



Research article

## HYGIENIC ASSESSMENT OF WORKING CONDITIONS AND OCCUPATIONAL INCIDENCE AMONG MINING WORKERS IN THE ARCTIC ZONE OF THE NORILSK INDUSTRIAL AREA

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*The development of the Arctic zone as a strategic resource base and its rational use aimed at the economic growth acceleration is a key interest of the Russian Federation in this region. The occupational environment in mining industry is associated with unique working conditions. Underground mining makes workers' health protection the most significant task.*

*The aim of this study was to perform hygienic assessment of working conditions, occupational incidence and occupational health risks for workers employed in mining industry in the Arctic zone of the Norilsk industrial area. Occupational health risks were assessed using indicators outlined in the Guide R 2.2.2006-05 The Guide on Hygienic Assessment of Factors Related to Working Environment and Work Process. Exposure to occupational noise and considerable work hardness are priority factors in the analyzed industry that cause occupational diseases. Occupational diseases among workers employed in mining industry in the Norilsk industrial area belonged to six nosologies. Vibration disease, stages 1 and 2, makes the greatest contribution to the overall structure of occupational incidence since it accounts for 68.6 % in it. The second place belongs to two-sided sensorineural hearing loss, stages 1 and 2, 13.5 %. Radiculopathy occupies the third rank place accounting for 10.9 %.*

*Unacceptable occupational health risks were identified at 76.8 % of workplaces. A high share of workplaces with unacceptable occupational health risks leads to high occupational incidence among mining workers in the Norilsk industrial area, its levels being higher than the national average.*

**Keywords:** special assessment of working conditions, occupational factors, risk assessment, violation of hygienic standards, occupational diseases, mining industry, Arctic zone, Norilsk industrial area.

The development of the Arctic zone as a strategic resource base and its rational use aimed at the economic growth acceleration is a key interest of the Russian Federation in

this region<sup>1</sup> [1–5]. The occupational environment in mining industry is associated with unique working conditions, which, according to the International Labor Organiza-

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tion, pose a serious hazard for workers' health [6].

The Norilsk mining sector is the leading area in the Russian Federation as regards mining and production of nickel, copper, cobalt, silver, and platinum metals [7–11].

Protection of workers' health becomes the most significant task in Norilsk due to harsh climate in the Arctic zone and hard working conditions associated with underground mining [12–17].

In this study, our **aim** was to perform hygienic assessment of working conditions, occupational incidence and occupational health risks for workers employed in mining industry in the Arctic zone of the Norilsk industrial area.

**Materials and methods.** We analyzed the results of special assessment of working conditions at mining workers' workplaces in the Norilsk industrial area and occupational incidence over a 10-year period, from 2013 to 2022. All the relevant data for the analysis were taken from the State Report on Sanitary-Epidemiological Welfare of the Population in Krasnoyarsk Region and from the archives of the Rospotrebnadzor Regional Office in Krasnoyarsk. Occupational health risks were assessed using indicators outlined in the Guidelines R 2.2.2006-05 'The Guide on Hygienic Assessment of Factors Related to Working Environment and Work Process'<sup>2</sup>.

**Results and discussion.** We analyzed working conditions at workplaces of 7872 workers employed in the mining industry in the Norilsk industrial area. As a result, we established that, according to the special assessment of working conditions (SAWC) performed in 2016, hygienic standards were violated as per one or several harmful occupational factors at 1838 workplaces (76.8 %).

The most common harmful occupational factors include occupational noise, work hardness, chemical factors, aerosols with predominantly fibrogenic effects, total and local vibration (Figure 1).

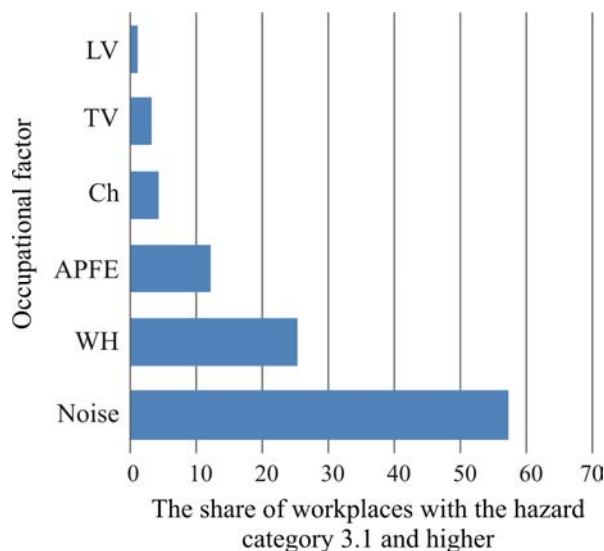


Figure 1. The share of workplaces (%) with the hazard category 3.1 and higher at mining enterprises in the Norilsk industrial area: LV is local vibration, TV is total vibration, Ch is chemicals in workplace air, APFE is aerosols with predominantly fibrogenic effects, WH is work hardness

According to the SAWC results, occupational noise was higher than the established hygienic standards at 1368 workplaces (57.2 %) and reached 105 dBA; this level is by 25 dBA higher than the maximum permissible one (MPL is 80 dBA) and therefore working conditions with this exposure are classified as having the hazard category 3.3 (harmful, the hazard degree is 3). The highest noise levels were established for such occupations as drilling unit operator, cargo handling machine operator, self-propelled mining machine operator, electric locomotive driver, working face miner, drift miner, blast-hole driller, breaker, hatch handler, and others.

<sup>2</sup> The Guidelines R 2.2.2006-05. Guide on Hygienic Assessment of Factors of Working Environment and Work Load. Criteria and Classification of Working Conditions (approved by the RF Chief Sanitary Inspector on July 29, 2005; became valid on November 01, 2005). *KODEKS: electronic fund for legal and reference documentation*. Available at: <https://docs.cntd.ru/document/1200040973> (April 12, 2023) (in Russian).

The second place as per frequency belongs to work hardness according to the SAWC results. The hygienic standards were violated as per this harmful occupational factor at 606 workplaces (25.3 %). Most workplaces of basic mining occupations such as mining foreman, working face miner, underground miner, blaster, fueler, drift miner, drilling unit operator, cargo handling machine operator and some others have working conditions that belong to the hazard category 3.2 (harmful, the hazard degree is 2).

The hygienic standards established for levels of fibrogenic aerosols were violated at 291 workplaces (12.2 %) and working conditions there were classified as having the hazard category 3.1. Very high levels of aerosols with predominantly fibrogenic effects were identified only at two workplaces of timber-men and one workplace of an electric gas welder and therefore working conditions at these workplaces were classified as having the hazard category 3.2.

Chemical pollution in workplace air was established at 101 workplaces (4.2 %); working conditions were classified as having the hazard category 3.2 as per this factor only at four of them (electric gas welder, cargo handling machine operator, and drilling unit operator).

Total vibration was higher than the established hygienic standards at 74 workplaces (3.1 %) at mining enterprises located in the Norilsk industrial area. Levels that were 12 dB higher than permissible ones were identified at 26 of them (cargo handling machine operator, breaker, drilling unit operator) (the hazard category 3.2).

The hygienic standards established for local vibration were violated at 24 workplaces (1 %); local vibration levels were 6 dB higher than the permissible ones at eight of them (working face miner, drift miner, fueler), the working conditions had the hazard category 3.2.

Complex exposure to harmful occupational factors was established to produce negative effects on health of workers employed at

mining enterprises in the Norilsk industrial area. Unsafe levels of such factors that exceeded MPL were identified at workplaces of cargo handling machine (CHM) operators, electric gas welders, drift miners, working face miners, self-propelled mining machine (SPMM) operators, mine testers, electric locomotive drivers, grinder operators, conveyor operators, hatch handlers, blast-hole drillers, workers responsible for timber delivery to a mine, breakers, and drilling unit operators (Table 1).

Having analyzed the SAWC results obtained at mining enterprises in the Norilsk industrial area, we established that the share of workplaces with negligible (tolerable) health risks was 23.16 %; low (moderate) risk, 34.28 %; average (considerable) risk, 27.3 %; high (intolerable) risk, 15.26 %. We did not identify any workplaces with extremely high (intolerable) health risks (Table 2).

Harmful working conditions and simultaneous exposure to several harmful occupational factors (the hazard category 3.1 and higher) caused 957 cases of occupational diseases that were diagnosed over 10 years from 2013 to 2022 at mining enterprises located in the Norilsk industrial area (Figure 2).

An occupational disease was diagnosed at an average worker's age being 50.4 years; working records for work under harmful and hazardous conditions, 23.1 years; working records for an occupation for which an occupational disease was diagnosed, 16.1 years. The greatest number of occupational diseases was identified among cargo handling machine operators, 226 (23.6 %); blast-hole drillers, 143 (14.9 %); working face miners, 126 (13.2 %); blasters (including blaster foremen), 89 (9.3 %); timber-men, 73 (7.5 %); drift miners, 69 (7.2 %); electric locomotive drivers, 53 (5.5 %); drilling unit operators, 44 (4.6 %). The remaining 14 % of occupational diseases were diagnosed in such occupations as hatch handlers, self-propelled mining machine operators, breakers, repairmen, welders, road workers, and some others.

Table 1

Hygienic assessment of occupational risks according to the SAWC for different workplaces at mining enterprises in the Norilsk industrial area

No.	Occupation	Harmful occupational factors (the hazard category 3.1 and higher)					
		Noise	Total vibration	Local vibration	Work hardness	APFE	Chemical factor
1	CHM operator	+	+	+	+	-	+
2	Drift miner	+	-	-	+	+	+
3	Working face miner	+	-	-	+	+	+
4	SPMM operator	+	+	+	+	+	+
5	Electric locomotive driver	+	+	-	-	+	-
6	Grinder operator	+	-	-	+	+	-
7	Drilling unit operator	+	+	+	+	-	-
8	Conveyor operator	+	+	-	+	+	-
9	Mine tester	+	-	-	+	+	+
10	Hatch handler	+	-	-	+	+	-
11	Blast-hole driller	+	-	-	+	+	-
12	Worker responsible for timber delivery to a mine	+	-	-	+	+	-
13	Breaker	+	+	-	+	+	-
14	Timber-man	+	-	-	+	+	-

Table 2

Hygienic assessment of occupational risks according to the SAWC for different workplaces at mining enterprises in the Norilsk industrial area

The number of workplaces	Negligible (tolerable) risk		Low (moderate) risk		Average (considerable) risk		High (intolerable) risk		Very high (intolerable) risk	
	abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
2392	554	23.16	820	34.28	653	27.30	365	15.26	-	-

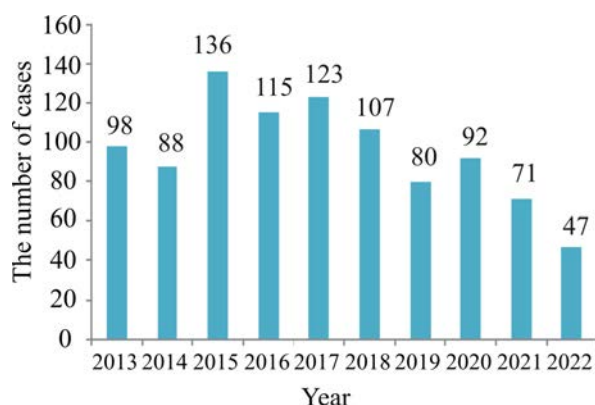


Figure 2. The number of confirmed occupational disease cases among workers employed at mining enterprises located in the Norilsk industrial area

Occupational diseases among workers employed in mining industry in the Norilsk industrial area belong to six nosologies. Vibration disease, stages 1 and 2, makes the greatest contribution to the overall structure of occupational incidence since it accounts for 68.6 % in it. The second place belongs to two-sided sensorineural hearing loss, stages 1 and 2, 13.5 %. Radiculopathy occupies the third rank place accounting for 10.9 %. Occupational respiratory diseases, malignant neoplasms of various localization, and diseases of the autonomous nervous system account for 7 %.

Our study has established that working conditions do not conform to the existing hygienic standards at more than 75 % of workplaces at mining enterprises located in the Norilsk industrial area. This level becomes obvious due to higher occupational incidence among mining workers; it is higher than both the average Krasnoyarsk level and the national average. An identified decline in levels of occupational diseases over the last three years requires further investigation and substantiation of reasons for the trend.

Harmful occupational factors have caused 93 % of all the established occupational diseases among workers employed in mining industry in the Norilsk industrial area. This can be due to automation of technological processes, active use of dust suppression inside a mine, and lower emissions from mining machinery equipped with internal combustion engines.

Seventy-five point seven percent of all the occupational diseases have been established for only six occupations, namely, cargo handling machine operators, blast-hole drillers, working face miners, blasters (including blaster foremen), timber-men, and drift miners. At these workplaces, a worker is simultaneously

exposed to several harmful factors, between 2 and 5 usually, with their levels deviating from the maximum permissible ones.

**Conclusion.** Exposure to occupational noise and considerable work hardness are priority factors in the analyzed industry that cause occupational diseases; this is in line with findings by other authors [18–20]. Also the hygienic standards have been established to be violated at workplaces as per such factors as aerosols with predominantly fibrogenic actions and chemical pollution in workplace air. Combined exposure to several harmful occupational factors produces negative effects on workers' health and creates unacceptable occupational health risks at 76.8 % of the analyzed workplaces. A high share of workplaces with unacceptable occupational health risks leads to high occupational incidence among mining workers in the Norilsk industrial area, its levels being higher than the national average.

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## References

1. Gryaznov S.N., Malyshev V.P. Obespechenie kompleksnoi bezopasnosti pri osvoenii resursnoi bazy Arkticheskoi zony Rossiiskoi Federatsii [Providing integrated security in the development of resources in the Arctic zone of the Russian Federation]. *Strategiya grazhdanskoi zashchity: problemy i issledovaniy*, 2014, vol. 4, no. 1 (6), pp. 62–66 (in Russian).
2. Ivchenko B.P., Kudryashov V.S. Osnovnye polozheniya razvitiya Arkticheskoi zony Rossiiskoi Federatsii, kak strategicheskoi resursnoi bazy strany [The main provisions of the development of the Arctic zone of the Russian Federation as a strategic resource base of the country]. *Ekonomika i upravlenie narodnym khozyaistvom (Sankt-Peterburg)*, 2019, no. 6 (8), pp. 8–13 (in Russian).
3. Kazakova S.M., Klimanov V.V. Transformation of the development goals of the Russian Arctic. *Gosudarstvennoe i munitsipal'noe upravlenie. Uchenye zapiski*, 2022, no. 1, pp. 96–110. DOI: 10.22394/2079-1690-2022-1-1-96-110 (in Russian).
4. Sukhodaeva T.S. Development of the Russian segment of the Arctic zone as a regional measurement of world geopolitics. *Razvitie territorii*, 2020, no. 2 (20), pp. 73–77. DOI: 10.32324/2412-8945-2020-2-73-77 (in Russian).

5. Nalivaichenko E.V., Tishkov S.V., Volkov A.D. Effektivnost' realizatsii gosudarstvennoi energeticheskoi politiki v Arkticheskoi zone Rossii [The effectiveness of the implementation of the state energy policy in the Arctic zone of Russia]. *Aktual'nye problemy i perspektivy razvitiya ekonomiki: trudy XIX Vserossiiskoi s mezhdunarodnym uchastiem nauchno-prakticheskoi konferentsii. Simferopol'*, 2020, pp. 50–53 (in Russian).
6. Moscicka-Teske A., Sadtowska-Wrzesinska J., Najder A., Butlewski M. The relationship between psychosocial risk and occupational functioning among miners. *Int. J. Occup. Med. Environ. Health*, 2019, vol. 32, no. 1, pp. 87–98. DOI: 10.13075/ijomeh.1896.01162
7. Volkov A.V., Galyamov A.L., Lobanov K.V. The mineral wealth of the Circum-Arctic Belt. *Arktika: ekologiya i ekonomika*, 2019, no. 1 (33), pp. 106–117. DOI: 10.25283/2223-4594-2019-1-106-117 (in Russian).
8. Ferova I.S., Yankina Yu.S. Current state and prospects for innovative development of the mining and metallurgical sector. *Industrial'naya ekonomika*, 2022, vol. 1, no. 1, pp. 6–14. DOI: 10.47576/2712-7559-2022-1-1-6 (in Russian).
9. Veretennikov N.P. Natural resource economics in the Arctic regions. *Regional'naya ekonomika i upravlenie: elektronnyi nauchnyi zhurnal*, 2020, no. 4 (64), pp. 16 (in Russian).
10. Dmitrak Yu.V., Tsidaev B.S., Dzaparov V.Kh., Kharebov G.Kh. Mineral'no-syr'evaya baza tsvetnoi metallurgii Rossii [Mineral and raw materials base of non-ferrous metallurgy of Russia]. *Vektor GeoNauk*, 2019, vol. 2, no. 1, pp. 9–18. DOI: 10.24411/2619-0761-2019-10002 (in Russian).
11. Kuznetsov S.K., Burtsev I.N., Timonina N.N., Kuznetsov D.S. Mineral resources of the Russian North. *Izvestiya Komi nauchnogo tsentra Ural'skogo otdeleniya Rossiiskoi akademii nauk*, 2022, no. 2 (54), pp. 72–83. DOI: 10.19110/1994-5655-2022-2-72-83 (in Russian).
12. Syurin S.A. Health risks of mining in the Arctic. *ZNiSO*, 2020, no. 11 (332), pp. 55–61. DOI: 10.35627/2219-5238/2020-332-11-55-61 (in Russian).
13. Bukhtiyarov I.V., Chebotarev A.G., Courierov N.N., Sokur O.V. Topical issues of improving working conditions and preserving the health of workers of mining enterprises. *Medsitsina truda i promyshlennaya ekologiya*, 2019, vol. 59, no. 7, pp. 424–429. DOI: 10.31089/1026-9428-2019-59-7-424-429 (in Russian).
14. Talykova L.V., Bykov V.R. Study of the effect of occupational exposure at the Arctic zone (literature review). *Rossiiskaya Arktika*, 2021, no. 3 (14), pp. 41–53. DOI: 10.24412/2658-4255-2021-3-00-04 (in Russian).
15. Syurin S.A., Gorbanev S.A. Working conditions and occupational pathology of Kola Polar miners. *Medsitsina truda i promyshlennaya ekologiya*, 2020, vol. 60, no. 7, pp. 456–461. DOI: 10.31089/1026-9428-2020-60-7-456-461 (in Russian).
16. Chebotarev A.G., Sementsova D.D. Comprehensive Assessment of Working Conditions and Occupational Disease Rates at Mining and Metallurgical Enterprises. *Gornaya promyshlennost'*, 2021, no. 1, pp. 114–119. DOI: 10.30686/1609-9192-2021-1-114-119 (in Russian).
17. Fomin A.I., Grunskoy T.V. Analytical review of occupational morbidity cases in underground mineral mining on the Komi republic territory. *Vestnik nauchnogo tsentra po bezopasnosti rabot v ugol'noi promyshlennosti*, 2021, no. 4, pp. 45–54 (in Russian).
18. Gorbanev S., Syurin S., Kovshov A. Features of Occupational Health Risks in the Russian Arctic (on the Example of Nenets Autonomous Okrug and Chukotka Autonomous Okrug). *Int. J. Environ. Res. Public Health*, 2021, vol. 18, no. 3, pp. 1061. DOI: 10.3390/ijerph18031061
19. Strzemecka J., Gozdziwska M., Skrodziuk J., Galinska E.M., Lachowski S. Factors of work environment hazardous for health in opinions of employees working underground in the 'Bogdanka' coal mine. *Ann. Agric. Environ. Med.*, 2019, vol. 26, no. 3, pp. 409–414. DOI: 10.26444/aaem/106224

20. Kumar V., Palei S.K., Karmakar N.C., Chaudhary D.K. Whole-body vibration exposure vis-à-vis musculoskeletal health risk of dumper operators compared to a control group in coal mines. *Saf. Health Work*, 2022, vol. 13, no. 1, pp. 73–77. DOI: 10.1016/j.shaw.2021.10.007

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