Specificity of the charoite dust influence on human respiratory tracks

A Yu Aleksandrova and S S Timofeeva
Irkutsk National Research Technical University, 83, Lermontov st., Irkutsk, Russian Federation

E-mail: aleksandrova.angelina1993@yandex.ru

Abstract. When investigating the dust of decorative stones, it was noticed that some of them contain dust with a high content of nanosized particles having a tubular and needle-shaped crystalline structure. Despite the positive side of the nanotechnology development in the world, it also has a negative side in terms of the negative impact on the body and human health. The paper considers the relationship between the structure of charoite 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. It is based on studies on the presentation of descriptions and systematics of tubular fragments in the structures of natural and synthetic silicates.

1. Introduction
The study of the negative impact of such structures on the human body is overlooked due to the interest in tubular natural structures, based on the development of the science of nanostructured formations, which predict the technological revolution status. [1] The relationship between a structure of charoite rock and the ingrowth of tubular particles into human lung epithelial cells is considered on the basis of studies on the description and systematics of tubular fragments in the structures of natural and synthetic silicates [1]. Charoite refers to minerals with the structure where tubular silicon-oxygen radicals are allocated, i.e., one-dimensional silicate anions having a tube shape and possessing internal “channels” are distinguished [2]. According to the electron microscopic analysis, studies of a charoite sample showed that a sample is a single asbestos-like fiber about 200 nm in diameter, elongated along the z axis, but differently oriented in the (x - y) plane [3; 4; 5]. The study of the causes and frequency of occupational diseases among mining workers will be based on indicators that take into account the level and degree of harmony of physical and mental development, reactivity and resistance to diseases, assessment of age-related changes, the presence of chronic diseases, indicators of disability caused by diseases or injuries, etc. The indicators will be used based on data on morbidity and mortality, on health groups, on the time of maintaining health over a certain age period to estimate the health state at the population level or for individual groups of the population. It is planned to determine the relation of the causes of diseases from the chemical and dispersed structure of dust based on these information.

2. Materials and research methods
The charoite structure with the crystal chemical formula \((K, Sr, Ba, Mn)_{15.16} (Ca, Na)_{32}[Si_6O_{11} (O,OH)_{10}]_2 [Si_{12}O_{18} (O,OH)_{12}]_2 [Si_{17}O_{25} (O,OH)_{18}]_2 (OH,F)_{4.0} 3.18H_2O\) was recently determined with...
the help of the high resolution transmission electron microscopy and electron diffraction [6].

It can be represented as consisting of three different silicate radicals: a three-unit double-row radical \([\text{[Si}_6\text{O}_{17}]_{10}\text{]}\), a tubular cyclically branched three-unit three-row radical \([\text{[Si}_{12}\text{O}_{30}]_{12}\text{]}\) and a tubular hybrid three-unit four-row radical \([\text{[Si}_{17}\text{O}_{43}]_{18}\text{]}\) (Figure 1). All radicals are elongated along the z axis, dissected by a plane of symmetry and connected by apical oxygen to groups of \((\text{Ca, Na})\) octahedra, whose columns are also parallel to the z axis [1].

![Figure 1. The projection of the charoite structure onto the plane (001) (a) and the relative position of three silicate radicals in the projection onto the plane (001) (b).](image)

The employees of enterprises engaged in the extraction and processing of charoite rocks are exposed at the workplace by industrial carcinogenic agents, exactly industrial dust of the host rocks, containing nanosized dust particles and having an asbestos-like tubular crystalline structure. 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.

The importance of this mineral is great in the development of the gemstone industry despite the fact that the extraction of charoite is not realized in huge volume at only one known field in the world. The
industrial and economic role, as well as little knowledge regarding the effect on the human body, prompted the authors to conduct the investigation on the presence of a carcinogenic risk in this mineral.

The investigation estimated the risks of lung diseases associated with the occupational influence of charoite rock fibers and associated factors of the production environment. The estimation and analysis of the pulmonary morbidity levels among personnel of the charoite mining and processing plant was carried out by automatic information comparison of databases on the charoite mining enterprise located on the border of Irkutsk Oblast and Republic of Sakha Yakutia. The period of epidemiological surveillance is 15 years (2000 – 2015). A number of workers is 70 people, total age is 1050. In case of detection of pathology of the upper respiratory tract and lungs of the personnel, the data analysis on the presence of contact with dust from the host rocks during the professional duties performance (based on the certification of the workplace) was done. The estimation of individual carcinogenic risk for workers in this category was carried out according to the methodology proposed by the US Environmental Protection Agency (USEPA) [7-8].

Over a 15-year period of statistical observation, among the personnel of the charoite mining enterprise, 24 people fell ill with the upper respiratory tract and lung diseases (2.2% of employees for the whole time period), the average annual incidence level of 13.8 persons per 1000 workers, which is lower than in the general population of Irkutsk Oblast and Republic of Sakha Yakutia.

There is an increase in gender-standardized levels of the general incidence of respiratory organs among male workers (24.2 men per 1000 and, 12.1 women per 1000). We pointed out the age and sex indicators for the diseases localization.

Among men-workers, there is an increase in the incidence of silicosis (2.4 times compared with the general population), as well as low incidence of pneumoconiosis of the lungs (0.4 times). They have a sufficient degree of evidence in terms of diagnosing the disease of the worker. At the same time, there are unproven indicators of an increase in the incidence of silicosis among women (1.3 times more than in men). This is probably due to the specifics of the professional activities of women, they often work in contact with the breed (processing, grinding, polishing).

3. Discussion and results
The results of an analytical epidemiological study indicate that among personnel of the charoite mining enterprise, the probability of respiratory diseases depends on their working place and the specifics of the operations performed. The greatest probability of such diseases is on milling, grinding machines, when working with a grinding machine, as well as during rock explosions. As for the occupational groups, workers in professions such as ancillary worker, blast worker, jeweler and grinder are more susceptible to morbidity. It should also be noted that the target organs for the disease occurrence under the influence of dust from the host rocks are the pharynx, bronchi, lung and pleura. Indeed, the occurrence of respiratory diseases should probably be associated with nanocrystalline structures of charoite rock. However, there exist other related factors that increase the risk of the disease. Such risk factors are age, genetic determination (hereditary predisposition), chronic pathology in these organs, lifestyle features (active and passive smoking of tobacco, alcohol abuse). Also, the environmental and professional influence of some physical, chemical and biological carcinogenic agents can cause respiratory diseases.

4. Conclusion
The personnel of charoite mining and processing enterprises at workplaces are exposed to a production agent, i.e., industrial dust containing nanosized particles having a tubular and needle structure, as well as due to the structure of crystalline silicon dioxide (quartz). The presence of this carcinogenic factor can cause respiratory diseases in both light and strong forms, as well as cause malignant neoplasms in the respiratory system.

Thus, in order to improve the control of the risk management of respiratory diseases in the conditions of the enterprise for the extraction and processing of charoite rocks, it is advisable to:
• conduct constant epidemiological observations of the personnel of the enterprise for at least 40-45 years of observation;
• equip properly the sealing of all technological processes, ensure uninterrupted operation of the forced and exhaust ventilation systems and conduct wet cleaning of industrial premises at least 4 times per shift;
• strengthen control over the air safety of the working area in terms of dust pollution of charoite rocks;
• ensure proper implementation of rules and measures for labor protection, as well as to improve the quality of issued personal protective equipment to the personnel of all technological lines;
• carry out on an ongoing basis for the measures implementation for medical supervision of the health state and rehabilitation of workers exposed to dust;
• strengthen educational and upbringing work in terms of developing workers' safety culture and culture of preserving their own health.

All of these methods are generally recognized and applied for the dust suppression in the conditions of mining at different stages of the technological process such as drilling, blasting, secondary crushing, excavation and loading operations and operations associated with the movement of rock mass, as well as pumping, crushing, enrichment and agglomeration, storage of tailings.

The practical results are quite modest and dust emissions, dust accumulation and its concentration still increase despite the considerable scope of the studies of the dust load problem and the proposed design solutions.

In this regard, the search for rational tools and methods of reducing dust emissions into the atmosphere and dust accumulation, as before, is an urgent task, especially for mining.

The essence of this approach underlying the reduction of dust levels is to apply the dust suppression method in mining quarries applying a method based on the data of flow fractionation in a transverse field in a rotating spiral column to capture dust nanoparticles in the air of a mining quarry working zone.

Acknowledgements
The research was carried out with the financial support of the Russian Federal Property Fund in the framework of the scientific project No. 19-31-27001.

References
[1] Rozhdestvenskaya I V and Krivovichev S V 2011 Tubular fragments in the structures of natural and synthetic silicates Crystallography 56(6) 1076–87
[2] Rozhdestvenskaya I V, Shishelova T I, Shulga V V 2016 The diffraction pattern of charoite according to X-ray powder data Uspehi sovremennogo estestvoznaniya 1(10) 157–61
[3] Rozhdestvenskaya I, Mugnaioli E, Czank M, Depmeier W, Kolb U, Reinholdt A and Weirich T 2010 The structure of charoite, (K, Sr, Ba, Mn)15–16(Ca, Na)32[(Si70(O, OH)180](OH,F)4,0×nH2O, solved by conventional and automated electron diffraction Mineral Mag 74(1) 159–77
[4] Rozhdestvenskaya I, Mugnaioli E, Czank M, Depmeier W, Kolb U and Merlino S 2011 Essential features of the polytypic charoite-96 structure compared to charoite-90 Mineral Mag 75(6) 2833–46
[5] Dodie Fikfak M 2003 The amphibole hypothesis – a nested case-control study of lung cancer and exposure to chrysotile and amphiboles Arh Hig RadaToksikol 54 169–76
[6] Nagornaya A M, Kundiev Yu I, Varivonchik D V and et al 2008 Oncological incidence of workers in asbestos-cement production Meditsina truda I promishlennaya ecologiya 3 27–33
[7] Dodie Fikfak M 2003 The amphibole hypothesis – a nested case-control study of lung cancer
and exposure to chrysotile and amphiboles *Arh Hig Rada Toksikol* **54** 169–76

[8] Hodgson J T and Darnton A 2000 The quantitative risks of mesothelioma and lung cancer in relation to asbestos exposure *Ann Occup Hyg* **44**(8) 565–601