Stone dust nanoparticles investigation and their role in the negative phenomena for mining workers formation

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Abstract. In connection with the active production development and nanomaterials use, a new urgent task has appeared - the determination of the potential harm of nanoparticles to human health. This article analyses the influence of nanoparticles formed as a result of the extraction, processing and transportation of granite crushed stone. The paper presents data from an industrial survey of ventilation systems and the results of dust analysis of crushed stone production at the Angasolskoye field in the Irkutsk Region, which stands out at different stages of the technological cycle for producing granite crushed stone. Based on the results of the dispersion analysis of granite dust, functional dependences of the integral distribution over the equivalent size of dust particles are given. The main sources of small dust particles (nanoparticles) in the environment are determined.

1. Introduction

Nanomaterials and nanostructures include various objects whose magnitude is even less than 100 nm in at least one of the three dimensions (1 nanometer is a billionth of a meter or 10 angstroms). They can be three-dimensional (fullerons, nanocrystals), two-dimensional (nanotubes) and one-dimensional.

The origin of the nanoparticles is different. Both natural and artificial. The natural are mainly viruses and DNA molecules, as well as nanoparticles formed during dust extraction and mining. Artificial nanostructures include those that were created by modern high technology processes for their further use in production. Significant production of nanoparticles, both natural and artificial, is based on such formation mechanisms as deposition of a colloidal solution, condensation from the gas phase, and solid disintegration. In the mining industry, the disintegration mechanism is working. A solid substance, in this case, natural stone, granite is destroyed during extraction and processing, divided into tens of thousands of individual particles, invisible to the naked eye.

In addition to the main list of nanoparticles, in some industries there are so-called secondary technogenic nanoparticles. They are formed in the fumes of metallurgical and chemical enterprises, in the exhaust gases of gasoline and diesel engines, in condensation aerosols generated during gas and electric welding operations. As a side note, the primary particle sizes of tobacco smoke of conventional cigarettes are entirely located in the nanoscale region [1]. With this open method of mining, a large amount of fine and nanoparticles of dust is formed. In this work, the dimension and chemical composition of dust nanoparticles of such minerals as granites, migmatites, jades, ophiocalcites, and charoites are investigated. When studying the dust of ornamental stones, it was noticed that some of them produce dust with a high content of nano-sized particles having a tubular and needle-shaped
crystalline structure, which negatively affect the human body.

Based on studies on the description and systematics of tubular fragments in the structures of natural and synthetic silicates, the relationship between the structure of the rock and the ingrowth of tubular particles into human lung epithelial cells and the effect of this ingrowth on the development and spread of respiratory diseases has been considered [2]. The main danger of such particles is that when they enter the human body, tubular and needle fibers cause an inflammatory process and entail the development of cancers associated with diseases of the epithelium of the lungs.

Nanoparticles are not only interdisciplinarily observed in numerous production technologies, but also from the point of view of safety problems, they penetrate into all spheres of human activity, exerting impact on humans and the environment. With regard to the nanologization of society, a list of intentionally created sources of nanoparticle entry into various natural environments appears, including through the extraction of solid minerals and the mining industry as a whole (table 1) [3]. The migration pattern of nanoparticles in the environment is presented in figure 1.

**Table 1. Sources of nanoparticle release into the environment.**

| Natural | Unintentional | Intentional |
|---------|---------------|-------------|
| Gas clustering and aerosol formation | Fuel combustion in engines, power plants, etc. | Engineered nanoobjects |
| Forest fires | Garbage burning | Fullerenes |
| Volcanic emissions | Welding, soldering | Nanotubes |
| Dust raised from the surface, water stirring | Mining, quarries, mines | Inorganic nanocrystals, quantum points |
| Viruses | Household waste | “Precise” action medications |
| Human wastes (overwrap, colloids, etc.) | Industrial production building | Nanofilms, micelles, colloids |
| Bioobjects (pollen of plants, spores, bacteria, etc.) | Cooking and other household needs | The use of BUT in everyday life |

**Figure 1.** Ways of migration of nanoparticles (according to G.E. Krichevsky) [4], confirmed experimentally (solid line) and assumed (points). Possible sources and causes of degradation are indicated in italics.
2. Materials and research methods

Further, considering the nanoparticles formed as a result of mining in quarries and mines, as well as from dust raised from the surface of overburden rocks and dumps, an analogy with other types of nanoparticles will be drawn and the ways of their entry into the human body will be determined.

The receipt of this kind of particles occurs:

- through the respiratory tract;
- with water and food through the intestinal tract;
- through the skin and mucous membranes;
- from contaminated surfaces.

Mining industry workers are exposed to the ingress of nanoparticles into the body mainly through the respiratory tract and mucous membranes. If we turn to a few, non-systemic studies on the influence of such particles on animals and humans according to the concept of toxicological studies, risk assessment methodology, methods of identification and quantification of nanomaterials from the decision of the Chief State Sanitary Physician of the Russian Federation of 31 October 2007, № 79, it should be assumed that the nanoparticles formed as a result of mining cause unwanted changes in the body, the intensity of which depends on the exposure of nanoparticles. Also such particles tend to accumulate in organs and tissues (bone marrow, nerve cells of the Central and peripheral nervous systems, lymph nodes, brain, lungs, liver, kidneys). The problem is in the fact that nanoparticles penetrate living cells, overcoming produced by the body protective response to a particular danger. With this penetration of particles:

- affect the components of a living cell, disrupting it mainly due to the generation of active particles (radicals, various forms of oxygen, peroxides);
- penetrate into the metachondria and block their active function;
- cause DNA damage, block the activity of ribosomes [5].

The seriousness of the nanotechnology dangers has recently been recognized by many scientists and public figures around the world. Since 2006, the special journal Nanotoxicology began to be published; The US National Institute of Health, EPA Environmental Protection Agency, NCI National Cancer Institute, and others deal with this problem. In Russia, the nanoindustry itself is still very weak and accordingly there is no systematic control over this problem, and even more so, there is no monitoring of the uncontrolled formation of nanoparticles in the mining industry.

The most significant features characterizing nanoparticles are surface properties, reactivity, semiconductivity, and biological effects, which, in turn, can manifest themselves differently when they affect the human body. Both positively and negatively [6].

Nanoparticles formed during the extraction, processing and transportation of stone material, in particular granites and crushed granite, due to their small size penetrate through thin lipoprotein films of the body and enter cells, tissues and organs. During inspiration, they enter the lungs and from there can be transported to the circulatory system and then transferred throughout the body. A similar situation can occur if particles enter the gastrointestinal tract. Such particles can enter the bloodstream and later circulate through it, as well as accumulate in such vital organs as the brain, liver, kidneys, spleen, and others [7]. Particles entering our body can disrupt the functioning of cells, cause harmful reactions that can subsequently provoke cell death.

In this work, we examined the enterprise for the extraction, processing, and sale of granite raw materials of OJSC “First Nonmetallic Company”. The company produces crushed stone for ballasting railways and the construction of roadways.

In the production of crushed stone a number of dusty ingredients stand out, the bulk of which is granite dust with SiO2 of 20 to 70%. To study the dust environment specific dust emission and dust concentration in the areas of reception and unloading of aggregates for its further transportation to the
place of use is defined. The results showed that at the points of loading of crushed stone dust is allocated with a specific allocation \( SP = 1.8 \text{ kg/m}^3 \). As for dust removal ventilation and other systems that are formed from the technological capacities (silos- bunkers, granulators, scrubbers, exhaust ventilation), at this stage of the technology dust may occur in the initial portions of about 20 g/m³ [7-8]. On transport mechanisms (conveyors, designated clearance) load is around 23-25 g/m³. Thus, in some parts of the vacuum systems maximum one-time values have reached a value of 30-35 g/m³.

After analyzing the results of the dust load, it became clear that fine fractions with granite dust particles (dust with a SiO₂ content of 20 to 70%) equal to 5 \( \mu \text{m} \) or less account for about 95% of the total mass of dust emitted into the atmosphere. The percentage of fine fractions in the dust varies in the range of 80-95%, depending on the type of technological stage in the production of crushed stone.

Figure 2 shows a graphical dependence of the integral distribution of dust particles of granite crushed stone before and after the dust removal system adopted by the company “First Nonmetallic Company” ventilation systems for the production of crushed stone by the dry method and at the rubble loading area, on which experimental studies were carried out. Where \( D_{pe}(x) \) is the percentage of particles in the captured stone material, \( dr \) is the diameter (size) of the particles of captured dust.

![Graph](image)

**Figure 2.** The dependence of the integral distribution of dust particles of granite crushed stone before and after the dust removal system.

From the graph it follows that the dust removal systems currently adopted at the enterprise do not work properly and do not protect workers from potentially dangerous micro and nanoparticles formed in the production process. It is recommended to review this system and take appropriate measures to eliminate the problem or minimize it.

The author suggests that improving systems for cleaning the working area of a mining enterprise from dust emissions (including nanoparticles) can be achieved by using the proposed modification of a laboratory facility for the analysis and capture of fine dust fractions [8].

3. Results and discussion
To reduce the negative consequences of particles entering the body, it is proposed to develop portable plants for collecting dust nanoparticles for work in mining conditions. Experiments on the capture of dust nanoparticles in mountain quarries relies on an approach based on the data of flow fractionation in a transverse field in a rotating spiral column [8].

This will make it possible to determine the dependence of the frequency of occupational diseases of
the lungs of mining workers on the content of dust nanoparticles in the air and their chemical composition. The result of the work will be a new method of dust suppression, which allows to reduce the concentration of dust particles not only with sizes from 100 to 10 microns, but also of nanosized particles. Significance will lie in the universality of the use of new dust suppression methods not only in the mining industry, but also in other industries where there is a high concentration of nanoparticles in the air.

4. Conclusion
Protecting miners from dust emissions from industrial enterprises is one of the most difficult tasks of modern labor protection science. According to the estimates of the International Labor Organization, annually industrial dust takes about 100 thousand lives, and in a dusty atmosphere anthracosis develops on average in 10 years, but in some cases the disease occurs within 6 months. At present, in a number of countries, a transition has been made to rationing the content of dust particles in the air with dimensions not exceeding 2.5 microns or up to 10 microns. The most harmful are particles with a particle size of less than 10 microns, which are retained by the upper respiratory tract, and particles with a particle size of 0.5-5 microns, which penetrate the lungs and are retained there. In the Russian Federation, rationing of airborne dust is carried out without taking into account the dispersed composition of dust. The main direction of reducing the level of dust in the atmosphere of quarries is dust suppression.

Since when studying dust collecting equipment, the dispersed composition of dust in the under-sieve area is often determined, a comparative assessment of the most common instruments for determining the dispersed composition in this area led to the conclusion that the most reliable results are obtained on a pipette device, i.e., by sedimentometric analysis by taking weight samples. The essence of the method consists in sequential sampling at a known depth of the suspension at fixed times and determining the mass of the solid phase in the selected sample after evaporation. This method allows to determine particle fractions from 1 to 63 μm with a density of powdered materials 2000–3000 kg / m³.

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