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Features of the elemental status of the indigenous population of the south of Central Siberia

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Abstract. Particularly relevant are studies to establish the microelement status of territories in environmentally unfavorable regions with high anthropogenic load, which include the Krasnoyarsk Territory. Natural and geochemical features of territories, as a complex of factors constantly acting on the human body, can cause not only endemic diseases, but also potentiate anthropogenic effects. A large number of studies on geochemistry, biogeochemistry, soil science, and the ecology of microelements in the natural environment have been carried out in different regions of Siberia. At the same time, in the southern part of the Krasnoyarsk Territory, data on a comprehensive assessment of the content of microelements in different parts of the ecosystem have not been sufficiently studied, summarized and systematized. Thus, the purpose of the work was to study the characteristics of the elemental status of the indigenous population of the south of Central Siberia. Laboratory studies to determine the concentration of trace elements in the hair of the examined individuals were carried out using mass spectrometry with inductively coupled argon plasma. When considering the results of the study, certain groups of the population of the city of Krasnoyarsk were recorded in elemental status between the sexes. In men, there was an increase in potassium content by 1.7 times, phosphorus by 1.2 times relative to the 75th centile. The content of cobalt and calcium corresponded to the 25th centile of normal content in bio substrates. For women living in the city of Krasnoyarsk,

an increased excretion of calcium and zinc from the body by 1.2 times relative to the 75th centile was noted. In this gender group, normal average and median values for the content of iron and chromium in bio substrates (hair) have been established and are 21 and 0.46 μg/g, respectively. The level of toxic elements such as nickel, mercury, cadmium and lead were normal and the range of maximum values did not exceed the 75th centile interval in both study groups.

Keywords: elemental status, trace elements, heavy metals

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Особенности элементного статуса коренного населения юга Средней Сибири

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Аннотация. В настоящее время особенно актуальными являются исследования по установлению элементного статуса территорий экологически неблагополучных регионов с высокой антропогенной нагрузкой, к которым относится Красноярский край. Природно-геохимические особенности территорий, как комплекс факторов, постоянно действующих на организм человека, могут вызвать не только эндемические заболевания, но и потенцировать антропогенное воздействие. В разных регионах Сибири проведено большое количество исследований по агрохимии, биогеохимии, почвоведению, экологии микроэлементов в природной среде. В то же время в южной части Красноярского края недостаточно изучены, обобщены и систематизированы данные о комплексной оценке содержания химических элементов в разных звеньях экосистемы. В связи с этим целью настоящего исследования явилось изучение особенностей элементного статуса коренного населения юга Средней Сибири. Лабораторные исследования по определению концентрации химических элементов в волосах обследованных лиц выполнены методом масс-спектрометрии с индукционно-связанной аргоновой плазмой. При рассмотрении результатов исследования отдельных групп населения города Красноярска зафиксированы половые различия в элементном статусе. У мужчин отмечалось увеличение содержания калия в 1,7 раза, фосфора в 1,2 раза относительно 75 центиля. Содержание кобальта и кальция соответствовало 25 центилю нормального содержания в биосубстратах. Для женщин, проживающих в городе Красноярске, было отмечено повышенное выведение из организма кальция и цинка в 1,2 раза относительно 75 центиля. В данной гендерной группе установлены нормальные как средние, так и медианные значения по содержанию железа и хрома в биосубстратах (волосы) и составили 21 и 0,46 мкг/г соответственно. Уровень токсичных элементов, таких как никель, ртуть, кадмий и свинец,

был в норме и разброс максимальных значений не превышал 75-центильный интервал в обеих исследуемых группах.

Ключевые слова: элементный статус, макроэлементы, микроэлементы, тяжелые металлы

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Introduction

It is known from numerous literature sources that hair is the most qualitative and informative biological object carrying information about the environmental situation, nutritional quality, presence of diseases or deviations in human health [1–3]. There are debates in medical elementology that hair is not a level indicator for all trace elements. However, they are not affected by chemical elements such as lead, selenium, mercury, cadmium, etc. Therefore, hair can be used to determine the elemental status of individuals and populations [4; 5].

The choice of hair as a subject of analysis is due to numerous studies confirming its suitability as an object in studies of the elemental status of the population [6; 7]. Hair is an easily accessible biological material, its collection is simple and painless. The storage of hair is practically unlimited for a long period of time and does not require any special conditions. Due to the low growth rate of hair, the results of the analysis do not show the immediate content of macro- and microelements in the sample, but the average level for several months [8]. The chemical composition of hair reflects both the internal state of the organism and the consequence of various exogenous factors [9; 10].

In this regard, we used hair as biosubstrates to assess the content of chemical elements of the residents of Krasnoyarsk, which was the purpose of our study. Hair samples from adults (18-25 years old) living in Krasnoyarsk for a long time (82 men and 247 women) were selected as research objects. Studies on the content of trace elements in biosubstrates (hair) were carried out in CDL ANO ‘Biotic Medicine Center’ (Moscow): accreditation (certificate № GSEN.RU.TSOA.311); medical licence (MDKZ №13665/5124); licence for laboratory activities (MDKZ №14690/6149); registration number in the state register ROSS.RU.0001.513118 from 29.05.2003.

Laboratory studies to determine the concentration of trace elements in the hair of the examined persons were carried out by mass spectrometry with induction-coupled argon plasma (MC-ICP).

Results and discussion

In the course of our work we studied hair to assess the possible influence of the ecological environment of residence and nutrition on the content of chemical elements in biosubstrates of the residents of Krasnoyarsk. The results of our study of the elemental composition of hair of the residents of Krasnoyarsk are presented in Tables 1 and 2.

Table 1. **Content (μkg/g) of trace elements in the hair of men in Krasnoyarsk (n = 82)**

Indicator	Average value ($M \pm m$)	Confidence interval P = 0.95(±)	Median (Me)	Min	Max	25-75 Centil*
Sodium	318±50	99	139	3.4	2755	73–331
Magnesium	61±7	14	40	7	393	39–137
Potassium	282±42 ↑	83	120	12	1764	29–159
Phosphorus	197±9 ↑	17	183	9	634	83–165
Calcium	548±49 ↓	97	416	37	2496	494–1619
Manganese	0.46±0.69	0.135	0.26	0.0024	4.58	0.32–1.13
Cobalt	0.04±0.01 ↓	0.03	0.006	0.0	0.855	0.04–0.16
Copper	11±1.3	2.6	9.85	0.8	113	9–14
Chrome	0.46±0.06	0.13	0.309	0.0	4.8	0.32–0.96
Iron	19±3	6	13	0.9	239	11–24
Zinc	191±10 ↑	19	178	0.9	699	155–206
Iodine	0.51±0.13	0.26	0.232	0.0	10.8	0.27–4.2
Selenium	0.70±0.12	0.24	0.489	0.0	8.41	0.2–1.8
Toxic						
Nickel	0.248±0.036	0.07	0.15	0.0	2.53	0.0021–0.53
Mercury	0.283±0.03	0.06	0.212	0.016	1.79	0.05–2.0
Cadmium	0.042±0.018	0.04	0.009	0.0	1.09	0.05–0.12
Lead	0.815±0.12	0.25	0.34	0.04	4.7	0.38–1.4

Note: * – [11].

Table 2. **Content of trace elements (μkg/g) in the hair of women in Krasnoyarsk (n= 247)**

Indicator	Average value ($M \pm m$)	Confidence interval P=0.95(±)	Median (Me)	Min	Max	25-75 Centil*
Sodium	149 ±18	33	71	6	2248	73–331
Magnesium	131±9 ↑	19	83	13	986	39–137
Potassium	115±18	35	35	139	10204	29–159
Phosphorus	170±4 ↑	8	162	25	534	83–165
Calcium	1813±113 ↑	222	1247	139	10204	494–1619
Manganese	1.1±0.09 ↑	0.18	0.64	0.102	12	0.32–1.13
Cobalt	0.06± 0.009	0.018	0.0147	0.0007	1.29	0.04–0.16
Copper	14±0.9 ↑	1.8	11.5	1.86	139	9–14
Chrome	0.46±0.03	0.058	0.336	0.01	3.14	0.32–0.96
Iron	21±1.3	2.5	15	4.5	154	11–24
Zinc	247±11 ↑	22	195	37	1135	155–206
Iodine	0.62±0.08	0.16	0.276	0.0	11.9	0.27–4.2
Selenium	0.66±0.11	0.215	0.405	0.0	13.8	0.2–1.8
Toxic						
Nickel	0.28±0.02	0.04	0.192	0.02	1.96	0.0021–0.53
Mercury	0.328±0.02	0.04	0.232	0.0	1.97	0.05–2.0
Cadmium	0.018±0.006	0.011	0.007	0.0	1.18	0.05–0.12
Lead	0.389±0.03	0.06	0.183	0.03	4.16	0.38–1.4

Note: * – [11].

When considering the results of the study of separate groups of the population of Krasnoyarsk city it is possible to note significant gender differences in the elemental status. Thus, increased excretion of such elements as potassium 1.7 times and phosphorus 1.2 times relative to the 75th centile from the organism of men was noted, while the content of zinc in biosubstrates corresponds to the upper limit of permissible excretion. Along with this, it was noted that the content of cobalt and calcium corresponds to the 25th centile of normal content in the studied biosubstrates. It is shown that the content of sodium is 318 μg/g, which corresponds to the upper limit of normal content, while the median of the sample is only 139 μg/g, this is due to a large scatter of data so the minimum value is only 3.4 μg/g, and the maximum value is 2755 μg/g. The same phenomenon is observed for magnesium, manganese and iodine. Thus, the content of these elements in hair is, on average, 61; 0.46 and 0.51 μg/g respectively, while the median of the sample is many times lower than the average values and is only 40, 0.26 and 0.23 μg/g respectively.

As for women living in the city of Krasnoyarsk, they are characterised by increased excretion of calcium and zinc 1.2 times relative to the 75th centile. Besides, the content of phosphorus, magnesium, manganese, and copper in the studied hair corresponds to the upper limit of normal content. It should be noted that the median values of the above elements also tend to the extreme values of the norm.

Estimating the content in biosubstrates of such elements as sodium, potassium, cobalt and iodine their average content was found to be at the level of norm, while their median values of sodium, potassium, cobalt and iodine sample are 71, 35, 0.0147 and 0.27 μg/g, respectively, these indicators tend to the values of 25th centile. It was found that this gender group revealed normal both mean and median values for iron and chromium in hair and are 21 and 0.46 μg/g respectively.

As for the toxic elements such as nickel, mercury, cadmium and lead, their values were normal and despite a considerable variation in maximum values, did not exceed the 75 centile interval in both studied groups.

Fig. 1 shows the elemental profile of the residents of Krasnoyarsk depending on gender groups. When considering the figure, significant reliable differences are noted ($p<0.05$). Thus, these differences are characteristic for sodium, magnesium and calcium, the coincidence of increased excretion from the organism of the examined residents is noted only for zinc. The elemental portrait of men is as follows: ↑ P, K, Zn / ↓Co, women – ↑Mg, Ca, Zn, Mn, Cu.

At present, the population of the entire planet is experiencing the stress of anthropogenic pollution of all environments – hydrosphere, atmosphere and lithosphere. Often anthropogenic impact is associated with emissions into the environment of various substances, including heavy metals, which adversely affects the human body. Therefore, there is a need to study the elemental status of the human body in order to identify and correct various elementosis. The relevance of the study is that, according to some authors, there is a connection between the main

demographic indicators of the population, as well as the state of health of persons living in different territories and the provision of some essential macro- and microelements [12–14]. At the same time, not only absolute population indicators of the content of chemical elements in hair, but also relative ones (frequency of deviations from the norm) are an important biomarker of the demographic state.

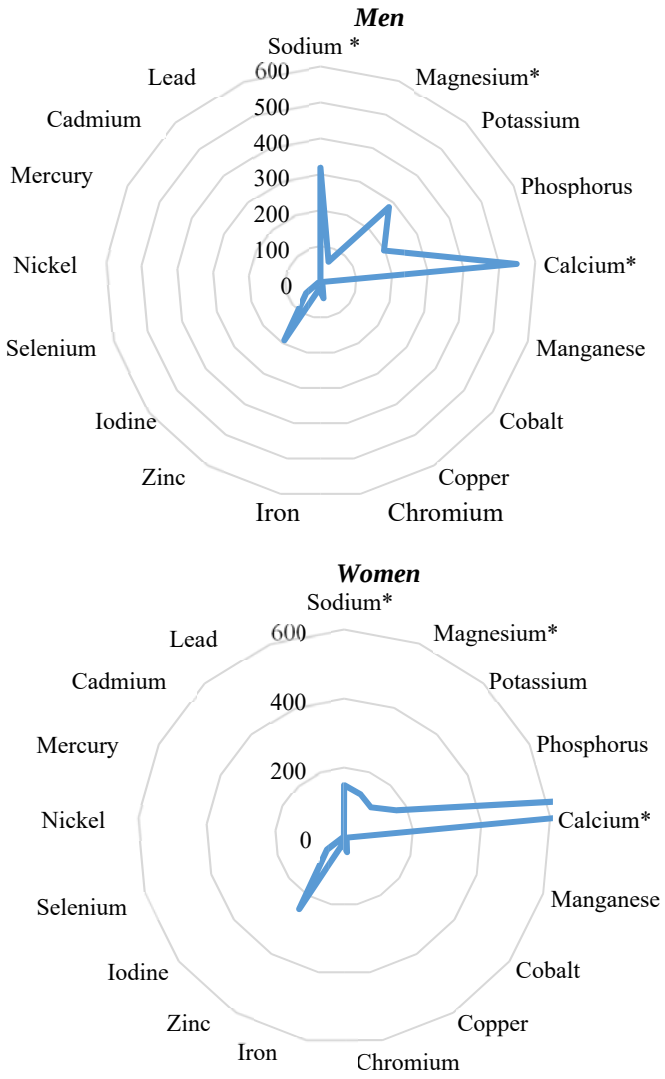

Figure 1. Elemental profile of Krasnoyarsk residents in the context of gender groups
Note: * – the difference is significant ($p<0.05$).
Source: compiled by the authors.

The article shows the relationship between the exchange of macro- and microelements and a number of demographic indicators. For instance, an increase in the prevalence of excessive accumulation of Fe, Al, K in men, deficiency of Cu, Co in women against the background of Mn imbalance can be considered a negative

prognostic sign in demographic terms. In addition, calcium-phosphorus metabolism, as well as cobalt metabolism correlates with the level of fertility [15]. In particular, the authors have shown that male life expectancy is negatively correlated with an increase in the content of Fe, Mn, A1 in hair (r = –0.69; r = –0.61; r = –0.79, 2005; and r = –0.78, r = –0.60; r = –0.58, 2006), i.e. those industrial ecotoxicants whose accumulation in hair, as shown above, correlates with an increase in the mortality rate. Increased levels in hair of K, as recorded in our study, according to researchers [15] also negatively and significantly correlate with male life expectancy (r = –0.54; r = –0.51). It is known that disturbance of K metabolism, which is reflected in the form of changes in its content in hair [16], is noted in individuals with overstimulation of the sympathoadrenal system, those under chronic stress, those suffering from hypertension and diabetes mellitus, as well as in patients with schizophrenia [17]. Moreover, as shown in the study of A.R. Grabeklis et al [18], the increased level of K in hair correlates with a decrease in its concentration in whole blood, i.e. hypokalaemia, and can be considered as an indicator of the risk of cardiovascular diseases and mortality. It has been shown in extensive studies that increased Fe, Mp content in hair is usually positively correlated with increased accumulation of these, on the one hand, essential chemical elements and, on the other hand, industrial ecotoxicants in the body [18].

The elemental status of the population probably has a significant impact on clinical and demographic indicators such as fertility, life expectancy and mortality, and the development of various diseases. It is important to note that the leading role in these influences should be attributed to the excessive accumulation of conditionally essential and toxic chemical elements. The development and implementation of scientifically sound regional programmes to correct the elemental status of the population can be one of the effective measures to improve the demographic situation and health of the population of certain territories, including Krasnoyarsk Territory.

Conclusion

Thus, during the study we have established gender differences in the microelement profile of the residents of Krasnoyarsk, which consist in the following formulas:

$$\text{men} = \frac{\uparrow \text{K,P,Zn}}{\downarrow \text{Co}}; \text{ women} = \uparrow \text{Mg, P, K, Ca, Mn, Cu, Zn.}$$

Thus, the elemental composition of human hair is a kind of indicator that can be used to assess the level of human health. At the same time, scientific literature sources pay much attention to the deficiency and excessive accumulation of both toxic and essential metal-microelements, which may be accompanied by various behavioural disorders and a significant decrease in mentality [16].

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