The Study of Dust Nanoparticles and Their Impact on the Health of Mining Workers

A Yu Aleksandrova¹, S S Timofeeva²

¹Graduate student, Irkutsk National Research Technical University, Irkutsk, Russia
²D. Sc., Professor, Irkutsk National Research Technical University, Irkutsk, Russia

E-Mail: aleksandrova.angelina1993@yandex.ru

Abstract. Throughout evolution, human lungs adapted to fighting respiratory tract infections and less so to mitigating the impacts of non-organic microparticles. When an infectious agent, immune complex, or a dust particle contacts with the phagocyte membrane, the oxygen consumption increases so intensively that this phenomenon received the name of “respiratory explosion”. The miner diseases are too numerous to cover them all in this article. Therefore, this work deals with the negative effects of marble and granite dust on the development of professional diseases. These are the most widely spread mineral rocks in Irkutsk Oblast and Russia in general. This research found that the inspected workshops in Irkutsk Oblast have high levels of pollution with granite and marble dust. Marble and granite dust from the quarries of Irkutsk Oblast contains between 40 and 80% of silicon dioxide (SiO₂) in a free state. The dust of marble and granite mines causes dust-related lung diseases. We shall focus on their symptoms, diagnosis, and clinical features. This research was carried out with financial support from RFBR within the scope of the research project No 19-35-90096.

1. Introduction

Various stone production processes (for granites, marble, ophiocalcite, green stones, charoits, etc) emit large amounts of mineral nanoparticles. They also increase the industrial dust emissions into the environment, especially air. They are formed as a result of the continuing fragmentation of rocks and they harm the internal organs of people and provoke pulmonary, cardiovascular, and brain diseases. These particles are dangerous because they permeate cellular barriers and cause cellular-level changes in the organism. Bioindication and biomonitoring of environment-related diseases (the ones that are propagated by the adverse environmental conditions as a result of biosphere pollution) play a special role in the study of nanotoxicity of minerals. Even though the research of atmospheric pollution has reached a new level due to the possibility to identify new toxicity classes for nano- and microparticles, their impact mechanisms have not been determined yet. Dust particles sized between 1 and 100 nm are the most dangerous for humans and other living beings[1].

Throughout evolution, human lungs adapted to fighting respiratory tract infections and less so to mitigating the impacts of non-organic microparticles. When an infectious agent, immune complex, or a dust particle contacts with the phagocyte membrane, the oxygen consumption increases so intensively that this phenomenon received the name of “respiratory explosion”. For instance, when macrophages are activated by quartz particles, oxygen consumption increases 4 times, and 1.5 times for coal dust or titanium dioxide particles. Excessive oxygen consumption is seldom used to satisfy the
energy or construction needs of the cells [2]. According to [3], the studies of lung toxicity show that
the exposure of lungs to ultrafine or nanoparticles leads to more profound inflammatory responses as
compared to larger particles of the same composition and weight concentration. Surface properties
(especially its area) and the formation of free radicals when particles interact with cells play a crucial
role in nanoparticle toxicity. These effects are complemented by the settling of very large inhaled
nanoparticles as single rather than aggregate units. Some data suggest that it is impossible to avoid the
settling of ultrafine and nanoparticles in the lungs if they are inhaled, while the observations of
alveolar macrophages show that they access pulmonary interstitium, which is a potentially vulnerable
body part. The toxicological database is limited, which draws us to the assumption that all of the
nanoparticles are toxic.

The correlation between the mining industry and professional lung diseases was established in the
1500es when Agricola described caustic dust that can penetrate the lungs and then other organs of a
living organism. Today, the impacts of the silicon earth (quartz) dust are studied intensively, including
in the context of the informal and unregulated mining sector, where dust concentration control in
quarries is optional rather than compulsory. The incidence rate and severity of mining-related lung
diseases depend on the amount of dust inhaled, the level of respiratory explosion, the duration of
exposure, concurrent diseases, climate conditions, and lifestyle. Miner diseases are too numerous to
cover them all in this article. Therefore, this work deals with the negative effects of marble and granite
dust on the development of professional diseases. These are the most widely spread mineral rocks in
Irkutsk Oblast and Russia in general. They are important to the residents of the region, the related
industries are developing and they have extensive healthcare and legal framework in terms of
regulating the working conditions of the mining personnel [4, 5].

2. Research materials and methods
The high rates of lung diseases among miners are attributed to adverse impacts of the working
environment, including the stone dust. The analysis of professional diseases receives minimum
attention, and many employees expose themselves to risks because they do not know about the
consequences of inhaling stone dust during their work. According to the international classification
presented in the International Labor Organisation (ILO) guidelines, miners’ diseases belong to the
pneumoconiosis class based on their radiographic appearance. Pneumoconiosis is a class of
parenchymatous lung diseases (normally) caused by inhaling non-organic dust during stone processing
[6]. The majority of miners in Irkutsk Oblast have silicosis. Silicosis is the most wide-spread kind of
pneumoconiosis caused by inhaling quartz (silicon earth) dust containing silicon dioxide (SiO2) in
a free state. Marble and granite dust from the quarries of Irkutsk Oblast contains between 40 and 80% of
silicon dioxide (SiO2) in a free state [7].

The dust of marble and granite mines causes dust-related lung diseases. We shall focus on their
symptoms, diagnosis, and clinical features.

Lung cancer According to the World Health Organization data, lung cancer can be caused by the
impact of stone dust in the most extreme cases. However, there is an on-going argument that the
impact of stone dust itself causes an increase in lung cancer incidence risks, while the transition of one
disease into another results in irreversible changes. Cancer development risks among the miners
working with stone dust significantly increase if the impact is intensive and it depends on the type of
particles that enter the lungs. The size of dust particles plays a big role in the disease process [8].

Fibrosis Its progress and course intensity directly depends on the impact of stone dust. It is
conditioned by the overall dustiness and the chemical composition of the dust particles [9]. Stone dust
containing quartz particles may have a relatively large surface area, and, consequently, higher
numbers of free radicals on this surface. This may increase the probability of fibrosis development,
which may then transition to silicosis [10].

Silicosis remains a serious problem for miners and people of other professions, including stone
extraction, all over the world, even in developed countries. This disease can be prevented, and yet it
remains a key cause of health problems and deaths. In some cases, the number of overall silicosis
cases is seriously underestimated [11-12], and in some other cases, the proportion of silicosis is growing. Silicon earth dust is one of the most wide-spread harmful factors in the workplace. There are discrepancies concerning the exact quantitative relationship between inhaling dust and disease rates but scientific research demonstrates that the exposure to a standard dosage of 0.1 mg/m³ throughout the working life results in a significant deterioration of miners’ health and active development of silicosis leading to lung cancer, and death [13]. Currently, there is enough evidence to claim that it is necessary to reduce dustiness to 0.05 mg/m³ with a further goal of 0.01 mg/m³ in mind to protect the miners [14]. Although dust is the main factor of silicosis development, we also obtain evidence that other parameters can contribute to the development of this disease, including the newly-exploded marble and granite, the admixtures of minerals in rocks, and clay components covering the surface of the rock.

Dust fineness is a key silicosis factor. There is evidence that various physical states of the dust, such as newly-destructed granite or marble and the admixtures of minerals that are contained in them, can result in disease peaks. SiO₂ dust impact results in the inflammatory processes and fibrogenesis in the lungs. Thus, silicosis remains the most wide-spread disease among the mining workers. Recent research draws attention to other silicon-earth-related diseases. For example, lung cancer. Recent expert reviews claim that there is enough data to confirm the correlation between silicosis and lung cancer. Cancer risks can be aggravated by unhealthy habits and other carcinogens at the workplace (diesel combustion products, equipment operation) [15-16].

Chronic destructive respiratory tract diseases. These include emphysema and chronic bronchitis. They often develop as a result of a prolonged exposure to silicon earth (granite, marble, quartz) dust at work. They can develop in people exposed to silicon dioxide with or without silicosis symptoms. This disease can cause dyspnea due to the progressing massive fibrosis or tuberculosis, or concurrent respiratory disease. Cough and expectoration are common symptoms, and they are usually attributed to chronic bronchitis but they can also signify the development of tuberculosis or lung cancer. Symptoms: coughing, hemoptyisis, weight loss, fever [17].

3. Results and discussion

In Irkutsk Oblast, there are about 30 workshops engaged in granite and marble processing. For this research, we selected 3 workshops and registered the average, maximum and minimum concentrations of the dust inhaled by the employees (see the measurement results in Table 1).

| Workshops       | Average concentration of dust (mg/m³) | Maximum concentration of dust (mg/m³) | Minimum concentration of dust (mg/m³) |
|-----------------|--------------------------------------|--------------------------------------|--------------------------------------|
| 1 (Irkutsk)     | 29.8                                 | 79.3                                 | 1.9                                  |
| 2 (Angarsk)     | 74.2                                 | 141.2                                | 10.1                                 |
| 3 (Cheremkhovo) | 72.4                                 | 111.8                                | 8.9                                  |

In most cases, the registered concentrations exceed the existing maximum concentration limits for workplace air (MCL = 1 mg/m³). Occupational disease expert committees all over the world recommend reducing the sanitary limit to 0.2 mg/m³ to reduce the risks of the eye and respiratory tract irritation and prevent respiratory diseases. The highest levels of silicon oxide dust were observed during the cutoff machine operation and when polishing the stone surface. When such large amounts of dust are emitted into the atmosphere, people living around the workshops also suffer from negative impacts. They have high risks of silicosis and chronic bronchitis development.

The analysis of marble and granite dust levels in the 3 workshops in Irkutsk Oblast shows that 2.24% of the inhaled dust was below the maximum concentration level, and 14.1% was above that value. The level of inhaled dust was 70% above the maximum concentration level (Table 2). The exposure of people to dust, in most cases, does not comply with the existing standards.
Table 2. The percentage of inhaled marble dust in the workshops (1, 2, and 3).

| Workshops          | Inhaled marble and granite dust |
|--------------------|---------------------------------|
|                    | Number of specimens | Concentration, mg/m³ | Content, % |
| 1 (Irkutsk)        | 82                 | 32.2-51.9           | 17.44     |
| 2 (Angarsk)        | 107                | 54.1-73.6           | 24.33     |
| 3 (Cheremkhovo)    | 89                 | 71.2-100.1          | 29.81     |

This research found that the inspected workshops in Irkutsk Oblast have high levels of pollution with granite and marble dust. The workshop employees did not have dust respirators or wore them the wrong way, and the ventilation systems were in poor condition. The employees suffered from chronic bronchitis, silicosis, and pneumoconiosis. Employees do not know about the hazards associated with inhaling dust or about the negative impact of granite and marble dust on their health. Only a small number of operations in the workshop does not have any negative impacts on the human organism. In all other cases, something must be done immediately to improve labor conditions.

4. Conclusion
Granite and marble production as an industrial sector contributes to the development of the smaller regions of the country. It has a good effect on regional development. However, we must not forget about the health and environmental hazards associated with it. We should pay proper attention to the problems brought up in this article and prevent them. To this end, we can give the following recommendations:

- Introduce the wet processing of marble and granite.
- Control the removal of solid wastes to prevent their drainage into the sewer system and, subsequently, into the water bodies.
- Use air filtration systems to prevent the discharge of the dust into the atmosphere;
- Promote education on the impacts of marble and granite dust and the consequences of inhaling dust for the workers.
- Re-use the dust collected after the main business processes.
- Relocate the workshops outside the cities.

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