

# Particle size distribution of mineral phases and metals in dusts collected at different workplaces

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**Summary.** Airborne dusts were collected by a two-stage sampler on an electrically activated filter at different working places. Inhalable size (particles are less than  $5\text{ }\mu\text{m}$ ) and course fractions were separated by a cyclone. The particle size distribution of three minerals (quartz, calcite, albite) and four metals (Pb, Cd, Cr, Co) was determined. Infrared spectroscopic and AAS methods were applied. The quartz concentrated in the course fractions while the calcite in the inhalable ones. No direct relation to the size fractions was found for albite. The toxic metals were extremely enriched in the fine fractions, in some cases 5–12 times more than in the course fractions. Since only the fine particles might be deposited in the deepest parts of the lung the importance of elimination of pollution sources should be taken into account.

## Introduction

Most occupational diseases are probably caused by inhalation of certain pollutants, i. e. toxic minerals and/or metals, used in workplaces. A part of the airborne particulates can be secured in the lungs. Lung tissue is an efficient medium for catching and absorbing contaminants produced during the working process. The surface area of lung tissue averages  $55\text{--}75\text{ m}^2$  and that of the skin is only about  $2\text{ m}^2$  [1].

However, the respiratory system intercepts a large portion of inhaled airborne particles as they move through the mouth or nose and along the trachea before reaching the lung. Furthermore the lung can remove a large portion of the deposited dust and the partially damaged surface cells of the lung are quickly replaced by new cells. The capacity of self-protection and repair of injured cells can be exceeded, and excessive dust deposition can cause adverse effects within the breathing apparatus [2].

An increasing of scientific evidence has established that the health effect of airborne particulates significantly depends upon the size distribution and chemical composition of the particles. Both factors are greatly influenced by several factors such as technological conditions, operational parameters, type of source and emission control equipment, use of protective device or local ventilation, etc. Based on the physical behaviour of particles in air and the anatomic arrangement of the respiratory system, particles larger than

$10\text{ }\mu\text{m}$  would probably be removed through the nose and the upper respiratory tract and particles smaller than  $10\text{ }\mu\text{m}$  would penetrate in the trachea. From this fraction the particles with an aerodynamic diameter of less than  $3\text{--}5\text{ }\mu\text{m}$  can penetrate deeper into the lung and can reach the alveoli where the exchange of oxygen and carbon dioxide takes place [3].

For evaluation of the hazards and determination of the particle size distribution of pollutants the sampling methods are of great importance. Individual and gravimetric samplers are usually applied and the airborne dust is size-separated by the design and flow characteristics of the sampling head. With a two-stage sampling head the amount of the inhalable particles ( $d < 5\text{ }\mu\text{m}$ ) and the course dust ( $d = 5\text{--}20\text{ }\mu\text{m}$ ) could be obtained by one sampling and the total mass should be calculated.

## Experimental

Airborne dusts produced at different working places were sampled by an SPG 210 (Germany) sampler on an electrically activated fiber-like filter ring [4]. Dust can be recovered from the filter in an ultrasonic-bath using ethanol. The filter was shaken for 10 min and the suspension was centrifuged for 15 min at 6500 rev/min. The supernatant was poured out and the above procedure was repeated twice. Finally, for removal of the ethanol traces, the centrifuge tube was dried at  $105^\circ\text{C}$  for 2 h. Mineralogical phase analysis of the dusts was carried out by X-ray powder diffraction (XRD), Philips M-1051 (USA) and infrared (IR) spectroscopy, SPECORD 75 IR (Germany). Pellets were prepared as discussed recently [5]. Analysis of toxic metals was performed by atomic absorption spectrometry (AAS) using a Perkin-Elmer 303 (Austria) instrument. Calibration curves were prepared from Titrisol® (Merck, Germany). Relative standard deviation (RSD) of the measurements ranged between  $\pm 1\text{--}5\%$  depending upon the metals and wavelengths used. Samples were digested according to their nature; methods were discussed elsewhere [6, 7]. Quartz concentration of dusts was determined by IR spectroscopy using the base-line method [8].

## Results and discussion

The results of the analysis carried out on dusts collected at a foundry are given in Table 1.

It can be seen that the quartz content of the dusts is higher in the course fractions than in the inhalable ones.

**Table 1.** Quartz and metal content of dusts collected in a foundry workshop

| Sample | Quartz<br>(m/m%) | Pb<br>(mg/kg) | Cd<br>(mg/kg) | Cr<br>(mg/kg) | Co<br>(mg/kg) | Job description  |
|--------|------------------|---------------|---------------|---------------|---------------|------------------|
| 1C     | 23.0 ± 0.8       | 115 ± 1       | 3 ± 0.6       | 280 ± 4       | 30 ± 5        | mold preparation |
| 1I     | 14.9 ± 0.5       | 2382 ± 26     | 79 ± 2        | 384 ± 3       | 32 ± 6        | mold preparation |
| 2C     | 17.8 ± 0.6       | 203 ± 2       | 62 ± 1.5      | 359 ± 3       | 83 ± 5        | handworking      |
| 2I     | 2.7 ± 0.5        | 2394 ± 22     | 32 ± 0.9      | 2672 ± 17     | 92 ± 5        | handworking      |
| 3C     | 26.0 ± 1.0       | 66 ± 1        | 2 ± 0.6       | 70 ± 3        | 14 ± 5        | sand preparation |
| 3I     | 21.4 ± 0.8       | 196 ± 2       | 5 ± 0.6       | 122 ± 3       | 21 ± 5        | sand preparation |
| 4C     | 34.8 ± 1.3       | 43 ± 1        | <1            | 122 ± 3       | 16 ± 5        | form-making      |
| 4I     | 24.1 ± 0.9       | 329 ± 3       | 91 ± 2        | 366 ± 5       | 20 ± 8        | form-making      |
| 5C     | 31.4 ± 1.1       | 120 ± 1       | 1.5 ± 0.6     | 71 ± 3        | <5            | core-making      |
| 5I     | 26.0 ± 0.9       | 316 ± 3       | 14 ± 0.6      | 109 ± 3       | 17 ± 5        | core-making      |
| 6C     | 6.5 ± 0.6        | 113 ± 1       | 2.4 ± 0.6     | 1983 ± 13     | 151 ± 5       | fine cleaning    |
| 6I     | 2.7 ± 0.6        | 491 ± 4       | 7.7 ± 0.6     | 1723 ± 11     | 220 ± 5       | fine cleaning    |

C = course fraction (d = 5–20 µm); I = inhalable fraction (d < 5 µm); m/m% = mass/mass%

**Table 2.** Mineral and metal content of dusts collected in a grave-stone polishing-cutting workshop

| Sample | Quartz<br>(m/m%) | Calcite<br>(m/m%) | Albite<br>(mg/kg) | Pb<br>(mg/kg) | Cd<br>(mg/kg) | Cr<br>(mg/kg) | Co<br>(mg/kg) | Job description |
|--------|------------------|-------------------|-------------------|---------------|---------------|---------------|---------------|-----------------|
| 1C     | 5.8 ± 0.3        | 19.4 ± 0.6        | 33.8 ± 0.6        | 86 ± 2        | 119 ± 0.5     | 48 ± 2        | 1863 ± 24     | letter-cutting  |
| 1I     | 4.8 ± 0.3        | 41.8 ± 1.0        | 33.3 ± 0.6        | 202 ± 2       | 16 ± 0.2      | 71 ± 2        | 2001 ± 26     | letter-cutting  |
| 2C     | 12.4 ± 0.4       | 28.3 ± 0.8        | 50.6 ± 0.8        | 66 ± 2        | 6.7 ± 0.2     | 42 ± 2        | 557 ± 9       | stone cutter    |
| 2I     | 6.1 ± 0.2        | 61.5 ± 1.6        | 29.6 ± 0.5        | 238 ± 8       | 46 ± 1        | <20           | 822 ± 30      | stone cutter    |
| 3C     | 19.2 ± 0.7       | 18.2 ± 0.6        | 45.7 ± 0.7        | 62 ± 2        | 13 ± 0.2      | 47 ± 2        | 1550 ± 20     | letter-cutting  |
| 3I     | 9.2 ± 0.3        | 20.5 ± 0.7        | 29.8 ± 0.6        | 284 ± 2       | 37 ± 0.2      | 59 ± 2        | 1058 ± 14     | letter-cutting  |
| 4C     | 7.8 ± 0.3        | 11.0 ± 0.6        | 29.1 ± 0.6        | 23 ± 2        | 3.6 ± 0.2     | 42 ± 2        | 197 ± 7       | stone cutter    |
| 4I     | 6.5 ± 0.3        | 34.1 ± 0.9        | 34.4 ± 0.6        | 196 ± 2       | 17 ± 0.3      | 73 ± 3        | 370 ± 9       | stone cutter    |
| 5C     | 4.2 ± 0.2        | 38.5 ± 0.9        | 19.1 ± 0.5        | 5 ± 2         | 9.3 ± 0.2     | 90 ± 2        | 355 ± 8       | stone cutter    |
| 5I     | 2.8 ± 0.4        | 33.1 ± 0.8        | 20.6 ± 0.7        | 26 ± 9        | 19 ± 1        | 88 ± 2        | 593 ± 34      | stone cutter    |

C = course fraction (d = 5–20 µm); I = inhalable fraction (d < 5 µm); m/m% = mass/mass%

Silicosis can be characterized as a lung disease caused by the inhalation of free crystalline silica (FCS) dust [1]. In nature, quartz occurs as the most common form of FCS and it is the one which contributes most to occupational exposures. Hygienic exposure values for dust containing quartz have been based on the concept that the toxicity is proportional to the concentration of FCS in dust. Threshold limit values (TLVs) can be calculated by measuring the quartz content in the inhalable particulate fraction [1]. In the foundry the workers breathed air containing, in some cases, 25 m/m% (mass/mass %) quartz; this fact means that the TLVs are less than 0.4 mg dust/m<sup>3</sup>. To keep low exposure levels and protect the health of workers, local ventilation or personal safety devices should be used.

While examining the results of the metal content it has been observed that lead and cobalt concentrated, in all cases, in the inhalable fractions. Concerning two worker groups (mold preparation and hand-working) less than 8% of the total lead accumulated in the course fractions and the 92% in the fine ones. Furthermore, in these two workplaces the lead exposure has been found to be about 5–12 times higher than in the others.

The cobalt content of the dust in the two size fractions did not differ very much and only the dust of the fine cleaning procedure proved to be more dangerous compared to other

samples. Cd and Cr are strongly enriched in the fine fractions but in some working procedures (hand working: Cd, and fine cleaning: Cr) the course fractions contained higher amount of metals. Considering the lowest and highest concentration of the metals in different fractions: for Cr No. 3C and 2I and for Cd No. 4C and 4I, very great deviations were obtained. The results show that the metal content of dust are mostly dependent upon the working place.

Along with the four metals and quartz, calcite and albite were also analysed in dusts collected at grave-stone polishing-cutting workshop. Albite and calcite were determined by IR-spectroscopy. For albite, absorbance values were measured at 580 cm<sup>-1</sup> (Si-O-Si bending vibration) and muscovite was added to the standard to suppress the matrix effects. Details of the IR measurements are discussed elsewhere [9]. Results are summarized in Table 2.

Operations that involve crushing, polishing or cutting of minerals or mineral mixtures frequently do not produce airborne dust of the same composition as that of the material being worked on. In many cases quartz is harder to polish or crush than is the remainder of the mixture, i.e. stones, so that in most processes airborne dust is produced with a lower percentage of quartz than it is found in the original mixture. Considering these factors it is necessary to actually obtain samples of airborne dust in different particle sizes.

It can be seen from the results that the quartz content of the coarse fractions was higher compared to the inhalable ones; the same distribution was obtained with the samples collected in a foundry workshop. A reverse tendency can be observed in case of the calcite concentration for the particle size; the calcite is enriched in the fine fractions. This fact confirms that in the polishing-cutting procedure the soft mineral can usually be found in the inhalable fraction of airborne dust. However, such a tendency was not obtained for albite; independently upon the working procedure, the amount of the mineral varied for the two size fractions.

One of the factors having a significant effect upon the evaluation is the reliable analysis of the coarse samples. When air samples are collected in the immediate vicinity of a dust-producing operation, larger particles which have not yet had time to settle from air may be collected. Fortunately, the larger particles seldom reach the lungs because they are filtered out in the nose and trachea.

The four toxic metals were mostly accumulated in the inhalable fractions and, since the airborne dusts were not soluble in body fluids, they might pollute the lung causing local or irritant damaging action. Santamaria and coworkers [3] studied the particle size distribution of metals in the atmosphere of Madrid. They found that lead, cadmium and nickel were the most enriched elements in the range of smaller particles.

Based upon the data obtained for minerals and toxic metals it can be concluded that:

- the quartz content of airborne dust collected in different working places is linearly proportional to the particle size up to 20  $\mu\text{m}$ ,
- the amount of lead is inversely proportional to the particle size up to 20  $\mu\text{m}$ ,
- calcite, and the elements cadmium, chromium and cobalt are mostly enriched in the fine fractions,
- the concentration of albite is independent upon the working procedure and particle size.

These findings were also confirmed by others [10, 11]. Therefore, it is recommended that protective devices (personal or local) which should be installed to reduce dust emissions into the atmosphere must be able to filter out the finest particles. Protection of the human health at workplaces has to be of the utmost importance for industrial hygiene.

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