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DETERMINATION OF MICRO AND NANOPARTICLES IN THE WORKPLACE AREA AT THE ENTERPRISES OF MINING INDUSTRY

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The results of the studies of working area air in mining operations on the content of micro and nanoparticles are presented. In eight of the nine workplaces the excess is detected to the control of fine dust fraction PM10 content from 4 to 13 times, fractions RM4,0 and PM2,5 from 4 to 9 times, fraction RM1,0 from 3.5 to 9.5 times, wherein the fine fraction RM1,0 is from 53 to 85 %. During the workplace study a significant excess of nanoparticles is found directly during the production process in relation to the control from 5 to 68 times.

Keywords: *working area air, mining production, fine particles, nanoparticles.*

The World Health Organization place suspended particles, especially small ones, amongst the biggest pollutants in terms of health effects.

The danger of dust particles for health is confirmed by many years of Russian and foreign studies. The greatest threat are the particles of $PM_{2,5}$ and PM_{10} fractions. $PM_{2,5}$ represents a particle with aerodynamic diameter less or equal to 2.5 micrometers in diameter and smaller, and PM_{10} represents particles with aerodynamic diameter smaller than 10 micrometers. PM_{10} and $PM_{2,5}$ contain respirable particles which have such a small diameter that they can penetrate the thoracic cavity of the respiratory system. The health effects of respirable fine particles are fully documented [1, 3].

They are caused by short-term (several hours or days) and long-term (several months or years) exposure and include respiratory and cardiovascular disease, such as asthma and respiratory symptoms, and increased number of hospitalizations; deaths from cardiovascular and respiratory diseases, lung cancer.

There's growing scientific interest to determination of nanoparticles with aerodynamic diameter smaller than 0.1 micrometers. The substance in a nanosized state takes on new chemical, physical, and biological features not usual for macro-volume state [2, 8, 10].

Analysis of a large number of scientific studies has shown that nanoparticles have higher toxicity than conventional microparticles, can penetrate intact through cellular barriers, as well as the blood-brain barrier into the central nervous system, circulate and accumulate in organs and tissues, cuase more severe pathologic lesions internal organs; nanoparticles are difficult to excrete because of long half-life [5, 7, 11, 13].

Toxic features of fine and ultrafine particles determine the need to control their levels in the outdoor air and workplace air at the industrial enterprises which produce suspended particles during operating activities.

Many industries - metallurgy, mining, building materials, mineral fertilizer – use mainly bulk and granular materials. During their processing and transportation, aerodispersed systems are created [6, 12]. In Russia, it is difficult to make a consistent assessment of the workplace

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exposure to fine dust and nanoparticles due to the lack of recent data about the particle size distribution of dust during the production processes, lack of pertinent regulatory documents on the levels of nanoparticles in the workplace air [2, 9].

Control of the total dust content is required in foundries, welding shops, mines, construction, cement and brick factories, etc. Industrial aerosols differ from natural ones by a higher concentration, dispersion, particle microstructure, and chemical composition.

Depending on the industry, the chemical and physical composition of dust changes which calls for systematic monitoring including studies of the disperse composition of dust, especially the finest fractions.

Due to a high level and toxicity of fine particles, it is necessary to monitor their content in the workplace air of industrial enterprises.

The purpose of the research. To study the content of micro- and nanoparticles in the workplace air at a mining enterprise.

Materials and methods. The content of fine particles in the workplace air was determined with the help of DustTrak 8533 aerosol monitor (USA). The monitor uses laser nephelometry to make measurements in a wider range of concentrations.

The range of sizes of registered particles is 0.1-15 micron. The range of measurement of aerosol mass concentrations is 0,1 – 150 mg/ m^3. The monitor is used to measure mass concentrations of aerosol particles in the workplace air, technical control over the AC system, air duct system, and the air quality at various facilities.

Identification of nanoparticles by size and estimation of the nanodust count were performed by means of a diffusive overspray spectrometer DAS 2702. The machine can distribute the particles by size in the range 3 – 200 nm; the limit of measurement - 50 000 particles per cm^3.

Instrumental studies of the workplace air quality were carried out at the mining enterprise in 2015. The studies were conducted at the workstation of a mill machinist, belt filtration specialist, centrifuge operator, dosing operator in the shop with a bath for amine residues from the barrels, in drying and granulating unit (DGU), conveyor transport operator, dye preparation tank operator, operators of Venturi scrubber dryer for wet gas cleaning, granulating double-roll crusher operator, and granulating chain conveyor operator. For the purposes of a comparative analysis, we tested the air quality in the administrative building isolated from the production facility.

The enterprise under study is one of the largest potassium producers in the world responsible for 20 percent of the world's potash fertilizer output. It is the world's top producer of potash chloride. The main production department employs 11,300 workers. As for hazardous workplace factors, they include sylvinite dust (leading factor), noise, severity of the labor process, work in underground conditions.

According to scientific literature, potash dust should be classified as a mixed-type aerosol with predominance of systemic toxicity. The extent and nature of changes in morbidity, respiratory function, lipid peroxidation and activity of serum enzymes in miners reflect the intensity and duration of exposure to the dust factor [4, 9, 14].

Results and discussion. Based on the assessment of the workplace air quality at Uralkalii during the production process, we were able to determine the mass concentration of suspended particles of PM_1, $PM_{2,5}$, PM_{10} fractions (Table 1).

The highest level of dust was registered at the workplace of a drying and 4th class granulating unit operator (double-roll crush), 5th class dryer operator at the DGU (dye preparation tank), transport operator (conveyor) at the DGU, and 5th class dryer operator at the DGU (Venturi scrubbers), mass concentration of suspended particles PM_{10} fractions (by mean value) totaled 2,197 mg/m^3, 1,520 mg/m^3, 1,500 mg/m^3, 1,487 mg/m^3 respectively, by maximum value 3,467 mg/m^3, 4,013 mg/m^3, 2,127 mg/m^3, 2,123 mg/m^3, respectively.

The lowest level of fine dust was registered at the workplace of a dosing operator (a bath for amine residues from the barrels) at average 0,061 mg/m^3, which can be explained by a high level of humidity, higher than 85%, and fast setting-out of particles.

A comparative analysis of the data in Table 1 has shown that 8 out of 9 studied work stations have a higher level of PM_{10} fine dust particles, by 4-13 times, $PM_{4,0}$ fraction and $PM_{2,5}$ from 4-9 times, $PM_{1,0}$ fractions fromт 3,5 to 9,5 times.

Additionally, when analyzing the content of fine particles ($PM_{1,0}$, $PM_{2,5}$, PM_{10}) in the workplace air of all the facilities under study (administration, work stations), we determined that the particles sized 1 micron and smaller prevail ($PM_{1,0}$). Fine $PM_{1,0}$ fraction constitutes 53 - 85%.

Table 1

Concentration of fine dusts in the workplace air

Work station	PM1, mg/m^3		PM2.5, mg/m^3		PM10, mg/m^3	
	M±m	min max	M±m	min max	M±m	min max
Administration	0,122±0,022	0,097 0,227	0,130±0,026	0,111 0,237	0,166±0,033	0,117 0,308
Mill machinist	0,577±0,115	0,316 0,876	0,599±0,120	0,346 0,901	0,679±0,136	0,396 1,012
Belt filtration specialist, transshipping of the ready-made product	0,483±0,097	0,317 0,751	0,531±0,106	0,389 0,816	0,778±0,156	0,476 1,420
Centrifuge operator	0,443±0,089	0,321 0,816	0,489±0,098	0,395 0,873	0,769±0,154	0,475 1,630
Dosing operator in the shop with a bath for amine residues from the barrels	0,061±0,012	0,041 0,106	0,064±0,013	0,043 0,112	0,073±0,015	0,045 0,141
Transport operator (shift-based), conveyor's DGU	0,840±0,168	0,707 1,078	0,911±0,182	0,856 1,150	1,500	1,153 2,123
Drying and granulating unit operators, operators of Venturi scrubber dryer for wet gas cleaning	0,947±0,189	0,730 1,237	1,057±0,211	0,814 1,357	1,487±0,297	1,006 2,127
Drying unit operator, dye preparation tank operator	0,915±0,183	0,717 2,973	1,053±0,211	0,827 3,140	1,520±0,304	1,097 4,013
Granulating unit operator, double-roll crush operator	1,177±0,235	0,665 1,893	1,260±0,252	0,739 1,997	2,197±0,439	1,220 3,467
Granulating unit operator (scrubber conveyor)	0,700±0,140	0,317 1,117	0,786±0,157	0,359 1,220	1,323±0,265	0,648 2,227

Table 2

Analysis of the workplace air in the nanorange

Work station	Maximum concentration of the particles, mln/m^3	Range of the particle size with the maximum concentration, nm
Administration	1012±202	30–35
Mill operator	13805±2761	20–25
Filter operator (shift-based), belt conveyor for transferring ready-made products	6075±1215	10–15
Class 3 centrifuge operator, centrifuges	9698±1940	10–15
Class 4 dosing operator, bath for amine residues from the barrels	42468±8494	15–20
Transport operator (shift-based) DGU (containers)	54279±10856	25–30
Class 5 drying and granulating unit operators, operators of Venturi scrubber dryer for wet gas cleaning	68466±13693	45–50
class 5 drying unit operator, dye preparation tank operator	67144±13429	45–50
class 4 granulating unit operator, double-roll crush operator	19440±3888	35–40
Class 3 granulating unit operator (scrubber conveyor)	26218±5243	25–30

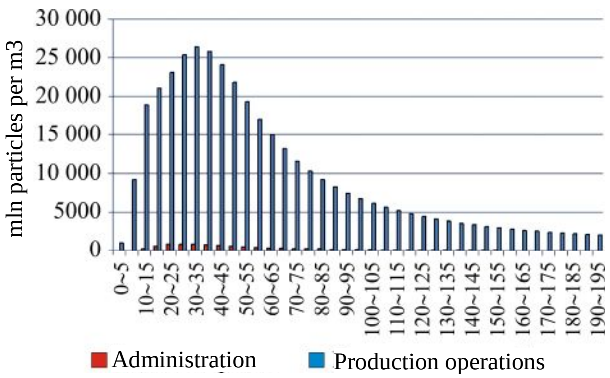

Fig. 1 A comparison of the nanoparticle concentrations during the production operations and in the administrative building

Elevated levels of fine $PM_{1,0}$ fraction particles implies the presence of even finer particles and invites further studies. The research results are presented in Table 2 and in figures below.

In the air of the administrative building (comparison work station), the maximum concentration of the particles is within the 25 nm range, number concentration ~ 953-1012 million particles per m^3 (with the maximum of particles in the range ~ 30-35 nm).

The maximum number concentration of nanoparticles was registered in the air at the work station of class 5 DGU dryer operator (dye preparation tank), 5 class DGU dryer operator (Venturi scrubbers for wet gas cleaning) and totaled ~ 63925 - 68466 mln particles per m^3, with the maximum particles sized~ 40 - 50 nm.

In general, we established an overall excess in the concentration of nanoparticles in the workplace air during the production operations as compared to the control from 5 to 68 times.

The study of the air quality at the dosing operator's work station (a bath for amine residues from the barrels) had interesting results: the concentration of suspended particles was at a minimum, 2 times lower than in the administrative building; PM1,0 fraction here totaled approximately 83%.

A fractional analysis of the nano-sized particles for this process showed a rather high value of the number concentration exceeding the control by more than 40 times, ~ 41822 – 42468 mln particles per m^3 with the maximum of the particles sized ~ 10-20 нм.

Conclusion. This study can be used as reference material when assessing labor conditions, hazardous factors, and professional risk in the production process and use of the materials that contain micro- and nanosized particles as wells as operating processes that produce those.

Moreover, the results of the study above raise the question of monitoring the levels of suspended particles in the workplace air. The obtained results confirm the need for the assessment of the fractional composition of the workplace air for further development and validation of the standards for maximum permissible concentrations which is significant from the hygienic point of view in the assessment of employee health, prevention and treatment of occupational diseases.

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