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Statistical Indicators of the Concentration of Chemical Elements in Biological Tissues in the Akmola Region

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ABSTRACT

The study investigates the concentration of chemical elements in biological tissues (placenta and blood) of women from the Akmola region, Kazakhstan to assess the impact of environmental pollution on maternal and newborn health. The research conducted from 2018 to 2021 involved 67 placental and umbilical cord blood samples collected from women in four Akmola districts. The study utilized instrumental neutron activation analysis and electronic microscopy to determine the concentration of 28 chemical elements. Statistical methods were applied to analyze the distribution, including the mean values, standard deviations, and frequency distribution curves. Significant variability in chemical element concentrations was observed across samples, with notable differences in rare earth elements and heavy metals. Elements such as sodium (Na), calcium (Ca), and chromium (Cr) displayed high variation. The study identified a strong environmental influence on the accumulation of toxic elements in the placenta and blood. The accumulation of chemical elements in biological tissues was heterogeneous, influenced by natural and anthropogenic factors. Blood was found to be more sensitive to environmental contamination compared to the placenta, indicating the need for enhanced environmental health monitoring in the region.

1. INTRODUCTION

The factors contributing to the formation of an environmental emergency (emissions from production plants, accumulation of industrial debris, vehicle exhaust, urban development, etc.) do not allow for optimal safety of the population. In recent years, pregnant women have been most sensitive to environmental influences. They are characterized by increased sensitivity to anthropogenic influences throughout the entire period of fetal growth, including at the stage of intrauterine development. Ecologically caused health disorders can develop under the influence of not only high but also low concentrations of ecotoxins [1, 2].

Kazakhstan, and particularly the Akmola region, is of particular interest here because of its significant environmental problems, including industrial emissions, mining activities, and poor air quality. The legacy of the region's industrialization, combined with limited regulatory oversight of environmental protection, has led to increased exposure of the local population to ecotoxins [3-5].

Kazakhstan's unique geographical and industrial conditions make it an important example of how environmental pollution affects human health, especially vulnerable groups, such as pregnant women and newborns [6, 7]. In Kokshetau, one of the most important factors that harm the human body is the environmental situation of the region. The normative indicator of the content of heavy metals in biological substrates in a healthy person has not yet been fully developed. Still, some scientists have carried out work in this field. In our studies using 28 chemical elements, acceptable standards for their content in the placenta of new mothers and the umbilical blood of a newborn were established for this region, which determines the novelty of this study [8, 9].

The state of health of women, including pregnant women, is an important indicator of the future workforce, economic, and cultural potential of society. The study of biological tissues in terms of elemental composition in North Kazakhstan remains insufficient [10]. Consideration of the placenta/blood system allows us to look at the manifestation of the ecological component in a new way. The high sensitivity of these tissues to changes in the environmental situation contributes to a deeper understanding of the processes in the human body as the final stage of the trophic chain.

The influence of the environment on the content of chemical elements in the human placenta was determined in the placenta and umbilical cord blood from four districts of the Akmola region using analytical methods [11]. In addition to the mean values and the standard deviation, the curves of the frequency distribution of chemical elements are given.

Ecology uses concepts of real-time monitoring (RTM) and long-term monitoring (LTM). The placenta belongs to RTM of the changes in pollutant profiles that use routine clinical samples, such as blood and urine and sometimes breast milk, saliva, and placenta.

Thus, the aim of this study is to investigate the impact of pollution on the health of mothers and newborns.

2. MATERIALS AND METHODS

The study was conducted from 2018 to 2021 in the Akmola region.

Authors of the article followed ethical guidelines that were approved by the Bioethics Committee of the Kokshetau Higher Medical College (approval granted on 24.06.2019). Consent was obtained from all participants before to sample collection. Participants were provided with detailed information about the study objectives, procedures and potential risks. All data were anonymized to protect participants' privacy, in accordance with ethical research standards.

The study material included samples from the placenta and umbilical blood of the fetus taken from 67 new mothers and 48 blood samples from the veins of Akmola region residents in districts with various ecological situations: Kokshetau, Stepnogorsk, Shuchinsk, Zerenda, Korgalzhyn, and Makinsk. While the sample size of 67 placental and 48 blood samples may be considered small, it provides a clear and representative reflection of the environmental and biological conditions within the Akmola region. The study was specifically designed to investigate the unique environmental impacts on maternal and newborn health in this area, rather than to generalize findings to other regions.

The biopsy material was obtained from the placenta and umbilical blood of the fetus taken during childbirth at the Kokshetau Perinatal Center (PC) by random selection with the consent of the mothers [12].

The analytical methods used to study these samples included instrumental neutron activation analysis (INAA) and electron microscopy [13-15].

The concentration of chemical elements in the blood and the analysis was performed with the IRT-T TPU research nuclear reactor (accreditation certificate No. RA.RU.21AB27, issued on 08.04.2015). Samples were irradiated with neutrons in the reactor, resulting in the formation of radioactive isotopes specific to each element. These isotopes emit gamma radiation at characteristic energy levels, which were measured using high-purity germanium detectors to identify and quantify the elemental concentrations with precision.

Calibration of the equipment was conducted using certified reference materials (standards for biological matrices and environmental samples), ensuring the accuracy and reliability of the results. The detection limits of the method varied by element but were typically in the range of micrograms per kilogram (μg/kg) for trace elements and milligrams per kilogram (mg/kg) for major elements.

The sampling was carried out in the maternity ward of the Kokshetau PC (Figure 1). The use of the study materials was approved by the Bioethics Committee of the Kokshetau Higher Medical College (KHMC).

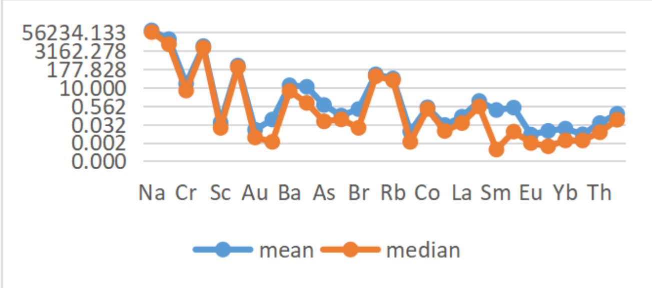


Figure 1. Comparative indicators of the arithmetic mean and median contents of chemical elements in the placenta of residents of North Kazakhstan (mg/kg, logarithmic scale)

The local Ethical Commission of the KHMC reviewed the materials of the research work of A.T. Yerzhanova on the topic "Chemical elements in the placenta of new mothers in the Akmola region as an indicator of the medical and environmental situation", within the framework of compliance with the medical ethics and the rights of respondents.

The data was processed using Microsoft Excel and STATISTICA 64 software [16]. Concerning the sociological survey and biomedical research, at the meeting dated June 24, 2019, the committee decided to approve and allow the collection of materials for this work. The participants in the study were informed about the progress of the research and provided consent to participate.

Sampling was carried out according to the recommendations [17]. Each sample was accompanied by filling out a short questionnaire (No. 1), consisting of 17 items, in the form of a questionnaire during childbirth and collecting biological material from the mother [18].

The arithmetic mean, standard error, geometric mean, median, mode, minimum and maximum values, standard deviation, asymmetry, kurtosis, and their standard errors and Pearson correlation coefficient were determined by statistical data processing. Histograms of the distribution of elements were constructed using the Shapiro-Wilk test. The relationships of the elements were presented in the form of tree diagrams of correlation matrices, considering the Pearson coefficient. When comparing the differences in the samples, the Kruskal-Wallis test was used, and only significant differences were considered in the analysis ($p < 0.05$) [19].

To identify the biogeochemical specificity, a concentration coefficient was used, which was calculated as the ratio of the mean element content in a locality to the median in the sample.

The critical value of the correlation coefficients was determined following the tabular values based on the number of samples in the sample according to the recommendations [20]. For North Kazakhstan, with 33 samples, the critical value of the correlation coefficient was 0.45 with a reliability of 99.0% [21]. The accumulation coefficient (AC) of elements in the placenta relative to blood was calculated via formula (1), where C is concentration of the element:

(1) AC = C placenta/C blood

The concentration coefficient (CC) in placenta and blood was calculated via formula (2):

(2) CC placenta (blood)=C placenta (blood)/C median placenta (blood)

The total accumulation index of elements for each biological tissue was calculated via formula (3): $Z=\sum cc$ of elements with a coefficient index of more than one.

3. RESULTS

Statistical analysis is necessary to understand the homogeneity of the sample. In our work, we analyzed the arithmetic mean values of chemical elements and the median, standard deviation, and variation. The studied parameters are shown in Table 1 for the placenta and Table 2 for the blood.

As the analysis of the tables shows, the samples are extremely heterogeneous. This is evidenced by such indicators as the minimum/maximum spread and a very high percentage of variability. For example, the coefficients of variation of rare earth elements in the placenta exceed 100%, and for blood, the variability varies from 60 to 600%. Elements such as sodium and calcium showed considerable variability, while rare earth elements and heavy metals exhibited even greater dispersion, reflecting the diverse environmental and biological influences in the Akmola region. The placenta displayed a more uniform distribution of elements compared to blood, which showed higher variability, particularly for trace elements like zinc and bromine.

Table 1. Statistical indicators of the content of chemical elements in the placenta of residents of the Akmola region, mg/kg

Element	M	σ	S	Xmed	Xmo	Min	Max	V, %
Na	77,119.77	6,561.879	68,735	no data (n/d)	44,985.97	26,283	192,205.7	68.67
Ca	33,957.56	6,183.235	10,587	4,358	42,390.12	1,088.117	190,167	136.77
Cr	6,168.08	499.4632	6,023	3,282	3,424.147	161	12,191.77	228.02
Fe	0.041817	0.012513	0.0184	0.02	0.085788	0.001775	0.48	72.274
Sc	12.83638	2.699305	7.07286	0.1	18.5055	0.1	90.3	202.16
Zn	0.004901	0.000832	0.003302	0.0008	0.005703	7.18E-06	0.030053	82.69
Au	0.006246	0.001476	0.002291	0.0005	0.010118	0.000126	0.0454	295.71
Hf	0.011251	0.00291	0.0032	0.001	0.019953	8.9E-05	0.114125	469.78
Ba	48.62789	4.282999	40.63	40.63	29.36276	14.70406	139.829	243.90
Sr	0.599121	0.164361	0.05	0.5	1.1268	0.05	5.632749	230.94
As	0.021201	0.005312	0.002727	0.002	0.036414	0.00132	0.178	217.53
Ag	0.112043	0.018339	0.069942	0.0008	0.125726	0.0008	0.444557	141.01
Br	25.02537	8.571753	5.67	0.5	58.76498	0.47	368.4	383.37
Cs	93.57687	9.279609	79.7	100	63.61779	22.23991	292.8913	74.83
Rb	13.19765	4.575032	0.9	0.9	31.36484	0.9	135.8057	62.32
Ta	0.013211	0.004282	0.001	0.01	0.029359	0.01	0.162948	151.48
Co	353.8202	31.9182	292.7	222.5	218.8202	106.65	924.4679	81.24
Sb	0.160182	0.042562	0.023	0.01	0.291792	0.01	1.609949	165.03
La	0.01	0.002327	0.001	0.001	0.015953	0.001	0.057551	242.36
Ce	0.40546	0.033846	0.349	0.33	0.232034	0.161	1.306	232.76
Sm	0.152013	0.034668	0.035	0.001	0.237673	0.001	1.536	350.90
Nd	0.028791	0.004701	0.02123	0.001	0.03223	0.001	0.152013	207.43
Eu	1.28738	0.491952	0.436	0.01	3.372656	0.01	22.71991	136.87
Tb	0.337103	0.17042	0.0006	0.0006	1.168341	0.0006	7.770505	190.42
Yb	0.54	0.144421	0.01	0.01	0.990102	0.01	3.92619	184.19
Lu	0.010736	0.001946	0.007845	0.0003	0.013343	9.71E-05	0.074	162.02
Th	0.041027	0.01215	0.002447	0.002	0.083298	0.000817	0.392	228.07
U	0.274712	0.061418	0.0921	0.004	0.42061	0.004	2.464043	164.5

Note:
1. M is the mean.
2. σ is the standard error of the mean.
3. Xmed is the median, Xmo is the mode.
4. S is the standard deviation.
5. Min is the minimum.
6. Max is the maximum.
7. V is the coefficient of variation.

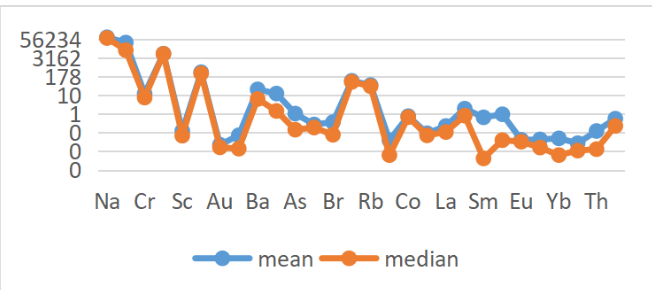


Figure 2. Comparative indicators of the arithmetic mean and median contents of chemical elements in the blood of residents of North Kazakhstan (mg/kg, logarithmic scale)

Our analysis of the differences between the mean content and the median shows differences, especially between rare earth elements in both the placenta and blood (Figures 1 and 2).

The mean values of chemical elements in the placenta and the blood are very close, with rare exceptions. This is well demonstrated by in Figure 3. Minor differences are observed for calcium, gold, hafnium, barium, strontium, and bromine and some rare earth and radioactive elements (Figure 3).

Histograms of the distribution of elements in the blood and placenta are given in the appendix.

The analysis of the histograms showed that the elements are divided into groups. The vital elements are characterized by a more uniform distribution in the placenta than in the blood.

Microelements and ultramicroelements are characterized by equally high heterogeneity in the blood and placenta. In our opinion, this distribution of elements is influenced by the multifactorial nature of their intake from the environment. A powerful factor is the technogenesis existing in the studied area. Technogenesis is a term introduced by academician A.E. Fersman in 1937 to denote processes related to human geochemical activity.

The histograms in Figures 4 and 5 show the distribution of zinc and sodium in the blood and placenta. The blood is characterized by abnormally high values (for zinc up to more than 2,000mg/kg and sodium up to 30,000 mg/kg) (Figure 4 (A) and 5 (A)).

The placenta is characterized by a more uniform distribution of zinc and sodium. The coefficients of variation of these elements are also lower. In contrast, the distribution of hafnium is heterogeneous in the blood and placenta (Figure 6).

We established the same pattern for bromine and rare earth elements (Figures 7 and 8). We attribute this to the excessive intake of these elements from the external environment. Thus, bromine can come from bromine-iodine waters typical for this region. The sources of rare earth elements are natural geochemical provinces and enterprises of the mining complex (for example, Obukhov Mining and Processing Plant).

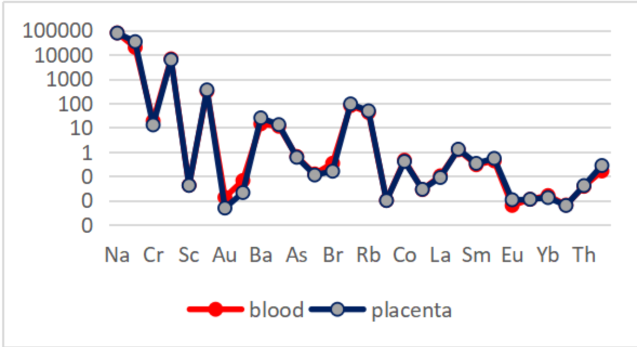


Figure 3. Mean concentrations of chemical elements in the blood and placenta of residents of North Kazakhstan (mg/kg of ash, logarithmic scale)

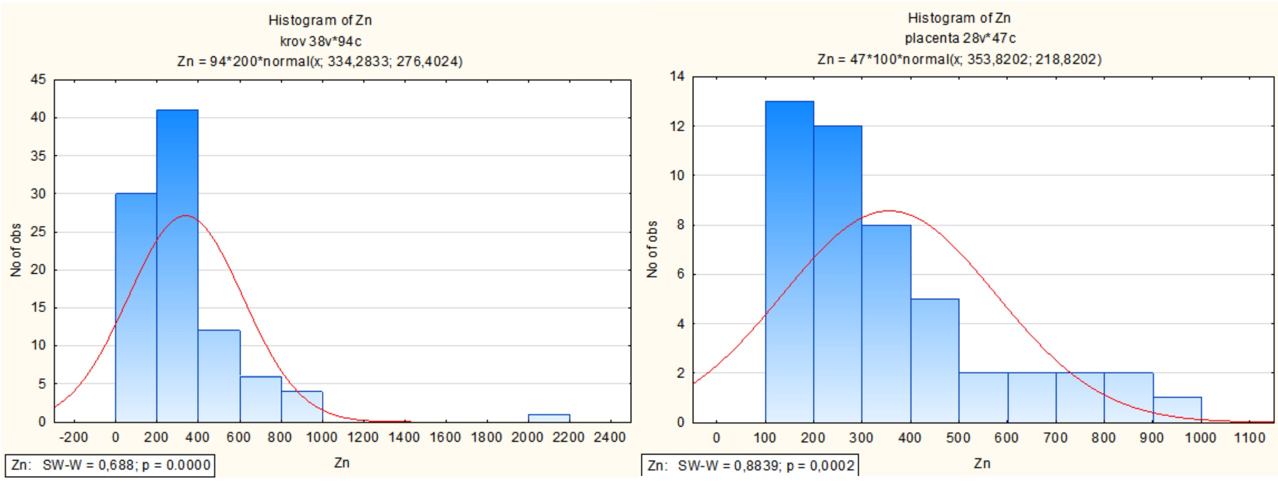
Table 2. Statistical indicators of the content of chemical elements in the blood of residents of the Akmola region

Element	M	σ	S	Xmed	Xmo	min	Max	V, %
Na	77,967.42	8,880.532	60,881.86	59,706.0	n/d	11,736	323,496	78
Ca	19,731.94	4,190.222	28,726.71	8,852.00	1,853	155	116,500	145.5
Cr	18.66	6.915	47.41	6.20	3.945	0.02	297.5	254
Fe	6,671.77	820.894	5,627.76	5,124.0	17,129	19	27,049	84.3
Sc	0.042	0.012	0.09	0.018	0.016	0	0.4601	201.3
Zn	314.75	47.444	325.26	241.00	168.9	50	2,185.9	103.3
Au	0.013	0.005	0.04	0.004	0.005	0.00005	0.21138	280.2
Hf	0.066	0.042	0.29	0.002	0.002	0.0006	1.971	434.5
Ba	14.219	4.877	33.43	5.800	0.5	0.5	210.5	235.1
Sr	11.264	3.654	25.05	0.900	0.9	0.9	94.92	222.3
As	0.645	0.227	1.56	0.050	0.05	0.03	8.037	241.7
Ag	0.124	0.029	0.2	0.068	0.0008	0.0008	1,316	161.6
Br	0.342	0.194	1.33	0.018	0.01	0.01	9.168	389.3
Cs	79.806	9.636	66.06	58.900	58.9	11.78	378.7	82.7
Rb	41.753	3.906	26.78	31.600	51.94	9.76	123.3	64.1
Ta	0.010	0.002	0.01	0.002	0.001	0.001	0.0638	144.8
Co	0.456	0.064	0.44	0.350	0.402	0.077	2.613	96.2
Sb	0.028	0.009	0.06	0.011	0.001	0.006	0.299	205.3
La	0.104	0.349	2.39	0.038	0.012	0.000517	1.203	197.4
Ce	1.211	0.154	1.06	0.514	0.001	0.006	14.037	358.8
Sm	0.295	0.15	1.03	0.001	0.006	0.0006	5.84	239.4
Nd	0.430	0.001	0.01	0.010	0.001	0.0006	6.253	147.5
Eu	0.006	0.003	0.02	0.002	0.003	0.00004	0.033	204.6
Tb	0.011	0.004	0.02	0.001	0.001	0.001	0.105	152.7
Yb	0.016	0.002	0.01	0.003	0.001	0.001	0.091	163.6
Lu	0.007	0.014	0.1	0.003	0.0005	0.0005	0.578	255.9
Th	0.038	0.041	0.28	0.009	0.002	0.001	0.0581	171.8
U	0.163	8,880.532	60,881.86	0.064	0.0004	0.0002	1.237	78

Note:

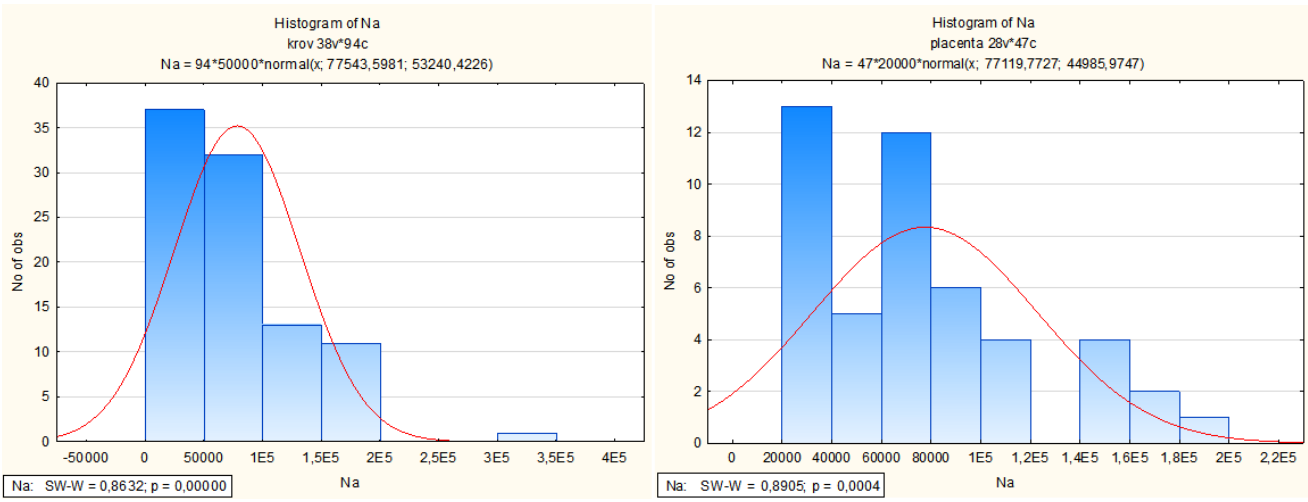
1. M is the mean.
2. σ is the standard error of the mean.
3. Xmed is the median, Xmo is the mode.
4. S is the standard deviation.
5. min is the minimum.
6. max is the maximum.

V is the coefficient of variation.



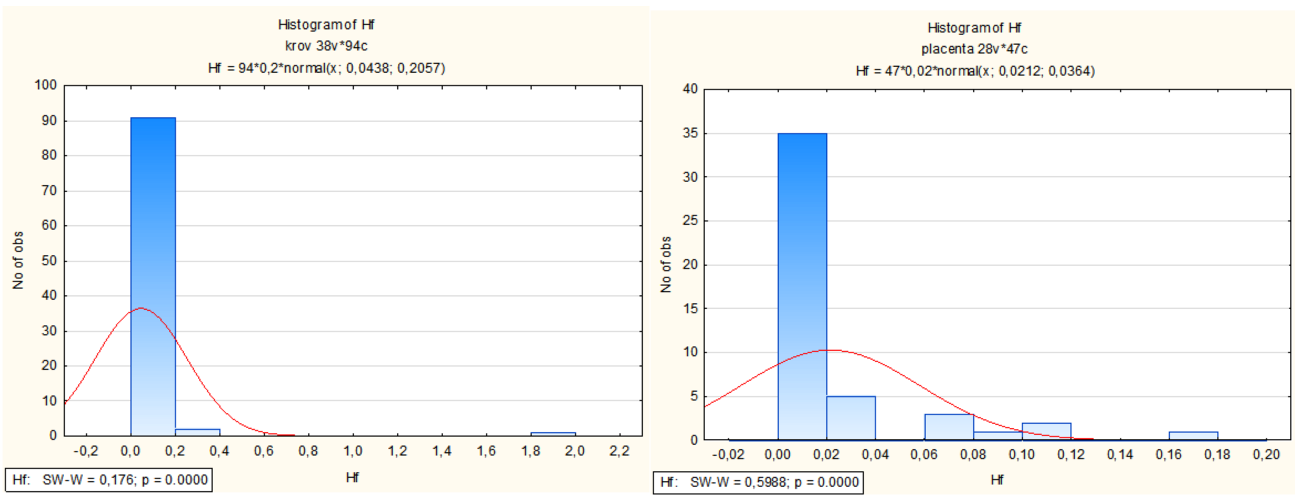
A - Histogram of zinc content in the blood   B - Histogram of zinc content in the placenta

Figure 4. Histograms of zinc distribution in biological tissues of residents of North Kazakhstan (X-axis shows content, mg/kg of ash, Y-axis shows the number of samples)



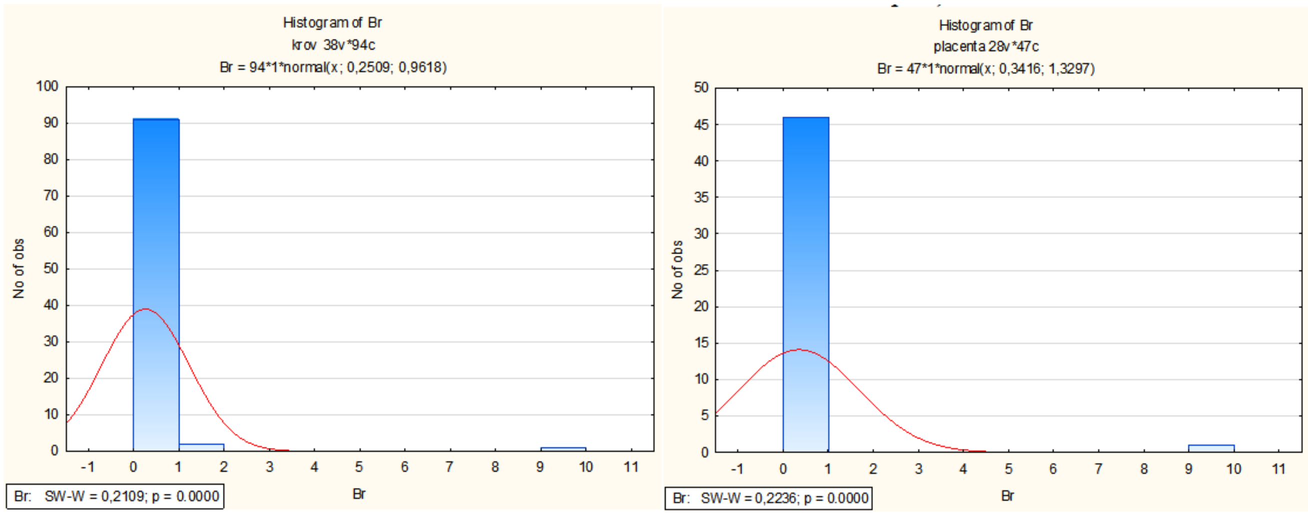
A - Histogram of the sodium content in the blood   B - Histogram of the sodium content in the placenta

Figure 5. Histograms of sodium distribution in biological tissues of residents of North Kazakhstan (X-axis shows content, mg/kg of ash, Y-axis shows the number of samples)



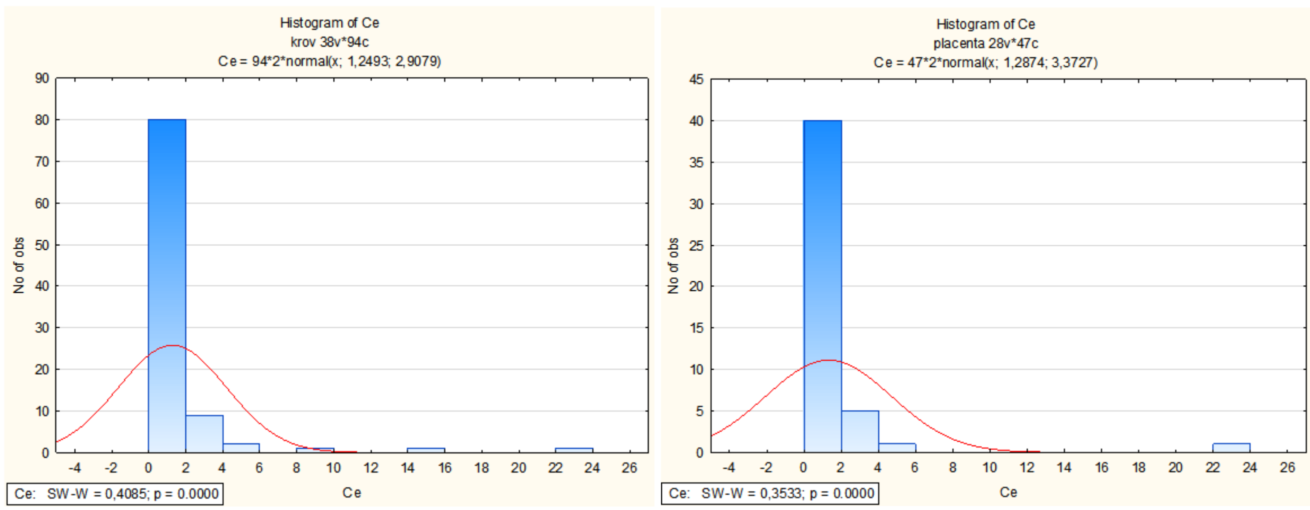
A - Histogram of hafnium content in the blood   B - Histogram of hafnium content in the placenta

Figure 6. Histograms of hafnium distribution in biological tissues of residents of North Kazakhstan (X-axis shows the content, mg/kg of ash, Y-axis shows the number of samples)



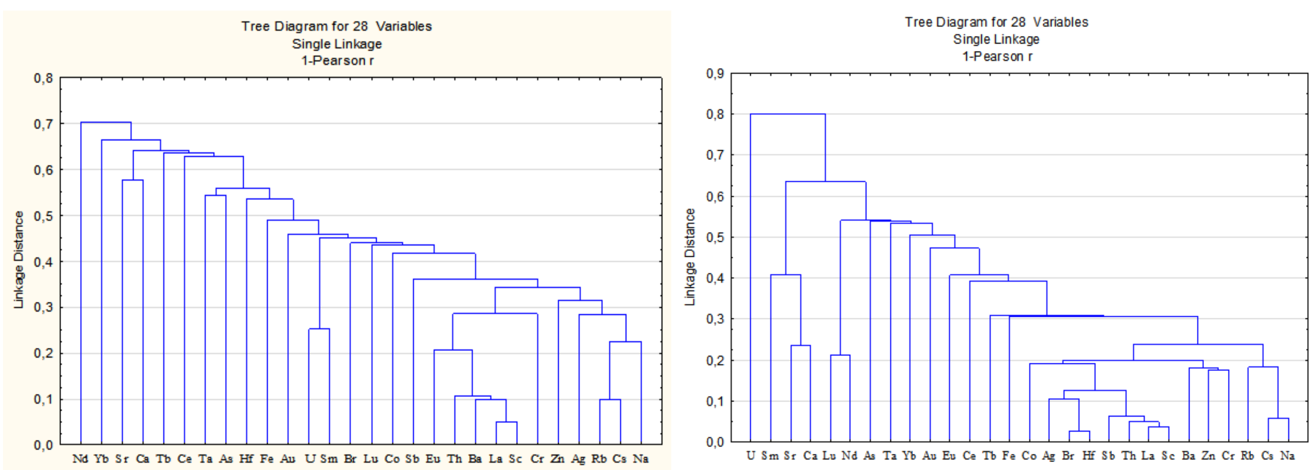
A - Histogram of the bromine content in the blood B - Histogram of the bromine content in the placenta

Figure 7. Histograms of bromine distribution in biological tissues of residents of North Kazakhstan (X-axis shows the content, mg/kg of ash, Y-axis shows the number of samples)



A - Histogram of the cerium content in the blood B - Histogram of the cerium content in the placenta

Figure 8. Histograms of cerium distribution in biological tissues of residents of North Kazakhstan (X-axis shows the content, mg/kg of ash, Y-axis shows the number of samples)



A B

Figure 9. Diagram of the correlation matrix of chemical elements in the placenta (A) and blood (B) of residents of North Kazakhstan (n=47, significance level: 0.3 at p<0.05; 1-Pearson r =0.7)

	Na	Ca	Cr	Fe	Sc	Zn	Au	Hf	Ba	Sr	As	Ag	Br	Cs	Rb	Ta	Co	Sb	La	Ce	Sm	Nd	Eu	Tb	Yb	Lu	Th	U
Na	1																											
Ca	-0,2	1																										
Cr	0,0	-0,0	1,0																									
Fe	0,4	-0,1	0,1	1,0																								
Sc	0,0	0,0	0,7	0,1	1,0																							
Zn	0,4	0,3	0,6	0,4	0,7	1,0																						
Au	0,3	-0,1	0,5	0,3	0,4	0,5	1,0																					
Hf	0,1	0,0	0,4	-0,1	0,4	0,3	0,3	1,0																				
Ba	-0,1	0,3	0,7	-0,0	0,8	0,5	0,2	0,4	1,0																			
Sr	-0,0	0,4	0,2	-0,1	-0,1	0,2	0,2	-0,0	0,1	1,0																		
As	0,0	0,2	0,1	0,1	0,4	0,4	0,1	-0,1	0,1	-0,1	1,0																	
Ag	0,4	0,1	0,3	0,5	0,5	0,7	0,3	0,2	0,3	-0,1	0,3	1,0																
Br	0,1	-0,0	0,4	0,2	0,6	0,3	0,2	0,2	0,3	-0,0	0,4	0,2	1,0															
Cs	0,8	-0,1	0,3	0,4	0,2	0,6	0,3	0,0	-0,0	0,1	0,1	0,6	0,1	1,0														
Rb	0,8	0,0	0,1	0,5	0,1	0,6	0,2	-0,1	0,0	0,1	0,2	0,7	0,0	0,9	1,0													
Ta	0,1	0,0	0,2	0,1	0,3	0,4	0,2	0,0	0,2	-0,0	0,5	0,1	0,2	0,1	0,1	1,0												
Co	0,4	-0,1	0,6	0,3	0,3	0,6	0,5	0,1	0,1	0,1	0,3	0,4	0,0	0,6	0,5	0,4	1,0											
Sb	0,1	0,3	0,1	0,4	0,3	0,5	0,4	0,2	0,2	0,0	0,4	0,6	0,0	0,2	0,3	0,3	0,3	1,0										
La	-0,1	0,0	0,7	0,0	0,9	0,5	0,2	0,5	0,9	-0,0	0,2	0,4	0,4	0,1	0,0	0,2	0,2	0,2	1,0									
Ce	-0,2	0,3	-0,0	0,1	0,0	0,1	-0,1	0,4	0,0	-0,1	-0,1	0,1	-0,1	-0,1	-0,1	-0,1	-0,1	0,2	0,1	1,0								
Sm	0,0	0,0	0,1	0,2	0,2	0,4	0,2	0,0	0,0	-0,1	0,3	0,4	-0,1	0,2	0,2	0,4	0,4	0,6	0,1	-0,0	1,0							
Nd	0,2	0,2	-0,1	0,1	-0,1	0,1	0,2	0,0	-0,1	0,3	-0,2	0,1	-0,1	0,1	0,1	0,0	-0,0	0,1	-0,1	0,2	-0,1	1,0						
Eu	0,1	0,1	0,5	0,0	0,8	0,4	0,2	0,3	0,8	0,0	0,2	0,4	0,4	0,2	0,2	0,2	0,0	0,2	0,8	-0,0	-0,0	-0,0	1,0					
Tb	-0,0	-0,1	-0,1	0,2	-0,1	-0,1	0,0	-0,1	-0,1	-0,0	-0,1	-0,3	0,4	-0,1	-0,1	0,0	-0,2	-0,1	-0,1	-0,1	-0,1	-0,1	-0,3	1,0				
Yb	-0,1	0,2	-0,0	0,1	0,0	0,1	0,1	0,1	0,1	-0,1	0,2	0,1	-0,1	-0,1	0,0	-0,1	0,0	0,3	0,0	0,1	-0,1	-0,0	0,2	-0,1	1,0			
Lu	-0,0	0,4	0,4	0,0	0,4	0,3	0,5	0,2	0,6	0,1	0,2	0,1	0,4	-0,1	-0,1	0,2	0,0	0,3	0,4	0,0	-0,1	-0,0	0,3	0,1	0,1	1,0		
Th	0,0	-0,0	0,6	0,1	0,9	0,6	0,3	0,3	0,7	-0,1	0,4	0,4	0,4	0,0	0,0	0,3	0,4	0,3	0,8	-0,0	0,2	-0,1	0,6	-0,1	0,1	0,3	1,0	
U	-0,1	0,3	-0,1	0,0	-0,0	0,3	-0,0	-0,1	-0,1	0,1	0,2	0,3	-0,1	0,1	0,1	0,4	0,2	0,5	-0,1	0,1	0,7	0,2	-0,1	-0,1	0,1	-0,0	-0,0	1

Figure 10. Correlation matrix of chemical elements in the placenta. The most significant correlations are highlighted. The significance level is 0.3 at p<0.05 (95% confidence), n=47

The most pronounced natural and man-made factors are manifested when analyzing their relationship in the composition of the placenta and blood. Thus, the tree diagrams of the correlation matrix constructed by us for the placenta (Figure 9 (A)) and blood (Figure 9 (B)) demonstrate the presence of the same association of such elements as rubidium, cesium, and sodium. Similar associations were noted by other researchers who studied the biological tissues (hair) in this locality.

Associations such as rubidium-cesium-sodium reflect natural geochemical backgrounds, while others, such as uranium-thorium, suggest anthropogenic influence.

We believe that this association is related to the natural geochemical background. The other associations of elements we identified differ for blood and placenta. Significant connections between the elements La-Sc-Ba-Th-Eu, U-Sm and Sr-Ca-Ta-As were observed in the placenta (Figure 4.1.10). The most significant connections in the blood were observed between the following elements: Sc-La-Th-Sb, Br-Hf-Ag, Sr-Ca, and Lu-Nd (Figure 10). These interactions are also well demonstrated by the correlation matrices of paired correlations (Figures 11 and 12). It can be seen from the figures that the maximum (at a significance level of 0.9) interactions are characteristic of the following pairs of elements in the placenta: Th-Sc, La-Ba, and Cs-Rb (Figure 11). Previously, researchers noted these relationships in the hair composition of the population of North Kazakhstan. Studies of all significant correlations show that the placenta and other biological media reflect the rare earth/gold/uranium specialization of North Kazakhstan.

The matrix of paired correlations for blood shows a greater number of interconnections of elements at a significance level of 0.9 (almost direct correlation) (Figure 13). This tissue is characterized by the relationship between scandium and lanthanum, as well as hafnium and bromine at the level of 1. This indicates a high sensitivity of blood to ecological and geochemical conditions and confirms the possibility of its use as an indicator biological tissue in environmental studies.

The maximum relationships between the elements are well demonstrated in Figure 13.

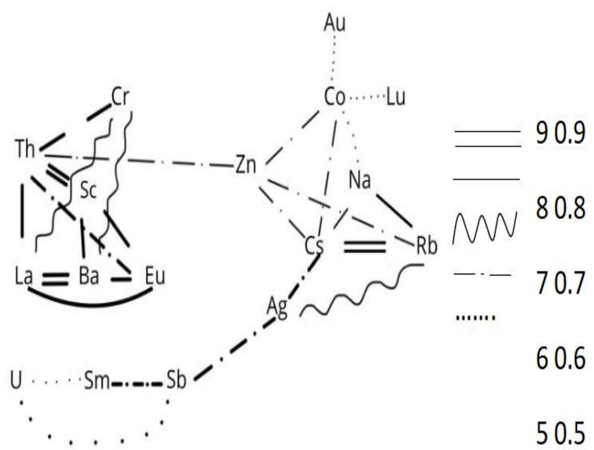


Figure 11. Correlation relationships of chemical elements in the placenta. The significance level is 0.3 at p<0.05 (95% confidence), n=47

	Na	Ca	Cr	Fe	Sc	Zn	Au	Hf	Ba	Sr	As	Ag	Br	Cs	Rb	Ta	Co	Sb	La	Ce	Sm	Nd	Eu	Tb	Yb	Lu	Th	U
Na	1																											
Ca	-0,1	1,0																										
Cr	0,5	-0,1	1,0																									
Fe	0,2	-0,1	0,5	1,0																								
Sc	0,2	-0,1	0,7	0,7	1,0																							
Zn	0,6	0,1	0,8	0,6	0,7	1,0																						
Au	0,0	-0,1	0,4	0,5	0,5	0,4	1,0																					
Hf	-0,1	-0,1	0,1	0,5	0,7	0,1	0,3	1,0																				
Ba	0,3	0,1	0,8	0,6	0,8	0,8	0,5	0,2	1,0																			
Sr	-0,2	0,8	-0,1	-0,2	-0,1	0,0	-0,1	-0,0	-0,0	1,0																		
As	0,1	0,3	0,1	0,2	0,2	0,0	0,1	0,5	0,1	0,2	1,0																	
Ag	0,1	-0,0	0,1	0,4	0,6	0,1	0,2	0,9	0,2	-0,0	0,4	1,0																
Br	-0,1	-0,1	0,0	0,4	0,6	-0,0	0,3	1,0	0,1	-0,1	0,5	0,9	1,0															
Cs	0,9	-0,0	0,5	0,2	0,1	0,6	0,0	-0,1	0,3	-0,1	0,2	0,1	-0,1	1,0														
Rb	0,8	0,1	0,5	0,5	0,3	0,8	0,2	-0,1	0,5	-0,1	0,1	0,2	-0,1	0,8	1,0													
Ta	-0,0	0,0	0,3	0,2	0,4	0,2	0,4	0,3	0,4	-0,1	0,1	0,3	0,2	-0,1	0,1	1,0												
Co	0,4	-0,2	0,6	0,6	0,8	0,5	0,4	0,8	0,5	-0,2	0,4	0,8	0,7	0,4	0,4	0,3	1,0											
Sb	0,2	-0,0	0,7	0,7	0,9	0,6	0,5	0,7	0,8	-0,1	0,3	0,6	0,6	0,1	0,3	0,5	0,8	1,0										
La	0,0	-0,1	0,6	0,7	1,0	0,5	0,5	0,8	0,6	-0,1	0,3	0,7	0,7	-0,0	0,2	0,4	0,8	0,9	1,0									
Ce	0,5	0,1	0,2	0,2	0,1	0,3	0,0	0,1	0,2	0,0	0,3	0,1	0,1	0,6	0,5	-0,1	0,3	0,1	0,1	1,0								
Sm	-0,1	0,6	0,1	-0,0	0,1	0,1	0,0	-0,0	0,1	0,6	0,4	-0,1	-0,0	-0,1	-0,0	0,1	-0,1	0,1	0,1	-0,0	1,0							
Nd	0,3	0,1	-0,1	0,2	0,0	0,2	-0,0	0,1	-0,0	-0,0	0,2	0,2	0,1	0,3	0,4	-0,1	0,1	0,0	0,0	0,2	0,1	1,0						
Eu	0,3	0,1	0,5	0,5	0,6	0,5	0,3	0,5	0,5	0,0	0,4	0,5	0,4	0,3	0,4	0,2	0,6	0,6	0,5	0,5	0,3	-0,0	1,0					
Tb	0,2	0,1	0,5	0,6	0,7	0,6	0,4	0,5	0,6	-0,0	0,1	0,5	0,4	0,2	0,4	0,2	0,5	0,7	0,7	0,1	0,2	0,5	0,4	1,0				
Yb	0,3	-0,2	0,1	0,2	0,2	-0,0	0,1	0,4	-0,0	-0,2	0,4	0,4	0,4	0,3	0,1	0,1	0,5	0,2	0,2	0,1	-0,1	0,0	0,2	0,1	1,0			
Lu	0,4	0,1	0,0	0,1	-0,0	0,2	-0,1	0,0	0,0	0,1	0,4	0,1	0,0	0,4	0,4	0,1	0,1	-0,0	-0,0	0,3	0,2	0,8	0,1	0,3	0,1	1,0		
Th	-0,1	-0,1	0,4	0,6	0,9	0,3	0,4	0,9	0,5	-0,1	0,3	0,7	0,8	-0,1	0,0	0,3	0,8	0,9	1,0	0,1	0,0	0,0	0,5	0,6	0,4	-0,1	1,0	
U	0,1	0,1	-0,1	0,1	-0,0	0,0	-0,0	0,1	-0,1	0,0	0,2	0,0	0,1	0,1	0,1	-0,1	-0,0	-0,0	0,0	0,1	0,1	0,2	-0,1	0,1	0,0	0,1	-0,0	1

Figure 12. Correlation matrix of chemical elements in the blood. The most significant correlations are highlighted. The significance level is 0.3 at p<0.05 (95% confidence), n=47

Table 3. Indicators of factor analysis (principal component method) of the elemental composition of the blood and placenta of residents of North Kazakhstan

Chemical Elements	**Factor Value, Blood**			**Factor Value, Placenta**		
	F1	**F2**	**F3**	**F1**	**F2**	**F3**
Na	0.355751	-0.793832	0.023933	0.302462	0.637503	0.481396
Ca	-0.059561	-0.130236	0.405847	0.130203	-.089277	-0.632114
Cr	0.691054	-0.384897	-0.420324	0.749429	-0.272009	0.258797
Fe	0.762558	-0.043416	-0.141849	0.352913	0.490723	0.159546
<u>Sc</u>	0.924363	0.165106	-0.207460	0.870488	-0.392435	0.073742
Zn	0.682822	-0.567216	-0.272724	0.873656	0.255898	-0.077284
Au	0.544057	0.097503	-0.317248	0.548058	0.117004	0.149412
Hf	0.748175	0.543177	0.285761	0.405969	-0.308298	0.027856
<u>Ba</u>	0.724168	-0.242154	-0.408739	0.709292	-0.565334	-0.016648
Sr	-0.120254	-0.012082	0.422780	0.061380	0.029948	-0.121812
As	0.397785	0.066489	0.657004	0.442660	0.093012	-0.309677
<u>Ag</u>	0.717977	0.352834	0.368379	0.707577	0.442566	-0.054351
Br	0.656489	0.582305	0.360127	0.474162	-0.290892	0.222885
Cs	0.355282	-0.808630	0.132086	0.474686	0.675770	0.392134
Rb	0.474257	-0.785190	0.001240	0.451325	0.736333	0.248608
Ta	0.396284	0.184359	-0.202608	0.412645	0.126939	-0.283228
Co	0.897375	0.067821	0.103506	0.570620	0.437493	0.120977
Sb	0.925664	0.153631	-0.161397	0.545333	0.302864	-0.553274
<u>La</u>	0.898675	0.313730	-0.104176	0.778244	-0.519413	0.079681
Ce	0.295525	-0.493330	0.295210	0.006954	-0.119673	-0.342820
Sm	0.077861	-0.057529	0.364263	0.352517	0.398985	-0.508047
Nd	0.183421	-0.367999	0.512742	-0.000933	0.202312	-0.144771
Eu	0.686920	-0.120586	0.118726	0.698579	-0.373637	0.107792
Tb	0.732751	-0.107568	0.020213	-0.138799	-0.083643	0.146541
Yb	0.358940	0.101008	0.304366	0.116738	-0.023893	-0.304026
Lu	0.173926	-0.438249	0.572585	0.454094	-0.380047	-0.140299
<u>Th</u>	0.846254	0.454278	-0.006658	0.783827	-0.356063	0.019130
U	0.029723	-0.087236	0.314830	0.154361	0.385352	-0.741702
Expl.Var	9.999076	4.232967	2.827673	7.526727	4.016246	2.637080
Prp.Total	0.357110	0.151177	0.100988	0.268812	0.143437	0.094181

Note: the elements for which the first factor is important for both blood and placenta are written in bold with italics and underscores (Factor Loadings (Unrotated) Extraction: Principal components, (Marked loadings are >.700000))

The most important factors forming the relationship of elements in the composition of the blood and placenta are demonstrated by the factor analysis table. Table 3 demonstrates that two main factors are involved in the formation of the blood and placenta. Thus, for such elements as cesium and rubidium, the second factor is important. The first factor forms a wider elemental spectrum of biological tissues. The first factor includes the anthropogenic impact, in addition to the natural impact. This is evidenced by the correspondence of the spectrum of elements with the most significant factor value to the emission spectrum of enterprises located in this territory.

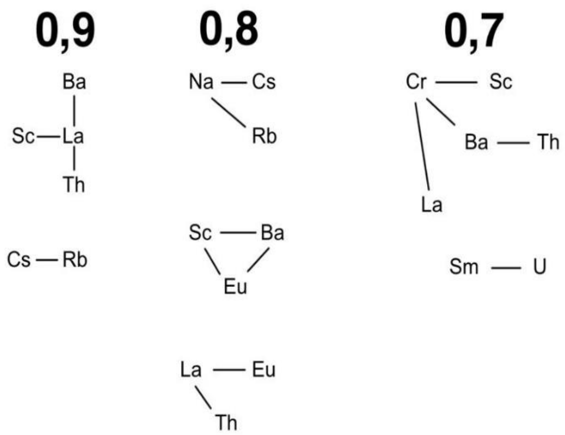


Figure 13. Correlation relationships of chemical elements in the blood. The significance level is 0.3 at p<0.05 (95% confidence), n=47

4. CONCLUSIONS

This study provides valuable insights into the environmental impact on maternal and newborn health through the analysis of chemical elements in biological tissues.

The analysis of statistical parameters characterizing chemical elements in the blood and placenta of residents of North Kazakhstan allows showed the nature of the accumulation and distribution of chemical elements in biological tissues is heterogeneous, which indicates a multifactorial effect on their formation. Also, the correlational relationships of the elements correspond to the specifics of the natural and anthropogenic influence of the territory of residence of the population. Furthermore, blood is a more sensitive biological tissue compared to the placenta, which performs barrier and depositing functions.

As a limitation, it should be noted that the sample size of 67 placental and 48 blood samples, while reflective of the environmental and biological conditions in the Akmola region, is relatively small. This study was designed to focus on the unique environmental impacts specific to this region, and the findings cannot be generalized to other areas. Future research with larger sample sizes may provide greater statistical power and broader applicability.

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