OCCUPATIONAL HEALTH RISKS IN OIL AND GAS WORKERS IN THE RUSSIAN ARCTIC

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Abstract

To study the occupational health risks in oil and gas industry in the Russian Arctic in order to plan and guide further occupational disease prevention programs.

We studied and analyzed the data of "Working conditions and occupational morbidity" dataset with regard to the population of the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021.

Noise (38.9%), cooling microclimate (12.3%), non-ionizing electromagnetic fields and radiation (10.7%) were the most prevalent hazards in the oil and gas industry in the Russian Arctic. Combined effect of two hazards was observed in 19.0% of workers. During 15 years of follow-up, 54 new cases of occupational disease were identified in 50 employees, including sensorineural deafness (46.3%), radiculopathy (18.5%) and vibration disease (13.0%). Occupational diseases were mainly found in harmful classes 3.1 and 3.2 (85.1%) due to outdated technological processes and equipment design flaws (75.9%). In 2007-2021, occupational disease cases in the oil and gas industry made 14.8% of their overall count in the region. The mean rate of occupational morbidity was 0.426 cases / 10,000 employees, five times less than elsewhere in the industry (1,939 cases / 10,000 employees). The risk to obtain an occupational disease otherwise was higher compared to the oil and gas enterprises (RR=4.55; 95% CI 3.40-197.2; p<0.001).

The risk to gain an occupational disease in oil and gas production in the Russian Arctic was lower compared to other industries. This may be due to better working conditions, but can also result from incomplete existing diseases verification or still from some other yet unknown reasons.

Keywords: oil and gas industry, health risks, occupational diseases, Russian Arctic

I. Introduction

Hydrocarbon extraction is an important part of Russian economy. At present, up to 90% of natural gas, 14% of oil and gas condensate are produced jointly in the Yamalo-Nenets Autonomous Okrug (population 544.4 thousand people, territory 769.3 thousand km^2) and Nenets Autonomous Okrug (population 44.5 thousand people, territory 176.8 thousand km^2). Such enormous amount of material is then transported to elsewhere in Russia and other countries [1, 2]. Both regions are situated in the Russian Arctic known for harsh climate, low population density of less than 1 person/km2, underdeveloped infrastructure, and significant remoteness [3].

Human activity in the Arctic, including hydrocarbons extraction and transportation, is associated with extreme ambient conditions. These hazards include general and local cooling, geomagnetic intensity, pronounced seasonal photoperiodicity, frequent shift from cyclones to anticyclones, low oxygen content in the air and other factors [4, 5].

Those working in the oil and gas industry demonstrate an increased risk of occupational

disease resulting from an exposure to a range of occupational hazards, including noise, vibration, increased labor severity and poor workplace microclimate [6-8]. Furthermore, sulfur-containing compounds of gas and oil, such as hydrogen sulfide, mercaptans, carbon disulfide, sulfur anhydride, sulfur dioxide and sulfur dust, attributed to chemicals of the second, third and fourth hazard classes are a specific occupational exposure in these workers [9-11]. The combination of occupational exposures with specific Arctic climatic conditions has been reported to increase the prevalence of ocular, respiratory, cardiovascular, musculoskeletal diseases along with malignancies [12-15], and to modify the rate and clinical manifestations of occupational diseases [16]. In addition, many oil and gas employees work shifts, usually associated with chronic stress [17].

The presented data substantiate the need for more effective health building programs for oil and gas workers in the Russian Arctic [18, 19], including the proper and timely occupational risks identification and management [20, 21].

II. Methods

We studied and analyzed the data of "Working conditions and occupational morbidity" dataset with regard to the population of the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021 (Federal Service for Supervision of Consumer Rights Protection and Human Well-Being). We assessed occupational risks in the oil and gas industry when comparing work conditions and occupational disease profile with other industries in the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021.

Data were analyzed using Microsoft Excel 2016 and IBM SPSS Statistics v. 22. We calculated Student t-values for the independent groups, followed by χ^2, relative risk (RR) and the corresponding 95% confidence interval (CI). Data are presented as absolute values with percent to the overall count in the group, as well as means with their standard errors (M ± m). P-values below 0.05 were considered significant.

This study received approval from the Committee of Bioethics of the Northwest Public Health Research Center and was conducted in accordance with the relevant guidelines and regulations.

III. Results

An analysis of hygienic studies has shown that most often oil and gas industry workers in the Nenets and Yamalo-Nenets Autonomous Okrugs are exposed to noise, a cooling microclimate, non-ionizing electromagnetic fields and radiation, whole-body vibration, increased labor severity and harmful chemicals. Individual shares of other harmful factors were much smaller and did not exceed 1.5% level. The second place in the structure of harmful factors was occupied by the combined action of two factors, which created an increased risk of developing occupational diseases [16]. Despite the similarity of working conditions in the two groups of employers, there were also significant differences. Thus, in oil and gas production, exposure to noise occurred more often, while in other sectors of the economy whole-body vibration and harmful chemicals were more prevalent factors (Table 1). In addition, the risk of contact with harmful production factors at enterprises in other industries was higher than in oil and gas production: RR=1.01; CI 1.01-1.02; $\chi 2$=9.69; p=0.002.

In addition to studying the workers′ exposure to certain harmful production factors, a comprehensive assessment of working conditions at enterprises was carried out to determine their group of sanitary and epidemiological well-being (Table 2). It was found that oil and gas industry workers were more often employed at the facilities of the first (satisfactory working conditions) and the second (unsatisfactory working conditions) groups, while their number was significantly

lower at the facilities of the third (extremely unsatisfactory working conditions) group. Thus, it was shown that working conditions in the oil and gas industry were more favorable compared to enterprises in other sectors of the economy.

Table 1: *The number of workers in contact with harmful production factors, (%)*

Harmful production factor	Oil and gas industry	Other industries	p
Noise	16190 (38.9)	12069 (22.7)	<0.001
Cooling microclimate	5105 (12.3)	5917 (11.1)	0.384
Non-ionizing electromagnetic fields and radiation	4431 (10.7)	6333 (11.9)	0.443
Whole-body vibration	1789 (4.3)	4948 (9.3)	0.004
Increased labor severity	1721 (4.1)	3246 (6.1)	0.184
Harmful chemicals	1199 (2.9)	5211 (9.8)	<0.001
Ionizing radiation	625 (1.5)	335 (0.6)	0.168
Fibrogenic aerosols	617 (1.5)	928 (1.7)	0.761
Insufficient lighting	590 (1.4)	1444 (2.7)	0.205
Infrasound	457 (1.1)	701 (1.3)	0.617
Biological agents	395 (0.9)	271 (0.5)	0.478
Increased labor intensity	301 (0.7)	1189 (2.2)	0.061
Hand-arm vibration	298 (0.7)	655 (1.2)	0,520
Combined impact of factors	7887 (19.0)	9946 (18.7)	0,953
Total	41605 (100.0)	53193 (100.0)	

Table 2: *Number of jobs at enterprises with different sanitary and epidemiological well-being, (%)*

Sanitary and epidemiological well-being	Oil and gas industry	Other industries	p
Satisfactory (first group)	38187 (45.0)	39520 (39.0)	<0.001
Unsatisfactory (second group)	43989 (51.8)	48811 (48.1)	<0.001
Extremely unsatisfactory (third group)	2693 (3.2)	13132 (12.9)	<0.001
Total	84869 (100.0)	101463 (100.0)	

In 2007-2021, in the Nenets and Yamalo-Nenets Autonomous Okrugs, 364 new occupational diseases were detected in 358 workers. Of these, 257 (70.6%) diseases occurred at transport enterprises, and 54 (14.8%), that is, 4.8 times less often, among people involved in the extraction and transportation of oil and gas. Occupational diseases were even less frequently diagnosed among workers in other sectors of the regional economy (Fig. 1).

One nosological form of occupational disease was diagnosed in 352 (98.3%) out of 358 workers and 6 (1.7%) workers had two diseases. Of 50 workers involved in the extraction of gas and oil, 46 (92.0%) workers were diagnosed with one occupational disease each, and four employers had two diseases. In cases of a combination of two nosological forms of occupational diseases, one of them was sensorineural hearing loss, and the second was radiculopathy. In 2007-2021, the annual number of new occupational diseases among employees of oil and gas companies varied from one to six. For other employees of the Nenets and Yamalo-Nenets Autonomous Okrug, their number ranged from 11 to 32 cases. In both groups, there was no trend towards a decrease or increase in the annual number of occupational diseases (horizontal trend lines in Fig. 2).

Occupational diseases were diagnosed in workers of 13 specialties engaged in oil and gas production and transportation. They included 16 drilling rig operators, 6 locksmiths, 4 steam generator plant operators, 3 pipelayer operators. Workers of each of the remaining 9 specialties were diagnosed with 1-2 diseases. In other sectors of the economy, occupational diseases more often developed among employers engaged in air cargo and passenger transportation: 142 pilots and 84 flight mechanics (engineers).

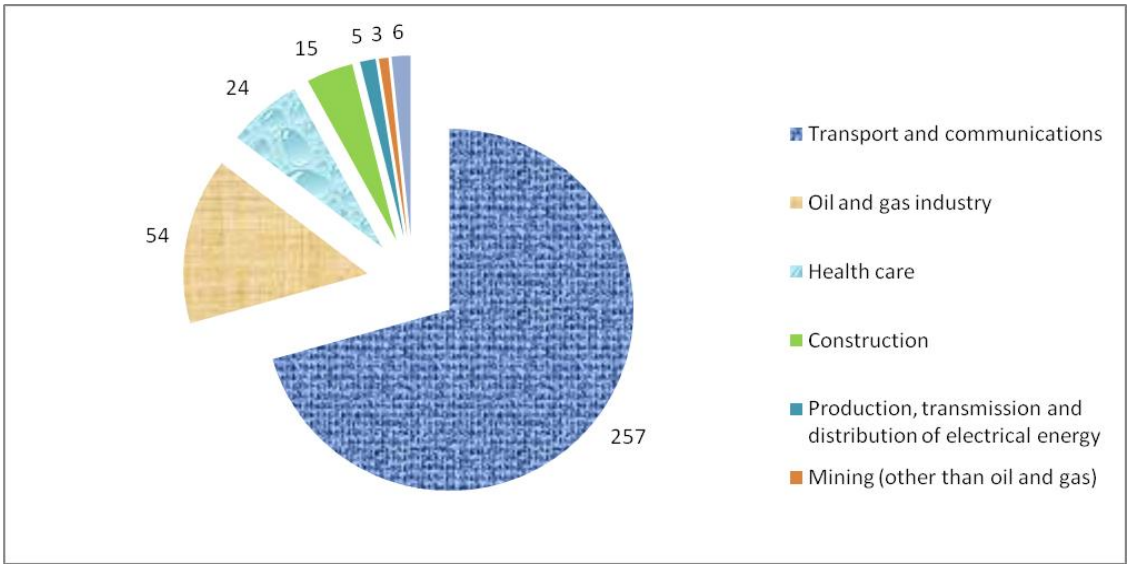

Fig. 1: *Occupational diseases in various types of economic activity in the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021 (cases)*

No significant differences were found between employees of the oil and gas industry and other sectors of the economy in age (53.9±0.7 and 55.1±0.4 years, p=0.138) and length of service (27.6±1.2 and 28.9 ±0.5 years, p=0.318) at which occupational diseases were first diagnosed. Also, there were no gender differences between the two groups, although only men were engaged in oil and gas production, while women accounted for 6.5% of 308 workers in other sectors of the economy (p = 0.064).

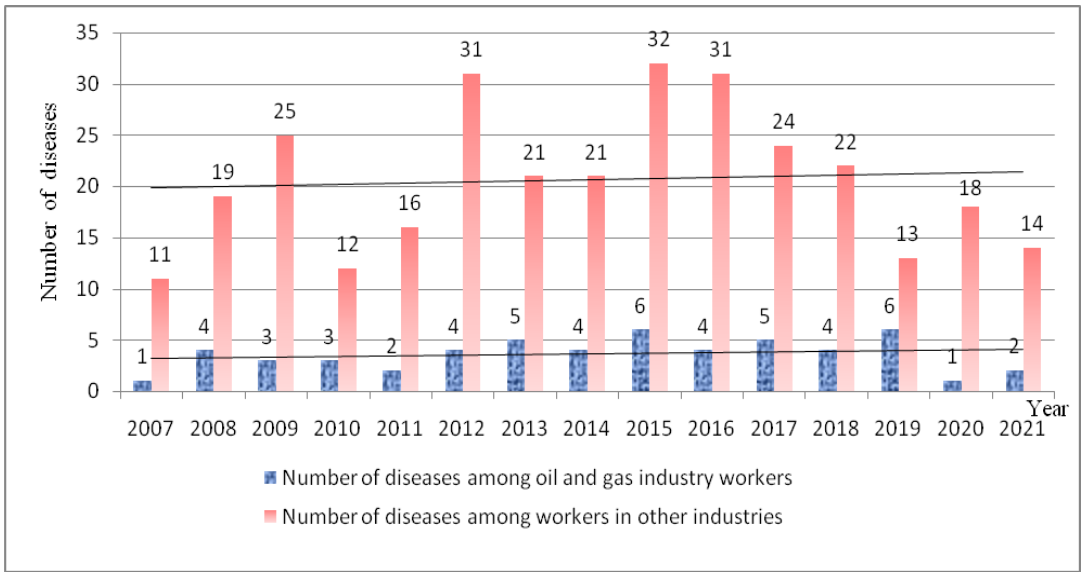

Fig. 2: *The annual number of newly diagnosed occupational diseases among employees of oil and gas industry and other industries*

Special attention in assessing the risks of developing occupational diseases is given to the study of working conditions. According to Russian legislation (Guide on Hygienic Assessment of Factors of Working Environment and Work Load. Criteria and Classification of Working Conditions. 2005), hygiene specialists establish a class of working conditions for each employee, which depends on the extent to which the actual levels of harmful production factors exceed their permissible levels (OEL). The current classification includes four classes of working conditions: 1) optimal (<OEL); 2) permissible (≤OEL); 3) harmful with the allocation of four subclasses; 4) extreme (>OEL). The degree of excess of permissible levels for the main harmful production factors and the corresponding classes of working conditions are presented in Table 3.

Table 3: *Working condition grading classification with regard to OEL exceedance*

Harmful production factor	Harmful class (3)				Extreme class (4)
	3.1	3.2	3.3	3.4	
Chemicals	1.1-3.0 OEL	3.1-10.0 OEL	10.1-15.0 OEL	15.1-20,0 OEL	>20.0 OEL
Weak fibrogenic aerosols (OEL>2 mg/m^3)*	1.1-3.0 OEL	3.1-6.0 OEL	6.1-10.0 OEL	>10.0 OEL	none
Whole-body vibration	6 dB	12 dB	18 dB	24 dB	>24 dB
Hand-arm vibration	3 dB	6 dB	9 dB	12 dB	>12 dB
Noise	5 dBA	15 dBA	25 dBA	35 dBA	>35 dBA

Note: OEL – occupational exposure limit;
** - no exposure to other types of aerosols according to the degree of fibrogenicity in this category of worker.*

The methodology to define class of working conditions with regard to labor severity, labor intensity and workplace microclimate is more complex since it is based on taking into account a set of indicators. Labor severity grading includes dynamic and static workloads, motions stereotype, lifting and moving weights and work posture. Labor intensity grading takes into account intellectual, sensor and emotional loads, as well as their monotony. Workplace microclimate assessment considers combined influence on employees of temperature, humidity, air flow velocity and physical load intensity. As for other harmful production factors, four classes of working conditions are also used to assess the labor severity, labor intensity and workplace microclimate.

As our data showed, more than 80% of all cases of occupational diseases in both groups were due to harmful production factors that corresponded to harmful classes 3.1 and 3.2. However, class 3.1 was more prevalent among employees of oil and gas enterprises, while employees in other industries were more often exposed to factors corresponding to class 3.2 (Table 4).

Noise occupied a leading place in the spectrum of harmful production factors resulting in the development of occupational diseases among employees of all industries in the Nenets and Yamalo-Nenets Autonomous Okrugs. At the same time, for workers at oil and gas enterprises, its share approached 50%, whereas noise-related diseases dominated the structure of occupational pathology of workers in other industries, exceeding 80%. A feature of occupational health disorders in oil and gas industry workers was their greater etiological relationship with the labor severity, whole-body vibration and exposure to harmful chemicals. In addition to noise, biological (infectious) factors played a greater role in the occurrence of occupational diseases among workers in other sectors of the economy. This was due to the presence of health workers in their ranks. It should be noted that only in one case an occupational disease in oil and gas workers was due to industry-specific sulfur-containing chemical compounds.

Significant differences were revealed between the structure of harmful production factors that caused occupational diseases in oil and gas industry workers and the structure of harmful production factors to which they were exposed at their workplaces. Thus, the share of labor

severity among the factors causing disease development was 5.88 times greater than its share in the structure of factors with which workers were in contact at work. A similar difference for whole-body vibration was 3.89 times, for hand-arm vibration - 2.71 times, for harmful chemicals - 2.55 times. There were no differences between the shares of noise and weak fibrogenic action aerosols in the structures of disease-causing factors and the factors with which contact was noted at work. And only in the case of a cooling microclimate, the etiological significance of this factor in causing occupational diseases was 6.47 times less than its share in the structure of all existing harmful production factors. Not a single case of occupational disease in oil and gas industry workers was associated with such influences as non-ionizing fields and radiation, ionizing radiation, biological factors, infrasound, increased labor intensity and unsatisfactory lighting parameters. The main circumstances that made possible the impact of harmful production factors on employees of oil and gas enterprises were the imperfection of technological processes and design flaws in equipment. The imperfection of workplaces and the imperfection of sanitary installations created such conditions 3-4 times less often. Among employees of oil and gas enterprises, in comparison with employees of other industries, exposure to harmful factors more often arose due to imperfection of technological processes and imperfection of workplaces, and, conversely, less often the cause of exposure was the design flaws of equipment (Table 4).

Table 4: *Conditions and circumstances for development of occupational diseases in the Nenets and Yamalo-Nenets Autonomous Okrugs, cases (%)*

Indicator	Oil and gas industry	Other industries	p
Working condition class			
Class 2	2 (3.7)	3 (1.0)	0.111
Class 3.1	22 (40.7)	79 (25.5)	0.021
Class 3.2	24 (44.4)	183 (57.7)	0.046
Class 3.3	6 (11.1)	40 (12.9)	0.644
Class 3.4	0	5 (1.6)	0.348
Harmful production factors			
Noise	25 (46.3)	254 (81.9)	<0.001
Labor severity (above permissible level)	13 (24.1)	15 (4.8)	<0.001
Whole-body vibration	9 (16.7)	8 (2.6)	<0.001
Harmful chemicals	4 (7.4)	7 (2.3)	0.042
Weak fibrogenic action aerosols	1 (1.9)	1 (0.3)	0.161
Hand-arm vibration	1 (1.9)	1 (0.3)	0.161
Microclimate cooling	1 (1.9)	1 (0.3)	0.161
Ionizing radiation	0	1 (0.3)	0.676
Biological (infectious)	0	22 (7.1)	0.044
Circumstances of exposure to harmful production factors			
Imperfection of technological processes	21 (38.9)	64 (20.6)	<0.001
Design defects of machines, mechanisms and other equipment	20 (37.0)	193 (62.3)	<0.001
Imperfection of workplaces	6 (11.1)	12 (3.9)	0.024
Imperfection of sanitary installations	4 (7.4)	9 (2.9)	0.100
Contact with an infectious agent	0	16 (5.2)	0.088
Other circumstances	3 (1.9)	16 (5.2)	0.905

Ear diseases occupied the largest share in the structure of occupational diseases in oil and gas production workers. Musculoskeletal diseases were diagnosed 2.5 times less often, injuries and

intoxications - 3 times less often, nervous diseases - 5 times less often. Skin and respiratory disorders were found only in isolated cases. For comparison, in the structure of diseases in other industry workers ear diseases were also the most prevalent, but to a much greater extent, since their share reached 81.9%. In this group of workers, infectious diseases ranked second, so musculoskeletal diseases, injuries and intoxications were less important than in oil and gas industry workers. The frequency of detection of the most common nosological forms of diseases corresponded to the structure of disease classes. A feature of oil and gas workers was a higher proportion of radiculopathy, vibration disease, and monopolyneropathy (Table 5).

The most prevalent nosological forms of occupational diseases belonged to the categories of ear and musculoskeletal diseases, as well as injuries and intjxications. A feature of oil and gas industry workers consisted in a higher proportion of radiculopathy, vibration disease, and monopolyneropathy (Table 5).

Table 5: *Categories and nosological forms of occupational diseases in the Nenets and Yamalo-Nenets Autonomous Okrugs, (%)*

Indicator	Oil and gas industry	Other industries	p
Occupational disease categories			
Ear and mastoid process	26 (48.1)	254 (81.9)	<0.001
Musculoskeletal system	11 (20.4)	16 (5.2)	<0.001
Injuries, poisonings and some other consequences of external causes	9 (16.7)	9 (2.9)	<0.001
Nervous system	5 (9.3)	2 (0.6)	<0.001
Skin and subcutaneous tissue	2 (3.7)	3 (1.0)	0.113
Respiratory system	1 (1.9)	3 (1.0)	0.570
Infectious and parasitic diseases	0	22 (7.1)	0.044
Malignant neoplasms	0	1 (0.3)	0.676
Prevalent nosological forms of occupational diseases			
Sensorineural hearing loss	25 (46.3)	254 (81.9)	<0.001
Radiculopathy	10 (18.5)	14 (4.5)	<0.001
Vibration disease	7 (13.0)	7 (2.3)	<0.001
Monopolyneropathy	4 (7.4)	2 (0.6)	<0.001
Allergic dermatitis	2	2 (0.6)	0.047
Tuberculosis of the respiratory organs	0	12 (3.9)	0.142
COVID-19	0	8 (2.6)	0.233

At the final stage of the study, the levels of occupational morbidity in two compared groups of workers in the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021 were assessed. No such information was found in the open literature, which served as the basis for the corresponding calculations. Due to the lack of official data on the average annual regional number of employees in the studied industries (necessary for calculating the incidence), we used the indicator of the average annual number of employees registered at all facilities of sanitary and hygienic well-being, that is, the number of officially employed people in the region.

According to the socio-hygienic monitoring "Working conditions and occupational morbidity" of the Nenets and Yamalo-Nenets Autonomous Okrugs′ population in 2007-2021, the average annual number of employees at sanitary and epidemiological welfare facilities in the oil and gas industry amounted to 84,869 people, and at all facilities in other sectors of the economy it

reached 101463 people. Thus, the average annual level of occupational morbidity of oil and gas industry workers in the Arctic in 2007-2021 was established at 0.426 cases / 10,000 workers. For persons employed in 2007-2021 in all other sectors of the economy of the region, the same indicator was almost 5 times higher - 1,939 cases / 10,000 employees. The risk of developing occupational disease in 2007-2021 among workers in all industries in the Nenets and Yamalo-Nenets Autonomous Okrugs (except for the oil and gas industry) was higher than among workers in oil and gas enterprises: RR=4.55; CI 3.40-197.2; $\chi 2=6.07$; $p<0.001$.

IV. Discussion

The current study made it possible to establish a number of facts that deserve attention and discussion. First of all, we hypothesized that those employed in the oil and gas industry in the Arctic would have increased occupational health risks. This hypothesis was based on the data from other occupational groups employed in the Arctic with a known combination of occupational hazards and working shifts [12, 13, 17]. Nevertheless, other studies reported lower incidence of occupational disease in the oil and gas industry compared to that of workers of mining and coal mines [22], including occupational hearing loss [23]. Our analysis showed that in 2007-2021, occupational diseases were more often diagnosed in the transportation industry, including air transportation, and the rate of occupational disease in the oil and gas enterprises was five times lower than that of employees of other industries in the region. In addition, it was 2-5 times lower compared to the mean rate in Russia, which ranged from 1.92 cases/10,000 employees in 2011 to 0.78 cases/employees in 2020.

We offer at least six reasons of that (from most likely to least likely):

1. Better working conditions at already developed fields (this can be proven by the better state of sanitary and epidemiological well-being and the lower prevalence of certain harmful production factors) compared to other industries. Occupational hazards in this industry are likely more pronounced during mining initiation. The effect of severe climate may be most evident prior to the stage when acceptable dwelling and accommodation conditions are set. More occupational disease in drillers supports this explanation.

2. The widespread use of the shift work, making health disorders identification and registration challenging, including occupational disease. Low quality of annual screening may also contribute to that [17]. In addition, occupational diseases registration becomes impossible at a place of employment (Nenets and Yamalo-Nenets Autonomous Okrugs), if it was diagnosed at a place of permanent residence. These regions fail to set up a system of reliable information exchange regarding the cases of newly detected occupational diseases among shift workers.

3. The employees, especially those working shifts, prefer to conceal the signs of occupational disease with the purpose to keep a better paid job in the Russian Arctic. This may be even more relevant in a period of deterioration in the economy.

4. Insufficient occupational diseases detection both in Russia as a whole [24] and in the Nenets and Yamalo-Nenets Autonomous Okrugs, including that of pre-employment and periodic medical examinations. This results in an underestimation of the reported occupational disease incidence as compared to the real picture. Exposure assessment and occupational hygiene procedures quality are also of great concern. It is not clear, as an example, why work-related hearing loss is less prevalent in oil and gas industry workers with much greater exposure to noise. Conversely, vibration disease is diagnosed more often with less exposure to the whole-body vibration compared to workers in other industries.

5. In the course of performing work on a rotational basis, there is a natural division of workers into those who tolerate Arctic climatic conditions well and poorly. The first group with the initially better state of health continues to work shifts and they rarely develop occupational diseases. The second group of workers stops business trips to the Arctic due to the deterioration of

health. Possible occupational diseases either do not occur or are not registered at the place of permanent residence. Thus, the phenomenon of the so-called "healthy worker" is created, when the level of health of people working in hazardous conditions is better than the level of health of the population as a whole [25].

6. It is possible that the shift method of performing work, in addition to the well-known negative impact on health, also has positive aspects. So, after a 4-8 week shift in the Arctic, a period of rest of the same duration at the permanent place of residence follows. At this time, contact with harmful production factors is interrupted and their cumulative negative effect on the health of the worker is not created. However, this hypothesis has no scientific evidence. In the literature, we did not find studies on the effect of long alternating periods of labor activity in harmful conditions with periods of rest in favorable conditions on the development of occupational diseases.

Given the harsh climatic conditions of the Arctic, the one would expect cooling microclimate to explain a large fraction of occupational disease in the studied group, which, however, remained as low as 1.9%. However, cold is usually considered a leading stressful factor for people living and working in the Russian Arctic. Cooling, both general and local, results in a decrease in physical and mental performance, disrupts movement coordination and the ability to perform precise and complex operations, promote musculoskeletal complaints and diseases [26, 27]. Apparently, an inadequate assessment of the impact of cold on workers in the Arctic is due to the lack of hygienic standards for the microclimate of open work areas.

Study limitations. No full data on the real incidence of occupational diseases in the oil and gas industry personnel in the Russian Arctic may be a limitation of this analysis. This underestimation occurs when workers prefer to conceal their signs and medical conditions, when shift work is widely used and when the diseases verification is limited at the periodic screening.

V. Conclusion

In 2007-2021, noise was a major health risk for those working in oil and gas industry in the Russian Arctic, most often causing sensorineural deafness (46.3% of all occupational disease cases). The level of occupational morbidity (0.426 cases / 10,000 employees) in oil and gas industry workers was lower than that of workers in other sectors of the region's economy, as well as official all-Russian indicators. On the one hand, this may be due to better working conditions, on the other hand, can also result from incomplete diagnosis and registration of existing diseases or still from some other yet unknown reasons.

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