37.8
Sulfates	500	44.2	44.23	44.31	42.2	44.5	44.6	44.0
Ammonia	2.0	0.01	0.07	0.07	0.05	0.04	0.06	0.05
Nitrates	3.3	0.016	0.021	0.23	0.013	0.018	0.021	0.021
Nitrites	45.0	0.02	0.08	0.08	0.07	0.09	0.09	0.08
pH		7.5	7.7	7.8	7.5	7.5	7.7	7.8
COD	15...30	17.6	17.8	18.3	17.3	17.4	17.7	17.3

During the autumn period, characterised by a reduction in discharge and a weakening of glacial feeding, the reaction of the aquatic environment remains neutral to slightly alkaline (pH 7.5...7.8). Chemical oxygen demand values vary within the range of 17.3...18.3 mg/dm³ and are comparable to those recorded in summer.

The ionic composition of the water remains of the sulphate–chloride type [23]. Chloride concentrations show a slight increase (up to 39.2 mg/dm³), while sulphates vary between 42.2 and 44.6 mg/dm³. A minor rise in sodium content (up to 12.3 mg/dm³) is also observed, which is associated with the reduced dilution effect of river discharge.

The concentrations of heavy metals and trace elements remain below maximum permissible limits; however, a moderate increase in several elements (Zn, Cr, Mn, Co, Ni, Sr) is recorded, particularly in the lower reaches of the rivers. In contrast to the summer period, anomalously high copper concentrations are not observed, and its levels stabilise at background values.

The concentrations of biogenic substances remain generally low; however, an increase in nitrate content (up to 0.23 mg/dm³) is noted, which may be associated with inputs from surface runoff. At the same time, nitrite concentrations decrease to 0.08...0.09 mg/dm³, indicating the stabilisation of biogeochemical processes.

Overall, the autumn period is characterised by a more stable hydrochemical regime and the absence of pronounced anomalies.

A comparative analysis of the July and September observations indicates that, while the general water type and acid–base conditions are preserved, differences are evident in the dynamics of trace elements and biogenic components. The summer period is characterised by greater variability and the presence of local anomalies associated with intensive glacier melting and enhanced surface runoff. In autumn, the chemical composition becomes more stable against the background of reduced water discharge.

A common pattern for both periods is the increase in the concentrations of most components downstream [25...26], reflecting the growing anthropogenic influence, particularly within urbanised areas, including the vicinity of the city of Tekeli [27...28].

Thus, the hydrochemical regime of the rivers in the Karatal basin is shaped by a combination of natural and anthropogenic factors, with glacial feeding and the transformation of runoff along the flow path from high-mountain regions to zones of economic activity playing a dominant role [29...31].

The obtained results reflect the interrelationship between natural and anthropogenic factors in shaping the hydrochemical composition of glacier-fed river runoff within the Karatal River basin [16...17]. The morphological structure of glaciation and its altitudinal position within the range of 3,300...4,000 m determine the role of glaciers as seasonal regulators of runoff: peak discharges of the Kora and Shyzhy rivers occur during the May–August period, when ablation processes intensify and the inflow of meltwater increases.

The geochemical characteristics of waters in the upper reaches primarily reflect the influence of natural factors [18], notably the weathering of rocks and the lithochemical background of the ablation zone [29]. Elevated concentrations of certain elements in samples associated with glacial headwaters may be attributed to the dissolution and migration of rock and moraine material components during the interaction of meltwater with unconsolidated deposits. An additional source of substances is atmospheric dust and aerosols, which accumulate on the surface of snow and ice and are subsequently incorporated into meltwater.

A comparison of upper sections of the river network with samples from the middle and lower reaches reveals divergent trends in the concentrations of chemical components [17]. Within transit reaches, some elements may decrease as a result of sorption and precipitation processes on alluvial channel deposits, forming zones of accumulation [24]. At the same time, an increase in the concentrations of a number of components is observed in the lower reaches of the Karatal River, indicating additional inputs associated with anthropogenic impact [27...28]. This may be linked to the influence of settlements, transport infrastructure, and economic activities.

From an environmental perspective, it is important to note that the concentrations of most monitored components in the analysed samples do not exceed current sanitary standards. However, the presence of spatial differentiation and localised increases in certain parameters indicates the need to consider potential cumulative effects. Bottom sediments may act as secondary accumulators of substances and, under changing hydrological conditions, may be remobilised into the aquatic environment.

A comparison of the obtained data with the results of previous glaciological studies suggests that changes in the state of glaciation may influence both the hydrological regime and the conditions governing the formation of water chemistry. In this context, regular water quality observations combined with monitoring of glacier systems are of particular importance.

The practical significance of the results lies in substantiating the need for the establishment of comprehensive monitoring within the Karatal River basin, including seasonal water sampling, control of the main chemical components, and consideration of both natural and anthropogenic factors influencing the formation of water quality.

4. CONCLUSION

Geochemical analysis of water samples revealed the presence of ions of heavy and rare metals (Pb, Cd, Zn, Cu, Cr, Mn, Sb, Sr, Se, Ni, Al, Mo, etc.), as well as major anions and biogenic components, in glacier-fed river runoff. In the upper reaches associated with glacial sources, the chemical composition is characterised by a combination of naturally determined concentrations, formed through the weathering of rocks and the migration of elements within the ablation zone, together with the possible influence of atmospheric deposition of aerosol particles on the surface of snow and ice.

As water flows downstream, changes in its chemical composition are observed: concentrations of certain components decrease as a result of sorption and precipitation processes on channel sediments, whereas in the lower reaches an increase in the concentrations of specific substances is recorded, indicating additional anthropogenic inputs associated with economic activity within the basin.

Overall, the concentrations of most potentially toxic components in the analysed samples do not exceed the current sanitary standards of the Republic of Kazakhstan. At the same time,

the identified spatial variability in water composition highlights the need to consider potential accumulation processes and the secondary mobilisation of substances from bottom sediments.

A comparison of the obtained results with data from previous glaciological studies suggests that changes in the state of glaciation may influence the conditions governing the formation of water chemistry, particularly during periods of intensive melting.

The practical significance of the study lies in substantiating the need for the establishment of a comprehensive monitoring system in the north-western part of the Karatal River basin, including remote sensing of glaciers, seasonal water sampling at reference cross-sections, and extended hydrochemical analysis. The implementation of such a system will enable the timely detection of changes in water quality, the assessment of environmental risks, and the provision of scientific support for the protection of mountain catchments in the Zhetysu Alatau.

DATA AVAILABILITY

The data used in this study were obtained by the authors from RSE Kazhydromet sources, Remote Sensing Data.

AUTHORS' CONTRIBUTIONS

Conceptualization – BO, MJ; data curation – YeT, DM; formal analysis – BO, YeA; methodology – BO, MJ, YeT; software – BO, DM; supervision – BO, YeA; visualization – BO; writing – original draft – BO; writing – review & editing – BO, MJ, YeT, YeA.

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ШЫЖЫ ЖӘНЕ ҚОРА ӨЗЕНДЕРІ АЛАПТАРЫНДАҒЫ МҰЗДЫҚТАРДЫҢ АЗАЮЫ КЕЗЕҢІНДЕГІ ҚАРАТАЛ ӨЗЕНІНІҢ СУ ЛАСТАНУЫНЫҢ ӨЗГЕРІСТЕРІ

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ТҮЙІН СӨЗДЕР

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АБСТРАКТ

Мақалада Қаратал өзені алабының (Жетісу Алатауының солтүстік-батыс бөлігі, Қазақстан) мұздықпен қоректенетін өзендеріндегі су сапасының кеңістіктік және маусымдық өзгерістері қарастырылған. Зерттеу нысандары ретінде Қаратал өзенінің ағынын қалыптастыратын Қора және Шыжы өзендері алынды. Далалық зерттеулер 2025 жылы жүргізіліп, үлгі алу екі кезеңде (шілде және қыркүйек) жүзеге асырылды; жалпы өзендердің жоғарғы, орта және төменгі ағыстарынан 30 су үлгісі алынды. Гидрохимиялық талдау нәтижелері суда негізгі иондардың, биогендік компоненттердің және микроэлементтердің (Pb, Cd, Zn, Cu, Cr, Mn, Sb, Sr, Se, Ni, Al, Mo) бар екенін көрсетті. Жоғарғы ағыстарда су құрамының қалыптасуы негізінен табиғи факторлармен – тау жыныстарының үгілуімен, еріген мұздық суларының мореналық шөгінділермен өзара әрекеттесуімен және мұздық бетінде аэрозольдердің атмосфералық

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жинақталуымен байланысты екені анықталды. Өзен бойымен химиялық құрамның екі бағытты динамикасы байқалады: бір жағынан, сорбция және тұну процестеріне байланысты кейбір компоненттердің концентрациясы төмендейді, екінші жағынан, антропогендік әсер байқалатын учаскелерде олардың артуы тіркеледі. Зерттелген үлгілердегі химиялық заттардың концентрациялары Қазақстан Республикасының қолданыстағы санитарлық нормативтерінен аспайды. Сонымен қатар, мұздықтардың деградациясы қарқынды еру кезеңінде жинақталған ластаушы заттардың босап шығуын күшейтуі мүмкін. Алынған нәтижелер су сапасын бағалау және экологиялық тәуекелдерді төмендету мақсатында мұздықпен қоректенетін өзен жүйелерінде кешенді мониторинг жүргізудің қажеттілігін негіздейді.

ИЗМЕНЕНИЯ ЗАГРЯЗНЕНИЯ ВОДЫ В РЕКЕ КАРАТАЛ В ПЕРИОД СОКРАЩЕНИЯ ЛЕДНИКОВ В БАСЕЙНАХ РЕК ШЫЖЫ И КОРА

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КЛЮЧЕВЫЕ СЛОВА

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АБСТРАКТ

В статье рассмотрены пространственные и сезонные изменения качества воды в ледниково-питаемых реках бассейна Каратал (северо-запад Жетысуского Алатау, Казахстан). Объектами исследования являлись реки Кора и Шыжы, формирующие сток реки Каратал. Полевые исследования проведены в 2025 году и включали два этапа отбора проб (июль и сентябрь), всего отобрано 30 проб воды в верхнем, среднем и нижнем течениях рек. Гидрохимический анализ выявил присутствие основных ионов, биогенных компонентов и микроэлементов (Pb, Cd, Zn, Cu, Cr, Mn, Sb, Sr, Se, Ni, Al, Mo). Установлено, что в верховьях состав воды определяется преимущественно природными факторами – выветриванием горных пород, взаимодействием талых вод с моренными отложениями и атмосферной аккумуляцией аэрозолей на поверхности ледников. Вниз по течению фиксируется двунаправленная динамика: снижение концентраций ряда компонентов вследствие сорбции и осаждения, а также их увеличение на участках с антропогенным воздействием. Концентрации химических веществ не превышают санитарные нормативы Республики Казахстан. Однако деградация оледенения может усиливать высвобождение накопленных загрязняющих веществ в период интенсивного таяния. Результаты обосновывают необходимость комплексного мониторинга ледниково-речных систем для оценки качества воды и снижения экологических рисков.

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