

REGIONAL SPECIFICS OF ELEMENT COMPOSITION IN THE HAIR OF CHILDREN LIVING ON THE TERRITORIES ADJACENT TO SEMIPALATINSK NUCLEAR TEST SITE

Apsalikov K.¹, Lipikhina A.¹, Abduazhitova A.¹, Zhakupova Sh.¹, Zingatinova Z.²

¹Research Institute for Radiation Medicine and Ecology

Ministry of Health of Republic of Kazakhstan, Semey

²Semey State University named after Shakarim, Republic of Kazakhstan, Semey

Abstract

Features of elemental composition of hair of children living in areas adjacent to the Semipalatinsk nuclear test site were established. In this work the concentrations of 29 chemical elements in the hair of children were determined using instrumental neutron activation analysis. All administrative areas are characterized by a spectrum of accumulation of elements relative to the average in the three villages. In Novopokrovka village it was found excessive accumulation of U, Sr, in Zenkovka village – Na, Fe, Nd, in Kokpekty village – Ag, Au. The results of this study are compared with the results obtained in other cities where such measurements have also been carried out.

Key words: Semipalatinsk nuclear test site, hair of children, element content, geochemical peculiarity.

Introduction

Semipalatinsk nuclear test site (SNTS) was one of the largest sites for the testing of nuclear weapons in the world. From 1949 until the site was closed in 1991, carried out more than 450 nuclear detonations. More than 110 of the tests were conducted in the air and on the surface of the earth. Over one million people have been recognized as having suffered (in a broad sense) from the SNTS [1].

The chemical composition of hair is a marker of ecological trouble territory [2], and can also be used as an indicator of natural technogenic environments, because it reflects regional characteristics in accumulation of elements in the territory of the populations [3]. Hairs of human reflect the level receipts of chemical elements in the human body. They are the most affordable for massive research bio substrates [4].

Materials and Methods

The studied territory is villages Novopokrovka and Zenkovka of East-Kazakhstan area. Those villages are the zone of maximal radiation risk according to Law “About social protection of Kazakhstan citizen suffered due to Nuclear Tests on SNTS”. They are located in the area of radiation traces of nuclear explosions conducted 29.08.1949, 29.07.1955, 07.08.1962. The control territory - village Kokpekty that refers to the zone of minimum radiation risk. Radiation situation here is due to global radioactive fallout.

A sampling of hair was conducted in accordance with the recommendations of the IAEA (1980) [5]. When sampling was recorded age, gender, full name, address and place of birth, as well as presence of pathology and chronic diseases. Sampling was carried out in children aged 3 to 15 years, with no deviations for medical reasons,

were born in this village. Total investigated 27 samples of hair, 10 from Novopokrovka, 10 from Zenkovka, 7 from Kokpekty.

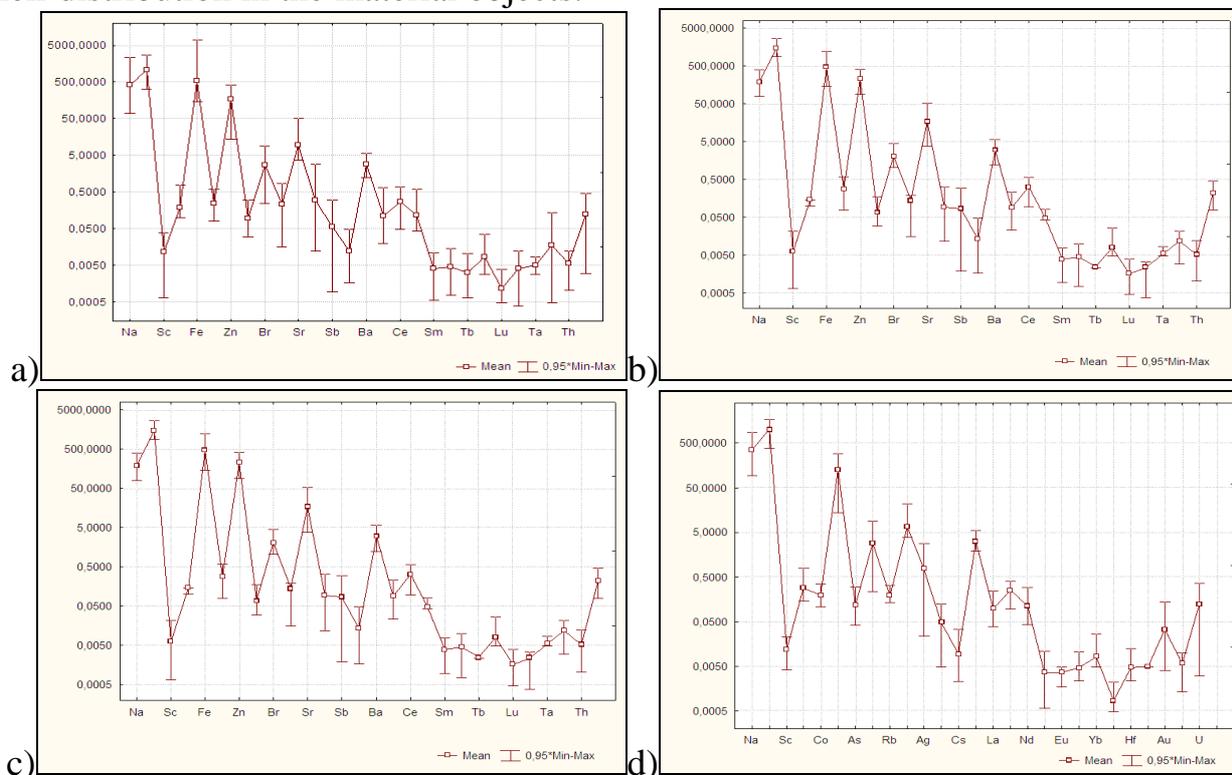
Determination of chemical elements was carried out in the laboratory of nuclear geochemical methods of investigation the Department of Environmental Geoscience Geochemistry of Tomsk Polytechnic University using the method of instrumental neutron activation analysis. Measurements were made on a gamma spectrometer with Ge-Li detector. Content 29 elements were determined, including the radioactive (U, Th) and the rare earth.

Aim of study is to identify patterns of accumulation of chemical elements in the hair of children living in areas around SNTS with varying degrees of radiation influence.

Discussion

The maximum average content more than 1000 mg/kg were for Ca, which is the basic component in the structure of hairs (Fig.1.). Na and Fe are on the second place. Zn and Sr have concentration in the range 10-1000 mg/kg. The presence of high concentrations of calcium and strontium in the hair, due to the process of hair growth, because these elements are active, in the processes of ossification.

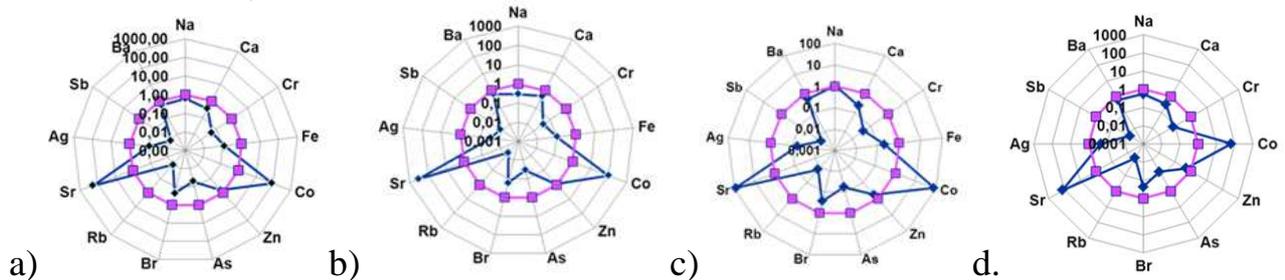
The distribution of the studied elements in the hair of children living in the studied localities corresponds to the geochemical laws of Clarke and Vernadsky (on general scattering of chemical elements), Mendeleev and Rule Oddo-Harkins (on the distribution of even and odd elements), which emphasizes the universal nature of their distribution in the material objects.



a) Average over three settlements, b) Novopokrovka, c) Zenkovka, d) Kokpekty
 Fig.1. Levels of chemical elements in the hair of children of East Kazakhstan region, mg/kg

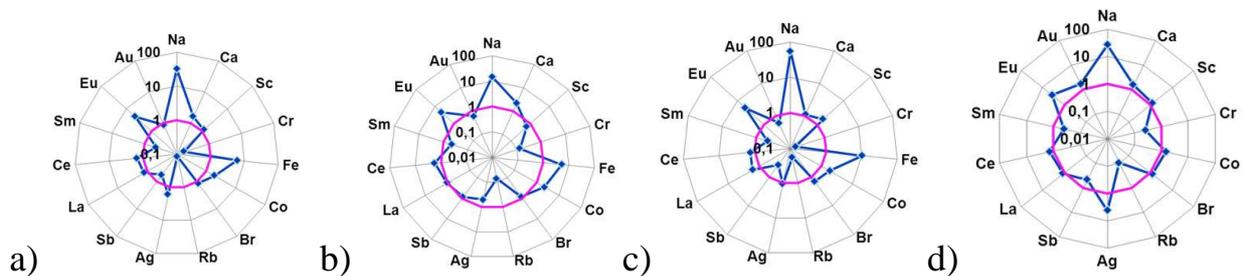
Figure 2 shows the concentration of elements in the hairs of children in comparison with published data of ICRP [6].

Studied hairs were rich with Co and Sr relative to conventional human according ICRP. Excess of Co was in average 83 times, maximum was in Novopokrovka village - 97 times. For Sr excess concentration was in average 189 times, in Novopokrovka - 338 times. The low concentration in comparison with data of ICRP was for Sb (in 113 times lower), Rb (in 101 times lower), Cr and As (in 20 times lower), Ag (11 times) and Fe (8 times).



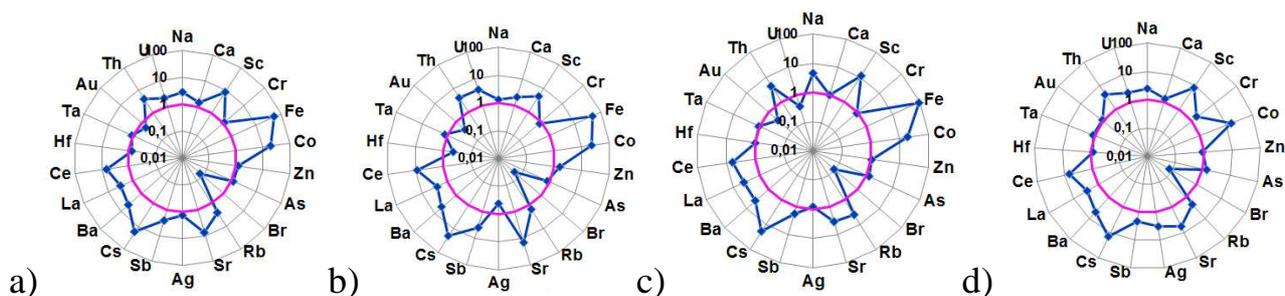
a) Average over three settlements, b) Novopokrovka, c) Zenkovka, d) Kokpekty
Fig.2. Concentration ratio relative conditional human according ICRP

In comparison with data of Saet Yu., Revich B. [7] in our study the level of Na in the hairs of children was higher in 32 times, Fe - in 6 times, Eu - in 4 times, Co - in 2 times. In Kokpekty concentration of Ag in the hair of children were higher in 4 times (Fig.3).



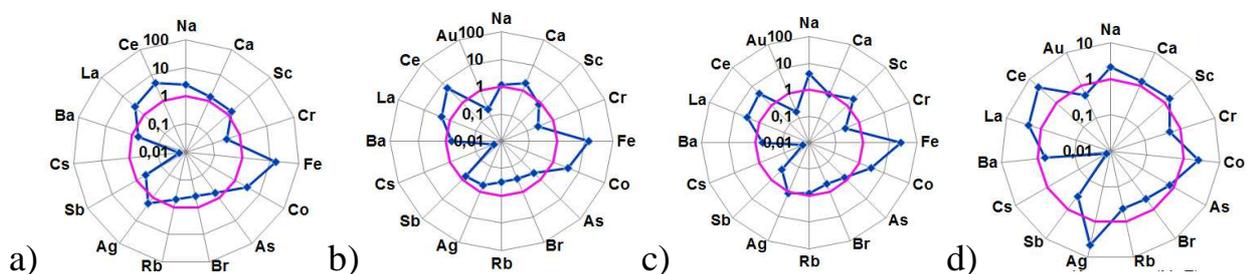
a) Average over three settlements, b) Novopokrovka, c) Zenkovka, d) Kokpekty
Fig.3. Concentration ratio relative the data Saet Yu., Revich B., 1990

In comparison with data of Rodushkin I., Axelsson M.D. [8] concentration of Fe in the hairs of studied children was higher in average 55 time, Co – in 19 times, Cs – in 18 times, Sc – in 8 times, Sr and Ce – in 7 times, Th and Ba – in 4 times, La, Na, Sb и Rb – in 3 times. Concentration of U was excessive in Novopokrovka in 4 times (Fig.4).



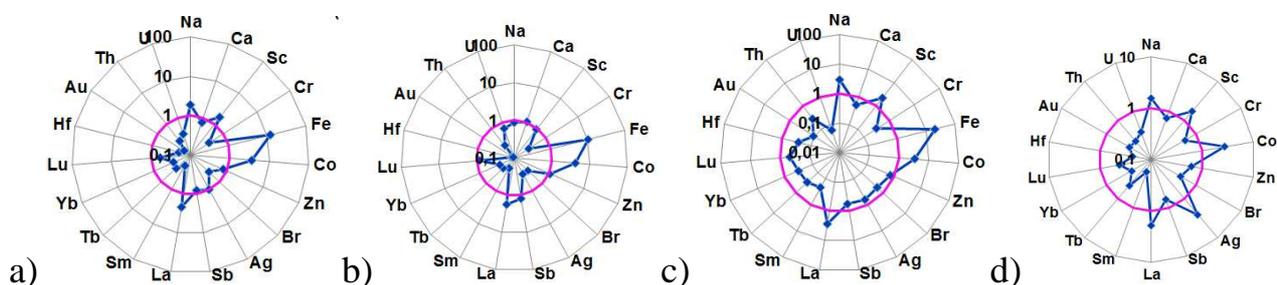
a) Average over three settlements, b) Novopokrovka, c) Zenkovka, d) Kokpekty
Fig.4. Concentration ratio relative the data Rodushkin I., Axelsson M.D., 2000.

In comparison with data of Ward N.I. et. al. [9] concentration of Fe in the hairs of studied children was higher in 16 times, Ce – 5 times, Co – 3 times, La and Na – 2.5 times. Concentration of Ag was highest in Kokpekty in 4.5 times (Fig.5.).



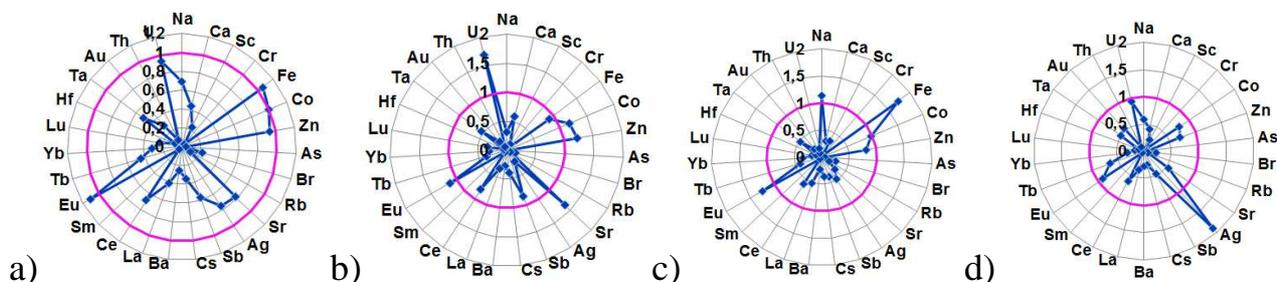
a) Average over three settlements, b) Novopokrovka, c) Zenkovka, d) Kokpekty
 Fig. 5. Concentration ratio relative the data Ward N.I. et. al., 1987.

Figure 6 shows concentration ratio of chemical elements in the hairs of children living in East-Kazakhstan Area in comparison with children from Pavlodar Area [10]. Concentration of Fe, Co, La and Na in average in three village are higher than in Pavlodar area in 11, 3, 2 и 1.8 times respectively. The content of Sc in the hair of children in Zenkovka and Kokpekty was higher than in the Pavlodar region in 2 and 1.7 times, respectively. In the hair of children in Kokpekty Ag content exceeds 2.5 times.



a) Average over three settlements, b) Novopokrovka, c) Zenkovka, d) Kokpekty
 Fig.6. Concentration ratio relative contents of elements in the hair of children the Pavlodar region

Figure 7 shows concentration ratio of chemical elements in the hair of studied children in comparison with Tomsk region. Of course, the sample size in this study is considerably lower than the volume of the Tomsk region. However, we decided to compare the data. Average content of the studied elements in three locations is lower than in the Tomsk region. The content of Fe and Eu are uniform in size. In the hair of children of Novopokrovka U content is higher than in the Tomsk region in 1.7 times, Sr – 1.4 times, Zn and Co 1.2 times. In the hair of children of Zenkovka the Fe content is higher than in the Tomsk region of 1.7 times, Eu – 1.2 times, Na – 1.1 times. In the hair of children of Kokpekty Ag content is higher than in the Tomsk region of 1.9 times.



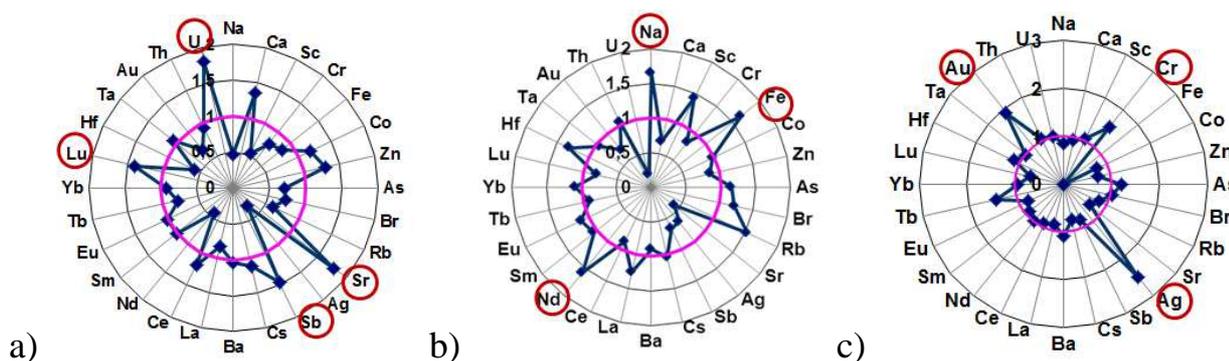
a) Average over three settlements, b) Novopokrovka, c) Zenkovka, d) Kokpekty
 Fig.7. Concentration ratio relative contents of elements in the hair of children the Tomsk region

Regional differences of hair in investigated settlements are reflected in table 1. Geochemical range of elements in the hair of children in the locality varied. The highest concentration rates for Ag and Au was in Kokpekty, U and Sr in Novopokrovka Na, Fe and Nd in Zenkovka

Table 1 - Biogeochemical specificity in the hair of children East Kazakhstan region on concentration ratios (relative to average)

| Biogeochemical specificity | |
|----------------------------|--|
| Novopokrovka | U1,8 – Sr1,8 – Sb1,5 – Lu1,4 – Ca1,4 – Zn1,3 – Ce1,2 – Co1,2 – Cs1,1 – Ta1,1 – Ba1,0 – Eu1,0 – Sm1,0 – Th0,9 – Yb0,9 – Fe0,9 – La0,8 – Cr0,8 – Tb0,8 – Br0,7 – As0,7 – Au0,7 – Rb0,6 – Hf0,6 – Sc0,5 – Na0,5 – Nd0,4 – Ag0,3 |
| Zenkovka | Na1,6 – Fe1,6 – Nd1,6 – Rb1,5 – Sc1,4 – La1,3 – Hf1,3 – Br1,2 – As1,2 – Sm1,1 – Eu1,1 – Yb1,1 – Th1,0 – Cs1,0 – Co0,9 – Zn0,9 – Ba0,9 – Ce0,9 – Tb0,9 – Ta0,9 – Cr0,8 – Lu0,8 – Ca0,7 – Sb0,7 – Au0,7 – Ag0,6 – Sr0,4 – U0,2 |
| Kokpekty | Ag2,5 – Au1,9 – Cr1,5 – Tb1,4 – As1,2 – Hf1,1 – Br1,1 – Ba1,1 – Sc1,0 – Th1,0 – U1,0 – Nd1,0 – Yb1,0 – Ta1,0 – Ca0,9 – La0,9 – Ce0,9 – Sm0,9 – Na0,8 – Co0,8 – Rb0,8 – Sb0,8 – Eu0,8 – Zn0,7 – Lu0,7 – Sr0,7 |

From our data we concluded that there are significant differences in the level of accumulation of elements in the studied substrate. It is indirect evidence of differences in geochemical situation in each village. Most expressed variation was typical for U in 10 times difference, Ag – 8 times, Nd, Na, and Sr – 4 times (Fig.8).



a) Novopokrovka, b) Zenkovka, c) Kokpekty

Fig.8. - Concentration ratio relative to the average content of elements in the hair of children of the three settlements.

In Novopokrovka village we have found accumulation of U и Sr in the hairs. Concentration ratio relative to the average for the three settlements is 1.8 for these elements. This confirms the technogenic specific of content of U and Sr in the hair of the children. The average content of U is $0,21 \pm 0,13$ mg/kg, with a maximum content of 0.49 mg/kg. The average content of Sr is 16.9 ± 16.7 mg/kg, with a maximum content of 54.9 mg/kg. The concentration of Sb, Lu, Ca, and Zn exceed the average values in 1.3-1.5 times.

In Zenkovka village we found high concentration of Na, Fe and Nd which prevailed average content in three villages in 1.6 times. Concentration of Rb, Sc, Hf, La and Sb exceeded the average content in 1.3-1.5 times. The high content of rare earth elements in the hair of children, likely indicates brings these components with groundwater from magmatic rocks.

In Kokpekty village it was found excessive accumulation of Ag in 2.5 times higher than in average in three village, Au – in 1.9 times. This may be an indirect indication of the presence in the area of hidden mineralization Au-Ag-Sb type or evidence of brings these components with groundwater from gold contenting areas.

The analysis of data shows that distribution of chemical elements confirms regularities of their accumulation according global rules of distribution in the environmental subjects: Mendellew-Klark on the abundance of the elements of different masses and Oddo-Harkins of the alternation of elements with even and odd numbers.

The elemental composition of children's hair spatially was associated with the accumulation of environmentally significant elements in drinking water. The spatial distribution of chemical elements and quantitative relationships between the levels of separate elements in the scale and in the hair of children can identify drinking water as potential sources of the elements.

Conclusion

We have evaluated average content of chemical elements in the hair of children living in areas adjacent to the Semipalatinsk nuclear test site. It was revealed their regional specificity of accumulation compared with other areas. Specificity includes higher content compared to the Pavlodar region of Fe, Co, La and Na. In Novopokrovka village compared with the Tomsk we found excessive concentration of U and Sr, in Zenkovka – Fe, in Kokpekty – Ag. We have found a very uneven distribution of elements in the hair in the studied areas. All administrative areas are characterized by a spectrum of accumulation of elements relative to the average in the three villages. It was found the features of the element status of children in areas with different natural and man-made situation.

Content of elements in hair of children are indicators of tense technogenic situation of territory. The most expressed of which U and Sr in the hair of children are living in the village Novopokrovka in the area of maximum influence of SNTS.

References

1. Yamamoto M., Tomita J., Sakaguchi A., Ohtsuka Y., Hoshi M., Apsalikov K.N. Uranium isotopes in well water samples as drinking sources in some settlements around the Semipalatinsk nuclear test site, Kazakhstan. // *Journal of Radioanalytical and Nuclear Chemistry*. 2010. Vol. 284. N2. P. 309-314.
2. Baranovskaja N., Rikhvanov L. Trace elements in composition of biosubstrates of people living in a district of the nuclear plant of Russia. // *Macro and Trace Element: 21 Workshop*. Friedrich Schiller University Jena, 2002. P.1266-1270.
3. Baranovskaya N.V., Shvetsova D.V., Rikhvanov L.P. Element content in children hair samples (Tomsk Region, Russia) // *Trace Elements in Human: New Perspectives: Proc. of the 7th Intern. Symp.* – Athens, Greece, 2009. – P. 290–303.
4. Ревич Б.А. Химические элементы в волосах человека как индикатор воздействия загрязнения производственной и окружающей среды // *Гигиена и санитария*. – 1990. – N3. – С. 55–59. (Revich B.A. Himicheskie element v volosah cheloveka kak indikator vozdeystviya zagryazneniya proizvodstvennoi in okruzhaiushei sredy // *Gigiena i sanitariya*. – 1990. – N 3. – P. 55–59.)
5. Element analysis of biological materials. Current problems and techniques with special reference to trace elements. Appendix II. Technical reports series. – №197. – Viena: IAEA, 1980. – P. 351–367
6. ICRP, 1977. Recommendations of the ICRP. ICRP Publication 26. Ann. ICRP 1 (3).
7. Сагт Ю.Е., Ревич Б.А., Янин Е.П. и др. Геохимия окружающей среды. – М.: Недра, 1990. – 335 с. (Saet Y.E., Revich B.A., Yanin E.P. et al. Geohimiya okruzhaiushei sredy. – M. Nedra, 1990. – 335 p.)
8. Rodushkin I., Axelsson M.D. Application of double focusing sector field ICP-MS for multielemental characterization of human hair and nails. Part I. Analytical methodology. // *The Science of the Total Environment*. 2000. Vol. 250. P.83-100.
9. Ward, N. I., Spyrou, N. M and Damyanova, A. A. - 1988. - Study of hair element content from an urban Bulgaria population using NAA assessment of environmental status // *J. Radianal Nucl. Chem.* 114: 125-135
10. Корогод Н.П., Шайморданова Б.Х., Асылбекова Г.Е., Барановская Н.В. Элементный состав волос детского населения города Павлодар // *Проблемы биогеохимии и геохимической экологии*. – 2008. – N 4 (8). – С. 99–109.