ANALYTICAL REVIEWS

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Review

HARMFUL CHEMICALS IN OCCUPATIONAL AIR IN THE ORE MINING SECTOR OF THE METAL INDUSTRY AS OCCUPATIONAL HEALTH RISK FACTORS (ANALYTICAL REVIEW)

A.G. Fadeev[1], D.V. Goryaev[1], P.Z. Shur[2], N.V. Zaitseva[2], V.A. Fokin[2], S.V. Red'ko[2]

[1]Krasnoyarsk Regional Office of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, 21 Karatanova St., Krasnoyarsk, 660049, Russian Federation
[2]Federal Scientific Center for Medical and Preventive Health Risk Management Technologies, 82 Monastyrskaya St., Perm, 614045, Russian Federation

Working conditions at non-ferrous metallurgical enterprises typically involve exposure to a whole set of harmful chemicals present in occupational air. These chemicals contribute to the development of pathologies in workers, respiratory diseases in particular. Research literature was analyzed using bibliographic databases in order to summarize available information on effects produced by harmful chemicals in workplace air on health of workers employed at mining enterprises.

Respiratory diseases such as pneumoconiosis, acute and chronic dust bronchitis prevail among occupational pathologies typical for underground miners. Acute and chronic bronchitis prevail among respiratory diseases as health disorders resulting in temporary disability of miners dealing with non-ferrous metal mining. Huge amounts of dust appear in occupational air at mining enterprises due to drilling, blasting and ore crushing. Priority chemicals found in workplace air in mining industry include several carcinogens such as nickel, lead, formaldehyde, cadmium, and benzo(a)pyrene. There is a unidirectional effect produced by sulfur dioxide, nickel, nitrogen oxides, acrolein, formaldehyde, cadmium, and particular matter on the respiratory organs. The nervous system can be affected by manganese, lead, and selenium; the blood, by nickel, lead, and carbon oxide; the cardiovascular system, by carbon oxide and selenium.

Working conditions of underground miners in non-ferrous metallurgy involve intensive exposure to chemicals in occupational air, which create health risks of occupational respiratory diseases and malignant tumors. Diseases of the nervous, immune, cardiovascular systems and the blood are also possible. When planning a set of preventive activities, it is advisable to identify groups of work-related diseases caused, among other things, by a specific chemical factor.

Keywords: *chemicals, occupational risk, workplace air, respiratory diseases, mining industry, working conditions, non-ferrous metallurgy enterprises, risk factor.*

Aleksei G. Fadeev – Head of the Department for Supervision of Working Conditions (e-mail: onut@24.rospotrebnadzor.ru; tel.: +7 (391) 227-66-43; ORCID: https://orcid.org/0000-0003-1712-9196).

Dmitrii V. Goryaev – Candidate of Medical Sciences, Head of the Administration, Chief State Sanitary Inspector for the Krasnoyarsk region (e-mail: office@24.rospotrebnadzor.ru; tel.: +7 (391) 226-89-50; ORCID: http://orcid.org/0000-0001-6450-4599).

Nina V. Zaitseva – Academician of the Russian Academy of Sciences, Doctor of Medical Sciences, Professor, Scientific Director (e-mail: znv@fcrisk.ru; tel.: +7 (342) 237-25-34; ORCID: http://orcid.org/0000-0003-2356-1145).

Pavel Z. Shur – Doctor of Medical Sciences, Chief Researcher-Academic Secretary (e-mail: shur@fcrisk.ru; tel.: +7 (342) 238-33-37; ORCID: https://orcid.org/0000-0001-5171-3105).

Svetlana V. Red'ko – Senior Researcher at the Health Risk Analysis Department (e-mail: redkosv@fcrisk.ru; tel.: +7 (342) 238-33-37; ORCID: http://orcid.org/0000-0002-2736-5013).

Vladimir A. Fokin – Researcher at the Health Risk Analysis Department (e-mail: fokin@fcrisk.ru; tel.: +7 (342) 238-33-37; ORCID: https://orcid.org/0000-0002-0539-7006).

Non-ferrous metallurgy, its mining sector included, is among the most competitive and rapidly developing economic branches in the Russian Federation [1]. Operation of non-ferrous metallurgy enterprises is based on the set of interacting technological stages that encompass ore mining, ore cleaning, metallurgic processing, further processing, loading and unloading, transportation of raw materials and metals. However, the basic process in industrial production in this sphere is extraction of raw materials for their further processing. This determines key harmful occupational elements that affect health of workers employed at these enterprises.

According to data obtained by special assessment of working conditions at workplaces in the mining sector of non-ferrous metal industry, safety standards are violated at more than 75 % of them as regards harmful occupational factors [2]. Long-term research work has established a set of harmful chemicals in occupational air at non-ferrous metallurgy enterprises. There are elevated levels of occupational exposure to chemicals and emissions of aerosols with predominantly fibrogenic effects; this contributes to the development of various pathological states in workers' organs and systems, including respiratory diseases [3–8].

Materials and methods. We analyzed data provided by authoritative scientific and practical editions and relevant scientific-technical literature. All data were taken from articles published in electronic research libraries Elibrary, CyberLeninka, PubMed, Scopus, Web of Science, MEDLINE, and RSCI. We examined studies aimed at investigating the current state of issues related to working conditions and incidence of underground ore miners dealing with non-ferrous metals. To make search more optimal and obtain results relevant to the established criteria, we used descriptors that contained such terms as 'non-ferrous metallurgy enterprises', 'working conditions', 'occupational and work-related morbidity'. Selection criteria and advisability of including a publication into the review were established by determining whether an article contained any information about an association between a chemical factor and incidence rates as well as by the collective expert mind of the review authors. This study did not require any ethical approval.

The objective of this study was to analyze data on effects produced on workers' health by chemicals present in workplace air at mining enterprises of metal industry.

Results and discussion. Leading harmful occupational and work-related factors present at workplaces of underground non-ferrous metal miners include exposure to airborne aerosols with predominantly fibrogenic effects, dusts, and chemicals; high levels of occupational noise; exposure to elevated vibration levels; high work hardness and intensity [3, 4, 9, 10]. In many studies, overall assessment of working conditions for underground miners (drift miners, blasters, drilling unit operators, and mine cleaners) reports combined exposure to several harmful occupational factors and therefore ranks these working conditions as harmful, classes 3.2–3.4 [11–13]. These classes of working conditions correspond to prior health risks ranging from average to extremely high in accordance with the Guide R 2.2.3969-23[1].

[1] Guide R 2.2.3969-23. Rukovodstvo po otsenke professional'nogo riska dlya zdorov'ya rabotnikov. Organizatsionno-metodicheskie osnovy, printsipy i kriterii otsenki; utv. Glavnym gosudarstvennym sanitarnym vrachom RF 07.09.2023 [The Guide on Assessment of Occupational Health Risk for Workers. Organization and methodical essentials, principles and assessment criteria; approved by the RF Chief Sanitary Inspector on September 07, 2023]. Moscow, the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, 2023, 77 p. (in Russian).

Dust particles occur in large amounts in workplace air due to such mining operations as drilling, blasting, ore crushing and ore grinding. If dust and aerosol concentrations are beyond their safe levels, they can have fibrogenic [14], toxic, irritating, and allergenic effects [15]. Underground mining as an occupation is often accompanied with a wide range of diseases of the respiratory system including pneumoconiosis, acute and chronic dust bronchitis [15]. Findings reported by Russian experts are supported by these of their foreign colleagues; for example, studies with their focus on occupational diseases typical for underground miners, which are caused by exposure to dust, show that pneumoconiosis is widely spread among miners in America, China and South Africa [16–19].

Acute and chronic bronchitis prevail among respiratory diseases as health disorders resulting in temporary disability of miners dealing with non-ferrous metal mining [20, 21].

Hygienic assessment of working conditions shows that dust, which is emitted during basic technological processes at metal production, is finely dispersed and more than 80 % of particles in it are smaller than 1 micron. High levels of dusts, sulfur dioxide, metallic nickel, nickel hydroaerosols, and lead are detected in workplace air when sulfide copper-nickel ores are processed in smelting workshops, agglomerations and feinstein-processing workshops, etc. Ore crushing, grinding and processing that relies on using mechanic and thermal treatment usually leads to emission of considerable amounts of industrial aerosols into workplace air [22]. In mining industry, this primarily concerns crushing equipment but is also true for using sintering and smelting furnaces where concentrations of silica-containing dusts and aerosols are higher than maximum permissible levels in a half of samples taken at titanium alloy production; kaolin grog concentrations vary between 1.4 and 150.0 mg/m^3 whereas its average daily MPL is 8.0 mg/m^3 [23].

High somatic incidence against high carcinogenic loads associated with occupational factors of copper and nickel production requires constant monitoring of oncological diseases. The highest levels of individual carcinogenic risks for workers were identified for such cancer sites as colon cancer (the risk level is $7.7 \cdot 10^{-3}$) and stomach cancer (the risk level is $5.9 \cdot 10^{-3}$). Miners also had the highest levels of risk as regards lung cancer (the risk level is $1.07 \cdot 10^{-3}$) and large intestine cancer (the risk level is $1.06 \cdot 10^{-3}$) [24]. In addition to that, several chemicals such as zinc, cadmium, arsenic, antimony, copper, lead and some others are able to affect the central nervous system prolonging the time of audial-motor and visual-motor reactions by reducing agility of nervous processes in the analyzer systems [25–26].

Workers employed at copper and nickel production, apart from respiratory diseases, often suffer from diseases of the skin and subcutaneous fat tissues such as contact dermatitis, onychomycosis, seborrhea and psoriasis. Skin diseases were established to be more frequent among workers dealing with carbonyl nickel processing than among miners or workers employed at copper electrolysis processing plants ($p < 0.02$) [27]. Analysis of data obtained by profound medical check-ups of workers established cardiovascular diseases to have a leading place both among occupational and work-related diseases. Workers employed at light and rare-earth metal production whose work records exceeded 15 years were established to have high occupational causation of essential hypertension, the etiological role of occupational factors accounting for 65.5 % [28–31].

Ore materials are loaded and transported by drivers of loading machines and other heavy-load diesel vehicles; drivers of road-building and excavating machines are also involved in these operations. Working conditions for these workers differ significantly from those of underground miners and other workers with basic mining occupations. Air at workplaces of drivers and self-propelled mining machine operators contains nitrogen oxides, acrolein and formaldehyde in concentrations that can be 2 or 3 times higher than maximum permissible levels [32]. There are no dust eliminating mechanisms inside an excavator cabin and its levels there can vary between 4 and 25 mg per one cubic meter; they can reach hundreds of mg per one cubic meter in an area where an excavator operates. Most dusts and aerosols (80–90 %) in workplace air have fibrogenic properties. This determines high prevalence of occupational pneumoconiosis and chronic dust bronchitis due to exposure to fibrogenic dusts and frequent exposure to cold as well as due to effects of irritating gases and toxic chemicals [33].

Exposure to dust of sulfide copper and nickel ores with levels of free silica reaching 1 % together with uncomfortable microclimate is a risk factor able to cause respiratory diseases in miners in Norilsk area. Dust levels reach 4.3 mg per one cubic meter during drilling and sinking and 6.75 mg per one cubic meter during ore unloading (the class of working conditions is 3.2–3.3, high and extremely high risk). Dust levels reach 6–7.2 mg per one cubic meter at workplaces of underground welders; chromium anhydride, 0.29–0.35 mg per one cubic meter; manganese oxides, 0.149–0.5 mg per one cubic meter (the class of working conditions is 3.4, extremely high risk) [34].

There are abundant data available in research literature about investigations of the qualitative structure of dust typical for mining excavation operations. In the Arctic zone, copper and nickel compounds are priority elements identified in such dust [35]. Basic clinical signs of excessive copper introduction into the body include functional disorders of the central nervous system; copper fever; irritated conjunctiva and eye mucosa; gastrointestinal diseases; functional disorders of the liver and kidneys. Still, some authors note that copper does not have any significant effects on the human respiratory organs [36, 37]. Nickel, as one of basic chemicals identified in workplace air, produces carcinogenic, toxic and allergenic effects [38–41]. Inhalation exposure to water-soluble nickel compounds can cause irritation in the nose and paranasal sinuses and also results in loss of smell and nasal septum perforation. Inhaled insoluble nickel compounds induce tumor development [42–44]. In addition to copper and nickel, occupational air can also contain micro- and nano-sized particles of arsenic, lead, cadmium, selenium, thallium and zinc [45], which can cause diseases of the eye and adnexa, nervous system and immune system. Such priority contaminants as nitrogen oxide, carbon oxide, trinitrotoluene, and benzo(a)pyrene are also identified in ore aerosols [46].

Such carcinogens as nickel and its compounds, lead, formaldehyde, cadmium, and benzo(a)pyrene (according to the Guide R 2.1.10.3968-23[2]) are among basic chemi-

[2] Guide R 2.1.10.3968-23. Rukovodstvo po otsenke riska zdorov'yu naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh okruzhayushchuyu sredu; utv. Glavnym gosudarstvennym sanitarnym vrachom RF 06.09.2023 g. [The Guide on Assessing Population Health Risks under Exposure to Chemical Environmental Pollutants; approved by the RF Chief Sanitary Inspector on September 06, 2023]. *GARANT: information and legal support*. Available at: https://base.garant.ru/408644981/ (April 17, 2024) (in Russian).

cals found in workplace air in mining industry. There is a unidirectional effect produced by sulfur dioxide, nickel and its compounds, nitrogen oxides, acrolein, formaldehyde, cadmium, and particular matter, aerosols with predominantly fibrogenic effects included, on the respiratory organs. The nervous system can be affected by manganese and its compounds, lead, and selenium; the blood, by nickel and its compounds, lead, and carbon oxide; the cardiovascular system, by carbon oxide and selenium.

Conclusion. Working conditions at mining enterprises of the metal industry typically involve high levels of inhalation exposure to industrial aerosols, dust, and chemicals. Underground miners who deal with non-ferrous metal ore mining (miners, drift miners, drilling unit operators, and cargo handling machine operators) are exposed to harmful chemicals at their workplaces. Basic diseases associated with exposure to harmful chemicals at workplaces include such respiratory diseases as pneumoconiosis, chronic bronchitis, bronchial asthma and chronic obstructive pulmonary disease as well as oncologic diseases of the lungs and upper airways.

The respiratory system, nervous system, immune system, blood and the cardiovascular system should be considered priority critical ones when assessing occupational health risks under airborne exposures for workers employed in the ore mining sector of the metal industry. Potential negative health outcomes in workers can include diseases of the skin and subcutaneous tissue, blood and the central nervous system. Therefore, when planning a set of preventive activities at non-ferrous metallurgy enterprises and the ore mining sector in particular, it is advisable to identify groups of work-related diseases caused, among other things, by a specific chemical factor able to create risks for workers' health.

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