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INDUSTRIAL VIBRATION AND VIBRATION-RELATED PATHOLOGY IN THE ARCTIC FACILITIES

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Introduction. Industrial vibration is a common harmful effect, ranking third among physical factors after noise and adverse lighting conditions. The purpose of the study was to investigate the nature of industrial vibration and its influence on formation of occupational pathology among workers at enterprises in the Arctic. Materials and methods. The data of social and hygienic monitoring “Working conditions and occupational morbidity” of the population of the Arctic zone of Russia in 2007-2017 were studied. Research results. It was found out that vibration occupies 7.13% in the structure of harmful production factors, and its impact causes development of 29.9% of occupational diseases. General vibration, as compared to local vibration, causes development of vibration disease (87.8% and 61.9%, p<0.001) and radiculopathy (4.7% and 0.9%, P<0.01), and less frequently - mono-polineuropathy (6.0% and 22.0%) and vegetative-sensory polyneuropathy (0.4% and 14.4%, P<0.001). In 2007-2017, Arctic enterprises registered an excess incidence (from 2.55 to 3.80 per 10,000 workers) and vibration-related pathology risk (RR=1.49; CI 1.21-1.84), while in Russia as a whole there was a decrease in the incidence rate. In 99.3% of cases, exposure to vibration was a consequence of imperfection of technological processes and workplaces, structural defects of machines and equipment. Conclusions. In order to reduce the vibration-related pathology risk at the Arctic enterprises, it is necessary to reduce the vibration level, first of all, by improvement of technological processes and structural improvements of vibration-hazardous equipment.

Keywords: Industrial vibration, occupational vibration-related pathology, the Arctic.

Introduction. In modern conditions, industrial vibration is one of the most common harmful production factors [1].

In 2014-2017, within the structure of harmful physical factors of the work process, industrial vibration at the Russian enterprises ranked third in terms of prevalence (after noise and adverse conditions of workplace illumination) and second in terms of frequency of occupational diseases (after noise) [2, 3]. Hygienic standardization of industrial vibration is based on the criteria of human health under the influence of vibration. The maximum permissible level of vibration is a level which, during daily work (except for weekends), but not more than 40 hours a week during the whole working experience, should not cause diseases or deviations in the health condition, which are detected by modern methods of research in the process of work or in the distant terms of life of present and future generations [4].

Under the influence of industrial vibration, exceeding the permissible levels, numerous functional and morphological changes of musculo-skeletal, nervous, cardiovascular, endocrine and other systems occur in the human body [5, 6, 7]. In Russia, the complex of the above mentioned pathological changes among workers of vibration-hazardous professions is defined as a vibration disease - a term that is absent in most national classifications and the current International Statistical Classification of Diseases and Related Health Problems, 10th Revision.

The industrial vibration action is aggravated by simultaneous influence of such concomitant occupational hazards as general and local cooling, a forced working posture, increased static-dynamic load on muscles and joints, noise and some others [8, 9]. It has been proven that industrial activities in the extreme Arctic climate, especially chronic cold stress, form additional threat to the working population health through increased exposure to harmful factors of production, including industrial vibration [10, 11, 12]. It should be understood that the largest mining and processing enterprises are located in the Arctic, the workers of which are most frequently and intensively exposed to the industrial vibration effects [13, 14, 15]. Considering dramatically limited labour resources of the Arctic region, improvement of working conditions and preservation of health of the working population is a priority and long-term political task for the state in the Arctic region [16, 17].

The purpose of the study was to investigate the nature of industrial vibration and its influence on formation of occupational pathology among workers at Russian Arctic enterprises.

Materials and methods. The results of the social and hygienic monitoring upon section “Working conditions and occupational morbidity” of the population of the Arctic zone of Russia in 2007-2017 have been analysed (Federal Hygiene and Epidemiology Centre of the Federal Service for Supervision of Consumer Protection and Welfare, Federal State-Funded Healthcare Institution, Moscow). Statistical data processing was carried out using Microsoft Excel 2010 software and Epi Info, v. 6.04d. The Student’s t-test for independent samples, approval criterion, relative risk (RR) and 95% confidence interval (CI) were determined. The numbers are given as an arithmetic mean and a standard error (M ± m). The null hypothesis significance level was assumed 0.05.

Results of the study. In 2007-2017, the number of workers exposed to industrial vibration at the enterprises of the Russian Arctic zone ranged from 5.85% to 8.04% of the number of persons who had contact with the harmful production factors. The average annual value of this figure was 7.13%, less prevailing than such harmful production factors as noise (21.5%), intensity (8.6%) and severity (8.2%) of the labour process, non-ionizing electromagnetic fields and radiation (7.3%), chemical factors (7.2%). As in previous years, the highest degree of exposure to industrial vibration was observed among workers of mining enterprises and iron and steel works [18, 19, 20].

In view of significant differences in health disorders arising from exposure to general and local vibration [5, 21, 22], their proportion in the structure of the harmful production factors by years and types of economic activity was evaluated separately. It is established that in 2007-2017 in the Arctic region, within the structure of all harmful production factors, the proportion of total vibration was 4.55%-6.34%. Amongst the exposed to general vibration, there were 94.3% men and 5.7% women. The highest absolute number of employees was exposed to total vibration in 2007, and the lowest in 2010. The relative number of employees exposed to total vibration (taking into account the number of employees exposed to all harmful production factors) was maximum in 2017 and 2012 (6.34% and 6.17%). It is important to note that in 2017 this indicator was higher than in 2007. The impact of general vibration was most often observed among those employed in transport, mining enterprises and iron and steel works in the region. The trend of the number of workers exposed to general vibration in 2007-2017 was various. Thus, it decreased significantly in the mining industry, but increased in metallurgy, processing industry and construction. In view of the changes of absolute and relative indicators, there is reason to believe that there is no significant dynamics of the general vibration impact on employees of the enterprises in the Arctic for the analysed eleven-year period (table 1).

Table 1

Number of employees of enterprises of various types of economic activities who were exposed to general vibration

Types of economic activities	Year					Average annual figures
	2007	2010	2012	2014	2017	
Transport	7365	5404	8345	5251	6711	6615.2 (28.1%)
Extraction of mineral resources	8448	4734	7791	4284	4664	5984.2 (25.5%)
Steelmaking industry	3495	3220	3214	4738	4977	3928.8 (16.7%)
Processing industry	1344	1116	1446	3118	3471	2099.0 (8.9%)
Electric power, water and steam production and distribution	2808	1930	1240	1785	1963	1945.2 (8.3%)
Construction	937	1551	1260	2219	2146	1622.6 (6.9%)
Healthcare Service	221	177	368	306	125	239.4 (1.0%)
Agriculture	196	174	204	164	192	186.0 (0.8%)
Other types of activities	1291	444	404	1047	504	738.0 (3.1%)
All types of economic activity (totally)	26878	18750	24272	22913	24753	23513.2 (100.0%)
Total vibration / all harmful production factors, %	5.36	4.55	6.17	5.52	6.34	5.59

The proportion of local vibration in the structure of all harmful production factors was 1.30%-1.86%, which is 3-4 times less than total vibration. The most frequent exposure to local vibration was observed among workers of mining companies, and less often among employees of transport enterprises and iron and steel works of the region. Amongst the exposed to local vibration, there were 90.7% men and 9.3% women. The dynamics of workers' exposure to local and general vibration had similar features. Thus, the highest absolute number of employees was exposed to local vibration in 2007, and the lowest in 2010. The relative number of employees exposed to local vibration was the highest in 2007 and it exceeded the 2017 figure.

It is important to note that in 2007-2017 there was a decrease in the number of workers exposed to local vibration at mining and transport enterprises. In view of the levels of absolute and relative indicators in 2007 and 2017, we can talk about a decrease in the local vibration impact on the employees of the Arctic region for the analysed period (tab. 2).

Table 2

Number of employees of enterprises of various types of economic activities who were exposed to local vibration

Types of economic activities	Year					Average annual figures
	2007	2010	2012	2014	2017	
Transport	1883	710	1947	855	817	1242.4 (18.9%)
Extraction of mineral resources	4064	1272	871	801	1184	1638.4 (24.9%)
Steelmaking industry	1138	1013	882	1169	1763	1193.0 (18.1%)
Processing industry	521	423	453	996	1134	705.4 (10.7%)
Electric power, water and steam production and distribution	322	274	166	350	351	292.6 (4.4%)
Construction	680	595	634	796	672	675.4 (10.3%)
Healthcare Service	485	688	565	509	441	537.6 (8.2%)
Agriculture	17	21	38	64	63	40.6 (0.6%)
Other types of activities	229	378	127	342	199	255.0 (3.9%)
All types of economic activity (totally)	9339	5374	5683	5882	6624	6580.4 (100.0%)
Local vibration / all harmful production factors, %	1.86	1.30	1.44	1.42	1.70	1.54

In 2007-2017, for the first time, 2,372 employees of enterprises in the Arctic were diagnosed with occupational diseases caused by exposure to industrial vibration. Employees of the enterprises of the Arctic zone of Krasnoyarsk Krai (1196 people or 50.4%), Murmansk Oblast (614 people or 25.9%) and the Komi Republic (460 people or 19.4%) were among the diseased. In the rest of the Arctic region there were only isolated cases of vibration-related pathology: in the Chukotka Autonomous Okrug and the Yamalo-Nenets Autonomous Okrug - 42 (1.8%) and 17 (0.7%) respectively, in the Arctic zone of the Arkhangelsk region - 28 (1.2%), in the Arctic zone of the Karelian Republic and the Sakha Republic - 8 (0.3%) and 7 (0.3%) patients respectively. In the Nenets Autonomous Okrug, no cases of occupational diseases caused by vibration were registered in the period of 2007-2017.

Vibration-related pathology was diagnosed in the vast majority of cases (93.8%) in mining (1125 people), iron and steel (677 people) and construction (422 people) enterprises. Vibration-related pathology from the general vibration impact most often occurred among drivers of various mining equipment (425 people), drillers (217 people), drivers of mine dump trucks and other vehicles (201 people). The group of professions with the highest risk of vibration pathology due to local vibration consists of shaftmen (486 people), machine operators of various mining equipment (290 people) and stope miners (223 people).

Among the diseased, there were 2355 (99.3%) men and 27 (0.7%) women, the average age of whom was 51.1±0.1 years old, and the work experience of whom was 24.2±0.1 years. The age and work experience of the diseased workers exposed to local vibration were less than that of those exposed to general vibration. In the work experience range of 11-20 years, the vibration-related pathology developed more often due to the local vibration impact, and when work experience exceeded 30 years, the reason was general vibration.

In the structure of vibration-related pathology vibration disease occupied 73.4%, and among all professional diseases - 22.0%. Indicators of the vibration disease prevalence in the Arctic region did not differ significantly from those in the Murmansk region (12.55%-28.1%), exceeded their level in the Samara region (7.0%-18.9%), but was lower than in the Irkutsk region (21.1%-35.9%) [23, 24, 25]. It is hard to compare with the similar indicators of other countries, because terms “white finger syndrome”, “hand-arm vibration”, “low back pain”, which are widely used abroad, are not identical to the Russian term “vibration disease due to local or general vibration impact” [26, 27, 28]. Development of nervous system diseases (23.3%) and musculoskeletal system diseases (3.3%) was related to the vibration impact less frequently. No circulatory diseases, which are a distinctive manifestation of vibration disorders, were revealed [6, 29].

The nature of health disorders under the influence of general and local vibration had significant differences. Thus, health disorders related to the category of diseases “Injuries, intoxication and other consequences of external causes” more often arose at exposure to general vibration, and diseases of musculoskeletal and nervous systems - on exposure to local vibration. Persons, exposed to general vibration, most often had vibration disease ($p<0.001$) and radiculopathy ($p<0.001$). When exposed to local vibration in the structure of vibration-related pathology, mono-polineuropathy and vegetative-sensory polyneuropathy dominated ($p<0.001$) (Table 3). The occupational pathology risk due to the influence of local vibration was higher than the general risk: RR=3.91; CI 3.62-4.23; $\chi 2$=1369.4;

p<0.001. According to the results of periodic medical examinations, 1348 (56.8%) patients with vibration-related pathology were revealed. In 1024 (43.2%) cases, the diagnosis was established when workers consulted a doctor on their own due to deterioration of health.

Table 3

General characteristics of patients and number of occupational diseases of vibration etiology under influence of general and local vibration (cases)

Indicator	Industrial vibration		
	General	Local	All cases
Sex: men women	 1040 (99.0%) 10 (1.0%)	 1315 (99.5%) 7 (0.5%)	 2355 (99,3%) 17 (0,7%)
Age (y.o.) Work experience (years), including ≤ 10 years 11– 20 years 21– 30 years ≥ 30 years	52,1±0,1 25,3±0,2 8 (0,8%) 242 (23,1%) 558 (53,1%) 241 (23,0%)	50,3±0,2* 23,3±0,2* 19 (1,4%) 410 (31,0%)* 743 (56,3%) 150 (11,3%)*	51,1±0,1 24,2±0,1 27 (1,1%) 653 (27,5%) 1301 (54,8%) 391 (16,5%)
Categories of diseases:			
injuries, intoxication and some other con-sequences of external causes	922 (87,8%)	818 (61,9%)*	1740 (73,4%)
musculoskeletal disorders	58 (5,5%)	21 (1,6%)*	79 (3,3%)
nervous disorders	70 (6,7%)	483 (36,5%)*	553 (23,3%)
Nosological entities:			
vibration disease	922 (87,8%)	818 (61,9%)*	1740 (73,4%)
mono-polyneuropathy	63 (6,0%)	291 (22,0%)*	354 (14,9%)
vegetative-sensory polyneuropathy	4 (0,4%)	190 (14,4%)*	194 (8,2%)
radiculopathy	49 (4,7%)	12 (0,9%)*	61 (2,6%)
arthrosis, periarthrosis, osteoarthritis de-formans	7 (0,7%)	4 (0,3%)	11 (0,5%)
arm polyneuritis (polyneuropathy)	3 (0,3%)	3 (0,2%)	6 (0,3%)
internal epicondylitis	2 (0,2%)	1 (0,07%)	3 (0,1%)
forearm myofibrosis	-	2 (0,2%)	2 (0,08%)
degenerative disk disorder	-	1 (0,07%)	1 (0,04%)

Note * statistically significant differences of indicators (p<0.05) on exposure to general and local vibration

Under the harmful working conditions of classes 3.1-3.2), vibration-related pathology was more often caused by general vibration, and under the hazardous working conditions (classes 3.3-3.4) the most common reason for development of occupational pathology was local vibration. The revealed rare cases of vibration-related pathology development at permissible levels of industrial vibration (0.7%) call for individual hypersensitivity, which may have both congenital and evoked (vascular diseases, consequences of cold injury, etc.) character [5, 6]. Almost in all cases (99.3%) the exposure to unacceptable levels of industrial vibration at the enterprises in the Arctic was a consequence of imperfection of technological processes, structural defects of machines and other equipment, as well as imperfection of workplaces. Unacceptable levels of general vibration were more often conditioned by imperfection of technological processes and workplaces, and by local structural defects of machines, mechanisms, equipment, devices and tools. Only in one case the development of vibration pathology was related to the so-called "human factor" (violation of the established work and rest schedule), which emphasizes importance of technological retrofit of the industry in the Arctic region (Table 4).

Table 4

Number of occupational diseases of vibration etiology in different classes of working conditions and circumstances of their development (cases)

Indicator	Industrial vibration		
	General	Local	All cases
Class of working conditions:			
Class 2	6 (0,6%)	11 (0,8%)	17 (0,7%)
class 3.1	286 (27,2%)	160(12,1%)*	446 (18,8%)
class 3.2	637(60,7%)	362(27,4%)*	999 (42,1%)
class 3.3	110(10,5%)	438(33,1%)*	548 (23,1%)
class 3.4	8 (0,8%)	254(19,2%)*	262 (11,0%)
class 4	3 (0,3%)	97 (7,3%)*	100 (4,2%)
Circumstances of occupational pathology development			
technological process imperfection	669(63,7%)	643 (48,6%)*	1312 (55,3%)
design defects of machinery, mechanisms, equipment, devices and tools	243(23,1%)	612 (46,3%)*	855 (36,0%)
imperfection of workplaces	132(12,6%)	57 (4,3%)*	189 (8,0%)
malfunctioning of machinery, mechanisms, equipment, devices and tools	3 (0,3%)	9 (0,7%)	12 (0,5%)
imperfection of technical medical equipment	3 (0,3%)	-	3 (0,1%)
violation of the established work and rest schedule	1 (0,1%)	-	1 (0,04%)

*Note * statistically significant differences of indicators ($p<0.05$) on exposure to general and local vibration.*

In 2007-2017, there was an increase in the number of cases and morbidity of occupational pathology of vibrational genesis at Arctic enterprises, while nationwide we have observed their decrease recently [2, 3]. The number of newly detected cases varied from 154 (2007) to 329 (2015). The proportion of vibrational pathology in the total structure of occupational diseases was in the range from 24.4% (2013) to 38.0% (2015), making an average of 29.9% and having a rising trend. From 2007 to 2017, the proportion of vibration disease in the structure of vibration pathology increased from 48.1% to 95.1% (an exponentially rising trend).

In 2017, as compared to 2007, there was a negative trend due to an increase in the number of cases of vibration-related pathology (by 1.33 times), an increase in its incidence (from 2.55 to 3.80 per 10,000 employees) and a higher risk of development (OP=1.49; CI 1.21-1.84; $\chi2=14.2$; $p=0.00016$). It is also necessary to note a steep increase in the prevalence of vibration disease - a nosological form of vibration-related pathology with the most unfavourable clinical prediction. Changes in the number of all newly detected nosological forms of occupational pathology differed from the vibration-related pathology dynamics by the fact that in the first case, in 2010-2013, there was an increase in morbidity rate, and in the second case we observed its stabilization (Fig.).

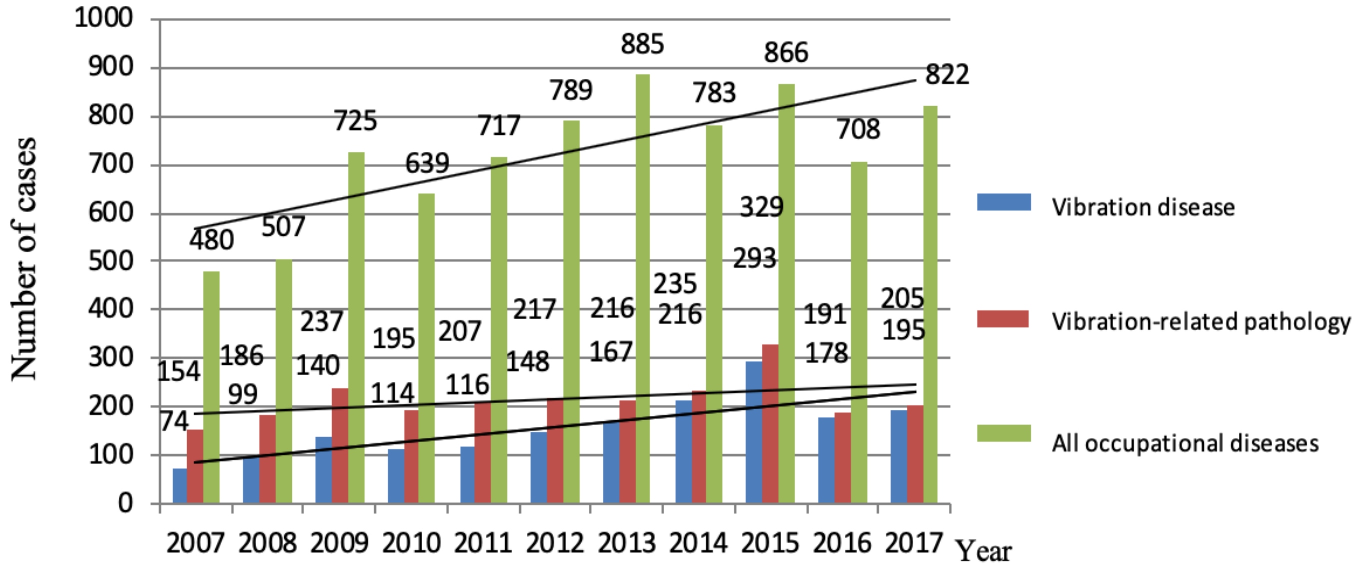

Figure. The number of newly diagnosed vibration diseases, vibration-related pathology and all occupational diseases in the Arctic in 2007-2017.

As a result of these studies, no cause-and-effect relations were established between changes in working conditions and frequency of detection of incipient cases of vibration-related pathology. Their growth and reduction occurred regardless of the dynamics of workers' exposure to general and local vibration. Difficulty of detection of such relations is known both because of a time lag between the two phenomena, and simultaneous action of many other factors, including therapeutic and preventive measures, quality of medical examinations, work motivation, administrative resources of employers to control the indicators of occupational diseases and others [30]. At the moment, we can particularly note that the eleven-year observation period is not sufficient to establish a cause-and-effect relation between changes in working conditions and levels of occupational diseases. By no means has this fact downplayed the importance of production measures to reduce the level of industrial vibration and improve anti-vibration personal protective equipment.

Conclusion: Almost 30% of the occupational diseases in the Arctic are caused by the industrial vibration impact. Over the past eleven years, their number, morbidity rates and risk of incidence have tended to grow. To prevent vibration-related pathology, it is necessaryto improve vibration-hazardous equipment and technological processes, as well as to introduce effective anti-vibration personal protective equipment.

References:

1. Gigiena truda: uchebnik / pod red. N. F. Izmerova, V. F. Kirillova [Occupational health: a textbook / ed. N.F. Izmerov, V.F. Kirillov]. M.: GEOTAR-Media, 2016. (In Russian).
2. O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Rossijskoj Federacii v 2016 godu: Gosudarstvennyj doklad. Federal'naya sluzhba po nadzoru v sfere zashchity prav potrebitelej i blagopoluchiya cheloveka [On the state of sanitary and epidemiological welfare of the population in the Russian Federation in 2016: State report. Federal Service for Supervision of Consumer Rights Protection and Human Welfare]. M.: 2017. (In Russian).
3. O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Rossijskoj Federacii v 2017 godu: Gosudarstvennyj doklad. Federal'naya sluzhba po nadzoru v sfere zashchity prav potrebitelej i blagopoluchiya cheloveka [On the state of sanitary and epidemiological welfare of the population in the Russian Federation in 2017: State report. Federal Service for Supervision of Consumer Rights Protection and Human Welfare]. M.: 2018. (In Russian).
4. Sanitarnye normy i pravila 2.2.4.3359-16 «Sanitarno-epidemiologicheskie trebovaniya k fizicheskim faktoram narabochih mestah» ot 21 iyunya 2016 goda № 81[Sanitary norms and rules 2.2.4.3359-16 "Sanitary-epidemiological requirements for physical factors at workplaces" of June 21, 2016, No. 81]. (In Russian).
5. Vibracionnaya bolezn' / Babanov S.A., Azovskova T.A., Vakurova N.V. Vuzovskij uchebnik [Vibration disease / Babanov SA, Azovskova T.A., Vakurova N.V. University textbook]. M.: NIC INFRA, 2016. (In Russian).
6. Vakurova N.V. ,Azovskova T.A., Lavrent'eva N.E. O sovremennyh aspektah diagnostiki i klassifikacii vibracionnoj bolezni [On the modern aspects of diagnosis and classification of vibration disease]. Regulyarnyevypuski «RMZh». 2014. № 16. Available at: https://www.rmj.ru/articles/nevrologiya (датаобращения: 08.06.2019). (In Russian).
7. Vibracionnaya bolezn' i mery po ee preduprezhdeniyu: Uchebnoe posobie [Vibration disease and measures to prevent it: Tutorial] / E.R. Shajhlislamova, A.B. Bakirov, G.G. Gimranova i dr. - Ufa: Izd-vo, 2016. (In Russian).
8. Profilaktika professional'nyh zabolevanij, vyzvannyh sochetannym vozdejstviem vibracii, shuma i ohlazhdayushchego mikroklimata na predpriyatiyah gornodobyvayushchej promyshlennosti: Metodicheskie rekomendacii [Prevention of occupational diseases caused by the combined effect of vibration, noise and a cooling microclimate at mining enterprises: Guidelines]. M, 1991.(In Russian).
9. Burström L., Nilsson T.,Walström J. Combined exposure to vibration and cold. Barents Newsletters on Occupational Health and Safety. 2015. Vol. 18. № 1. P. 17-18.
10. Myshinskaya Zh.M. Vliyanie klimaticheskih i ekologicheskih faktorov na zdorov'e cheloveka v usloviyah Krajnego Severa [The influence of climatic and environmental factors on human health in the Far North]. Yamal'skij vestnik. 2016. Vol. 2. № 7. P. 79-80. (In Russian).
11. Hasnulin V. I., Hasnulin P. V. Sovremennye predstavleniya o mekhanizmah formirovaniya severnogo stressa u cheloveka v vysokih shirotah [Modern ideas about the mechanisms of formation of northern stress in humans in high latitudes]. Ekologiya cheloveka. 2012. № 1. P.4-11. (In Russian).
12. Gorbanev S.A., Nikanov N.A., Chashchin V.P. Aktual'nye problem mediciny truda v Arkticheskoj zone Rossijskoj

Federacii [Actual problems of occupational medicine in the Arctic zone of the Russian Federation]. Medicina truda i promyshlennaya ekologiya. 2017. № 9. P. 50–51. (In Russian).

13. Buhtiyarov I.V., Golovkova N.P., Chebotarev A.G., Sal'nikov A.A., Nikolaev S.P. Usloviya truda, professional'naya zabolevaemost' na predpriyatiyah otkrytoj dobychi rud [Working conditions, occupational morbidity in open-pit mining enterprises]. Medicina truda i promyshlennaya ekologiya. 2017. № 5. P.44-49. (In Russian).
14. Preobrazhenskaya E.A., Suhova A.V., Zor'kina L.A., Bondareva M.V. Gigienicheskaya ocenka uslovij truda i sostoyanie zdorov'ya rabotnikov gorno-obogatitel'nyh kombinatov [Hygienic assessment of working conditions and health status of workers of mining and processing plants]. Gigiena i sanitariya. 2016. Vol. 95. № 11. P. 1065-1070. DOI: http://dx.doi.org/10.18821/0016-9900-2016-95-11-1065-1070. (In Russian).
15. Syurin S.A., Shilov V.V. Osobennosti vibracionnoj bolezni gornyakov pri sovremennyh tekhnologiyah dobychi rudnogo syr'ya v Kol'skom Zapolyar'e [Features of the vibration disease of the miners with the modern technologies of mining of ore raw materials in the Kola Polar Region]. Zdravoohranenie Rossijskoj Federacii. 2016. № 6. P. 312-316. (In Russian).
16. Rudenko D.YU. Analiz demograficheskih processov v Rossijskoj Arktike [Analysis of demographic processes in the Russian Arctic].MIR (Modernizaciya. Innovacii. Razvitie). 2015. Vol. 6. № 4. P. 51-57. (In Russian).
17. «Ob osnovah gosudarstvennoj politiki RF v Arktike na period do 2020 goda I dal'nejshuyu perspektivu» ["On the fundamentals of the state policy of the Russian Federation in the Arctic for the period up to 2020 and beyond"]. Rossijskaya gazeta. № 4877 (Oct.,18, 2080). (In Russian).
18. Skripal' B.A. Professional'naya zabolevaemost', ee osobennosti na predpriyatiyah gorno-himicheskogo kompleksa Kol'skogo Zapolyar'ya [Occupational morbidity, its features in the enterprises of the mining and chemical complex of the Kola Arctic]. Ekologiya cheloveka. 2008. № 10. P. 26-30. (In Russian).
19. Skripal' B.A. Sostoyanie zdorov'ya I zabolevaemost' rabochih podzemnyh rudnikov gorno-himicheskogo kompleksa Arkticheskoj zony Rossijskoj Federacii [The health status and morbidity of workers in underground mines of the mining and chemical complex of the Arctic zone of the Russian Federation]. Medicina truda I promyshlennaya ekologiya. 2016. № 6. P. 23-26. (In Russian).
20. Syurin S.A., Gorbanev S.A. Osobennosti formirovaniya narushenij zdorov'ya u gornyakov podzemnyh rudnikov Kol'skogo Zapolyar'ya [Features of the formation of health disorders in the miners of the underground mines of the Kola polar region]. Profilakticheskaya i klinicheskaya medicina. 2017. № 4. P. 12-18. (In Russian).
21. Shen S., House R.A. Hand-arm vibration syndrome. What family physicians should know //Canadian Family Physician. 2017. Vol. 63. № 3.P. 206–210.
22. Burström L., Hyvärinen V., Johnsen M., PetterssonH. Exposure to whole-body vibration in open-cast mines in the Barents region. International Journal of Circumpolar Health. 2016. Vol. 75. № 10. 3402/ijch.v75.29373. doi: 10.3402/ijch.v75.29373. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4749864/ (accessed June 6, 2019).
23. Rocheva I. I., Zhelepova O. V., Leshtaeva N. R., Mihajlov S. S. Vi bracionnaya bolezn' u gornorabochih Murmanskoj oblasti [Vibration disease in miners of the Murmansk region]. Medicina truda i promyshlennaya ekologiya. 2004. № 2. P. 44–47. (In Russian).
24. Popov M.N., T.A. Azovskova T.A., Vasyukova G.F. Vyyavlenie i profilaktika naibolee rasprostranennyh professional'nyh zabolevanij v Samarskoj oblasti [Identification and prevention of the most common occupational diseases in the Samara region]. Izvestiya Samarskogo nauchnogo centra Rossijskoj akademii nauk. 2015. Vol. 17. № 2. P. 362-366. (In Russian).
25. Kuleshova M.V., Pankov V.A., D'yakovich M.P. Vibracionnaya bolezn' u rabotnikov aviastroitel'nogo predpriyatiya: factory formirovaniya, klinicheskie proyavleniya, social'no-psihologicheskie osobennosti [Vibration disease in aircraft building workers: factors of formation, clinical manifestations, socio-psychological features]. Gigiena i sanitariya. 2018. Vol. 97. № 10. P. 915-920. DOI: http://dx.doi.org/10.18821/0016-9900-2018-97-10-915-920.
26. Kurtul S., Türk M. Vibration related white finger disease: a case report. The European Research Journal. 2019. Vol. 5. № 1.P. 226-229. DOI: 10.18621/eurj.379091. Available at: https://dergipark.org.tr/download/article-file/480116 (accessed June 6, 2019).
27. Campbell R. A., Matthew B.A., Janko R., Hacker R.I. Hand-arm vibration syndrome: A rarely seen diagnosis. Journal of Vascular Surgery Cases and Innovative Techniques.2017. Vol. 3. № 2.P. 60–62. doi: 10.1016/j.jvscit.2017.01.002. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5757815/ (accessed June 6, 2019).
28. Bovenzi M., Schust M., Mauro M. An overview of low back pain and occupational exposures to whole-body vibration and mechanical shocks. La Medicina del lavoro. 2017. Vol. 108. № 6. P. 419-433. DOI: 10.23749/mdl.v108i6.6639. Available at: https://www.researchgate.net/publication/321833438 (accessed June 6, 2019).
29. Poole C.J., Cleveland T.J. Vascular hand-arm vibration syndrome - magnetic resonance angiography. Occupational Medicine (London). 2016. Vol. 66. № 1.P. 75-8. doi: 10.1093/occmed/kqv151. Available at: https://www.ncbi.nlm.nih.gov/pubmed/26470947 (accessed June 6, 2019).
30. Babanov S.A., Budash D.S., Bajkova A.G., Baraeva R.A. Periodicheskie medicinskie osmotry i professional'nyj otbor v promyshlennoj medicine [Periodic medical examinations and professional selection in occupational medicine]. Zd orov'enaseleniyaisredaobitaniya. 2018. № 5. P. 48-53. (In Russian).