STUDY OF THE EFFECT OF OCCUPATIONAL EXPOSURE AT THE ARCTIC ZONE (LITERATURE REVIEW)

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ABSTRACT
The article describes the sequence of the main trends in the study of risk factors in the implementation of professional activities in the Arctic zone, shows the results of demographic processes and prospects for hygienic research at the current stage of the industrialization of the Arctic.

KEYWORDS Arctic zone, environmental and production factors, adaptation, disease risk, demography, shift work

The Arctic zone of the Russian Federation (AZRF) has the most extent border among the Arctic countries, such as the United States, Canada, Norway and Denmark. It is comprised of parts of regions or entire territories of the Republic of Sakha (Yakutia), Murmansk and Arkhangelsk regions, Krasnoyarsk Territory, Nenets Autonomous Okrug, Yamalo-Nenets Autonomous Okrug and Chukotka Autonomous Okrug. The Arctic zone (AZ) of Russia is the most important strategic reserve of energy and mineral resources; about 100% of antimony, apatite, phlogopite, vermiculite, rare metals and rare-earth metals, 98% of platinoids, 95% of natural gas, 90% of nickel and cobalt, 60% of copper and oil are mined there [1, 2, 3]. Arctic potential hydrocarbon reserves are the world's largest ones; they include 90 billion barrels of oil, 47.3 trillion cubic meters of natural gas and 44 billion barrels of natural gas luquids [4].

Mineral wealth of the Arctic stimulated the industrial development of the North. It began in the late 1920s as a result of active migration of population. Dozens of new towns and settlements were established in AZ and settled by construction workers, operating engineers and their families. Inflow of families required housing and social facilities construction. Reemployment of construction workers after the completion of construction required establishing of alternative industries. Construction expenses, as well as raw material and transportation costs and production value, are much higher in AZ than in habitable regions of Russia [5].

Loss of economic attractiveness of the Arctic zone in 1990s resulted in large scale migration

outflow of population, mainly of working and reproductive age.
At present, the area of the Arctic zone of the Russian Federation (AZRF) is larger than the joined area of several European states, while its population is only about 2 415 thousand people as of 2018. The population has halved in 30 years from 1989 to 2019 [6].

All of the above mentioned facilitated the development of the 'Foundations of the State Policy of the Russian Federation in the Arctic to 2020 and Beyond', approved by the President of the Russian Federation on September 18, 2008. The document proclaims that 'national interests determine basic objectives, primary goals and strategic priorities of the state policy of the Russian Federation in the Arctic, that means in sphere of science and technology (p.5d) to maintenance the sufficient level of fundamental and applied scientific researches on accumulation of knowledge and creation of modern scientific and geo-information basis of the Arctic management, including development of means of ***… reliable functioning of life-support systems and economic activity in environmental conditions of the Arctic'.***

However, the beginning of scientific researches in the Arctic is not associated with the Foundations of the State Policy. Background knowledge of environmental features of the region and their impact on human body was formed already in 1970-1980s. First of all, the extreme nature of the Arctic climate has been proved, as well as its impact on working activity, way of life and recreation of people due to critical levels of some of environmental parameters for human life or health [7, 8, 9, 10, 11].

The Arctic zone is characterized by photoperiodism with long daylight in summer and short in winter. Period of ultraviolet deprivation due to photoperiodism is 5-6 months and more [12, 13].

Mean annual air temperature in the Arctic ranges from +3°C in the West to -8°C in the East. Daily temperature variations may reach 15-20°C. The impact of cold weather on human body poses a risk of thermal disturbance or cold injure, especially for outdoor working activities in winter season [14].

The Arctic zone has more than 100 days per year with windstorms when wind speed exceeds 15 m/s up to 30-40 m/s. Mean monthly wind speed is 5.6 m/s. Maritime air masses at any season are responsible for high cloudiness and relative humidity of 70-96%. Relative humidity is less than or equal to 50% only a few days per year. These factors enhance the cooling effect of low temperatures [15].
The most severe aerodynamic conditions are typical for the European part of AZ. Abrupt extreme temperature changes are accompanied by atmospheric pressure oscillations with amplitude of 52.5-63.5 mm Hg in winter and 30.0-37.5 mm Hg in summer. Air pressure changes rate reach 6.7-9.0 mm Hg per 3 hours. The values mentioned above are up to 10 times higher than a threshold of health deterioration for people with cardiovascular pathology [16, 17].

Daily variations in partial density of oxygen in AZ are also significant. Oxygen partial density falls with rising temperature and humidity, though the percentage of oxygen in the air of high latitudes is constant at a level of 21% [18, 19].

According to V.P. Kaznacheev, environmental parameters of high latitudes include cosmic radiation and geomagnetic disturbances due to unique configuration of geomagnetic field, which cause the specific biological effects. The researches provide a basis for the hypothesis of 'polar stress syndrome'. It is based on biophysical regularities of interactions between organism and environment and resulted in changes in neuroendocrine regulation together with various functional alterations ranging from adaptive to pathological [20].

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Environmental geochemical conditions also play an important role in the complex adaptation of human organism to the Arctic conditions. These include insufficient fluorine in the drinking water, imbalances of magnesium and sodium, calcium and strontium ratio, which result in prevalence of dental pathologies and cause abnormalities in structure and function of bone tissue of indigenous and non-indigenous (alien) people [21, 22].

Thus extreme climate conditions of AZ require strong adaptive response of an organism, which is particularly important for working activity. This is the reason of high medical and social significance of studying geochemical impact on human health [22].

The researches reveal changes in cardiovascular functionality of non-indigenous population in AZ closely connected with the duration of living in extreme conditions. A number of cardiovascular changes correlate with age and season of examination. Many authors note the significant changes in functioning of left ventricle of heart and systemic circulation, which are evident both in the first months of working in the Arctic and in case of long-term residence, the same is observed in meteo-unfavourable days [23, 24, 25].

A number of studies have found a decrease in blood volume and increase in peripheral vascular resistance as a response to cold, with systolic blood pressure tending to decrease. According to some authors, prolonged residence in the Arctic conditions increases systolic blood pressure [26, 27].

Cold conditions cause intense functioning of the human respiratory system with developing of dyspnea and difficult breathing. Cold exposure causes reflex bronchial spasm, resulted in hypertrophy of circumferential muscle layers of bronchus and bronchial tubes, as well as changes of elasticity of the lung. These are often accompanied by dystrophic and destructive processes, resulting in a high respiratory disease incidence in the North [28, 29, 30, 31].

Respiratory water loss is increased in high-latitude conditions, thus provoking the development of hyper-ventilation syndrome. That produces tension in the pulmonary circulation. Pulmonary arterial hypertension is widespread among the healthy population of AZ, its intensity is directly depends on climate severity and duration of residence in AZ [32, 33].

Therefore, wasting of functional reserves of an organism under the Arctic conditions reduces its adaptive capacity and stress resistance, resulted in pathological processes in the organism [31, 34].

The joint monograph "Clinical Aspects of Polar Medicine" edited by V.P.Kaznacheev represents general principles of health studies in AZ, conducted in 1970-1980s. The main requirement to population involved to the study was 'long-term settled living in the regions of extreme climate conditions'. At the same time it was noted that the study required repeated health screening programs considering sex, age, duration of residence in the north, as well as assessment of seasonal and daily rhythms and occupational activity [35].

Intensive oil and natural gas extraction began in the West Siberia in 1970-1980s and promote introducing and wide expansion of rotational method of labor organization. Rotational organization of work supposes that workers from different regions arrive at a rotation settlement where 14 or 30 days of working period is shifted by a period of 14-days rest [36, 37].

Despite the economic advantages of rotational shift it is obvious that this kind of activity requires repeated movements associated with climatic contrasts, which provoke stress of physiological functions and change of body's circadian rhythms due to incomplete adaptation [38, 39]. Consequently, shift work is accompanied by chronic stress of homeostatic systems and functional reserves of an organism together with an increase in the number of diseases or exacerbation of chronic ones [40, 41].

General ideas on complete range of changes of health indicators and functional state of organism of a shift worker are presented in studies of A.B. Gudkov, A.S. Sarichev, O.N. Popova. The researchers state regularities of functioning of cardiorespiratory system and regulatory mechanisms, as well as levels of physical efficiency and reserve capacity of organism in conditions of different types of shift work in the Arctic [31, 34, 38, 40, 41]. All researches confirm the principles of fundamental studies.

Another conclusion is that work on rotational basis induces stress and overstress of regulatory systems due to failure to provide proper response of organism to environmental conditions by protective and adaptive mechanisms. These effects are detected for 86.7% of shift workers at the beginning of their working period, 50% of shift workers in the middle and 76.9% of workers at the end of their shift [26, 28, 86].

Specific features of rotational work organization completely change living environment of a worker [39, 40, 41]. Frequent disturbance of adaptive mechanisms results in stress, fatigue cumulation and disadaptation [38]. That break the regulatory mechanisms of physiological functions and consequently affects physical and mental efficiency [3, 27, 54].

Despite the considerable amount of data on shift workers medical examination, there is lack of data on further changes in health status of workers who have completed their rotational working activity (e.g. their lifetime, causes of depth, etc.), as opposed to corresponding data on fundamental health studies of population permanently employed in AZ [42].

Significant migration outflow from the Arctic regions causes depopulation of many cities and settlements with a high level of industrialization and location of mining industry (i.e. extraction and primary processing of mineral resources). This requires attracting of shift workers to the enterprises which were established in 1930-1960s and formerly served by settled population. The result is increased amount of persons who are unavailable for long-term health monitoring, including the period following the shift [43].

Resource extraction is a primary driver for development of population in AZ. In view of this, a large part of the Arctic population is affected both by extreme climatic and occupational factors.

The main attribute of AZ, which directly affects and aggravates other occupational conditions is cold, which is considered to be a function of low air temperatures, wind speed and humidity, since the last two factors increase the cooling effect on the organism [1]. Of special note is the limited amount of studies of specific impact of occupational exposures, conducted in 1970-1980s, and especially studies of the joint effect of natural and occupational factors, as compared with studies of impact of natural factors.

A number of studies have found that the conditions of the northern mines provoke faster development of pneumatic hammer disease together with more pronounced bone changes and haemodynamic compromises [44]. This is largely determined by cooling microclimate of underground mines where temperature varies from +3 to +8°C, humidity varies at a range of 80-100% and airflow speed is up to 4 m/s [15].

Data on joint effect of cold exposure and chemical factors in workplace is very limited. Taking into account the observed responses of respiratory system to the Arctic conditions, the respiratory ventilation volume is increased due to cold exposure and provides larger inhalation intake of toxic agents into the organism. Even moderate cooling results in increase of respiratory minute volume twice as in optimal temperature regime [47].

At the same time, the studies reveal the decrease of fluorine accumulation in dental and bone tissue in cold conditions, as in the case of aluminium industry in the Arctic zone. That is demonstrated in decelerated development of occupational fluorosis [45, 46].

Besides, it was shown for a number of so-called hot workshops in AZ, that they caused the release of excess of heat and emission of significant amounts of toxic substances and dust. On the other hand, to reduce waste concentration the self-ventilation was mainly used because of imperfection of industrial ventilation. Thus, workshop microclimate was greatly influenced by outdoor weather conditions. As a result, air temperature in hot workshops dropped below the regulated level for most of a year, reaching -26°C during the cold period. Strong airflows velocities ranged between 0.6 and 3.5 m/s. Indicated parameters defined the workshop microclimate as cooling. Examinations of physiological response showed stress of thermoregulation [47].

In subsequent decades working conditions have been changed significantly, particularly in economic sectors with large-cap enterprises. That can be illustrated by the results of modernization efforts carried out by Mining and Metallurgical Company Nornickel and PhosAgro-Apatit, which are the leaders of industry in Murmansk region. More than 80% of persons with occupational diseases in the region are workers of these enterprises.

In November 2019 Nornickel made a decision to close a smelting shop in the Nikel town in Murmansk region, where Nornickel's unit Kola MMC is located. This activity aims to completely eliminate sulfur dioxide emissions, which have the most significant negative environmental impact on the territory including the Russia-Norway border. Due to the implementation of the programme the intensity of sulfur dioxide emission decreased for 50% in 2020. It is aimed to reduce emission of sulfur dioxide by 85% to 2021. The shutdown of Kola MMC's smelting facility in Monchegorsk in 2006 resulted in a significant reduction of emissions of sulfur dioxide to the atmosphere from 278.0-257.2 to 112.6-97.5 thousand tons [48].

PhosAgro-Apatit has introduced the use of conveyor transportation system instead of dump trucks with diesel engines to transport ore from quarries. This modernization has significantly reduced the probability of smog formation in the quarries under temperature inversions, high atmospheric pressure and windless conditions. Besides, remote drilling technology is tested in mines, together with decreasing of the use of manual drilling [49].

The modernization of production facilities results in decreasing impact of occupational exposures, when their effects cannot be detected by ordinary medical examinations, regulated by the Oder of Ministry of Public Health №29н of January 28, 2021 (came into force on 01.04.2021).

The guidelines of recent study of impact of occupational exposures with a high level of performance suggest a multi-displinary integrated programme.

A number of this kind of researches is carried out in the North-West Public Health Research Center in Saint Petersburg and its branch in Kirovsk, Murmansk region. The Murmansk region was a part of AZ in 1995-2015.

The researches widely use the self-assessment questionnaires, developed for subjective assessment of a number of health indicators and level of disturbances. Respondents assess the effect of occupational exposure, environmental and living conditions. It is important to note that objective results are obtained on maximal coverage of workers. One of researches includes interviews of 93-98.2% of total number of workers of open-cut and underground mines (3350 respondents). Primary attention was paid to assessing the microclimate conditions, first of all cold and high moisture exposure, as well as working heaviness and vibration and their effect on workers. The survey found, that self-assessment of working conditions and state of musculoskeletal system by respondents coincided with objective hygienic assessment of working conditions in the mining industry. The self-assessment of the severity of pain associated with different spinal regions (cervical, thoracic or lumbar) was twice as high as the data on musculoskeletal disorders according to repeated medical examinations of all workers [50].

Source: kolagmk.ru

More than 80% of persons with occupational diseases in the region are workers of Mining and Metallurgical Company Nornickel and PhosAgro-Apatit.

The study of impact of nickel compounds on the organism, including reproduction, required creating of online version of Birth Registry in Monchegorsk (the center of nickel production in Murmansk region). During 1997-2005, all available data from the official medical sources were included to the Registry, totaled 26,848 records of fetus and newborn. Besides, the survey included data on natural abortion according to additional interviewing of women. The data allowed authors to relate congenital anomalies with occupational and social hazards [51].

The method of individual breathing zone sampling provides increased amount of data on content of pollutants in the air of the workplace. This method makes it possible to carry out a detailed personal assessment of impact of specific pollutants on workers involved in nickel refining.

In some cases, personal samplers are equipped with a special device for the fractional separation of respirable dust. It is important to study dust differentially because penetration of dust particle to respiratory tract depends on its size.

Exposure level of pollutants was determined by blood and urine analysis of workers. It was found, that at the end of the shift the concentrations of nickel in urine of workers in pyromatallurgical and hydrometallurgical divisions were equal, though before the next shift the concentration of nickel was lower in samples of those occupied in hydrometallurgical division. This indicated higher rate of nickel excretion of hydrometallurgical workers due to predominance of soluble fraction of nickel with different mechanism of toxicokinetics. Besides, it was noted that nickel excretion depends on the health status of persons with chronic diseases of cardiovascular and urinary systems [52].

The studies show the implicit toxic effect of diesel engine exhausts, though it is not available for clinical diagnostics, but has been identified by blood serum biomarkers.

A great number of studies under the projects show that they need high labor efforts, as well as advanced sampling methods and laboratory analysis, which require substantial funding. The results of the international research projects demonstrate their high scientific value for determination of levels and mechanisms of occupational health risks. This is essential for health maintenance of population, working in the Arctic, in view of labor shortage and lack of internal sources of sufficient labor supply in AZ. This is the only method of effective assessment of occupational exposers in the modern industry.

REFERENCES

1. Chashchin V.P. Harakteristika osnovnykh faktorov riska narushenij zdorov'ya naseleniya, prozhivayushchego na territoriyakh aktivnogo prirodopol'zovaniya v Arktike [Characteristics of the main risk factors for health disorders of the population living in the territories of active nature use in the Arctic.]/ V.P. Chashchin, A.B. Gudkov, O.N. Popova, YU.O. Odland, A.A. Kovshov // Ehkologiya Cheloveka [Human ecology].– 2014 – №1. – S. 3-12. (In Russian)
2. Istomin A.V., Pavlov K.V., Selin V.S. Ekonomika arkticheskoj zony Rossii [Economy of the Arctic zone of Russia] Obshchestvo i ekonomika [Society and Economy]. 2008, 7, pp. 158–172. (In Russian)
3. Loginov V. G. Social'no-ekonomicheskaya ocenka razvitiya prirodno-resursnyh rajonov Severa [Socio-economic assessment of development of natural resource regions of the North]. Yekaterinburg: In stitute of Economics Ural Department of the Russian Academy of Sciences. 2007, 311p. (In Russian)
4. Agranat G. A. Ispol'zovanie resursov i osvoenie territorii Zarubezhnogo Severa [Use of resources and development of the territory of the Foreign North] / Moscow: Nauka Publ., 1984, 263p. (In Russian)
5. Sergeeva I.V. Istoricheskie osobennosti, problemy i tendencii organizacii truda vahtovym metodom v usloviyah krajnego severa [Historical features, problems and trends in the organization of labour by the watch method in the conditions of the far north] Journal of the Research Center of Corporate Law, Management and Venture Investing, 2012, 2. (In Russian)

6. Fauzer V. V. Naselenie i demograficheskoe razvitie Severa Rossii [Population and demographic development of the North of Russia]. Sever kak ob»ekt kompleksnyh regional'nyh issledovanij [North as a comprehensive regional research facility]. Syktyvkar, 2005, pp. 96-101. (In Russian)
7. Baevskij R. M., Berseneva A. P Adaptacionnye vozmozhnosti organizma i ponyatie fiziologicheskoj normy [Adaptation capabilities of the body and the concept of physiological norm] // Materials of the 18 Congress of the Physiological Society I. P. Pavlova – Kazan, 2001. pp. 304. (In Russian)
8. Gribanov A. V., Danilova R.I. Obshchaya harakteristika klimato-geograficheskih uslovij Russkogo Severa i adaptivnyh reakcij cheloveka v holodnoj klimaticheskoj zone [General description of climatic and geographical conditions of the Russian North and adaptive human reactions in the cold climatic zone] // Sever. Deti. SHkola: sb. nauch. tr. [North. Children. School: collection of scientific works]. Arkhangelsk, 1994, Issue 1, pp. 3-27. (In Russian)
9. Degteva G. N, Zubov L. A. Aktual'nye voprosy social'noj, fiziologicheskoj i metabolicheskoj adaptacii organizma cheloveka k usloviyam Severa [Topical issues of social, physiological and metabolic adaptation of the human organism to the conditions of the North]. Ekologiya cheloveka [Human ecology]. 2004, 4, pp. 57–59. (In Russian)
10. Deryapa N. R., Ryabinin I. F. Adaptaciya cheloveka v polyarnyh rajonah Zemli [Human adaptation in the polar regions of the Earth].Leningrad: Meditsina Publ.1977, p.296. (In Russian)
11. Kaznacheev V. P. Mekhanizmy adaptacii cheloveka v usloviyah vysokih shirot [Mechanisms for human adaptation in high latitudes]. Leningrad: Meditcina Pabl, 1980, 200 p. (In Russian)
12. Bojko E.R., Loginova T.P., Potolicyna N.N. Rol' prirodnoj sezonnosti v regulyacii funkcional'nyh mekhanizmov fiziologicheskogo gomeostaza u cheloveka na Krajnem Severe [The role of natural seasonality in the regulation of functional mechanisms of physiological homeostasis in humans in the Far North]. Materials of the 18 Congress of the Physiological Society named after I. P. Pavlova. Kazan, 2001, pp. 482–483 (In Russian)
13. Vitinskij YU. I., Ol' A. I., Sozonov V. I. Solnce i atmosfera Zemli [The Sun and Atmosphere of the Earth] Leningrad, Nauka Publ., 1976, 148p. (In Russian)
14. Miroshnichenko L. I. Solnechnaya aktivnost' i Zemlya [Solar activity and Earth]. Moscow, Nauka Publ., 1981, 144 p. (In Russian)
15. CHashchin V. P., DedenkoI. I. Trud i zdorov'e cheloveka na Severe [Work and health in the North]. Murmansk, 1990, 104 p. (In Russian)
16. Bojko E. R. Meteotropnye reakcii i priroda adaptivnyh processov u cheloveka na Severe [Meteotropic reactions and the nature of adaptive processes in humans in the North]. Heliogeophysical Factors and Human Health: Materials of the International Simpozyme. Novosibirsk, 2005, pp. 46–48.(In Russian)
17. Ovcharova V. F. Medicinskaya interpretaciya sinopticheskih i meteorologicheskih prognozov [Medical interpretation of weather and meteorological forecasts]. In: Influence of geographical and meteorological factors on body activity. Novosibirsk, 1978, pp. 33–44. (In Russian)
18. Velichkovskij B. T. Molekulyarnye mekhanizmy narusheniya gazoobmennoj funkcii legkih na Krajnem Severe [Molecular mechanisms of lung gas exchange function disorders in the Far North]. Pul'monologiya [Pulmonology]. 2005, 4, pp. 61– 64. (In Russian)
19. Velichkovskij B. T. Polyarnaya odyshka: u severyan «osobye» legkie [Polar shortness of breath: northerners have «special» lungs] // Social'noe partnerstvo [Social partnership]. 2006, 3, pp. 111–113. (In Russian)
20. Kaznacheev V. P., Kulikov V. YU. Sindrom polyarnogo napryazheniya i nekotorye voprosy ekologii cheloveka v vysokih shirotah [Polar stress syndrome and some human ecology issues in high latitudes] Vestn. AN SERDECHNO-SOSUDISTAYA SISTEMA [Journal of the Academy of Sciences CARDIOVASCULAR SYSTEM].1980, 1, pp. 74–82. (In Russian)
21. Tedder YU.R., Gribanov A.B. Vliyanie mikroelementa ftora na adaptivnye reakcii serdca pri holodovom vozdejstvii na organism [Effect of Fluorine Trace Element on Adaptive Heart Responses in Cold Exposure to the Body]. Fiziologiya cheloveka [Human Physiology]. 1992, 1(18), pp. 141-145. (In Russian)
22. Sidorov P. I., Gudkov A.B. Ekologiya cheloveka na Evropejskom Severe Rossii [Human ecology in the European North of Russia]. Ekologiya cheloveka [Human Ecology]. 2004, 6, pp. 15-21. (In Russian)

23. Krivoshchekov S. G., Ohotnikov S. V. Proizvodstvennye migracii i zdorov'e cheloveka na Severe [Productive migration and health in the North]. Novosibirsk, Pabl. of Siberian branch of the Russian Academy of medical Sciences. 2000, 118p. (In Russian)
24. Marachev A. G. Morfofunkcional'nye osnovy adaptacii i patologii legkih, serdca i krasnoj krovi cheloveka v usloviyah Krajnego Severa [Morphofunctional bases of adaptation and pathology of human lungs, heart and red blood in the conditions of the Far North]: abstract of the dissertation of the doctor of medical Sciences. Moscow, 1980, 60 p. (In Russian)
25. Avtsyn A. P., Milovanov A.P. Stadiya adaptacii legkih cheloveka v usloviyah Krajnego Severa [Stage of human lung adaptation in the Far North] Fiziologiya cheloveka [Human physiology]. 1985, 3, pp. 389–399. (In Russian)
26. Hasnulin V.I. SHurgaya A.M. Kardiometeopatii na Severe [Kardiometeopatiya in the North]. Novosibirsk, 2000, 222 p. (In Russian)
27. Baranov V. L., Kurenkova I.G., Kazancev V.A. Issledovanie funkcii vneshnego dyhaniya [External Breathing Function Study] St. Petersburg: Elby– SPb Publ., 2002, 302 p. (In Russian)
28. Agajanyan N.A., Khrushchev V.L. Dinamika nekotoryh fiziologicheskih pokazatelej cheloveka pri vahtovom ekspedicionnom metode truda v Zapolyar'e [Dynamics of some physiological indices of the person in the watch expeditionary method of labor in the Polar region] Byul. SO AMN SERDECHNO–SOSUDISTAYA SISTEMA [Buleten Siberian Branch of the Academy of Medical Sciences of the USSR CARDIOVASCULAR SYSTEM]. 1984, 2 pp. 79–83. (In Russian)
29. Bojcov S.A., Belozerceva I.V., Kuchmin A.N. Vozrastnye osobennosti izmeneniya pokazatelej variabel'nosti serdechnogo ritma u prakticheski zdorovyh lic [Age-specific changes in heart rate variability in practically healthy individuals] // Vestn. aritmologii [Journal of Arrhythmology]. 2000, 20, pp.57-60. (In Russian)
30. Myznikov I.L., SHCHerbina F.A. Vliyanie vahtovoj organizacii truda na parametry central'noj gemodinamiki i postoyannyj potencial golovnogo mozga [Impact of watch organization of labor on parameters of central hemodynamics and permanent potential of brain]. Fiziologiya cheloveka (Human Physiology). 2005, 2, (31), pp. 58-68. (In Russian)
31. Gudkov A. B, Popova O. N. Vneshnee dyhanie cheloveka na Evropejskom Severe [External human breathing in the European North] Arhangel'sk : Izd– vo SGMU [Arkhangelsk: Northern State Medical University Publ.] 2009, 242 p. (In Russian)
32. Zuevskaya T.V., Ushakov V.F., Il'ina E.I. Vliyanie klimato-ekologicheskih faktorov na vozniknovenie i techenie bronholegochnoj patologii v usloviyah Severa [Features of the system of external breathing and gas exchange in the indigenous population of the North] // Khanty– Mansiysk: Khanty–Mansiyskiy State Medical Institute Publ. 2008, 150 p. (In Russian)
33. Kim L. B. Sostoyanie vneshnego dyhaniya u zhitelej Krajnego Severa v zavisimosti ot vozrasta i polyarnogo stazha [State of external breathing in residents of the Far North depending on age and polar seniority]. Byul. SO RAMN [Bulletin of the Siberian Branch of the Russian Academy of Medical Sciences]. 2010, 3, (30), pp. 18–23. (In Russian)
34. Popova O.N., Gudkov A.B. Osobennosti vneshnego dyhaniya u molodyh lic, urozhencev Evropejskogo Severa [Features of external respiration in young persons, natives of the European North] // News of the Samara Scientific Center of the Russian Academy of Sciences.–Ecology and human health [special issue]. – 2007. – pp. 71–76. (In Russian)
35. Klinicheskie aspekty polyarnoj mediciny [Clinical aspects of polar medicine] Pod red. V.P. Kaznacheeva. AMN SSSR. – M: Medicina, 1986, 208 p. (In Russian)
36. Dodin D. A. Problemy ustojchivogo razvitiya Arktiki i puti ih resheniya [Arctic development challenges and solutions] // Vestn. Goskomgeologii RS (YA) [Journal of State Committee of Geology of Saha Republic [Yakutia]. 2004, 1, pp. 3–20. (In Russian)
37. Krylov N. A. Vchera, segodnya, zavtra neftyanoj i gazovoj promyshlennosti Rossii [Yesterday, today, tomorrow of the Russian oil and gasindustry]. Moscow, Institute of Geology and Fuel Development, 1995, 448 p. (In Russian)
38. Gudkov A. B., Tedder YU. R., Pacevich YU. L. Fiziologicheskaya harakteristika netradicionnyh rezhimov organizacii truda v Zapolyar'e [Physiological characteristic of non– traditional labour organization

regimes in the Polar region] – Arhangel'sk : Izd-vo AGMA. [Arkhangelsk: Publishing of the Amurskaya State Medical Academy, 1998, 208 p. (In Russian)
39. Matyuhin V. A, Krivoshchekov S. G., Demin D. V. Fiziologiya peremeshchenij cheloveka i vahtovyj trud [Human movement physiology and watch work]. Novosibirsk: Nauka Publ., 1986, 198 p. (In Russian)
40. Sarychev A.S., Alekseenko V.D., Simonova N.N., Gudkov A.B. Problemy vahtovogo truda v Zapolyar'e [Problems of watch labor in the Polar Region] Medicinskij akademicheskij zhurnal. [Medical Academic Journal]. 2007, 4, (7), pp. 113–118. (In Russian)
41. Sarychev A.S, Gudkov A.B., Popova O.N. Harakteristika kompensatorno– prisposobitel'nyh reakcij vneshnego dyhaniya u neftyanikov v dinamike ekspedicionnogo rezhima truda v Zapolyar'e [Characteristics of compensation-adaptation reactions of external breathing in oilmen in dynamics of expeditionary labor regime in Polar region]. Ekologiya cheloveka [Human Ecology]. 2011, 3, pp. 7-13. (In Russian)
42. Davies D. G. Human problems in shift work / D. G. Davies // J. Jron Steel Inst. – 1971. – Vol. 209. – № 2. – pp. 114–120.
43. Talykova L.V. Demograficheskaya situaciya i professional'nyj risk u rabochih gornopromyshlennogo kompleksa Arkticheskoj zony RF [Demographic situation and occupational risk for mining workers in the Arctic zone of the Russian Federation] / L.V. Talykova, A.N.Nikanov, V.R.Bykov/ Vestnik ural'skoj medicinskoj akademicheskoj nauki. [Bulletin of the Ural medical academic science.] 2019. -T. 16. -№ 2. -S. 245–252 (In Russian)
44. Gigiena mikroklimata i fiziologiya teploobmena v processe truda na Krajnem Severe // Nauchny`j obzor / Pod. red. A. P. Shiczkovoj. [Microclimate hygiene and physiology of heat exchange during labor in the Far North // Scientific review /Under. edited by A. P. Checkowa]— M.: VNII med. informacii, 1983. — 64 s (In Russian)
45. Chashchin V.P. Gigiena truda pri ehlektroliticheskom poluchenii alyuminiya v usloviyakh severa. Avtoreferat dissertacii kandidata medicinskikh nauk.[Occupational hygiene in the electrolytic production of aluminum in the conditions of the north. Abstract of the dissertation of the Candidate of medical Sciences] – Moskva, 1979 – 19s. [n Russian]
46. Tedder Yu. R Nekotory`e voprosy` adaptacii rabochix e`lektrolizny`x cexov alyuminievy`x zavodov k vozdejstviyu proizvodstvennoj sredy` na Krajnem Severe [Some questions of adaptation of workers of electrolysis shops of aluminum plants to the impact of the production environment in the Far North] / Yu.R. Tedder, V.P. Chashhin // Gigiena i sanitariya [Hygiene and sanitation].— 1977. — № 3.- S. 91—94. (In Russian)
47. Chashchin V.P. Gigienicheskie problemy` mikroklimata metallurgicheskikh czekhov na Krajnem Severe. //Tezisy` dokladov VIII simpoziuma Adaptacziya cheloveka k usloviyam severa. - Kirovsk. – 1979. – S.239-240
48. https://www.vedomosti.ru/press_releases/2020/12/23/nornikel-zakrivaet-plavilnii-tseh-v-poselke-nikel
49. https://www.phosagro.ru/press/industry/proekt-distantsionnoe-burenie-skvazhin-kirovskogo-filiala-ao-apatit-stal-nominantom-premii-comnews-a
50. Skandfer M, Low back pain among mineworkers in relation to driving, cold environment and ergonomics/ Morten Skandfer, Liudmila Talykova, Tormod Brennc, Tohr Nilssond & Arild Vaktskjoldef // Ergonomics . - 2014. - Vol. 57, №. 10, pp.1541–1548.
51. Vaktshol'd, V.P.Chashchin, EH.Nieboehr, A.N. Nikanov, N.P.Romanova, YU.E.Udland. Kol'skij registr rodov – instrument ehpidemiologicheskikh issledovanij reproduktivnogo zdorov'ya zhenshchin [Kola Birth Register – a tool for epidemiological studies of women's reproductive health] //Medicina truda i promyshlennaya ehkologiya, [Occupational medicine and industrial ecology] №1,- 2006,- S.9-13 (In Russian)
52. Talykova L. Spontaneous abortions among nickel-exposed female workers / L. Talykova, A. Vaktskjold, V. Chashchin, E. Nieboer, J.O. Odland// Int. J. Environmental Health Research.-2008. – Vol.18, № 2.- pp.99-115.