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# COMPOSITION AND SPATIAL DISTRIBUTION OF CHEMICAL ELEMENTS IN SURFACE WATERS OF THE NURA RIVER BASIN

Gauhar Ospan, Zhanar Ozgeldinova PhD., associate professor, Saltanat Sadvakasova Candidate of geographical sciences

L.N. Gumilyov Eurasian National University, Astana, Kazakhstan; gauhara_ast@mail.ru (GO), ozgeldinova@mail.ru (ZhO), Sadvakassova_sr@enu.kz (SS)

* Corresponding author: Gauhar Ospan, gauhara_ast@mail.ru

**KEY WORDS**

the Nura river basin, geochemical composition, anthropogenic factor, pollution dynamics, heavy metals

**ABSTRACT**

This study explores the development of the geochemical composition of surface waters in the Nura River basin, influenced by human activities. Water samples were analyzed at the accredited «Kazhydromet» RSE laboratory in Karaganda city to measure pollutant concentrations. The results were compared to phonic values, showing the pollution trends in the Nura River basin. The main pollution sources are insufficiently treated discharges from industries in Karaganda-Temirtau industrial area, including key facilities such as «Karmed» LLP, «Bassel Group LLS», «Temirtau Electrometallurgical Plant» JSC, and other industrial operations, which release such contaminants as suspended solids, phenols, and heavy metals into the environment. The analysis indicates that anthropogenic activities have a significant impact on water quality, emphasizing the need for improved operation of treatment facilities to maintain the ecological balance of the Nura river and its surrounding water bodies

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## 1. INTRODUCTION

River water chemistry originates from precipitation and meltwater, accumulating salts and organics through soil interaction. However, contemporary surface water quality is primarily shaped by anthropogenic factors. Natural systems are highly sensitive to human-induced changes, specifically regarding industrial discharges and agricultural runoff.

The Nura River basin faces significant technogenic stress. Previous studies have documented extensive mercury contamination and heavy metal accumulation resulting from historical industrial activities [1,2]. Seasonal variations further exacerbate this, with water quality deteriorating during spring floods due to the influx of fertilizers and pesticides [3]. Currently, the primary pollutants are insufficiently treated wastewater from the Karaganda-Temirtau industrial hub and urban runoff. While external inputs are critical, internal processes like sedimentation and redox reactions also define the river's hydrochemical profile.

Despite historical research, contemporary data on pollutant migration patterns in this region remain insufficient. The purpose of this study is to evaluate the current hydrochemical status of the Nura River and identify the dominant factors driving its pollution under modern anthropogenic pressure.

## 2. MATERIALS AND METHODS

The study area is in the central part of Kazakhstan at the Karaganda and Akmola regions border. It has an area of over 100 thousand sq. km, and geographic coordinates between 48.3°...51.2° N, and 67.7°...76.4° E (Figure 1). It is 265 km long from South to North and over 600 km long from East to West. The highest point here is 1423 m, situated

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in the Eastern part of the river basin. The hillside area is in the Eastern half part, while the western part is below 300 m close to the Teniz-Korgalzhyn lake system. All the watercourses in the Nura basin run into the lake system.

The Nura River springs from the western spurs of the Kyzyltas Karkaraly-Aktau low-mountain massif at 1000...1200 m. The total length of the river is 978 km. It refers to steppe and semi-desert landscapes. The heterogeneity of soil formation conditions (climate, relief, vegetation, etc.) affects the basin area [4].

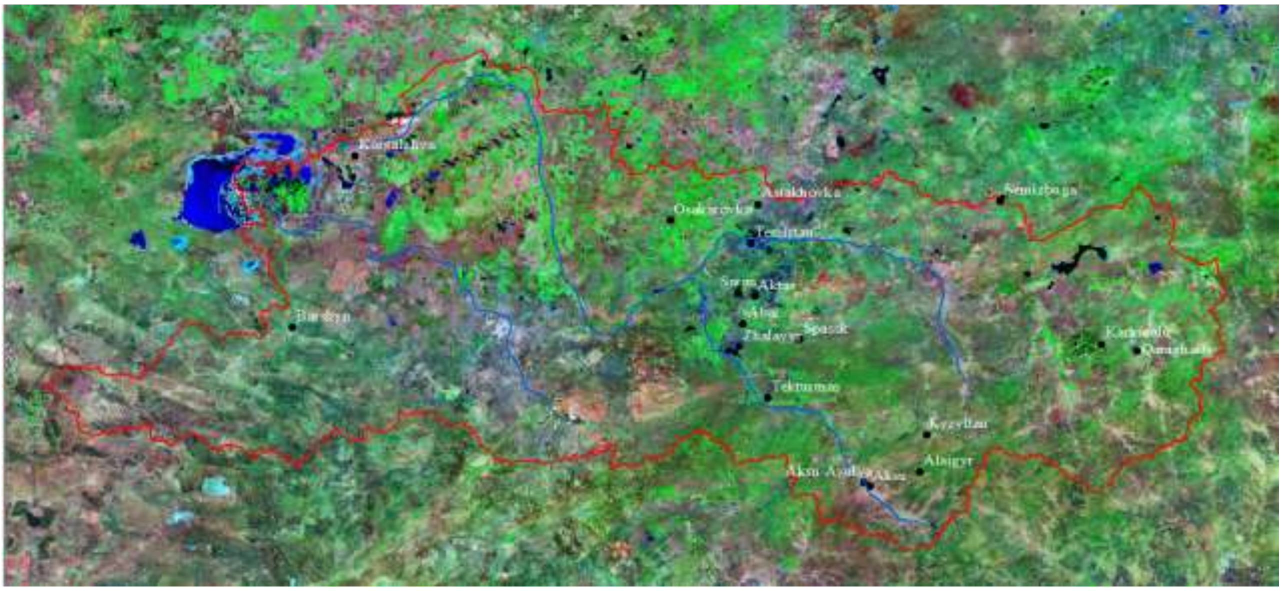


**Figure 1.** *Map of the Nura river basin*

The average annual precipitation in the study area is 265...322 mm, where 71...81% of the yearly rainfall in the warm season and 19...29% falls in winter. The maximum precipitation in the basin is most often observed in June-July, with a minimum in September [ 5].

A physicochemical analysis was conducted on 25 surface water samples to evaluate the concentrations of specific pollutants at the accredited laboratory of the «Kazhydromet» RSE (Karaganda). The sampling was performed during the vegetation period of 2023 (from May to September), which allowed for the assessment of the river's hydrochemical state during both high-water and low-water seasons under current anthropogenic pressure. Simultaneously, to assess the migration of contaminants in the "water-soil" system, soil samples were collected from the adjacent coastal zones at the same monitoring locations. All analyses were carried out at the accredited «EcoNUS» laboratory (Karaganda). The results presented in Table 1 represent the averaged values obtained from across the 25 sampling points distributed along the middle and lower reaches of the Nura River basin, providing a comprehensive overview of the regional water quality. The resulting experimental data were processed using variation statistical methods according to the approach of N.A. Plokhinsky (Table 1). This method involves the calculation of fundamental biometrical parameters, including the arithmetic mean (X), standard error (m), and confidence intervals, to ensure the reliability of the observed hydrochemical variations. The analysis focused on the assessment of the significance of differences and the dispersion of pollutant concentrations across the sampling sites. Statistical calculations were performed using Microsoft Excel tools and specialized biometric formulas [6].

To evaluate surface water pollution within the geosystems of the study area, comparisons with phonic values were made. Key locations within Karaganda-Temirtau industrial zone were selected to assess the dispersion of the tested pollutants. Water samples were collected at 500-meter intervals both upstream and downstream of the wastewater discharge point to assess the distribution of pollutants.

**Table 1**

*Variation-Statistical Indicators of the macro-component composition of water in the Nura basin in 2023*

| Parameters | $\overline{X} \pm S_x$ | lim | p | σ | Cv, % |
|---|---|---|---|---|---|
| | mg/dm³ | | | | |
| Total mineralization | 22575,76±40,09 | 645...1541 | 896 | 200,48 | 21,50 |
| Turbidity | 26,72±0,15 | 0,3...2,9 | 2,6 | 0,7316192 | 67,24 |
| pH | 140,2±0,33 | 2,14...8,14 | 6 | 1,648 | 28,2 |
| Water hardness | 109,04±0,31 | 2,18...8,15 | 5,97 | 1,54 | 34,09 |
| $HCO3^{-}$ | 4635,6±9,32 | 105...285 | 180 | 46,60 | 24,55 |
| CO2 | 77,90±1,30 | 0,1...20,5 | 20,4 | 6,51 | 208,54 |
| $Cl^{-}$ | 3568,26±17,17 | 80,2...345,2 | 265 | 85,85 | 58,59 |
| $SO4^{2-}$ | 4821,76±12,88 | 119...391 | 272 | 64,38 | 32,61 |
| $NO2^{-}$ | 7648,65±20,71 | 157,6...641,6 | 484 | 103,55 | 32,36 |
| $NO3^{-}$ | 630,96±2,54 | 13...65 | 52 | 12,69 | 48,52 |
| $NH4^{+}$ | 4,184±0,04 | 0,04...0,94 | 0,9 | 0,19 | 114,8 |
| Σ nitrogen | 19,508±0,14 | 0,2...2,9 | 2,7 | 0,68 | 85,94 |
| $Ca2^{+}$ | 5027,024±52,59 | 85,4...1458 | 1372,6 | 262,94 | 126,52 |
| $Mg2^{+}$ | 783,684±2,16 | 19,5...60,3 | 40,8 | 10,82 | 33,32 |
| $Na^{+}$ | 1139,844±3,80 | 19,4...89,4 | 70 | 18,98 | 40,66 |
| Suspended solids | 501,76±1,05 | 10...32 | 22 | 5,24 | 25,21 |
| Total phosphorus | 1,2234±0,004 | 0,019...0,087 | 0,068 | 0,019 | 37,06 |
| Petroleum products | 1,93±0,050 | 0,0...0,95 | 0,95 | 0,25 | 325,37 |

Notes

1 $\overline{X} \pm S_x$– average ± standard error of the mean;

2 lim – range of limits;

3 p – difference of limits;

4 σ – standard deviation;

5 Cv % - coefficients of variation.

A study conducted in 2023 identified the highest levels of mineralization in water samples from key sites within the impact zone of «Qarmed» JSC (Karaganda: 1541 mg/dm³, Temirtau: 1423 mg/dm³). These samples showed a marked increase in sulfate ion concentrations and exhibited abnormal levels of several chemical elements. The average sulfate ion concentration across the basin's waters was 4821,76 ± 12,88 mg/dm³, with a coefficient of variation of 32,61%, and values ranging from 119 to 391 mg/dm³. The enrichment of water with sulfate ions is attributed to sulfuric processes. When sulfide minerals are present, a sulfuric acid process occurs, linked to ore-forming deposits, as the oxidation of sulfides generates hydrolytically acidic compounds and sulfuric acid. Technogenic lithoaccumulations, which contain residual sulfites left behind from the mining and processing of ores, are found at mineral extraction sites. The formation of aggressive lateral flows of substances is facilitated by the intense oxidation of sulfides in the hypergenesis zone [7].

## 3. RESULTS AND DISCUSSION

The Nura River serves as a natural receptor for uncontrolled wastewater discharges from settlements located along its banks, resulting in considerable pollution of both the river and adjacent water bodies. Waste generated by livestock farms within the basin contributes substantial amounts of organic matter. A distinguishing feature of the Nura River basin is the pronounced impact of wastewater discharges on the quality of its surface waters. The hydrochemical properties and pollution levels of specific sections of the Nura River are largely influenced by the composition of the wastewater discharged, particularly in the stretch downstream from Temirtau city [8]. A key element in this pollution transport chain is the Sokyr River, a major tributary that acts as a technogenic collector for the Karaganda-Temirtau industrial hub. By receiving insufficiently treated effluents from heavy industry and municipal systems, the Sokyr River serves as a concentrated source of heavy metals.

In the context of geochemical processes, the interaction between highly acidic waters and carbonate-rich host rocks has been observed to result in an increase in the pH level. This increase, in turn, has been shown to lead to the accumulation of cationic chemical elements at a specific geochemical barrier composed of carbonate. A series of transformations of ore minerals in the oxidation zones of sulfide deposits occurs similarly: sulfides – sulfates – carbonates – oxides. Alongside elevated sulfate ion concentrations, the upper part of the basin also exhibits increased levels of carbon dioxide. The average carbon dioxide content in the basin waters was 77,90 ± 1,30 mg/dm³, with fluctuations ranging from 0,1 to 20,5 mg/dm³ and a variation coefficient of 208,54%. Across all key sites, hydrocarbon and phenol levels in the basin waters were close to absolute minimums.

Heavy metal ions, including zinc, copper, cadmium, lead, and others, are among the most detrimental contaminants in natural geosystems. The average concentration of $Cu^{2+}$ in water of the Nura River basin was measured at 0,0758 ± 0,00028 mg/dm³ level, with values ranging from 0,0014 to 0,0066 mg/dm³ and a variation coefficient of 47,30%. Research indicated that the average cadmium concentration in the basin water was 0,0036±1,01325 mg/dm³, with a variation coefficient of 35,18%. The mean mercury concentration was 0,00082±1,37 mg/dm³, with a variation coefficient of 209,85% and a range of 0,00001...0,0003 mg/dm³.

*Zinc (Zn).* Zinc is one of the most abundant elements in nature. Like other trace elements, it is predominantly transported in river water in a suspended state. In terms of the strength of bonds between metal ions and suspended particles, zinc ranks third, after lead and copper. Organic matter plays a crucial role in the adsorption of heavy metals, including zinc. Studies have demonstrated that suspended organic substances, such as algae, can adsorb $Zn^{2+}$, $Cu^{2+}$, and $Pb^{2+}$, with this effect being particularly pronounced in water bodies with high biological productivity [9].

In water bodies with controlled flow, approximately 30 to 40% of suspended zinc ions are deposited when the flow transitions from riverine to stagnant conditions. According to archived data from «Kazhydromet» RSE, zinc levels have exceeded the maximum allowable concentrations (MAC) from 1980 to 2022 in areas one kilometer upstream from the combined wastewater discharge points of «ArcelorMittal Temirtau» JSC and TEMK LLP Chemical Metallurgical Plant. Sudden zinc spikes in the river may originate from sources such as groundwater, which in turn may be influenced by mine waters. In any case, river zinc contamination is anthropogenic in nature.

In the Sherubay–Nura and Sokyr rivers, zinc concentrations rose sharply after 2014. Zinc content analysis has shown that concentrations of this element have increased since 2010, reaching their peak in 2022, exceeding the MAC by a factor of 2,2 [10].

To assess geochemical changes in geosystems, we applied a pollution index for environmental components. Extensive studies have shown that soil cover is commonly used as an indicator of environmental contamination [11]. Due to its ability to accumulate and retain substances deposited from both dry and wet atmospheric deposition, soil provides an ideal medium for studying and evaluating environmental pollution. Given that technogenic anomalies (pollutant halos) often have a multi-elemental composition, our research utilized a cumulative soil pollution index (horizon A1), Zc, to determine the extent to which trace element concentrations surpassed natural background levels, based on formula (1).

$$Zc = \sum_{i=1}^{n} \left(\frac{Ci}{Cf} - (n-1)\right) \quad (1)$$

where,

Zc - is the cumulative soil pollution index;

Ci - is the concentration of the i-th element in the soil;

Cf - is the background concentration of the i-th element;

n - is the number of elements.

Temirtau enterprises contaminate the river with heavy metals, as the concentration of heavy metals upstream is significantly lower than at other points along the river. The highest levels of heavy metal pollution were observed in 2010 (up to 0,003 mg/dm³) and 2014 (up to 0.0025 mg/dm³). This was linked to sources such as groundwater, which may be influenced by mine waters. In the middle reaches of the Nura River, the concentrations of heavy metals are generally exceeded. In the lower reaches of the Intumak Reservoir, elevated levels of heavy metals were noted in 2010. In any case, the pollution of the river with zinc is of anthropogenic origin (table 2). This improvement was influenced by the implementation of environmental protection measures, such as the rational use of water resources: modernization of the circulating water supply system for the reuse of process water in the production cycle, optimization of production processes to reduce the volume of wastewater discharged into natural bodies, repair and reconstruction of water supply and sewage networks, and the construction of evaporation ponds for mine water. Additionally, the self-purifying capacity of the rivers has contributed to the improvement in water quality [12].

**Table 2**

*Heavy Metal Content in Surface Waters, mg/dm³*

| Observation point | 1990 | | | 2010 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cu | Zn | Hg | Cu | Zn | Hg | Cu | Zn | Hg |
| Osakarovka | 0,0051 | 0,024 | 0,00054 | 0,0028 | 0,011 | 0,00005 | 0,0021 | 0,019 | 0,00008 |
| Barshyn | 0,0032 | 0,05 | 0,00004 | 0,0025 | 0,01 | 0,00005 | 0,0020 | 0,011 | 0,00003 |
| Abai | 0,0028 | 0,025 | 0,00092 | 0,0025 | 0,017 | 0,00019 | 0,0022 | 0,012 | 0,00006 |
| Temirtau | 0,0031 | 0,038 | 0,00019 | 0,0027 | 0,030 | 0,00194 | 0,0024 | 0,016 | 0,00023 |
| Karaganda | 0,0034 | 0,047 | 0,00022 | 0,0039 | 0,038 | 0,0098 | 0,0027 | 0,021 | 0,00028 |

The industrial activities of the Temirtau complex have resulted in elevated levels of pollutants, such as mercury, zinc, and copper, in the Nura River. The presence of mercury above the maximum allowable concentrations is particularly concerning. The intensity of anthropogenic impact on the landscapes of the Nura River basin determines the current ecological state of the Tengiz-Kurgaldzhin group of lakes.

The Tengiz-Kurgaldzhin group of lakes, being the final zone for the accumulation and dispersion of runoff from the Nura River, is entirely dependent on the hydrodynamics of its flow and, in general, on the intensity of landscape functioning in the Nura River basin. In 1968, the Kurgaldzhin State Nature Reserve was established in the territory adjacent to Lake Tengiz and Lake Kurgaldzhin as a wetland of international importance, primarily as a habitat for waterfowl. The increase in natural aridification processes in the region, associated with long-term climate fluctuations, along with intensive economic development of the landscapes of the Tengiz-Kurgaldzhin depression and the Nura River basin, has led to fundamental changes in the hydrological state of the lakes [13].

Regarding the potential for technogenic pollution of the Tengiz-Kurgaldzhin lakes, at the nearest hydrological observation point (village of Kabankay), exceedances of maximum allowable concentrations (MAC) for petroleum products and nitrites have frequently been recorded.

## 4. CONCLUSION

Based on the data provided, it can be inferred that the Sherubai-Nura river exhibits a higher degree of pollution, particularly with respect to chemical elements, including elevated concentrations of heavy metals. The low water flow also impacts the hydrochemical indicators. The quality of the Sherubai-Nura River is negatively affected by the Sokyr River, which flows into the Sherubai-Nura River 6 km from its mouth (near the village of Karazhar). The Sokyr River serves as a receptor for wastewater from the Karaganda-Temirtau industrial complex, which impacts the quality of rivers and reservoirs in the area. Wastewater enters the Sokyr River from enterprises such as «Karaganda Su» the «Saran» mine of «Qarmed» LLP, «Kapitalstroy» and «STINK TFK». Additionally, the river's quality is influenced by emergency discharges and natural alluvial runoff.

Based on the analysis conducted, high concentrations of pollutants such as copper, zinc, and mercury have been confirmed in all the studied rivers within the zone of technogenic influence. These contaminants enter the water primarily through wastewater discharges, domestic sewage releases, and emergency spills onto the land surface. The issue of mercury pollution in the rivers of this area remains very complex, as the concentration of this element exceeds the maximum allowable concentration (MAC). Repeated mercury contamination occurs due to technogenic sediments that have accumulated on the riverbeds, which are further dispersed downstream during spring floods.

The technogenic impact of intensive extraction from deep ore deposits in the Nura River basin has significantly altered the hydrogeological and engineering-geological conditions at many mining enterprises, leading to the emergence of various directional processes. In the areas where mines operate, depressional funnels have formed, covering areas of several dozen and even hundreds of square kilometers.

## DATA AVAILABILITY

The data used in this study were obtained by the authors from RSE Kazhydromet sources and the doctoral student's field research.

## AUTHORS’ CONTRIBUTIONS

Conceptualization – GO, ZhO; data curation – GO, SS; formal analysis – GO, SS; мethodology – GO, SS; software – GO, ZhO; supervision – SS, ZhO; visualization - GO; writing – original draft – GO; writing – review & editing – GO, ZhO, SS.

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# НҰРА ӨЗЕНІ АЛАБЫНДАҒЫ ЖЕРҮСТІ СУЛАРЫНЫҢ ХИМИЯЛЫҚ ЭЛЕМЕНТТЕРІНІҢ ҚҰРАМЫ МЕН КЕҢІСТІКТЕ ТАРАЛУЫ

Гауһар Т. Оспан, Жанар О. Озгелдиновна PhD, қауымдастырылған профессор, Салтанат Р.Садвакасова г.ғ.к.

Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан; gauhara_ast@mail.ru, ozgeldinova@mail.ru, Sadvakassova_sr@enu.kz
*Автор корреспондент: Гауһар Т. Оспан, gauhara_ast@mail.ru

**ТҮЙІН СӨЗДЕР**

Нұра өзені алабы,
геохимиялық құрам,
антропогендік фактор,
ластану динамикасы,
ауыр металдар

**АБСТРАКТ**

Бұл мақалада антропогендік факторлардың әсерінен Нұра өзені алабындағы жерүсті суларының геохимиялық құрамының қалыптасуы қарастырылады. Ластауыш заттардың концентрациясын анықтау мақсатында су үлгілері Қарағанды қаласындағы «Қазгидромет» РМК-ның аккредиттелген зертханасында талданды. Зерттеу нәтижелері фондық мәндермен салыстырылып, Нұра өзені алабындағы су сапасының ластану динамикасы анықталды.

Негізгі ластану көздеріне Қарағанды–Теміртау өнеркәсіптік аймағы кәсіпорындарының дұрыс тазартылмаған ағынды суларын төгуі жатады. Олардың қатарында ірі өндірістік нысандар — «Кармед» ЖШС, «Bassel Group LLS» ЖШС, «Теміртаулық электрметаллургиялық комбинат» АҚ және басқа да өнеркәсіптік нысандар бар. Бұл кәсіпорындардың төгінді сулары құрамында қалқымалы заттар, фенолдар, ауыр металдар сияқты ластаушы заттар кездеседі. Жүргізілген талдау антропогендік факторлардың су ресурстарының сапасына айтарлықтай әсер ететінін көрсетеді және Нұра өзені мен оның алабындағы су айдындарының тұрақты экологиялық жағдайын қамтамасыз ету үшін тазарту құрылыстарының техникалық жағдайын жақсартудың маңыздылығын атап өтеді.

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# СОСТАВ И ПРОСТРАНСТВЕННОЕ РАСПРЕДЕЛЕНИЕ ХИМИЧЕСКИХ ЭЛЕМЕНТОВ В ПОВЕРХНОСТНЫХ ВОДАХ БАССЕЙНА РЕКИ НУРА

Гауһар Т.Оспан, Жанар О.Озгелдинова PhD., ассоциированный профессор, Салтанат Р. Садвакасова к.г.н.

Евразийский национальный университет им. Л.Н. Гумилева, Астана, Казахстан; gauhara_ast@mail.ru, ozgeldinova@mail.ru, Sadvakassova_sr@enu.kz
*Автор корреспондент: Гауһар Т. Оспан, gauhara_ast@mail.ru

**КЛЮЧЕВЫЕ СЛОВА**

бассейн реки Нура,
геохимический состав,
антропогенный фактор,
динамика загрязнения,
тяжёлые металлы

**АБСТРАКТ**

В данной статье рассматривается формирование геохимического состава поверхностных вод бассейна реки Нура под влиянием антропогенных факторов. Образцы воды были проанализированы в аккредитированной лаборатории РГП «Казгидромет» в г. Караганда с целью определения концентраций загрязняющих веществ. Проведено сопоставление результатов с фоновыми значениями, выявлена динамика загрязнения вод на территории бассейна реки Нура. Основные источники загрязнения включают сбросы недостаточно очищенных сточных вод предприятий Караганда-Темиртауского промышленного района, в том числе таких крупных объектов, как ТОО «Кармед», ТОО «Bassel Group LLS», АО «Темиртауский электрометаллургический комбинат», и других промышленных объектов, сбросы которых содержат такие загрязнители как взвешенные вещества, фенолы, тяжёлые металлы. Проведенный анализ указывает на значительное влияние антропогенной деятельности на качество водных ресурсов, подчеркивая необходимость в улучшении технического состояния очистных сооружений для обеспечения стабильного экологического состояния реки и водоемов бассейна Нуры.

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