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ORIGINAL ARTICLE

The Health Impact of Mineral Dust Air Pollution on the Global and Local Scale (on the example from Slovakia)

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Abstract

BACKGROUND: A significant proportion of anthropogenic dust particles are present in the atmosphere. In particular, these include industrial and municipal dust, black carbon from fossil fuels and biomass. Mineralogical research of dust particles in the air is important for knowing their impact on public health in hazardous work environments (not only in Slovakia). In the recent past (in 2000–2010), research of dust fallouts from mining and processing of mineral resources was carried out. Specifically, it was focused on the Lubeník and Jelšava area, where the environment and population were adversely affected by mining activities and magnesite ($MgCO_3$) processing treatment.
METHODS: The dust obtained from the plastic containers at the sampling stations was filtered in distilled-water wash. Afterwards the dust dispersion, respirable fraction and chemical composition were determined by analytical methods. The mineralogical characteristics of the particles were determined by X-ray powder diffraction (XRD) and their morphology by Scanning electron microscopy (SEM).
RESULTS: The exposure to dust particles and associated contaminants can cause pulmonary diseases with a significant impact on the inhabitants health and quality of life. The most destructive action of the mineral dust particles comes after their penetration into the alveolar parts of the lungs. Pulmonary dusting, Pneumoconiosis, occurs, when the fibrogenic dust particles smaller than 2.5 μm passes through the alveolar wall into the interstitial space. Insoluble or sparingly soluble minerals are referred to as active, they initiate and activate fibrosis. In the samples from Jelšava-Lubeník, the dominant mineral phases include magnesite occurring as crystals and their fragments and periclase present as irregular allotriomorphic grains, aggregates and masses. According to dusting monitoring, a trend of decreasing in the periclase proportion was observed.

CONCLUSIONS: Mineral composition and morphology of dust fallouts in the air from mining areas directly affects the health of the population and contributes to the increased incidence of respiratory diseases in the region, even several years after closing the mines or after the change of filters in mineral processing plants. Reducing unwanted air pollution should be a priority for relevant ministries (of health, environment etc.), as well as a challenge for public health professionals.

INTRODUCTION

Dust particles can be divided into two types. Particles which get directly into the air in the solid state are primary particles (e.g. mineral dust). Those formed in the atmosphere by condensation from gas are called secondary particles (e.g. ammonium nitrate). The residence time of particles dispersed in the atmosphere can vary from a few days to several weeks.

According to their sources, we divide dust particles into natural and anthropogenic. Among natural resources, sea salt dispersed into the atmosphere from the sea water bubbles has the largest proportion. The second largest group is mineral dust, which is produced by weathering the rocks and carrying dust particles through the wind. In this case, sand and dust storms, which are typical of desert areas, play a major role. These two sources of dust have a greater share than all other sources combined. Natural sources of particulate matter include volcanic eruptions, biogenic sources (pollen, spores, algae, fungi, bacteria and viruses) and soot from forest fires. All these sources supply primary particles to the atmosphere (Andreae & Rosenfeld 2008; Durant *et al.* 2010). Natural secondary particles include mostly sulphates of volcanic and biogenic origin and secondary organic aerosols resulting from the condensation of biogenic volatile substances.

There is also a significant proportion of anthropogenic dust particles in the atmosphere. In particular, these include industrial and municipal dust (surface mining, metallurgy, waste incineration, building and demolition processes, transport), black carbon from fossil fuel and biomass burning. Human activity also produces secondary dust particles, especially sulphates, nitrates and organic substances (Gieré & Querol 2010).

The content of minor and trace elements in atmospheric particles can be diagnostic parameters for specific sources. For example, vanadium and nickel are typically associated with the combustion of fuel oil and petroleum coke; copper, antimony and tin in the urban environment indicate that particles are formed by the abrasion of car brake pads.

Both mineral and non-mineral anthropogenic particles have a worse effect on human health than natural particles. Immissions in a hazardous work environment encounter both the living and inanimate natural spheres, and there, they work both chemically and mechanically (Prospero 1999).

The use of pyrotechnics is especially unfavourable and dangerous. They abolish the nature of the mineral raw material and turn it into gaseous, liquid and solid components, which sometimes occur in high concentrations in the air. With these constituents, heavy metals (in addition to crystalline and non-crystalline substances, gases and liquid constituents) are also introduced into the atmosphere in the form of a solid dust.

Dust hazards for humans occur in the normal urban environment, as well as in hazardous working environments (mining, mineral processing, metallurgy, construction, transport). Dust particles in the atmosphere have an impact on the life of the entire society, on the economy performance and on the social life comfort, but first and foremost, they have a direct impact on the human health. The mineralogical research of dust fallouts in the air from the areas with mining activity conducted in the recent past in Slovakia could bring more light into this topic.

In the Lubeník and Jelšava area (in the years 2000–2010), magnesite was mined. It was then processed in local plants in the area and used to produce refractory materials. The raw magnesite went through not only the chemical but also the mineralogical conversion (Baluchová 2010). The main sources of solid dust and particulate drift include the rotary and shaft furnaces operations. Research results present some challenges for public health experts, mining and ore processing plants owners, but mostly for inhabitants (not only from regions where dust samples have been collected and measured).

METHODS

Several methods were used to investigate the mineral dust in the air in Slovakia. The dust collected from the plastic cylinders at the sampling sites was filtered after the distilled water wash and afterwards the dispersion of the dust, the respirable fraction, the chemical composition was determined by analytical methods. The mineralogical characteristics of the particles were determined by X-ray powder diffraction (XRD) and morphology by scanning electron microscopy (SEM) (Baluchová 2010).

The size is very important parameter in describing the characteristics and behaviour of dust fallouts. Particles with d <2.5 μm are referred to as PM2.5 (PM from particulate matter), with diameters up to 10 μm being referred to as PM10, and the smallest particles up to 1 μm being PM1.0. All the particles are different in terms of their formation, transport in the atmosphere, the rate of degradation, other physical and chemical characteristics, as well as the site of deposition in the respiratory tract (Newman 2001).

RESULTS

In the human body, the finest particles (up to 0.1 μm) enter the non-pulmonary spaces, the coarser particles in the human body accumulate in the lung alveoli.

PM2.5 and PM10 particles are generated by mechanical processes such as abrasion and fragmentation (Bačík & Markovič Baluchová 2018). They include mineral dust (mainly derived from arid regions), marine salt, biogenic and anthropogenic particles (derived from tire and brake abrasion). The coarse particles represent a significant proportion of the total volume and weight of the dust particles. They are fastened in the tracheabronchial or nasopharyngeal part of the human respiratory system. (Bačík & Baluchová 2012; Gieré & Querol 2010; Newman 2001)

The specific surface characterizes the dispersed mineral system very precisely. With regard to dust-particles morphology, solid particles have a shape dependent on the mineralogical characteristics of minerals, rocks and other solids present. Such particles can occur in the form of a cube, a plate, a leaf, a stick, a needle, a wedge, but also a very irregular shape. It depends on the physical and mechanical characteristics of minerals or other solids that are dispersed in the environment.

The mineral phases present in dust fallouts were identified in samples from Slovakia by XRD. In all the samples, periclase and magnesite were present, in some accompanied by calcite and dolomite.

XRD patterns were quantitatively evaluated and according to them, the most dominant phase in the analyzed samples is usually magnesite (Fig. 1). The periclase content is variable, with a general decreasing trend.

The morphological study of dust fallout samples from the Jelšava and Lubeník area by scanning electron microscopy (SEM) showed that the dominant mineral phases of dust are carbonates, of which magnesite as the crystals and fragments dominated, dolomite occurred rarely, calcite was not observed. Another dominant phase forming irregular allotriomorphic grains, aggregates and masses was identified as periclase (Fig. 2).

When the dust concentration and periclase proportion, as the main representative of emissions and immissions produced during the treatment and processing of magnesite by processing plants, are considered, a trend of decrease in the periclase content was observed. From the results of quantitative and qualitative analysis of dust fallouts, it was possible to state that the air pollution burden of the monitored areas of Jelšava-Lubeník in the observed period had a decreasing trend. It could be attributed to the implementation of modern filters of dust collection and dust control techniques in processing units by plants managements (Baluchová *et al.* 2011).

DISCUSSION

Dust particles are particularly dangerous to the respiratory tract because it is exposed to them mostly alongside the skin. However, due to its biological nature, the respiratory tract is much more sensitive than the skin. Human lungs contain more than forty different cell types with different specialized functions. The trachea and bronchial epithelial cells may be compared to tubular structures which, with the support of other cell types (e.g. fibroblasts), form collagen and other cell products for lung tissue. Epithelial cells and fibroblasts are also often attacked by minerals-related diseases, giving rise

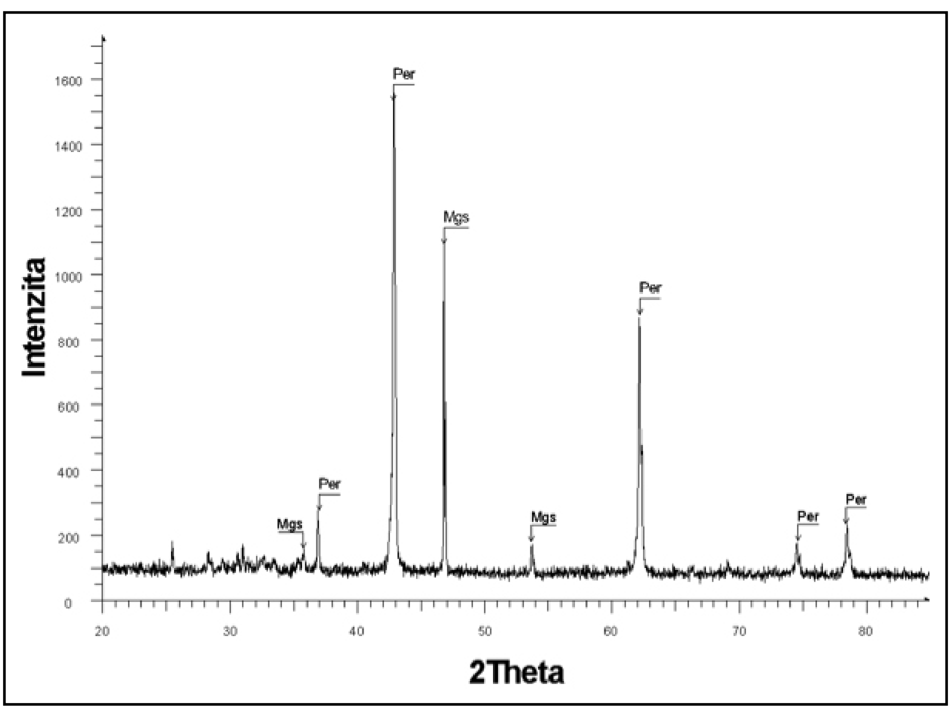

Fig. 1. Dust particles in dust sample no. J2 from the Jelšava and Lubeník area (Slovakia) by X-ray powder diffraction. Dominant phases (in intensity peaks): Per = periclase; Mgs = magnesite

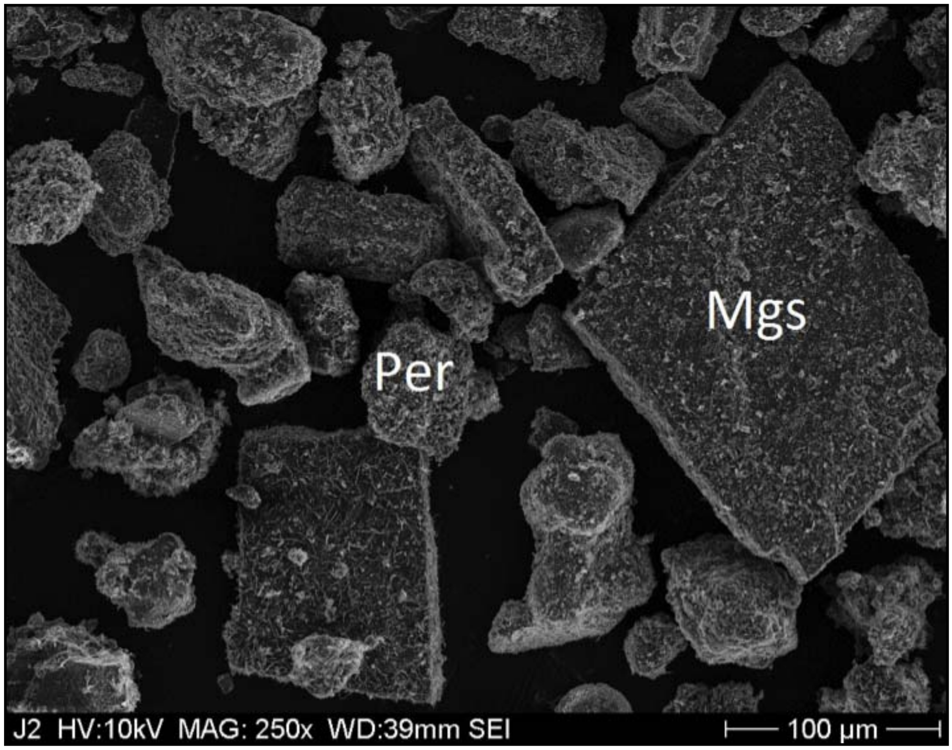

Fig. 2. Dust particles in dust sample no. J2 from the area of Jelšava and Lubeník (Slovakia) by SEM. Per = periclase – irregular grains; Mgs = magnesite – rhombohedral crystals.

to the bronchogenic carcinoma (or other lung tumors) and pulmonary fibrosis (silicosis and asbestosis) (Hepleston 1991, Mossman 1993, Baluchová 2010)

A great deal of attention is drawn to the search for the essence of mineral system fibrogenicity. This is fixed in the structural nature of the mineral grains that have arisen in the crushing and decoupling process. For example, the carrier of the fibrogenic properties of quartz is its internal structure – loose surfaces, edges, corners arise after disintegrating mineral particles and may have specific characteristics in contact with lung tissue (Baluchová *et al.* 2011). Fibrogenic effects of such quartz particles result from the mechanical irritation of a lung tissue due to the piezoelectric properties of quartz structure (Kayser 1992).

The most destructive action of the mineral phase of the dust fallouts comes after their penetration into the alveolar parts of the lungs. It results in the development of Pneumoconiosis, which is a lung disease caused by dust particles that are most often found in a work environment (Sissons 2017). Fibrogenic dust (less than 2.5 µm) passes through the alveolus into the interstitial space. Here, with its physicochemical characteristics, it acts and destroys healthy tissue and replaces it with a new non-functional (Mossman 1993). Long-term PM2.5 exposure increases not only the risk of chronic obstructive pulmonary disease, but also cardio-vascular disease and major depressive disorders among the general population (Sram *et al.* 2017).

Depending on the solubility in physiological fluids, mineral dust fallouts are divided into readily soluble, poorly soluble, and (in the worst case) insoluble dusts. We consider dust from gypsum, limestone, Na and K salts as easily soluble and harmless. They work only for a limited time and come out of the body. The dust containing cadmium, lead, arsenates and radioactive minerals is also soluble, but harmful. Although these are washed out of the body during relatively short time period, they can leave carcinogenic changes. Insoluble or sparingly soluble minerals are referred to as active, they initiate and activate fibrosis. Such include quartz powders, amphibole asbestos, mica, K-feldspar, talc and other silicates (Bobro 2002).

Research conducted in period 2000-2010 in the Lubeník and Jelšava area, where the environment was adversely affected by mining activities and magnesite processing treatment, brought similar results. Magnesite ($MgCO_3$) material was first adjusted by crushing and sorting as a part of furnace burning preparation. The raw material subjected to burning went through the conversion not only of chemical (decomposition of magnesium carbonate to magnesium oxide, with weight and volume reduction), but also of mineralogical conversion by forming periclase (MgO) grains. The main sources of particulate drift and dust fallouts are the operations of rotary and shaft furnaces (Hančuľák 2000).

A CONCLUSION AND FUTURE CHALLENGES

Mineralogical research of dust particles will be more and more important for knowing their impact on climate development, environment and public health (not only in Slovakia). Currently, similar research methods of dust fallout in the air and its impact on the population health have been conducted in developing countries (Kenya and Samoa so far).

In near future, it will also be crucial to continue the area-wide mineralogical research of dust in Slovakia, not only in urban agglomerations, industrial-loaded territories, but also in households. It will focus on the mineralogical characteristics of dust, its sources, but also its impacts, including impacts on human health and especially their respiratory tract.

In this paper, we deal only with mineral dust and its impact on human health. In the future, the research will focus on investigating aerosols (consisting of dust particles and gas in which dust particles are dispersed). Due to the great variability of their chemical, physical and mineralogical characteristics, and their spatial and temporal distribution, these atmospheric particles represent one of the main uncertainties in the creation of climate change models and its negative environmental and human impacts.

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