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Peculiarities of Elemental Status in Children Living in Industrial Regions of the Republic of Sakha (Yakutia)

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ABSTRACT
The relationship of the state of the human habitat, in particular its chemical composition, with indicators of health and quality of life is well known. However, in medicine, unlike biology, agriculture and a number of other sciences, the study and use of this knowledge remains limited and non-demanded by clinical disciplines. The stability of the chemical composition of the body is one of the most important and mandatory conditions for its normal functioning. Accordingly, deviations in the content of chemical elements caused by environmental, climatic-geographical factors or diseases will lead to a wide range of health disorders. Therefore, the detection and assessment of deviations in the macro and trace elements exchange, as well as their correction, are a promising direction of modern medicine. The development of the mining industry in the Republic of Sakha (Yakutia) is raising questions on the ecology preservation of the northern territories and the impact that ecology has on human health. The purpose of our work is to identify the features of elemental status in children living in the diamond-producing and coal-mining regions of the Republic of Sakha (Yakutia).

Keywords: *elemental status, life quality, industrial regions, Republic of Sakha, Yakutia*

1. INTRODUCTION

From the second half of the 20th century, with the beginning of the new territories development for mining and mining industry development in the Republic of Sakha (Yakutia), questions about the preservation of the ecology of the northern territories of the Russian Federation are acutely raised.

The entire territory of the Republic of Sakha (Yakutia) is located in the zone of extreme climatic factors, the climate is severe and continental. In the North, the processes of self-healing and self-cleaning of natural landscapes occur very slowly. In aquatic and terrestrial ecosystems, the rates of biological and chemical transformation are reduced, which leads to a significant accumulation of chemical components of anthropogenic impact in them [2, 3]. The adverse effects of the habitat until the end of the 20th century were little studied and unclaimed.

The health of the population is one of the main indicators of the ecological state of the environment and the quality of life. At present, negative factors of anthropogenic impact, including an excessive intake of heavy metals and a deficiency of vital chemical elements, and unfavorable climatic and geographic living conditions of a significant part of the population of Russia contribute to a decrease in health at the individual and population levels, and in some regions – to an increase in depopulation processes). Deviations in the intake of macro- and microelements into the body, violation of their ratios in the diet directly affect the activity of the body and can affect its resistance, and, consequently, the ability to adapt.

There are numerous evidence of the relationship between the chemical heterogeneity of the biosphere and the occurrence of various changes in the body and even diseases in the scientific researches of Lindh U, Plumlee G, Ziegler T and other authors [1, 4–10]. According to these ideas, biogeochemical factors (trace elements of soil, water, air, products of biotic and abiotic origin, industrial and agricultural waste) have a significant impact on the normal vital activity and functional reserves of the human body.

The human body is sensitive to the current ecological situation. The destabilization of adaptive capabilities serves as an indicator in assessing the negative consequences of local and global violations of ecological equilibrium. The sensitivity of the child's body to adverse environmental factors is known. Therefore, despite the complexity of identifying the causes of changes in the state of health of children, there are works in which the occurrence of various diseases and syndromes is associated with acute exposure or long-term aftereffect of subthreshold doses of various toxicants on the child's body [12–18].

Micronutrients play a central part in metabolism and in the maintenance of tissue function. An adequate intake therefore is necessary, but provision of excess supplements to people who do not need them may be harmful. Single micronutrient deficiency states are comparatively easily recognised and treated. Subclinical deficiency, often of multiple micronutrients, is more difficult to recognise, and laboratory assessment is often complicated by the acute phase response [19, 22, 26]. Clinical benefit is most likely in those people who are severely depleted and at risk of complications, and is unlikely if this is not the case. There is little evidence for supplements leading to a reduction in the incidence of infections in the elderly population, in coronary artery disease, or in malignant disease. The best evidence for benefit is in critical illness, and in children in developing countries consuming a deficient diet. More clinical trials are required with good clinical outcomes to optimise intake in prevention and treatment of disease [20, 21, 23–25].

The purpose of our work is to identify the features of elemental status in children living in the diamond-producing and coal-mining regions of the Republic of Sakha (Yakutia).

2. MATERIALS AND METHODS

A representative sample included 200 children aged from 7 to 17 years old permanently residing in these regions of Yakutia since their birth. A prerequisite for this sample was the equal probability of including children of the same gender and age among the entire population of examined children.

24 trace elements (Al, As, Be, Ca, Cd, Co, Cr, Cu, K, Li, Mg, Mn, Na, P, Pb, Se, Sn, Si, V, Ti, Zn) in human hair were examined by mass spectrometry.

Statistical processing of the study results was carried out with the Microsoft Excel XP and Statistica 6.0 software package. The mean arithmetic value (X) and its error (m), the mean quadratic deviation (δ) were calculated to estimate the indices characterizing the set and basic characteristics of the distribution.

To determine the tightness of the relationship between the studied features and its directions, the method of paired correlation analysis was used with the calculation of the correlation coefficient (r). Pairwise correlation coefficients were estimated as follows: less than 0.3 – weak connection, 0.3 to 0.5 – moderate, 0.5 to 0.7 – significant, 0.7 to 0.9 – strong, and more than 0.9 the connection was considered very strong.

The $p < 0.05$ and $p < 0.01$ values were used to evaluate the reliability of the differences. The validity of the differences between the data obtained in the study groups and the validity of the paired correlation coefficient was assessed according to Student's t-criterion.

3. RESULTS AND DISCUSSION

A comparative analysis of the average values of micro- macroelements concentrations in the hair of children permanently living in the diamond-producing region (Nyurbinsky, Verkhnevilyuisky districts), with the coal-mining region (Chulman, Neryungrinsky district) and the comparison group (Yakutsk) showed a statistically reliable difference in many chemical elements.

It should be noted that Pb and Mn concentration in the hair of children of Nyurba ulus, is maximum among all children examined.

Verkhnevilyuisky ulus differs from city Yakutsk significantly ($p < 0.05$) by a reduced concentration of Ca (350 ± 26 and 676 ± 48 μg/g), Cu (9.77 ± 0.23 and 13.52 ± 0.98 μg/g), Li (0.02 ± 0.002 and 0.04 ± 0.002 μg/g), Ni (0.42 ± 0.08 и 0.74 ± 0.12 μg/g), Se (0.12 ± 0.01 и 0.22 ± 0.01 μg/g), Sn (0.08 ± 0.04 и 0.2 ± 0.03 μg/g), Zn (153.67 ± 8.21 и 177.84 ± 7.29 μg/g) in hair. At the same time, children from the Verkhnevilyuisky ulus have a relatively higher concentration of Hg (0.37 ± 0.05 and 0.16 ± 0.01 μg/g), Mn (2.54 ± 0.43 and 1.03 ± 0.1 μg/g), Pb (3.79 ± 0.57 2.1 ± 0.35 μg/g), Ti (1.14 ± 0.06 and 0.92 ± 0.06 μg/g) than children from Yakutsk, respectively.

It should be noted that children of the coal mining region (Chulman, Neryungrinsky district) have maximum Ni (3.3 ± 1.3 mg/kg), Mn (11.5 ± 3.06 mg/kg) Ti (25.73 ± 7.9 mg/kg) in hair among the examined children. The average concentration of As exceeds refrain values and is 0.7 ± 0.3 mg/kg. The concentration of Zn is reduced by 2 times and averages 68.6 ± 18.6 mg/kg than in children in the diamond-producing region.

Thus, when analyzing the obtained data, a significant increase of aluminum, mercury, lead – chemical elements in the hair of children of the diamond-producing region with a general toxic effect deserves special attention.

Table 1. Average micro- and macroelement content, μg/kg

Element	diamond-producing region		Yakutsk (control)	coal-mining region
	Nyurbinsky	Verkhnevilyuisky		Neryungrinsky
Al	18.87±2.7	12.28±1.18 #	11.37±0.79	16.4±6.1
As	0.05±0.004	0.05±0.002	0.04±0.002	0.7±0.3
Be	0.01±0.001	0.01±0.001	0.01±0.001	–
Ca	381±34	350±26	676±48	–
Cd	0.12±0.02	0.06±0.01	0.08±0.02	0.04±0.008*
Co	0.03±0.004	0.02±0.003	0.02±0.001	0.08±0.04
Cr	0.43±0.07	0.68±0.03*	0.65±0.04	–
Cu	10.08±0.16	9.77±0.23	13.52±0.98	7.9±3.3
Fe	30.06±1.21	34.46±2.24	37.08±2.16	–
Hg	0.24±0.04	0.37±0.05	0.16±0.01	–
K	341±47	429±98	586±81	–
Li	0.03±0.003	0.02±0.002	0.04±0.002	–
Mg	68.6±10	79.7±14	74.1±5.9	–
Mn	3.51±0.5	2.54±0.43	1.03±0.1	11.5±3.06
Na	518±81	637±220	664±89	–
Ni	0.33±0.06	0.42±0.08	0.74±0.12	3.3±1.3
P	131±3	135±3	137±3	–
Pb	6.12±0.75	3.79±0.57	2.1±0.35	0.4±0.1
Se	0.14±0.01	0.12±0.01	0.22±0.01	–
Si	22.89±1.69	23.68±1.45	23.93±1.57	–
Sn	0.16±0.02	0.08±0.01	0.2±0.03	–
Ti	0.55±0.04	1.14±0.06 *	0.92±0.06	25.73±7.9
V	0.06±0.01	0.07±0.01	0.07±0.01	–
Zn	108.78±5.8	153.67±8.21 *	177.84±7.29	68.6±18.6

Note: bold font – a reliable difference compared to Yakutsk ($p < 0.05$); * – a reliable difference between uluses ($p < 0.05$)

When comparing the elemental hair composition of children living in Nyurba ulus with the data of children living in Verkhnevilyuisky ulus, a more pronounced degree of changes in the concentration in the hair of individual elements in the children of Nyurba ulus is noteworthy. Thus, the data on the content of Al, Cr, Ti, Zn in the hair of children of the examined uluses are significantly different from each other. Children living in the coal-mining southern region of the Republic of Sakha (Yakutia) are highly exposed to toxic elements such as nickel, arsenic.

Thus, children of the Republic of Sakha (Yakutia) living in the diamond-producing region are significantly exposed to toxic elements such as aluminum, lead, mercury, and nickel, arsenic in the coal-mining region.

We assessed the compliance with physiological standards to clarify the nature of changes in trace elements in the hair of children.

The data obtained during the examination of each child were compared with the norm indicators, thus finding out the nature of the change in the content of the elements and calculating the frequency of values beyond the normal range. In order to present the "elemental portrait" of the examined children of the diamond-producing region, the results are presented in the form of diagrams, where Pic. 1 shows the frequency of hyperelementoses and Pic. 2 – the frequency of hypoelementoses.

As shown in the diagram fig. 1, the most frequent hyperelementoses include the increased concentration of Pb, Mn, Fe, Cr, Na in the hair of the examined children in the diamond-producing region of Republic of Sakha (Yakutia).

There is a high frequency of concentration increase of 5 elements in hair: Mn – 88 %, Ti – 52.5 %, Ni 45.7 %, As – 15.3 %, Sr – 8.5 % in the coal mining region.

The pathogenetic importance for the body is not only an increase, but also a decrease of macro- and trace elements concentration. The frequency of hypoelementosis in the examined children of the diamond-producing region and children of Yakutsk, as well as the coal-mining regions is presented in fig. 2.

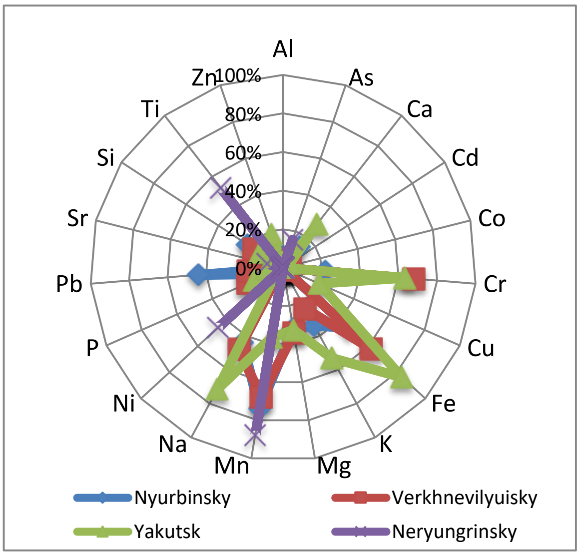

Figure 1. The registration frequency (%) of hyperelements in the hair of children living in the diamond-producing region of the Republic of Sakha (Yakutia) in comparison with Yakutsk and the coal-mining region

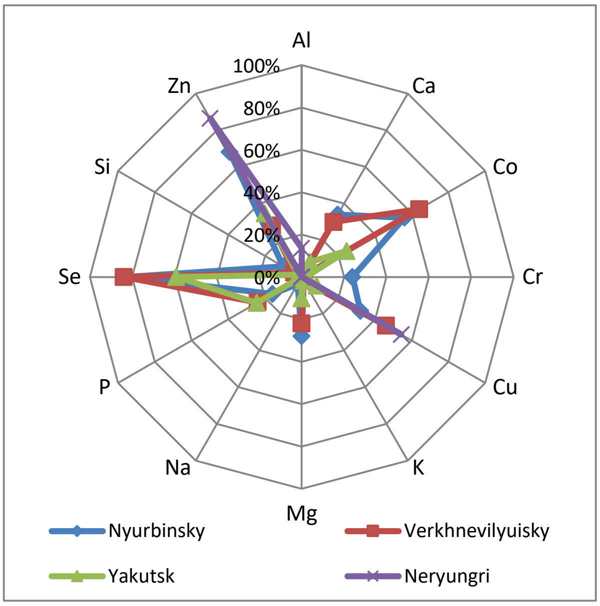

Figure 2. The registration frequency (%) of hypoelementoses in the hair of children living in the diamond-producing region of the Republic of Sakha (Yakutia) in comparison with Yakutsk and the coal-mining region

The diagrams presented in fig. 2 show the most frequent hypoelementoses including changes in Ca Mg Co Cu Se Zn concentration in the hair of the examined children in the diamond-producing region, compared to Yakutsk. There is a high frequency of lowering the concentration of 3 elements (Zn, Cu, Al) in hair in children in the coal mining region.

4. CONCLUSION

Thus, changes in the chemical composition of soils, mineralization of the river basin, suspended particles of coal dust in the air associated with the activities of coal mining enterprises predispose to the occurrence of microelement imbalances. In children of the coal mining region, the microelement profile has features and is characterized by an excess of Ni, Mn, Ti, As (more than 30 %), Sr (more than 10 %) and lack of Cu, Zn, (more than 30 %), Al (less than 10 %).

The content of five chemical elements – Ni, Mn, Sr, Ti, As – in the hair of children living in the coal-mining region of Yakutia was higher than the physiological norm. The content of such elements as Cu, Zn, Al in the hair of children from the coal-mining region of Yakutia was below the physiological norm. However, it is clearly possible to trace a 2-fold increase in the prevalence of hyperelementosis and low prevalence of hypoelementosis in children in puberty. Perhaps this is due to changes in hormonal levels and the presence of pathology of the digestive system. Children of prepubertal age have more hypoelementosis of Cu, Zn, Al, which may be associated with the intensive growth of the organism.

A direct correlation of the average strength between the content of Co, Cd, Pb, As and the weak strength of Mn in the hair of children and their content in water ($p<0.01$) has been revealed the emergence of microelement imbalances in children due to the chemical composition of water in the environment.

Children living in the Vilyui region of the Sakha Republic (Yakutia) are largely exposed to toxic elements such as aluminum, lead, and mercury. The concentration of lead, one of the most common elements of pollutants, exceeds the recommended upper limit of the normal physiological content in the hair of children of the Nyurba ulus, equal to 5 μg/g [5, 6]. Based on the analysis of the frequencies of the deviation of chemical elements in the hair of children from the Vilyui region from the normal level, it can be concluded that there is a high frequency of violations in the content of a significant number of chemical elements. On average, from 70 to 80 % of children had deviations in 6–8 elements simultaneously. In this case, we can talk about the presence of a characteristic elemental profile in the children of the Vilyui region in comparison with the children of the city of Yakutsk.

Thus, the identified changes in the elemental status of children of the Republic of Sakha (Yakutia) have common features depending on the area of residence. The imbalances specificity of children living in industrial regions compared with the control group of children in Yakutsk is excess lead and deficiency of calcium, magnesium, chromium in diamond mining region; and excess of titanium, nickel, arsenic and aluminum deficiency in coal mining region.

We can assume that the features of elemental status are associated with excessive or reduced content of micro- and macroelements in the external environment. These features can lead to an imbalance in the body of the individual and form an elementary "portrait" of the examined population.

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