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Microelement composition of serum in Dolgans, indigenous inhabitants of the Russian Arctic, in the conditions of industrial development of territories

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ABSTRACT

The geochemical conditions of landscapes are the content in the environment of certain chemical elements and their compounds, the lack or excess of which causes deviations in the state of human health. This problem has arisen in connection with the extraction of alluvial diamonds and the forthcoming development of the Tomtor deposit of rare-earth metals in the territories where the indigenous peoples of the North live. The study included 107 indigenous people of the North, belonging to the ethnic group of Dolgans living in the village of Yuryung-Khaya, Anabar district, Yakutia of Russia. The method of mass spectrometry was used to study the content of 13 trace elements in blood serum (P, Sc, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Rb, Sr, Cs, Pb). The study revealed an increase in the content of the macroelement phosphorus (148 mg/L) and trace elements of chromium (277 µg/L), manganese (133 µg/L), iron (5219 µg/L), nickel (57 µg/L) in serum of Dolgans, which may affect the development of diseases of the cardiovascular system and other diseases among indigenous inhabitants of the Arctic under conditions of industrial development of territories.

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Introduction

Northen Siberia produces alluvial diamond deposits. Alluvial diamond reserves are located in sediments under the channel of numerous tributaries of the Anabar River. The development of the Tomtorsky rare-earth metal deposit begins on the watershed of the right tributaries of the Anabar River (Figure 1) [1]. During development, the natural landscape structure and ecological situation have undergone and will continue to undergo significant changes. Extraction of placer diamonds is carried out along the riverbed in the winter after freezing by the method of explosions and excavation of bottom soil [2]. Of particular danger during the development of the deposit is the infection of the surface layer of soils with chemical elements with increased toxic and radioactive properties contained in the ore. The filtration effluents of the downstream mouth of the estuary dam of the processing plant form a clear technogenic hydrochemical anomaly of manganese (Mn), chromium (Cr), nickel (Ni), copper (Cu), lead (Pb) and molybdenum (Mo) [3,4]. Toxic elements, migrating to streams and rivers in the form of mineral particles, accumulate in bottom sediments and gradually decompose, over time, fall into large watercourses, on the banks of which settlements are located. The local population drinks this water, uses it for household purposes, eats fish that lives in this water and feeds on the microorganisms that inhabit these streams, thereby accumulating toxic elements in its body [5–7]. The danger of areal environmental pollution by toxic radioactive elements and heavy metals is associated with the wind dispersal of mineral particles from the quarry and from dumps of off-balance ores [3,4]. Area dispersion of mineral particles with toxic elements accumulates in plants, primarily in the reindeer moss, from where it enters the body of deer and birds. When consumed in food, a person also accumulates toxic elements in his body. Poisoning the body as a result of these factors, the process is hidden and "stretched" in time, depends on the individual characteristics of the human body and lifestyle, eating behaviour, as a result, it is impossible to establish the exact cause of a disease [8].

The European Union has taken several measures to control the presence of certain metals in the environment as a result of human activities [9,10]. Heavy metals show a great tendency to form complexes; as a result, changes in the molecular structure of proteins, breaking of hydrogen bonds or inhibition of enzymes can occur. These interactions, among other things, can explain the

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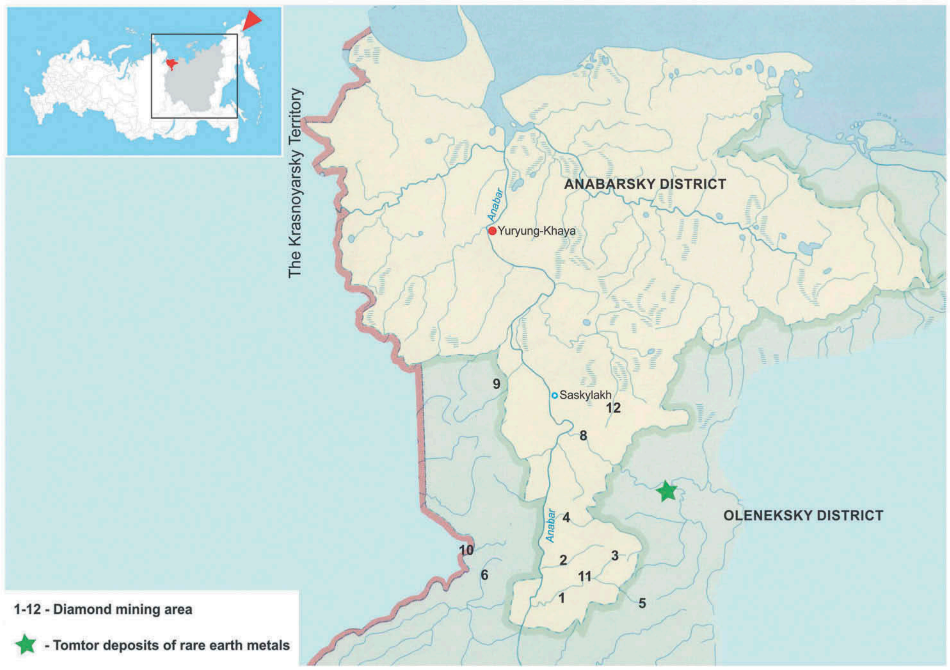

Figure 1. The map of the study area.

toxicological and carcinogenic effects of heavy metals [8,11]. Modern scientific studies have appeared that prove the worst that some trace elements – chromium (Cr), nickel (Ni), arsenic (As), selenium (Se), cadmium (Cd), mercury (Hg), lead (Pb) interfere with gene expression and contribute to the development of diseases, modulating with an epigen. Many heavy metals/environmental pollutants cause abnormal changes in the epigenetic status of the body, which are inherited by subsequent generations [12].

In this regard, we conducted this study with the aim of establishing a regional base level of indicators of the elemental status of the organism of indigenous inhabitants of the Arctic, on the basis of which future studies will be carried out.

Materials and research methods

This study involved 107 indigenous people of the North, Materials and research methods. In this study of blood composition, 107 dolgans participated. Dolgans are the indigenous people of the North living in Northen Siberia and are considered the northernmost Turkic-speaking people in the world. According to the results of the All-Russian Census of 2010, the population of Dolgans was 7,900 people. To date, Dolgans lead a nomadic and semi-nomadic lifestyle: they live in isolation in the tundra in national villages, are engaged in reindeer husbandry, hunting and fishing. A survey of the adult population of the village of Yuryung-Khaya, where 600 dolgans live, was conducted. The village is located on the banks of the Anabar River, located in the vicinity of the territories of industrial development (Figure 1). An informed written consent was obtained from each subject and blood collection was performed only after permission of the institutions ethic committees.

Serum was separated and stored in aliquots frozen at a temperature of −40°C. Quantitative determination of the metal content in blood serum was performed by inductively coupled plasma mass spectrometry (ICP MS) using an Elan 9000 instrument (Perkin Elmer, USA) at the Institute of Tectonics and Geophysics (Khabarovsk). The serum levels of the following 13 elements were studied: phosphorus (P), scandium (Sc), titanium (Ti), chromium (Cr), manganese (Mn), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn), rubidium (Rb), strontium (Sr), caesium (Cs), lead (Pb). Decomposition of the samples was carried out in glass-carbon crucibles by an open method. An aliquot of 0.5 ml was taken to determine the concentration of metals. To decompose the sample, 1 ml conc. HNO3 and H2O2, after evaporation, 10 ml of 10% HNO3 was added to the dry residue and warmed until the precipitate was completely dissolved. After this, the solution was cooled to room temperature, transferred to a volumetric tube and 2% HNO3 was added to a volume of 50.0 ml. Calibration lines were built on three points: 0, 20, and 40 µg/dm3, for which we used Perkin Elmer multi-element standard solutions. To reduce the influence of the matrix effect on the determination of element concentrations, we used the internal standard method, which was used as the isotope indium 115In, it was additionally added to all samples at a concentration of 40 µg/dm3. If possible, the most common isotopes with minimal isobaric and polyatomic interference were selected to determine the concentration of elements. The content of the studied chemical elements in the blood serum was expressed in micrograms per litre (µg/L). The limits of detection (LOD) were down to 0,001 µg/L.

Statistical processing of the results was carried out using the Statistica 12 application software package. The normality of the distribution of quantitative traits was checked using the Shapiro-Wilk criterion. A descriptive analysis of the numerical characteristics of the attributes was carried out (Me (Q25–Q75) – median (interquartile range 25 and 75). When comparing the differences in the groups, nonparametric evaluation criteria were used (U-test by the Mann-Whitney method). correlation analysis with calculation of Spearman's correlation coefficient (rs).The critical value of significance level (p) was taken equal to 0,05

Results

107 dolgans took part in the study of the microelement composition of the blood, of which 35 were men (32.7%), 72 women (67.3%) (Table 1). The age of the subjects was from 20 to 77 years. The average age of men was 51 (42–60) years, for women – 45.5 (34–54) years, without statistically significant differences.

The content of one of the major "structural" elements of man, phosphorus (P), was found to be increased in Dolgans when compared with literature data (Table 2). The content of trace elements in the serum of Dolgans is presented in Table 3. Comparison of the median of serum trace elements of Dolgans, studied by the method of MS-ICP, with the values of the literature data are given in Table 4.

The analysis of the content of elements separately in men and women (Table 5). When comparing by sex the medians of all the studied macro- and microelements, except rubidium (Rb), an element with a normal

Table 1. Age and gender distribution of Dolgan people who participated in this study.

Age, years	Male	Female	Total
20–29	4	13	17
30–39	3	13	16
40–49	9	13	22
50–59	10	25	35
60–69	7	7	14
70–77	2	1	3
Total	35	72	107

Table 2. The content of macroelement in the serum of Dolgans, mg/L.

Macroelement	n	Median	1st Qu. 25%	3rd Qu. 75%	Mean	SD[a]	Min	Max	Sh-W test[b]	Siberia, Russia 2005[c]	Switzerland 2017[d]	Germany, 2018[e]	St.Petersburg, Russia, 2015[f]
Phosphorus (P)	107	148,02	124,01	171,60	150,37	38,63	86,37	263,36	0,005	111–133	116,3	115,0	86,2

[a]SD – standard deviation.
[b]Sh-W test – Shapiro-Wilk test.
[c]Fedorov VI [61].
[d]Konz T. et al. [24].
[e]Wach S. et al. [25].
[f]Gulyaev NI et al. [49].

Table 3. The content of trace element in the serum of Dolgans, μg/L.

Microelement	n	Median	1st Qu. 25%	3rd Qu. 75%	Mean	SD[a]	Min	Max	Sh-W test[2]
Scandium(Sc)	105	13,9	9,1	19,6	15,0	7,9	1,93	48,82	0,000
Titanium (Ti)	101	151,4	84,2	246,5	217,2	215,8	3,6	1008,6	0,000
Chromium (Cr)	106	276,7	246,7	324,7	286,3	76,5	66,1	728,5	0,000
Manganese (Mn)	99	133,4	71,2	173,3	135,4	79,3	13,2	380,2	0,000
Iron (Fe)	98	5219,4	3123,3	9197,1	6707,9	5077,1	496,7	25,475,7	0,000
Nickel (Ni)	83	57,1	23,4	146,1	116,5	143,4	0,8	633,8	0,000
Copper (Cu)	78	1386,4	1003,8	1921,6	1488,0	724,7	174,5	3539,4	0,007
Zinc (Zn)	93	1076,1	677,5	1686,2	1225,7	750,3	18,8	3202,0	0,019
Rubidium (Rb)	105	299,5	264,4	346,3	303,0	56,3	126,9	414,8	**0,219**
Strontium (Sr)	87	146,6	78,0	234,1	168,9	115,3	5,2	486,6	0,001
Caesium (Cs)	103	1,05	0,69	1,39	1,10	0,53	0,09	3,00	0,010
Lead (Pb)	70	9,5	3,6	23,8	16,0	16,4	0,37	80,1	0,000

[a]SD – standard deviation; [2]Sh-W test – Shapiro-Wilk test.

Table 4. Comparison of the median of trace element in the serum of Dolgans with literature data, μg/L.

Microelement	Median	Siberia, Russia, 2005[a]	Switzerland, 2017[b]	Germany, 2018[c]	St.Petersburg, Russia, 2015[d]	Brazil, 2016[e]	Novgorod, Russia, 2014[f]	Korea, 2017[g]	USA, 2014[h]	Swedish, 2001[i]	Zurich, Switzerland, 2001j
Scandium(Sc)	13,9										
Titanium (Ti)	151,4	0,8	6,75	0,551							
Chromium (Cr)	276,7		5,69	33,0	100	1,96			3,38		
Manganese (Mn)	133,4	30	14,29	1,19	67	0,58–0,65	3,9		3,89		0,18
Iron (Fe)	5219,4	2000	2137,4	1320			1140		634		1323
Nickel (Ni)	57,1	0,26–2,1	8,75	3,1	25	0,72–0,98	5,6				4,97
Copper (Cu)	1386,4	800	1903,4	944,5	1420	910–1493	888	990,5	1145	1000–1300	915
Zinc (Zn)	1076,1	340–570	1607,2	682,0	2090	721,5–741,7	1070	871,5	710	810–1000	820
Rubidium (Rb)	299,5		9,46		240					220–250	172
Strontium (Sr)	146,6		112,2	21,95	110						34
Caesium (Cs)	1,05	0,22–0,27	<LOQ								
Lead (Pb)	9,5	0,16–0,34	0,61	1,93	22					0,19–0,58	

[a]Fedorov VI [61].
[b]Konz T. et al. [24].
[c]Wach S. et al. [25].
[d]Gulyaev NI et al. [49].
[e]Rocha GHOet al. [62].
[f]Agadzhanyan NA et al. [63].
[g]Kim H-J et al. [35].
[h]Harrington JM et al. [64].
[i]Barany E. et al. [45].
[j]Forrer R et al. [46].

Table 5. Comparison of median element values in serum Dolgan by gender,μg/L.

	Male				Female				
Trace element	n	Me(Q25-Q75)	min	max	n	Me(Q25-Q75)	min	max	p
Phosphorus (P)	35	143,9 (124,5–166,8)*	87,3*	256,1*	72	150,7 (120,6–174,1)*	86,4*	263,4*	0,765
Scandium(Sc)	34	13,4 (10,3–18,3)	3,4	28,4	71	14,3 (8,4–19,9)	1,9	48,8	0,816
Titanium (Ti)	34	157,4 (92,0–232,4)	5,42	851,5	67	140,2 (63,3–278)	3,6	1008,6	0,877
Chromium (Cr)	35	270,4 (237,4–321,4)	66,1	473,8	71	279,4 (253,6–326,3)	153,0	728,5	0,252
Manganese (Mn)	33	116,4 (79,7–188,4)	29,5	380,2	66	134,7 (69,2–170,1)	13,2	371,9	0,968
Iron (Fe)	32	4886,8 (1928,2–8449,0)	496,7	22,201,0	66	5296,4 (3797,5–9991,1)	1332,4	25,556,5	0,060
Nickel (Ni)	31	61,3 (19,9–142,4)	0,81	608,4	52	56,2 (25,7–162,5)	1,9	633,8	0,756
Copper (Cu)	22	1386,4 (1000,2–1952,7)	174,5	3151,3	56	1365,4 (997,5–1910,0)	339,1	3539,4	0,942
Zinc (Zn)	29	1035,4 (653,6–1629,6)	64,4	2727,4	64	1094,3 (761,0–1782,7)	18,8	3202,0	0,753
Rubidium (Rb)	35	323,0 (286,6–372,5)	214,5	414,8	70	292,9 (256,2–332,6)	126,9	413,8	**0,005**
Strontium (Sr)	26	181,6 (73,8–298,3)	11,2	486,6	61	134,4 (76,9–226,4)	5,2	428,9	0,256
Caesium (Cs)	35	1,24 (0,94–1,39)	0,09	1,90	68	0,94 (0,66–1,39)	0,13	3,00	0,111
Lead (Pb)	23	12,8 (3,9–23,5)	1,5	80,1	47	8,6 (3,5–26,0)	0,37	59,2	0,524

Me (Q25–Q75) – median (interquartile range 25 and 75).
p -statistical significance of the differences by the Mann-Whitney U-test.
* – mg/L.

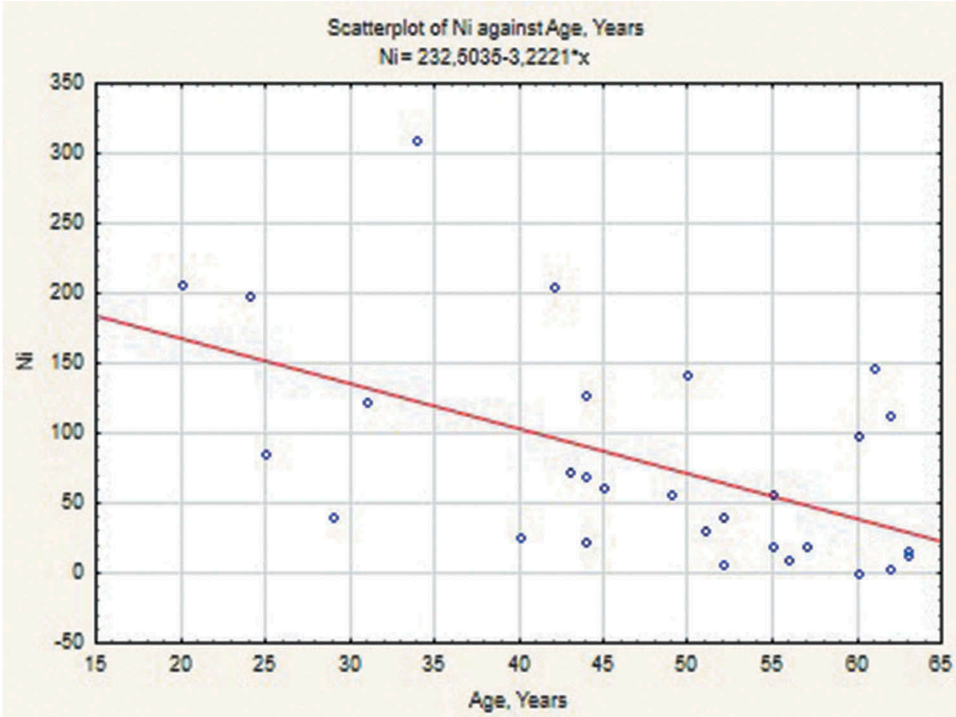

Figure 2. Dependence of serum nickel (Ni) in men on age.

distribution in the sample, no significant differences were revealed.

Further, the subjects were divided into two groups by age: the first group of young people – from 20–49 years old and the second group of the elderly – from 50–77 years old. The analysis separately by sex in these age groups revealed that nickel (Ni) in serum in young men was significantly higher than in older men (79.0 µg/L versus 20.0 µg/L, $p = 0.009$) and a negative correlation communication ($rs = -0.35$; $p = 0.049$) (Figure 2).

When comparing with young women, a group of elderly women showed a statistically significant high phosphorus (P) content (154.60 mg/L versus 133.91 mg/L, $p = 0.037$), while no correlation was found.

Discussion

Pollution of the living environment is a significant factor leading to undermining the health of the indigenous people of the North. In Russia, studies of the microelement status in the indigenous peoples of the North were mainly carried out to study the composition of the hair, and the few studies of trace elements in the blood of Aboriginal people were carried out by various methods [13–17]. Unfortunately, studies of the microelement status of blood in aborigines of other circumpolar territories are also still very scarce [18–22].

Phosphorus (P) is an essential element in the human body and an important clinical biomarker in serum. The content of serum macronutrient phosphorus (P) in Dolgans was higher (148 mg/L) than in residents of temperate latitudes (86–133 mg/L, Table 2), which may be due to the preserved traditional fish nutrition and the characteristics of the geochemical province [23]. In men (144 mg/L) and women (150 mg/L), no statistically significant differences were found in the phosphorus content. But a statistically significant high content of serum phosphorus was found in women older than 50 years – 155 mg/L, which correlates with studies [24]. In a study of patients with bladder cancer, an increase in the concentration of serum phosphorus to 157 mg/L was noted compared with the healthy control group (115 mg/L) [25].

Our study revealed the content of the trace element (Sc) trace element in the serum of Dolgans – 14 µg/L, without significant gender differences. Scandium is a rare earth element (REE) that will be mined in the Tomtor field. In the hair of the miners in China the result shows that the content of REE and Fe in the exposure group is significantly higher than that of the control group, but the content of Ca in the exposure group is significantly lower than that of the control group. Some differentially expressed proteins, in which 16 proteins are upregulated and 13 proteins are downregulated, may be related to neurovirulence, hepatotoxicity, pathological fibrosis, osteoporosis, and anticoagulation caused by REEs [26]. In children of two ethnic groups of Taiwan, serum Sc (2, 9 and 4.1 μg/L) was higher in girls [27].

The level of serum titanium (Ti) in Dolgans was high (151 μg/L), in men it was slightly higher (157 μg/L) than in women (140 μg/L). Ti is frequently used in implants and prostheses and it has been shown before that the presence of these in the human body can lead to elevated Ti concentrations in body fluids such as serum and urine, with values ranging between 0,200 μg/L and 200 μg/L [28–30]. The typical basal Ti level in human serum was found to be <1 μg/L, while values in the range of 2–6 μg/L were observed for implanted patients [28]. In patients with cancer (0,945 μg/L), a twofold increase in Ti is noted than in healthy patients (0,551) [25].

Chromium (Cr) and nickel (Ni) are anthropogenic pollutants. In the Urals, Taimyr, Siberia, in industrial zones of Russia, soil, water and air are polluted with heavy metals (Cr, Ni, Pb, Mn, Zn), which are received in excess into the body of the population of these regions [8,31–33]. When studying the health status of schoolchildren of Kazakhstan living in the region of extraction of chromium ores and in the city of chromium-processing enterprises, 11 times more birth defects were detected, respiratory, blood, nervous system and skin diseases were 4–5 times more than in the control group of children from an environmentally friendly region. The blood content was found to be Cr 4 times, Ni 3 times more in children living in these industrial regions [33]. In our study, serum Cr (277 μg/L) did not differ by sex in Dolgans and was higher than published data (1,96–100 μg/L).

In Dolgans, serum Ni was established at 57 μg/L, which is higher than the literature data, without significant gender differences. Moreover, in young men, the Ni content was significantly higher than in older men (79,0 μg/L versus 20,0 μg/L). It is possible that active employment and the dynamic daily life of reindeer herders and hunters can make young Dolgans more susceptible to heavy metals in the workplace, as well as in the environment. In a study of patients with cancer, an increase in the concentration of serum Ni to 22,5 mg/L was noted, compared with the healthy control group (3,0 mg/L) [25]. For non-smokers in Canada, a positive correlation was found between serum Ni levels and beef kidney consumption [19]. In the studied Dolgans, meat, deer offal, and fish mainly predominate in nutrition.

Manganese (Mn) is often a toxicological concern, as excessive exposure to the metal can lead to progressive neurodegenerative damage, leading to syndromes similar to Parkinson's disease [34]. In our study, manganese (Mn) in serum of Dolgans was found to be 133 μg/L, which is higher than the literature data (0,58–67,0 μg/L). In our observation, serum Mn in women (135 μg/L) is 16% higher than in men (116 μg/L), which is consistent with a study in Korea, China, Italy, where the female population in the blood Mn by 11–20% higher than men [35–37].

In human blood, iron (Fe) is mainly found in haemoglobin, while in men it is higher than in women. In Russia, the population of the northern regions has iron deficiency anaemia twice as often as in the middle zone [38,39]. As in circumpolar countries and in the world, the incidence of anaemia is higher among indigenous groups compared with the general population [40–42]. We got conflicting results. In our study, the content of iron (Fe) in the serum of Dolgans was 5220 μg/L, which is 2–2,5 times more than the accepted standards. In various publications, serum Fe has been found to be between 600–2100 μg/L (Table 4). In our study, the iron content in 66 women was higher (5300 μg/L) than in 32 men (4900 μg/L), although not statistically significant, while increasing with age. The excess content of iron (Fe) is associated with cytotoxic effects, which are caused by the ability of iron as a metal with a variable valency to initiate chain free radical reactions leading to lipid peroxidation of biological membranes, toxic damage to proteins and nucleic acids. The clinical consequences of iron overload (Fe) have been studied in patients with haemochromatosis. The accumulation of iron in the parenchymal organs of these patients is associated with degenerative changes in the cell parenchyma and the progressive development of fibrous tissue, which leads to irreversible dysfunction of vital organs, of which the liver, pancreas and heart are most vulnerable [43,44].

Copper (Cu) and zinc (Zn) are one of the main food metals necessary for numerous metalloproteins of biochemical reactions of the human body. In this study, the content of serum copper (Cu) was 1386 μg/L, with very different minimum and maximum values, no difference in the Cu content by gender, within the reference values (800–1900 μg/L). The content of serum Cu in Inuit, Mestizo, and Caucasoid women living in Arctic Canada did not differ by ethnic group [20]. According to published data, the Cu content in women is 15–17% higher than in men [35,37,45–47].

In this study, the median Zn content in Dolgan serum was 1076,1 μg/L, also within the range of published data (340–2090 µg/L). In women in labour in Arctic Canada, the content of serum Zn between Inuit and Caucasoids did not differ significantly [20]. In contrast, different data were established in different peoples of the North in Russia, for example, in coastal Eskimos in whole blood, the Zn content was higher than in the tundra Chukchi [14]. In Switzerland, in 120 elderly people, serum Zn was 1607 µg/L, decreasing with age, while women had higher Zn levels than men, as in our study [24]. In human diseases, Zn levels change, so when studying the serum of patients with tuberculosis (660 µg/L), a statistically significant decrease in Zn content was noted compared with healthy (1070 µg/L) [48]. In the Northwestern region of Russia, a statistically significant decrease in serum Zn level was noted in patients with calcified aortic stenosis (700 µg/L) compared with the control healthy group (2090 µg/L) [49]. In the serum of patients with noncancerous formations of the bladder (978 µg/L), on the contrary, an increase in the level of serum Zn was noted compared with healthy (682 µg/L) [25].

Most rubidium (Rb) (about 40%) is ingested with drinks like drinking water, tea, and coffee. In our study, serum Rb Dolgan was 300 µg/L, which is higher than published data (Table 4). According to our data, the median of serum Rb in male Dolgans (323 µg/L) was statistically significantly (p = 0,005) higher than in women (293 µg/L). In Russia, in whole blood, in tundra Chukchi, the level of Rb was higher than that of coastal Eskimos, while in both ethnic groups in men Rb was higher, as in our study [14]. The role of rubidium in the body is poorly understood. In China, 1,400 pregnant women had a serum Rb level of 223 µg/L and their content did not change with gestational age [50]. In Spain, studies show that, probably due to an increase in water and air intake, serum rubidium is significantly increased in male anaerobic sports athletes (254 µg/L) compared to men of low physical activity (147 µg/L) [51]. There is a study that the level of potassium and rubidium was significantly reduced in brain tissue in patients with Alzheimer's disease compared with the healthy group, but the decrease in serum Rb (170 µg/L) was insignificant, and in erythrocytes and cerebrospinal fluid was within norms [52].

In Dolgan`s serum, strontium (Sr) is set to 146 µg/L, which is higher than the literature data. In malignant formations, the level of serum Sr rises 2 times in comparison with healthy ones. Thus, serum Sr levels were established in patients with bladder cancer (52 µg/L) and in healthy (21 µg/L) [25], in patients with malignant formations of epithelial tissues (82 µg/L) and in the control healthy group (43 µg/L) [53]. Serum Sr level increased 3 times in patients with calcified aortic stenosis (320 µg/L) than in the control healthy group (110 µg/L) [49]. Using ISP-AES, serum Sr was determined in residents of temperate latitudes of Russia (60 µg/L) and 10 times higher in residents of northern Azerbaijan (620 µg/L) [54].

In our study, the ultramicroelement caesium (Cs) was detected in the serum of all subjects and the median was 1.05 µg/L, in men – 1.24 µg/L, in women less – 0.94 µg/L, the content of Cs did not depend on age that correlates with other studies. In the Korean population, the GM of blood Cs levels is 2.39 µg/L, which is similar in China (2.01 µg/L) and a little less in India (1.0 µg/L). In the Korean population, GM of blood Cs levels was 2.65 µg/L for men and 2.45 µg/L for women ($p < 0.001$). A distinct pattern of age association in Cs could not be found [35].

Lead is a toxic metal that is widely used in industry. Over the past decades, due to the reduction in the use of lead-containing gasoline, the ban on the production of lead-containing paints, and the tightening of control over industrial emissions of lead, industrialised countries have led to a decrease in the concentration of lead in the blood of the population [10,35,36,55]. The German Human Biomonitoring Commission gives Pb (RV95) in whole blood for men – 90 µg/L, in women – 70 µg/L, in children – 35 µg/L [56]. The study revealed a GM of 15.97 µg/L for blood Pb in this Korean population, which is lower than that of Chinese (34.9 µg/L), Italian (33.4 µg/L), Spanish (46.7 µg/L), and Brazilian (65.4 µg/L) populations, while the concentration of lead in whole blood was significantly higher in men (21.54 µg/L) than in women (15.07 µg/L) ($p < 0.01$) [35]. A cohort of 593 middle-aged men exposed to prolonged exposure to low doses of lead was observed. It was established that the accumulated level of lead in bones, and not in blood, regardless of other factors, is associated with an increase in pulse pressure. At the same time, lead accelerates the development of age-related changes in arteries, increasing their stiffness, pulse pressure, and contributes to increased mortality from CVD in industrialised countries [57]. It was revealed that in Russian cities with industrial facilities for the processing of lead there is a high level of lead in soil and air, in 25–28% of children in whole blood the lead content exceeded the safe level of 5 µg/dL, in 2–7% of children an excess of the level in 10 µg/L [58,59]. In adult residents of the western coast of Canada (non-smoking oyster growers), blood lead levels increased with age and in men was statistically significantly higher. The blood lead content had statistically significant relationships with the consumption of oysters, spinach, seaweed, and potatoes, which can absorb lead from the surrounding water and soil [19]. When researching maternal and cord blood in Arctic Canada, The Pb GM was significantly higher in Dene/Métis (30.9 µg/L) and Inuit (31.6 µg/L) participants than in the Caucasian group (20.6 µg/L) ($p < 0, 0001$), while there is a high percentage of smokers among participants of Inuit (77%) and Dene/Metis

(48%) [20]. In the Russian Arctic, anthropogenic environmental pollution of Taimyr with heavy metals contributes to their accumulation (Cu, Pb, Ni) in the blood of the indigenous and alien population [17,60]. In our study, the level of serum lead (Pb) in Dolgans was 9.5 µg/L, while men were expected to have higher concentrations (12.8 µg/L) than in women (8.6 µg/L), which is explainable lifestyle and occupation.

Our study revealed a high content of the phosphorus (P) macroelement and the chromium (Cr), manganese (Mn), iron (Fe), nickel (Ni) microelements in serum Dolgans, which can affect the development of diseases of the cardiovascular system and other diseases in indigenous residents of the Arctic.

Conclusion

The first study was conducted to evaluate the content of 13 trace elements in serum of Dolgans, the indigenous people of the North living in the territories of industrial development of the Russian Arctic. Microelement concentrations were measured using the ICP-MS method, with which it is possible to study several elements simultaneously and with high sensitivity. Of the weaknesses of the study, it should be noted that the sample was limited. The number of men was half that of women. Young men Dolgans from 20–40 years old did not participate in this study due to the absence at the time of the study in the village, they roam for many months by reindeer herders, hunters and fishermen on the tundra. A laboratory study of serum samples was performed once. Nevertheless, this study is the starting point in the study of the microelement composition of the blood of the indigenous peoples of the North of Russia in the context of developing industrial development of the Arctic.

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Disclosure statement

The authors declare that they have no conflict of interest.

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Ethical approval

Written informed consent was obtained from all individuals. This study was approved by the local Committee on Biomedical Ethics of the Yakut Science Center of Complex Medical Problems (Yakutsk, Russia, Protocol No. 46, 2017).

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