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Implementation of the biomonitoring system in large scientific expeditions on the example of the scientific and educational project "Arctic Floating University"

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Currently, biomonitoring research is actively developing in the Arctic region, despite this, groups of people who temporarily come to the Arctic remain outside the national monitoring system, unlike the local population. Participation in expeditions on ships implies special living conditions, such as limited space, sensory deprivation. The study aims to analyse the biochemical parameters of blood, the content of essential, toxic elements, persistent organic pollutants (POPs) and vitamin D in samples of the expedition group temporarily coming to work in extreme Arctic conditions. Scientists carried out a study on board the Mikhail Somov scientific expedition vessel as part of the Arctic Floating University project. The participants were 50 people: 26 men and 24 women aged 20 to 72 years. As a result of the analysis, the authors have determined: 8 biochemical blood parameters, vitamin D levels by high-performance liquid chromatography with tandem mass spectrometric detection, the content of essential (Co, Mn, Se, Cu, Zn), toxic elements (As, Cd, Hg, Pb) using an inductively coupled plasma mass spectrometer and POPs by gas chromatography-mass spectrometry. Almost 90% of the expedition participants had vitamin D concentrations below 20 ng/ml, which indicates a deficiency of this vitamin in the body. After conducting a comparative analysis between the expedition group and the permanent population of the Nenets Autonomous Okrug (NAO), it was found that the expedition group significantly reduced the content of not only toxic compounds (As, Cd, Hg, Pb, POPs), but also essential elements (Co, Mn, Se, Cu, Zn), according to compared to the local population. It is worth noting that the concentration of arsenic in the expedition group is 65 times lower (0.12 μg/L) than in permanent residents of the Arctic zone of the Russian Federation (7.29 μg/L), and the concentration of lead in the group of expedition workers was 42 times lower (0.30 μg/L) than in the local population (15.21 μg/L). The data obtained provide information about the elementary and toxic status of the urban population of the Russian Federation. One of the reasons for such differences may be the predominantly traditional lifestyle of the local NAO population and the biomagnification of toxic substances in food chains. If biomonitoring studies are carried out by specialists on an ongoing basis and the data obtained is accumulated, then a basis may appear for predicting risks of both a short-term and long-term nature. The conducted research contributes to the expansion of the biomonitoring system at the national level.

Keywords: *biomonitoring; heavy metals; essential elements; persistent organic pollutants; expedition group; population of the Arctic zone of the Russian Federation*

Ethics. The study was conducted in accordance with the local Ethics Committee of the Northern State Medical University (NSMU) (extract from the minutes of the meeting dated 06/09/2021 No. 04-06-2021).

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Introduction. Recently, the scientific community has been paying increasing attention to the problem of protecting the health of the indigenous population and people temporarily coming to the Arctic, which is reflected in the growing number of publications on this topic. The active development of the Arctic zone in the Russian Federation (AZRF) is associated with the intensive involvement of human resources in various sectors of oil and gas production with the introduction of shift and expeditionary work. The problem of preserving the health of the able-bodied population in the conditions of the Far North has acquired special relevance and great economic importance [1, 2]. The Arctic is a whole complex of natural and climatic factors that create a certain and significant risk of health disorders of persons exposed to them. The conditions of the Arctic region are harsh: low temperatures, the predominance of windy weather with blizzards and hurricanes in winter, a long period without sunlight, low phytoproductivity of landscapes [3].

It is worth noting that in relation to the permanent resident population, specialists conduct research that includes biomedical, socio-hygienic monitoring and the implementation of their results at the national level [4, 5–7]. Recently, scientists have also monitored the health status of shift workers [2, 8–9]. While members of the expedition groups temporarily arriving in the Arctic remain outside the national biomonitoring system. Unfavourable climatic and geographical conditions of the Arctic zone, such as low air temperatures, atmospheric pressure fluctuations and stormy conditions, affect the well-being of scientists engaged in research activities. Any stress causes the mobilization of functional reserves, which is constantly happening in the Arctic due to the peculiarities of the Arctic climate and working conditions.

For the same effect, in some people, the voltage of regulatory systems is low (the operating level of functional voltage), while in others the voltage may be pronounced [10]. Everything depends on the functional reserves of the body, on the reserve of vital forces. Participation in expeditions on ships implies special living conditions, such as limited space, sensory deprivation, in which expedition activities take place, therefore, the expedition group can become the object of research.

«The Arctic Floating University» is a scientific and educational expedition project implemented since 2012 in the high latitudes of the Russian Arctic. The organizers of the project are Northern (Arctic) Federal University named after M.V. Lomonosov (NArFU), Hydrometeorology and Environmental Monitoring (Rosgidromet), Russian Geographical Society. «Arctic Floating University» is a platform that brings together young people, researchers and various scientific projects from all over the world in order to explore the Arctic territories, train personnel and develop a multilateral dialogue and partnership in the field of joint scientific and educational development of the Arctic.

The thirteenth voyage of the «Arctic Floating University — 2021» took place on the Mikhail Somov scientific expedition vessel (SEV) in the period from June 10 to July 01, 2021, in twenty-one days the ship passed along the route: Arkhangelsk — Malye Karmakuli — Cape of Desire, Novaya Zemlya Archipelago — "Cape of Desire — O. Salm" — Franz Josef Land (landings on Hooker Island, Hayes Island and Bell Island) — Arkhangelsk.

The study aims to test biomonitoring research protocol on marine expeditionary groups temporarily coming to work in extreme Arctic conditions.

Materials and methods. The study participants were selected in accordance with the protocol, which was approved by the local Ethics Committee of the Northern State Medical University (NSMU), (extract from the minutes of the meeting dated 06/09/2021 No. 04-06-2021).

Inclusion criteria were: 1) the age must be 18 years (the age of majority under Russian law) and older; 2) physical presence on board of the Mikhail Somov vessel during the expedition period from June 10 to July 1, 2021. There were no requirements for gender, nationality, profession, lifestyle and nutrition. Since all participants underwent a medical examination before the expedition, and the ship's crew members undergo regular medical examinations, the authors proceeded from the position that all participants in the study are conditionally healthy.

The participants were informed about the protocol of the study under signature, they also signed the consent to voluntary participation in the study and consent to the processing of personal data in accordance with Article 9 of the Federal Law "On Personal Data" dated 07/27/2006 No. 152-FZ. Participation in the study was voluntary.

The work of the research team on board the ship consisted of the following stages:

1) survey of participants;
2) sampling of blood from the participants;
3) primary preparation of selected biological samples;
4) freezing and storage.

The survey. All the study participants filled out pre-prepared and printed questionnaires. The questionnaires consisted of the following questions: full name, date of birth, weight, height, level of education, main activity, etc.; lifestyle issues — bad habits and intake of vitamins and dietary supplements, etc.

The study involved 50 people (26 men and 24 women aged 20 to 72 years). Participants of the scientific and educational expedition project "Arctic Floating University — 2021", employees of the Russian Arctic National Park, participants of the environmental project "Master of the Arctic", employees of the A.N. Severtsov Institute of Ecology and Evolution of the Russian Academy of Sciences and crew members of the Mikhail Somov SEV joined the study ***(Table 1)***.

Sampling. The medical staff carried out blood sampling in a special room during the first three days of the expedition after the ship left the port of Arkhangelsk (from June 11 to 13, 2021). Blood sampling was carried out in an outpatient clinic on board of the ship. Blood was collected in vacuum tubes (Improvacuter, Russia) to determine the following indicators: toxic and essential elements, persistent organic pollutants (POPs), biochemical parameters, as well as vitamin D ***(Fig. 1)***.

Primary sample preparation of selected biological samples. All three vacutainers were slowly cooled for 45 minutes to room temperature. After cooling, all vacuum tubes, with the exception of a vacuum cleaner for essential and toxic elements, were subjected to a centrifugation procedure (Biosan, Latvia) for 10 minutes at a speed of 3000 turnovers per minute to obtain serum and plasma. After centrifugation, only plasma was taken from a vacuum tube with EDTA K2 (9 ml) with a disposable Pasteur pipette and transferred to a 10 ml glass vial (Glasstechnik Grafenroda, Germany). Serum from a test tube with a coagulation activator was transferred to three cryo tubes (SSlbio, USA) with a volume of 1.5 ml. Then all the prepared samples (whole blood in a vacuum cleaner, plasma in a glass vial and serum in cryo tubes) were frozen in a specially designated freezer (Gorenje, Serbia) at a temperature no higher than –18°C.

Upon arrival of the Mikhail Somov SEV at the port of Arkhangelsk, the samples were delivered to the Arctic biomonitoring laboratory of NArFU in medical thermocontainers (ThermoKont MK, Russia) without defrosting for further work with the samples.

Laboratory analysis. We have determined 8 biochemical parameters in the blood using the Random Access A-15 automatic biochemical analyser (Biosystems, Spain) at the Central Research Laboratory of Northern State Medical University (NSMU), (Arkhangelsk).

Laboratory assistants determined the concentration of vitamin D (25-hydroxyvitamin) in blood serum by high-performance liquid chromatography with tandem mass spectrometric detection (HPLC-MS/MS). Agilent 1200 liquid chromatograph (USA), AB Sciex 3200 MD mass spectrometer (Singapore), in the laboratory of Helix Research and production company (license

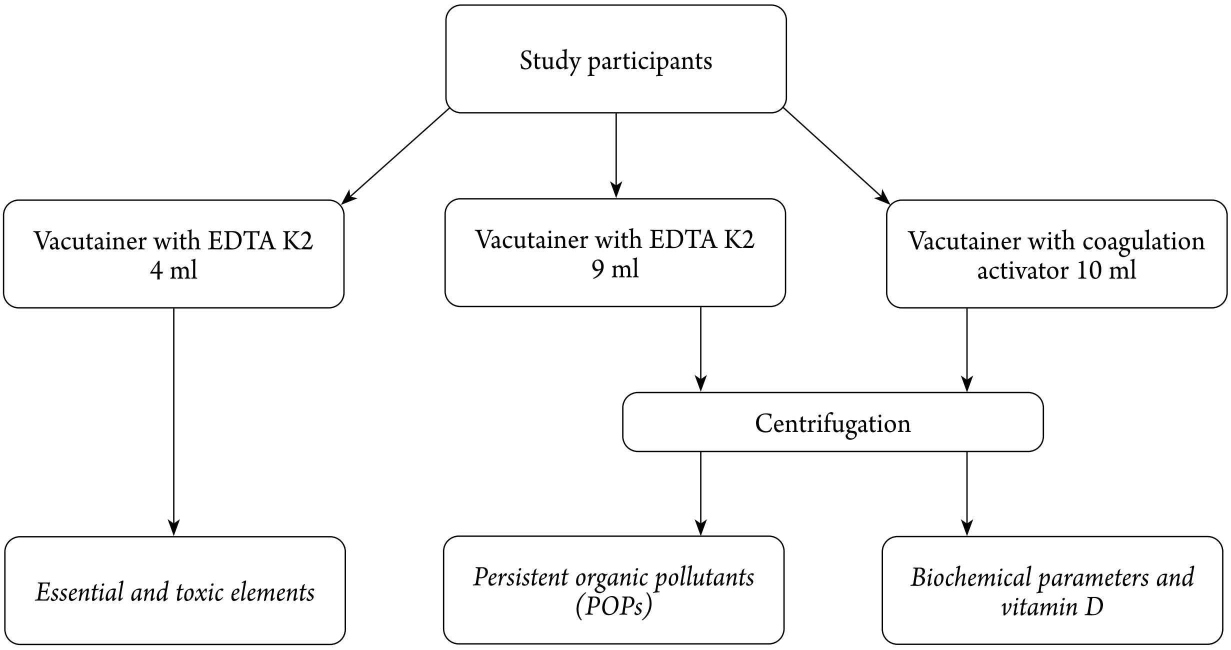

Fig. 1. The scheme of selection of biological samples.

No. L041-01126-23/00553381 dated 11.10.2020). To ensure the quality of measurements, specialists used a control material Recipe (Munich, Germany), LOT 1207.

An analysis of toxic and essential elements in whole blood in the Arctic biomonitoring laboratory of NArFU using an inductively coupled plasma mass spectrometer Agilent 7800 ICP-MS (USA). The device was calibrated for nitric acid and whole blood matrix ClinCal Whole Blood Calibrator 1 LOT 1458 (Munich). To ensure the quality of measurements Seronorm Trace Elements level-1 (LOT: 010010) and level-2 (LOT: 010011) (Norway) as described in our previous article [6].

The level of POPs in blood plasma was determined by gas chromatography mass spectrometry (GX-MS) in the NArFU's Arctic biomonitoring laboratory and the Core Facility Centre «Arktika» in accordance with the methodology described in our previous article [5].

We have analysed a total of 150 biological samples (whole blood, serum and blood plasma) for the content of toxic (Pb, Cd, As, Hg), essential (Co, Cu, Zn, Se, Mn), macronutrients (P, Ca, Mg) and 28 POPs (11 polychlorinated biphenyls (PCBs), 17 organochlorine pesticides (OCPs).

Specialists have conducted statistical data processing using SPSS software version 23.0 (IBM Corp., USA) and Microsoft Office Excel 2016 (Microsoft, USA).

The scientists obtained the data analysis by comparing it with previously obtained information on the actual concentrations of toxic and essential elements, as well as POPs in the blood of permanent residents of the North-western part of the Arctic Zone of the Russian Federation [5–6, 11].

Results. An analysis of anthropometric data showed that 14% of the study participants had a high body mass index (BMI) (more than 30.0 kg/m^2), excess BMI was recorded in 16% (25–30 kg/m^2) and 2% of participants had a low BMI, which corresponds to insufficient body weight (<18.5 kg/m^2) ***(Table 1)***.

Among the most frequently mentioned harmful factors were: sedentary lifestyle and electromagnetic radiation. Twelve percent of the participants indicated smoking as a bad habit.

The obtained biochemical analysis data were used to recalculate the POPs and assess the general condition of the study participants. The arithmetic mean (AM) data of the biochemical blood analysis of the participants, with the exception of cholesterol, were within the acceptable range provided by the staff of the central research laboratory at the NSMU ***(Table 2)***. The average cholesterol concentration was almost 9% less than the permissible concentration.

The range of vitamin D concentration in the blood serum of the study participants ranged from 9.9 ng/ml to 56.2 ng/ml. Almost 90% of the participants had vitamin D concentrations below 20 ng/ml, which indicates a deficiency of this vitamin in the body [12]. In women, the average concentration of vitamin D was 19.3 ng/ml, and in men 18.5 ng/ml.

Table 1

Anthropometric data of the study participants

Indicator	Women (*n*=24)	Men (*n*=26)	Total (*n*=50)
	AM* (min–max)	**AM (min–max)**	**AM (min–max)**
Age, years	29 (20–55)	33 (20–72)	31 (20–72)
Weight, kg	62 (47–95)	81 (69–115)	71 (47–115)
Height, cm	164 (152–175)	180 (166–194)	171 (152–194)
BMI, kg/m^2	23.9 (20.3–31.0)	25.5 (25.0–30.6)	24.7 (18.4–34.9)

Note: * — arithmetic mean.

Table 2

Results of biochemical analysis of blood serum

Indicator	AM (min–max)	Acceptable range
Cholesterol, mmol/L	4.7 (2.8–8.4)	5.2–6.2
Triglycerides, mmol/L	0.85 (0.28–2.53)	<1.70
Uric acid, mmol/L	279.5 (158.0–443.0)	10–420
Creatinine, mmol/L	91.0 (72.0–128.1)	53–115
HDL cholesterol, mmol/L	1.62 (1.08–2.58)	≥1.56
Ferritin, μg/L	25.8 (2.00–406)	20–250
Iron (Fe), mmol/L	13.7 (5.5–32.6)	9.0–31.3
Glucose, mmol/L	5.2 (4.3–6.3)	3.3–5.6

Note: HDL — high density lipoprotein cholesterol.

The questionnaire that the study participants filled out contained a question about taking vitamins. Twelve study participants reported taking dietary supplements containing vitamin D (7 women and 5 men). According to the answer to this question, all study participants were divided into two groups, regardless of gender: 1) taking vitamin D and 2) not taking it. The AM concentration of 25-hydroxyvitamin D in the participants who responded positively was almost 2 times higher (29.2 ng/ml) than in those who did not take additional dietary supplements containing vitamin D (17.0 ng/ml). Our study showed that in women the maximum concentration of vitamin D (56.2 ng/ml) was 1.5 times higher than in men (35.7 ng/ml). There is a relationship between the intake of dietary supplements containing vitamin D and the concentration of vitamin D in the blood of participants. All respondents who regularly consume vitamin D had a concentration of vitamin D in the normal range (30–100 ng/ml). While participants with lack and deficiency of vitamin D indicated in the questionnaire that they took vitamin D irregularly, seasonally or did not use it at all. The average concentrations of vitamin D in women (19.4 ng/ml) and in men (18.5 ng/ml) are approximately the same and correspond to insufficient levels. As a previous systematic review conducted earlier showed, in general, most of the Russian population is deficient in vitamin D of varying severity [13]. Our study confirms that vitamin D deficiency remains a serious public health problem.

Higher average concentrations of cobalt (0.09 μg/L), copper (1.02 mg/L) and calcium (73.1 μg/L) in whole blood were typical for women. The maximum individual concentration of cobalt (0.1 μg/L) was in a man. Higher average concentrations of mercury (1.07 μg/L), lead (0.70 μg/L), selenium (105.3 μg/L), zinc (4.02 mg/L), magnesium (29.4 μg/L) and phosphorus (271.1 μg/L) were found in men's blood samples. While the maximum individual concentrations of mercury (3.34 μg/L) and lead (39.1 μg/L) were observed in women. The concentrations of the remaining elements in the blood of women and men were at the same level ***(Table 3)***.

The researchers analysed the levels of the following POPs in the blood plasma of the participants: congeners 28, 52, 101, 105, 118, 123, 128, 153, 180, 183 PCB (ΣPCB); p,p'-DDE, o,p'-DDE, p,p'-DDD and o,p'-DDD (ΣDDT); *α*-HCG, *β*-HCG, *γ*-HCG, hexachlorobenzene (HCB), cis-nonachlor, trans-nonachlor, cis-chlordane, trans-chlordane, mirex, aldrin, 1,2,3,5-THB, and *β*-heptachlorepoxide (other HOP, Σother HOP).The concentration of all studied POPs was below the limits of quantitative detection (LQD) ***(Table 4)***.

Based on the questionnaire data, we divided all study participants into two age groups in accordance with the WHO

Table 3

The results of the elemental analysis of the whole blood of the expedition members

Element	Women (*n*=24)	Men (*n*=26)	Total (*n*=50)
	AM (min–max)	AM (min–max)	AM (min–max)
As, μg/L	0.13 (0.05–17.79)	0.11 (0.05–5.01)	0.12 (0.05–17.79)
Cd, μg/L	0.06 (0.05–1.05)	0.06 (0.04–0.42)	0.06 (0.04–1.05)
Hg, μg/L	0.69 (0.15–3.34)	1.07 (0.98–3.06)	0.85 (0.15–3.34)
Pb, μg/L	0.18 (0.05–9.36)	0.70 (0.05–39.09)	0.30 (0.05–39.09)
Co, μg/L	0.10 (0.04–0.70)	0.04 (0.04–0.10)	0.06 (0.04–0.70)
Mn, μg/L	19.1 (16.8–21.7)	18.6 (15.7–23.5)	18.8 (15.7–23.5)
Se, μg/L	98.8 (58.3–114.4)	105.3 (86.6–133.2)	102.1 (58.3–133.2)
Cu, mg/L	1.00 (0.80–1.59)	0.80 (0.64–1.23)	0.89 (0.64–1.59)
Zn, mg/L	3.34 (2.15–5.41)	4.02 (3.00–5.68)	3.66 (2.15–5.68)
Mg, μg/L	27.2 (24.0–33.3)	29.4 (24.8–36.9)	28.3 (24.0–36.9)
P, μg/L	253.3 (194.2–317.9)	271.1 (203.4–365.8)	262.2 (194.2–365.8)
Ca, μg/L	73.1 (59.8–86.5)	66.0 (52.7–85.1)	69.2 (52.7–86.5)

Table 4
The results of the analysis of the content of persistent organic pollutants in the blood serum of the expedition members

Показатель	Значение, нг/мл
ΣPCB	<0.50
ΣDDT	<0.20
Σother HOP	<0.75

classification [14]: 1. Formed by participants under the age of 24 inclusive (*n*=15) and 2. Participants over 25 years of age (*n*=35). There was a difference in serum ferritin (12.6 and 46.9 μg/L, respectively) and vitamin D levels (15.9 and 20.6 ng/ml), and elements in whole blood between these two groups. For example, the average cobalt concentration was 30% lower in the age group from 25 years and was (0.05 μg/L). The average concentrations of mercury and lead in the age group from 25 years old were 3 times and 10% higher respectively, than the concentration of these elements in the group under 24 years old. The results obtained are consistent with studies by R. Pamphlett [15], K. Berkowitz [16] and WHO [17, 18], which revealed differences in the content of mercury and lead depending on the age of the participants.

It is also worth noting the differences in vitamin D levels, in the age group under 24 the indicator was 15.9 ng/ml, which corresponds to a deficiency condition, and for participants over 25 years old the indicator was 20.6 ng/ml, which corresponds to an insufficient level [12]. The average concentration of ferritin in participants under the age of 24 was 12.6 μg/L, while in the older group this parameter was 3 times higher and amounted to 46.9 μg/L. Assessing the level of ferritin, it can be concluded that the indicators for both groups corresponded to the norm [19]. It should be borne in mind that students, whose age is most often between 18–24 years old, are one of the main risk groups for anemia, due to mental overstrain, stressful situations, endocrine restructuring of the body, an unbalanced diet [20].

Comparative analysis. We conducted a comparative analysis of the data obtained in this study with previously published data on the concentration of toxic elements in the blood of the local population of the Nenets Autonomous Okrug of the Russian Arctic (NAO). For a correct comparison of the indigenous population with the participants of the maritime expedition we have chosen settlement Indiga in NAO as there were the same number of participants (*n*=50) and included 35 women and 15 men from 19 to 86 years of age. It is worth noting that the participants of the expedition group were represented by the urban population, while in the NAO, the study participants lived in villages. The concentrations of magnesium, phosphorus and calcium in the blood of the indigenous population of the NAO have not been determined, and therefore it is not possible to compare them with the data obtained within the current study.

Arsenic. As a comparative analysis showed, the concentration of arsenic (0.11 μg/L) in men who participated in this study is 65 times lower, and in women (0.13 μg/L) who participated in this study is 73 times lower than in residents of the NAO (7.21 and 7.32 μg/L, respectively). As we previously described [21], high concentrations of arsenic in the inhabitants of the NAO may be associated with a predominantly traditional type of diet, namely the consumption of marine and anadromous fish. These fish species are capable of accumulating various forms of arsenic, the main predominant ones being arsenites, arsenobetaine methylated arsenic compounds (V) [22].

Cadmium. Cadmium concentrations in men and women amounted to 0.06 μg/L, which is almost 4 times lower than in men (0.22 μg/L) and women (0.21 μg/L) NAO. According to the results of the questionnaire, all participants of this study were divided into two groups, regardless of gender: 1. Smokers (*n*=7) and 2. Non-smokers (*n*=43). There was a difference in the levels of cadmium in blood of smokers (0.11 μg/L), and in non-smokers almost 2 times lower. Indiga village residents were also divided into two groups: 1. Smokers (*n*=8) and 2. Non-smokers (*n*=42). The cadmium levels were 0.52 μg/l in smokers' blood and almost 3 times lower in non-smokers' blood. The results obtained are consistent with previous studies [8, 24]. The concentration of cadmium in blood of non-smokers reflects the natural global background of the intake of the element with nutrition. The concentration of cadmium in smokers' blood from the NAO was 5 times higher than that of participants of the maritime expedition, which is most likely due to the duration of the habit. An average duration of smoking by Indiga residents was 21 years, where average duration of smoking by expedition participants was 12 years. This confirms the ability of cadmium to bioaccumulate in the human body.

Mercury. The average mercury concentration in the expedition group was 1.07 μg/L for men and 0.69 μg/L for women, which is 3–5 times lower than in residents of the North-Western part of the Russian Arctic.

The local population of the Arctic is primarily exposed to mercury mainly due to the traditional lifestyle of Arctic populations, which includes the consumption of large amounts of seafood, marine and freshwater fish and marine mammals [21, 24–25]. In our study, we did not find statistically significant differences between the mercury content in the blood of participants in this study depending on smoking, which is confirmed by the study of Pernilla Almerud [23]. While Doohee Hong's research has revealed a positive relationship between smoking and mercury accumulation in hair [26]. Participants in this study who reported smoking had a mercury concentration of 0.85 μg/L, and those who did not smoke had a mercury concentration of 0.82 μg/L.

Lead. The lead content in the blood of the expedition group participants is comparatively low: 22–64 times lower (0.18–0.70 μg/L) than that of the residents of the NAO (11.50 and 15.37 μg/L). One of the reasons for such high concentrations of lead in the blood of the local population may be traditional hunting, which remains to this day one of the main activities of residents of remote settlements of the Russian Arctic, over 50% of the local population declared fishing and hunting, whereas among the participants in this study only 6–10% declared these types of activities. Lead bullets and sinkers used for bird hunting and fishing can contaminate meat with lead fragments [27]. The second reason may be lead contamination of drinking water sources as a result of earlier mining operations [6].

A comparative analysis of the data obtained in the framework of this study was also carried out with previously obtained data on the concentration of essential elements in the blood of the local population of the NAO.

Cobalt. Cobalt is a part of vitamin B_{12}, the latter performs several important tasks, for example, the creation of red blood cells. In some cases, it can replace zinc and manganese in biochemical reactions [28, 29]. A comparative analysis revealed differences in the concentration of cobalt in the blood of women (0.1 μg/L) and men (0.04 μg/L) of the expedition group 6-15 times lower, than in the blood of women (0.65 μg/L) and men (0.6 μg/L) permanently residing in the North-Western parts of the Russian Arctic. According to the previously published data [21], reindeer meat and liver are rich in cobalt in their composition, which can affect the level of cobalt in the blood of the local population.

Manganese. Manganese is a cofactor of enzymes involved in bone formation and metabolism of glucose, carbohydrates and lipids [30]. The concentration of manganese was almost 1.5 times higher in men (18.6 μg/L) and women (19.1 μg/L) of the expedition group than in men (12.6 μg/L) and women (11.3 μg/L) permanently residing in the NAO. The best sources of manganese are vegetables [30], but the Arctic traditional diet does not contain many vegetables.

Selenium. The level of selenium in the blood was slightly higher in the group of permanent residents (125.3–124.3 μg/L) than in the expedition group (98.8–105.3 μg/L) ***(Fig. 2)***.

One of the factors of higher concentrations of selenium in the blood of the local population could be a predominantly traditional lifestyle, with a predominance of food of animal matter [21]. The results obtained are consistent with the study by Manisha Banerjee [31] and others indicating the use of selenium as a protective mediator against mercury toxicity. The presence of a molar excess of selenium over mercury causes potentially beneficial effects, which include the restoration of the redox function of selenoprotein, protection from DNA damage and outflow of mercury through the complexation of Hg:Se [32, 33].

Copper. Copper is a cofactor for "cuproferments" (for example, ceruloplasmin) involved in energy production and iron metabolism [34]. The copper content of the participants in this study and the permanent resident population was almost at the same level. The concentration of copper in women was higher than in men of the same group, which is consistent with other studies [6, 35–36]. According to the literature, higher concentrations of copper in the blood of women can be explained by taking oral contraceptives and the menopause period [37], because the questionnaire of this study did not contain these questions, then there is no reliable data confirming this fact.

Zinc. Zinc is associated with more than 50 different metalloenzymes, which have a variety of functions, including the synthesis of nucleic acids and specific proteins such as hormones and their receptors [38]. For these reasons, zinc plays a major role in cell growth, differentiation, and metabolism [39]. The concentration of zinc in the blood was 2 times higher in the local population (7.75–9.20 mg/L) than in the expedition group (3.34–4.02 mg/L) ***(Fig. 3)***. Perhaps this may be due to a predominantly traditional lifestyle of the local residents.

The concentration of zinc in the men's blood in both groups is higher than in women's, this fact is confirmed by previously published data [40]. The concentration of zinc is measured in serum, plasma, and whole blood, the latter containing about eight times more zinc than the rest. Therefore, whole blood is the best object for assessing the status of zinc [41].

POPs. An important analysed indicator of biomonitoring studies is the level of POPs in human blood. These toxic compounds include primarily organochlorine compounds, the content of which in the blood of residents of the Arctic region has been monitored since the end of the 20th century [42]. The previously reported concentrations of $\sum$ DDT and $\sum$ other HOP in residents of 7 settlements of the NAO are 2...5 times higher than the LOQ. The content of PCBs in the serum of the population of the island territories of the western sector of the Russian Arctic is approaching 3 ng/ml (Vaigach island), which is probably due to the entry of these POPs into the human body along the food chain and the much greater dependence of the inhabitants of the NAO on traditional food products (fish, wild birds) [5, 13]. At the same time, the average level of POPs in the blood serum of all participants of the expedition turned out to be significantly lower than the LOQ.

Limitations. The limitations of this study are: small sample size; heterogeneity of age groups; the need to improve the questionnaire.

Conclusion. *During the study we received data on the content of toxic, essential elements, and POPs in the blood of participants of the Arctic maritime expedition group. We conducted a comparative analysis of the results obtained within the current study with the corresponding data obtained in the NAO of the Russian Arctic. In fact, we were comparing the levels*

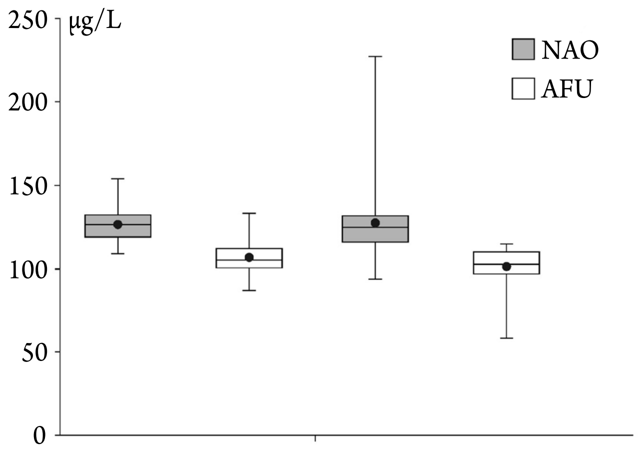

Fig. 2. Diagrams of the range of selenium concentrations in the blood of residents of the Nenets Autonomous Okrug and members of the expedition, depending on gender

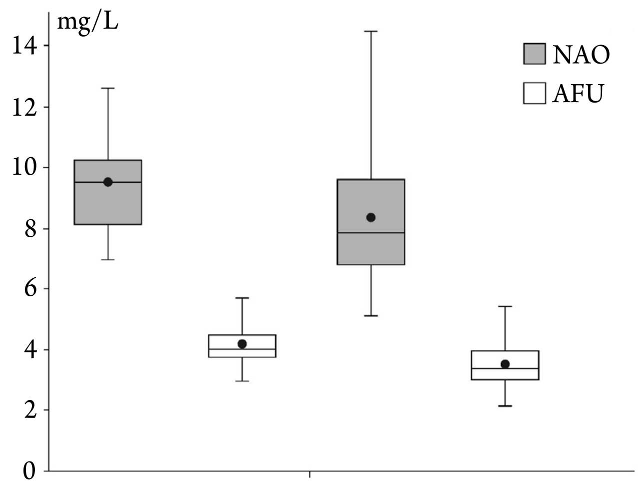

Fig. 3. Diagrams of the range of zinc concentrations in the blood of residents of the Nenets Autonomous Okrug and members of the expedition, depending on gender

of chemical compounds in blood of urban Russian residents and rural Arctic residents. We found that the content of toxic compounds (arsenic, cadmium, mercury, lead), as well as essential elements (cobalt, selenium, zinc) was significantly lower in blood of urban residents compared to the local population. And the concentration of POPs in blood plasma of urban residents was lower than the LOQ, while we detect trace concentrations of some chemicals in the blood of Indigo residents. Most likely, these differences are related to the diet and lifestyle of the study participants. Higher levels of cadmium were detected in the blood of Arctic residents, which may be related to the duration of smoking. Differences in the content of other elements are associated with dietary habits. On the one hand, the traditional lifestyle contributes to the intake of toxic elements with nutrition, on the other hand, it contributes to the intake of essential elements necessary for humans in the harsh conditions of the Arctic.

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