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Article

Comparative analysis of heavy metal accumulation in human hair living near gold mining enterprise

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Abstract. The article examines the specific features of the formation of the elemental composition of the population living within the impact zone of the gold mining enterprise JSC “Altyntau Kokshetau” (Konysbay village, Akmola region). The concentration of chemical elements in human hair was determined using inductively coupled plasma mass spectrometry (ICP - MS), which enabled the assessment of a wide spectrum of trace, minor, and potentially toxic elements. The relevance of this research is driven by the high concentration of mining enterprises in Kazakhstan and the environmental risks associated with their activities, including the accumulation of potentially toxic elements in environmental compartments and biological substrates of the exposed population. Hair was used as an informative biomarker reflecting long-term exposure to both natural geochemical conditions and anthropogenic pollution sources. Statistical processing of the obtained data was performed, and the results were compared with reference data from other regions of Kazakhstan as well as with the noosphere Clarke values. The study revealed localized anomalies in the accumulation of several heavy metals and trace elements including elevated concentrations of Cr, As, Hg, and Zn. These findings indicate the combined influence of regional geochemical background and technogenic pressure associated with gold mining activities, highlighting the importance of biomonitoring in environmentally stressed mining areas.

Keywords: ecological and geochemical status; heavy metals; human hair; gold mining enterprise; Konysbay village; Akmola region; anthropogenic impact.

1. Introduction

Kazakhstan is a unique territory where the geological structure and history of formation of the Earth’s subsurface have been leading to the presence of a huge variety of mineral resource bases. It includes fuel and energy resources (hydrocarbons, coal, uranium) and reserves of ferrous, non-ferrous, precious, and rare metals and industrial minerals. Such a diverse range of resources and ore deposits allows considering Kazakhstan as one of the strategic key regions. In a relatively short period of time, a lot of large – scale mining and mineral processing enterprises have appeared in Kazakhstan (Zhansetov et al., 1993).

Kazakhstan produces a great variety of mineral commodities and at present is a leading producer of uranium, chromite, coal, iron and steel, copper and zinc. The country is also a significant producer of lead, barite, cadmium, gold, titanium sponge and others (The World Bank Report, 2023). Such resource-based growth has led to the accumulation of billions of tons of waste, serious damage to land resources, a high level of air, underground and surface water pollution.

Over the past decades, a large number of studies have been conducted in different countries around the world, in which the impact of mining and industrial activities on the environment was assessed based on the chemical composition of various natural and biological media, such as groundwater and surface water, soils, agricultural crops, and human hair. It was proven that within the impact zones of mining and industrial enterprises, natural and biotic environments contained local and regional anomalies in the concentrations of toxic elements, indicating long-term technogenic influence. Contribution of the mining activity to elevated concentrations of heavy metals and metalloids, including As, Cd, Cr, Co, Cu, Fe, Pb, Hg, Mn, Ni, U and Zn in the environment is widely reported (Yang et al., 2021; Tibane et al., 2022; Abdul – Wahab et al., 2012).

Long-term discharges of dangerous chemical elements in the areas of mining activities lead to pollution of riverbed sediments. Especially, such elements as Cu, Pb и Cd are the highest in the areas with industrial effluents (Marrugo – Negrete et al., 2021). Such elements can negatively affect aquatic systems in general, people living nearby and river users. The study of soil, water, plant and sterile and mineralized waste near gold mine found exceeding the reference values of drinking water quality identified by the World Health Organization with As, Ba и Pb elements. Plants exhibited high Pb concentrations that caused health risks for the population. Mean concentration of toxic elements in soil was higher than reference values of soil quality defined by the legislation of the country (de Souza et al., 2017).

High concentrations of potentially toxic elements near mining areas cause a serious risk to the ecosystem and human health. Some heavy metals released during mining activity, such as arsenic and lead, are known as carcinogens and can elevate the risk of various cancers, anemia and intellectual disability. Children and pregnant women are among the most vulnerable groups to heavy metal exposure: in children it can impair brain and nervous system development, leading to learning difficulties, attention deficits, and behavioral disorders, while in pregnancy metals can cross the placental barrier and harm maternal and fetal health, increasing the risks of birth defects, miscarriage, and preterm birth (Feitosa et al., 2021; Chen et al., 2007).

For ecological and biogeochemical monitoring, many researchers used scalp hair of the population due to their convenience in sampling, storage, and transportation, as well as their ability to reflect long-term accumulation of chemical elements (Adav 2025; Zhang et al, 2023; Barbosa et al., 2005; Morton et al., 2002).

In Kazakhstan, similar studies have been conducted in many regions of the country. In North Kazakhstan (Baikenova et al., 2021), the authors compared the elemental composition of the population of North Kazakhstan and Akmola regions that were located within a large uranium ore province. In their study, the results of elemental composition were used as an indicator of the environmental and geochemical situation of the territory. The study revealed higher concentrations of rare, rare earth and radioactive elements (Th, U, and Au, Bi, Se), which characterized the impact of mining enterprises and the natural characteristics of ore fields.

In North Kazakhstan, Sharipova et al. (2023) studied the concentration of 28 chemical elements in the hair of the population living in the area of urbanization, industrial development and uranium mining operations. The study showed specific accumulation of Sr, Ba, and rare earth elements.

The study on the concentration of the toxic elements in the hair of children was conducted in the oil and gas-producing region of Western Kazakhstan. The author evaluated the relationship between the concentrations of toxic elements and the remoteness of their residence from oil and gas fields. The study showed the highest concentration of Al and Hg in the hair of children living close to oil and gas fields (0–16 km). Concentrations of As, Cd, and Pb in hair increased with distance from oil and gas production sites (Batyrova et al., 2021).

In the area of the Semipalatinsk Nuclear Test Site (Dzhambayev et al., 2018), in his study presented the results about the impact of nuclear technogenesis on ecosystem components (soil, salt deposits, wormwood, animal muscle tissue, and human biosubstrates). The natural geochemical specificity of the elemental composition of human biosubstrates in the territory adjacent to the Semipalatinsk Nuclear Test is reflected in the accumulation of Zn and U. The territories located at the greatest distance from the SIP are characterized by the highest chemical load.

The data obtained by Shaimardanova et al. (2010) showed that the accumulation level of the studied chemical elements in hair reflected the degree of anthropogenic impact of the developed industrial complex of Pavlodar and the surrounding areas on the entire soil-plant-animal (human) system. Moreover, judging by the spectrum of chemical elements, three main impacting sources can be identified: coal-fired power plants and the metalworking industry (Hg, Zn, Co, Cr, Sr); the chemical industry (Hg, Se, Rb); and petrochemical production (Zn, Se).

The study of (Korogod, 2010) reported spatial biogeochemical patterns of element accumulation in the hair of school-aged children (12–14 years) in Pavlodar Region. The results indicated territorially differentiated technogenic impacts associated with emissions from coal-fired thermal power plants, metal-processing, and petrochemical industries, with additional influence linked to river-mediated transport of pollutants. Based on the elemental spectrum, the authors distinguished two major source groups: (1) coal-fired power generation and metal-processing industries (Hg, Zn) and (2) chemical and petrochemical production (Hg, Se; Zn, Se).

Rich mineral resource base is an important factor in the economic development of the country. However, it can also lead to the formation of technogenic anomalies in different components of the environment. Of particular concern are the heavy and potentially toxic metals that are emitted from industry: ferrous and non-ferrous metallurgy, solid and liquid fuel extraction, and mining and mineral processing complexes.

Environmental protection specialists have identified a priority group of toxic metals. This group includes elements such as cadmium, copper, arsenic, nickel, mercury, lead, zinc, and chromium, as they pose the greatest risk to human health.

The aim of the study was to identify the specific patterns of elemental status development in the population living in the impact zone of the gold mining company JSC “Altyntau Kokshetau” (Konysbay settlement, Akmola Region).

2. Materials and methods

Hair sampling was conducted in the village of Konysbay in the Akmola region in the fall of 2024. A total of 25 adult hair samples were analyzed. Full names, residential addresses, age, gender, and place of birth were recorded during collection. The sample included residents who were absolutely healthy, without chronic or acute inflammatory processes, and they also lived for a sufficiently long time in the area where the selection was made (at least 10 years). The hair was collected and prepared for analysis according to IAEA recommendations (Element analysis of biological materials, 1980; Narkovich, 2012). The material was collected with stainless steel surgical scissors from five points on the scalp.

Sample preparation was carried out in the Department of Geology of Tomsk Polytechnic University.

The content of 73 chemical elements was determined using inductively coupled plasma mass spectrometry (ICP-MS) (Druzian et al., 2021). The work was carried out at the Problem Research Laboratory of Hydrogeochemistry at Tomsk Polytechnic University. The obtained data were processed using Microsoft Excel and STATISTICA 10 programs.

3. Results

In this study, it was decided to focus on the concentrations of heavy metals in the adult population, since this group of elements is traditionally considered a priority from the point of view of environmental and sanitary safety. Heavy metals are characterized by potential toxicity, the ability to accumulate in the body, and a long period of biological elimination. Their excessive intake can lead to the development of adverse health effects, including dysfunction of individual organs and systems, as well as an increased risk of chronic diseases. Therefore, assessing heavy metal levels in biological substrates is an informative approach for identifying potential environmentally induced risks and substantiating preventive measures.

For comparative analysis, previously published data on the elemental composition of biological samples from other regions of Kazakhstan were used in this study. This data allowed us to establish background and regional benchmarks and account for spatial variability in geochemical conditions.

Various factors from the external and internal environment can influence the distribution of elements in the hair of the population of the studied region, which leads to uneven content of individual chemical elements and the detection of abnormal values. Standard statistical parameters calculated for the studied sample are presented in Table 1.

Table 1. Statistical parameters of chemical elements in the hair of residents of Konysbay settlement, living near JSC Altyntau Kokshetau, (mg/kg)

Elements	Mean	G.mean	Median	Min	Max	St.dev.	Variation	St.error
Cr	11.21	9.96	10.74	2.36	20.7	4.83	43.0578	0.965
Ni	1.28	1.19	1.17	0.65	2.7	0.56	43.8938	0.113
Cu	10.37	10.18	10.10	7.15	17.5	2.13	20.5033	0.425
Zn	194.45	171.94	168.30	75.04	600.1	124.34	63.9450	24.868
As	0.52	0.26	0.20	0.03	2.4	0.69	132.8512	0.138
Cd	0.05	0.04	0.05	0.01	0.1	0.02	53.2722	0.005
Hg	0.73	0.57	0.60	0.14	2.0	0.51	70.4438	0.102
Pb	0.92	0.58	0.65	0.08	6.4	1.25	135.4987	0.250

The variation coefficients of the studied heavy metals vary widely - from 20 to 135 % - indicating varying degrees of spatial heterogeneity. At $V < 50$ %, a relatively uniform distribution pattern is noted for Cu (20 %), as well as Cr (43 %) and Ni (44 %), indicating predominantly natural (lithogenic) control of their content. Increased variability ($V = 50–100$ %) is characteristic of Cd (53 %), Zn (64 %), and Hg (70 %), which may indicate a mixed origin. The highest heterogeneity ($V > 100$ %) was established for As (133 %) and Pb (135 %), reflecting the presence of local anomalies and probable anthropogenic influence.

Overall, the geochemical structure of the territory is characterized by a combination of natural background element contents and localized areas of their increased accumulation, reflecting the heterogeneity of the heavy metal distribution. To determine regional patterns of chemical elements in the hair of residents of Konysbay settlement, located near the Altyntau-Kokshetau JSC, we compared average element concentrations with similar values in other areas of the Republic of Kazakhstan. The data in Table 2 demonstrate spatial heterogeneity in element content in hair among residents of different regions of Kazakhstan, indicating the influence of regional biogeochemical conditions and anthropogenic factors.

Table 2. Comparative characteristics of the accumulation of chemical elements in the hair of people living in Kazakhstan (mg/kg)

Elements	Akmola region	Residents of Konysbay settlement	South Kazakhstan territory	North Kazakhstan region	Ekibastuz city
Cd	0.22±0.12	0.05±0.005	0.05±0.008	0.17±0.09	0.04±0.01
Cu	16.2±2.7	10.37±0.42	11±0.5	12.5±1.33	9.0±1.5
As	0.07±0.01	0.52±0.13	0.67±0.1	0.04±0.007	0.04±0.02
Ni	0.97±0.25	1.28±0.11	0.47±0.03	0.7±0.27	0.6±0.3
Hg	0.24±0.05	0.73±0.10	1.1±0.3	0.22±0.04	0.2±0.05
Pb	1.55±0.45	0.92±0.25	1.3±0.22	0.72±0.29	1.1±0.4
Zn	328±49	194.45±24.86	236±25	288±86	455±130
Cr	0.5±0.05	11.21±0.96	0.76±0.1	0.52±0.05	0.41±0.03

High concentrations of cadmium were found in the hair of residents of the Akmola region and North Kazakhstan region, indicating the specific soil and geochemical background and agro-technogenic impacts in these areas. The lowest concentrations were observed in residents of Ekibastuz and Konysbay. Elevated arsenic and mercury levels were observed in residents of South Kazakhstan territory and Konysbay settlement, possibly due to natural geochemical anomalies or anthropogenic sources. Moderately elevated lead levels were found in the hair of residents of the Akmola region and South Kazakhstan. This is possibly due to industrial exposure and transport factors. Essential elements such as copper and zinc vary widely. The highest copper levels were recorded in the Akmola region, while the highest zinc levels were found in residents of Ekibastuz, indicating the region’s industrial profile and the specific mineral composition of the surrounding environment. Nickel concentrations are relatively stable across all regions, but elevated levels in Konysbay may indicate local geochemical peculiarities. Chromium levels are significantly higher among residents of Konysbay compared to other regions, where their levels remain close to background values. This indicates the possible presence of a localized technogenic or natural chromium-containing anomaly.

Overall, the element distribution in Table 2 reflects the combined influence of natural biogeochemical provinces and anthropogenic factors that shape the elemental status of the population. Elevated concentrations of toxic elements (As, Hg, Cd, Pb) in some regions can be considered potential environmental risk factors, while variability in essential elements indicates differences in mineral nutrition and environmental conditions.

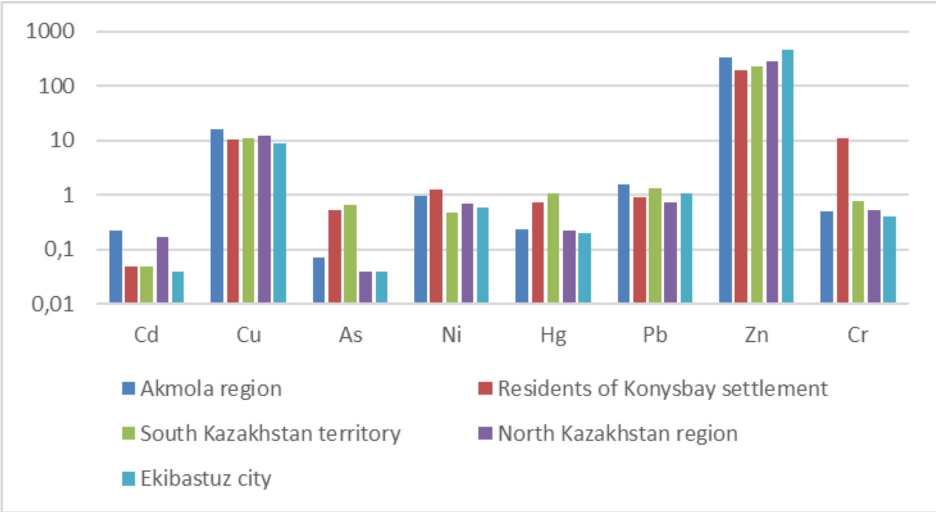

Figure 1. Comparative analysis of the content of chemical elements in the hair of people living in Kazakhstan (mg/kg) (Source: developed by the authors based on the research results)

The study analyzed the spatial distribution of heavy metals (Cd, Co, Cu, As, Ni, Hg, Pb, Zn, and Cr) in soils and environmental components in the Akmola region, Konysbay settlement, South Kazakhstan, North Kazakhstan region, and Ekibastuz. Element concentrations are presented on a logarithmic scale, allowing for comparison of elements with significantly different levels and identification of their biogeochemical patterns.

The results showed in Figure 1 that zinc concentrations were elevated in all studied regions. Elevated Zn concentrations are consistent with its role as a biophilic and lithophilic element, widespread in parent materials and actively involved in biological cycles. Furthermore, high Zn levels may be due to anthropogenic influences, including agricultural activities and man-made emissions.

Copper is characterized by consistently elevated values compared to most other trace elements. This is consistent with its high geochemical mobility and ability to accumulate in soils, especially under conditions of long-term anthropogenic impact. In a number of areas, Cu forms a pronounced local geochemical background, which is typical for regions with developed economic activity.

Cadmium, mercury, and arsenic levels generally remain relatively low; however, these elements are of particular interest from a biogeochemical hazard standpoint. Even at low concentrations, they are highly toxic and capable of bioaccumulation and biomagnification, requiring their mandatory inclusion in environmental assessments of the area.

Chromium exhibits significant regional variations. This is likely due to the mineralogical composition of the parent rocks and the redox conditions of the soils, which determine the valence state and migration capacity of the element.

Overall, the identified patterns reflect the geochemical heterogeneity of the study areas, which is influenced by natural (geological structure, soil formation, climatic conditions) and anthropogenic factors. The predominance of Zn and Cu corresponds to the classical biogeochemical series of trace elements, while the variability of the content of toxic elements (Cd, Hg, As, Pb) emphasizes the need for their systematic monitoring and assessment of potential environmental risks.

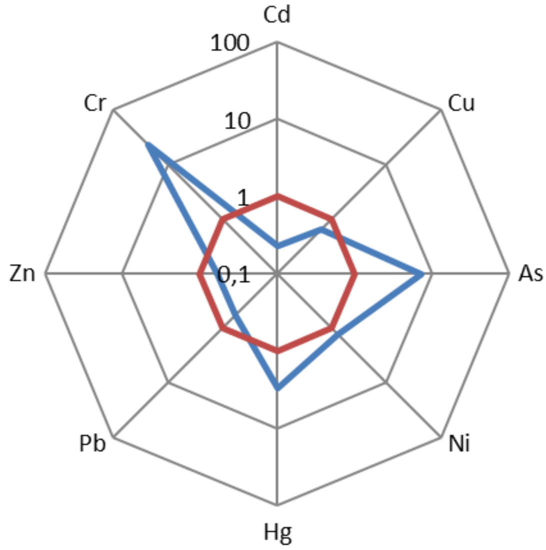

Figure 2. Concentration coefficients relative to the average for the sample of chemical elements in the hair of residents of Konysbay settlement (Source: developed by the authors based on the research results)

We examined the concentration ratios relative to the sample average for chemical elements in the hair of residents of Konysbay settlement. Data analysis reveals a pronounced predominance of chromium. Its concentration is significantly higher than that of other metals, indicating the formation of a specific geochemical background. The source of Cr may be related to both natural factors and anthropogenic impact. Biogeochemically, chromium is relatively stable and can accumulate in soils, especially under certain redox conditions.

Arsenic ranks second in concentration. Its elevated values are of environmental significance because As is a highly toxic element and actively participates in migration processes. It can transform into mobile forms and enter food chains through soil-plant and aquatic systems.

Nickel, copper, and zinc are characterized by moderate concentrations and form a relatively flat sector of the diagram. These elements are biophilic and widespread in the natural environment. However, at elevated levels, they may reflect anthropogenic impacts. Their combined presence may be due to both the natural geochemical background and diffuse pollution.

Cadmium, mercury, and lead are present in the smallest quantities. Despite their low concentrations, these elements are highly toxic and bioaccumulative. Even at low accumulation levels, they can pose a potential environmental hazard if exposed to ecosystems over long periods of time.

The data shown in Figure 2 demonstrates that the distribution of elements is uneven: Cr and As are higher values, while other elements are of lesser importance. This situation is typical for areas with a particular geochemical specialization and requires special attention to the most hazardous elements during environmental assessment and monitoring.

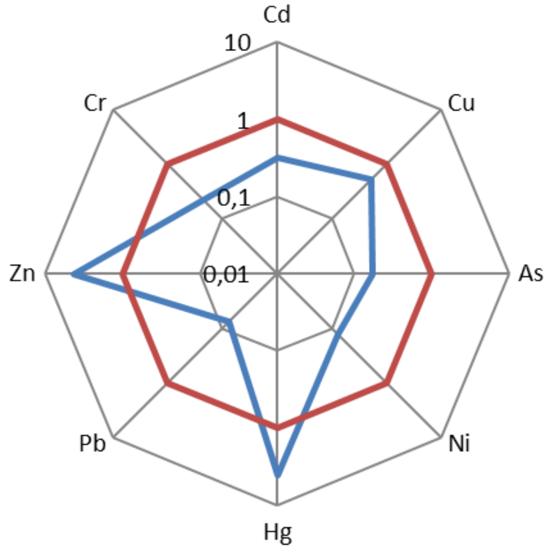

Figure 3. Concentration coefficients relative to the noosphere clarke of chemical elements in the hair of residents of Konysbay settlement (Source: developed by the authors based on the research results)

Chemical element clarkes are in demand in ecological-geochemical studies due to their broad elemental coverage, which allows for more detailed comparative assessments (Kasimov et al., 2015). In our study, we applied the noosphere clarke for the study area. Values greater than one indicate enrichment of the element, while values below one indicate its dispersion relative to the clarke level.

Analysis of the obtained data revealed that mercury and zinc are characterized by the most pronounced relative enrichment compared to the noosphere clarke. Hg exhibits the greatest excess over the clarke value, indicating its primary role in the formation of the technogenic-geochemical anomaly. Hg is known to be highly migratory and prone to accumulation in biogeochemical barriers, which increases its environmental hazard even at moderate absolute concentrations.

A significant excess of the Clarke value was also noted for Zn. This element is a biophilic trace element and is actively involved in biological cycling; however, its relative enrichment may be an indicator of anthropogenic impact, including industrial activity and agricultural sources.

Arsenic, copper, and nickel generally exhibit values close to the Clarke value, indicating the formation of a quasi-background geochemical state. This distribution may reflect the predominance of natural control factors, including the mineralogical composition of parent rocks and soil-forming processes.

Cadmium, lead, and chromium are characterized by values below the noospheric clarke value, indicating relative geochemical depletion. However, even with a Clarke deficiency, these elements retain high ecological and biogeochemical significance, as their toxicity and bioaccumulation potential do not directly correlate with their absolute levels.

Figure 3 shows that the concentration ratios relative to the noospheric clarke of chemical elements in the hair of residents of the village of Konysbay indicate an uneven redistribution of elements compared to the global noospheric background. Mercury (Hg) and zinc (Zn) can be considered indicators of anthropogenic impact, as their concentrations most clearly reflect the influence of anthropogenic factors.

4. Discussion

The obtained results indicate that the geochemical structure of the studied territory is formed under the combined influence of natural background conditions and localized zones of increased accumulation of chemical elements. This reflects a pronounced heterogeneity in the distribution of heavy metals and suggests a complex nature of the formation of the elemental composition of hair in the examined population.

To identify regional patterns, a comparative analysis of the average concentrations of chemical elements in the hair of residents of Konysbay village, located near JSC "Altyntau Kokshetau" was carried out in relation to similar data from other regions of the Republic of Kazakhstan. The comparison revealed spatial variability in element content, indicating that the elemental status of the population is influenced by both regional biogeochemical conditions and anthropogenic factors.

In general, the distribution of elements reflects the combined effect of natural biogeochemical provinces and technogenic impact. Elevated concentrations of toxic elements, such as As, Hg, Cd, and Pb, may be considered potential environmental risk factors. At the same time, the variability of essential elements suggests differences in mineral nutrition and environmental conditions affecting the population.

The analysis of individual elements demonstrates an uneven distribution pattern, with relatively higher values observed for Cr and As, while the remaining elements contribute less significantly to the overall geochemical profile. Such a distribution is characteristic of territories with specific geochemical specialization and highlights the importance of focusing on the most hazardous elements in environmental assessment and biomonitoring.

Furthermore, the analysis of concentration ratios relative to the noospheric clarke values indicates an uneven redistribution of elements in the hair of residents of Konysbay village compared to the global background levels. Among the studied elements, Hg and Zn can be considered the most indicative of anthropogenic influence, as their concentrations most clearly reflect the impact of technogenic factors.

Overall, the results confirm that the elemental composition of hair can serve as a sensitive indicator of environmental conditions and anthropogenic pressure in mining-affected areas.

5. Conclusion

The present study of the elemental composition of hair from residents of Konysbay settlement, located near the Altyntau Kokshetau JSC, revealed the characteristics of their biogeochemical status and assessed the possible influence of natural and anthropogenic factors.

Analysis of statistical parameters revealed that the distribution of heavy metals is heterogeneous. Relatively low variability was observed for some elements (Cu, Cr, Ni), indicating primarily natural (lithogenic) control of their content. However, elevated coefficients of variation for As, Pb, Hg, Zn, and Cd indicate the presence of local anomalies and probable anthropogenic influence.

A comparison with data from other regions of the Republic of Kazakhstan confirmed pronounced spatial differentiation in the elemental composition of hair. Konysbay settlement is characterized by elevated levels of chromium, arsenic, and mercury compared to several other areas, which may reflect both the specific geochemical background and the influence of industrial activity. An analysis of concentration coefficients relative to the sample mean revealed the dominance of Cr and As in the elemental profile. A comparison with the noosphere's clarke revealed a relative enrichment in Hg and Zn, allowing these elements to be considered indicators of anthropogenic impact. Although absolute concentrations of several toxic elements remain within moderate limits, their high toxicity and bioaccumulative potential necessitate regular monitoring.

Overall, the geochemical structure of the study area is shaped by the combined influence of natural biogeochemical conditions and anthropogenic factors. The identified patterns of heavy metal distribution in the hair of the population reflect the presence of local geochemical anomalies and highlight the importance of further ecological and biogeochemical research aimed at assessing environmental risks and developing preventative measures to reduce potential adverse impacts on public health.

6. Supplementary Materials: no supplementary materials

7. Author Contributions

Conceptualization - L.B., G.B.; methodology – L.B.; format analysis – B.Sh.; investigation – L.B.; resources – L.B.; data curation –N.B.; writing – original draft preparation – L.B.; writing-review and editing – L.B.; visualization – A.K.; supervision – A.K. All authors have read and agreed to the published version of the manuscript.

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Алтын өндіру кәсіпорнының жанында тұратын халықтың шашындағы ауыр металдардың жиналуын салыстырмалы талдау

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Аңдатпа. Мақалада Ақмола облысы, Қонысбай ауылында орналасқан «Алтынтау Көкшетау» АҚ алтын өндіруші кәсіпорнының әсер ету аймағында тұратын халықтың элементтік құрамының қалыптасу ерекшеліктері қарастырылды. Адам шашындағы химиялық элементтердің концентрациясы индуктивті байланысқан плазмалық масс-спектрометрия (ICP-MS) әдісімен анықталды, бұл микро-, макро- және әлеуетті уытты элементтердің кең спектрін бағалауға мүмкіндік берді. Зерттеудің өзектілігі Қазақстанда тау-кен өндіруші кәсіпорындардың жоғары шоғырлануымен және олардың қызметіне байланысты экологиялық тәуекелдермен, соның ішінде қоршаған орта компоненттері мен халықтың биологиялық субстраттарында әлеуетті уытты элементтердің жинақталуымен түсіндіріледі. Шаш табиғи геохимиялық жағдайлар мен антропогендік ластану көздерінің ұзақ мерзімді әсерін көрсететін ақпараттық биомаркер ретінде пайдаланылды. Алынған деректерге статистикалық өңдеу жүргізіліп, нәтижелер Қазақстанның басқа өңірлері үшін референттік мәндермен, сондай-ақ ноосфералық кларктармен салыстырылды. Зерттеу барысында Cr, As, Hg және Zn сияқты бірқатар ауыр металдар мен микроэлементтердің жинақталуының жергілікті аномалиялары анықталды. Алынған нәтижелер аймақтық геохимиялық фон мен алтын өндіруші кәсіпорындардың қызметіне байланысты техногендік жүктеменің бірлескен әсерін көрсетеді, бұл экологиялық шиеленісті тау-кен өндіру өңірлерінде биомониторингтің маңыздылығын айқындайды.

Түйін сөздер: экологиялық және геохимиялық жағдай; ауыр металдар; адам шашы; алтын өндіруші кәсіпорын; Қонысбай ауылы; Ақмола облысы; антропогендік әсер.

Сравнительный анализ накопления тяжёлых металлов в волосах населения, проживающего вблизи золотодобывающего предприятия

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Аннотация. В статье рассматриваются особенности формирования элементного состава населения, проживающего в зоне воздействия золотодобывающего предприятия АО «Алтынтау Кокшетау» (посёлок Конысбай, Акмолинская область). Концентрации химических элементов в волосах человека были определены методом индуктивно связанной плазменной масс-спектрометрии (ICP-MS), что позволило оценить широкий спектр микро-, макро- и потенциально токсичных элементов. Актуальность исследования обусловлена высокой концентрацией горнодобывающих предприятий в Казахстане и экологическими рисками, связанными с их деятельностью, включая накопление потенциально токсичных элементов в компонентах окружающей среды и биологических субстратах населения. Волосы использовались в качестве информативного биомаркера, отражающего длительное воздействие как природных геохимических условий, так и антропогенных источников загрязнения. Была проведена статистическая обработка полученных данных, а результаты сопоставлены с референтными значениями для других регионов Казахстана, а также с кларками ноосферы. В ходе исследования выявлены локальные аномалии накопления ряда тяжёлых металлов и микроэлементов, включая повышенные концентрации Cr, As, Hg и Zn. Полученные результаты свидетельствуют о комбинированном влиянии регионального геохимического фона и техногенной нагрузки, связанной с деятельностью золотодобывающих предприятий, что подчёркивает важность биомониторинга в экологически напряжённых горнодобывающих регионах.

Ключевые слова: экологическое и геохимическое состояние; тяжёлые металлы; волосы человека; золотодобывающее предприятие; посёлок Конысбай; Акмолинская область; антропогенное воздействие.