

Safety In Mines Research Advisory Committee

Project Summary :

Project Title:	Investigation of Crystalline Phases in Silica Fume (29 pages)		
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Summary

Despite intervention in exposure of workers to crystalline silica over many decades, silicosis remains an important occupational disease. Exposure to amorphous silica has not been regarded as a contributing factor, but a possible link with silicosis remains controversial. Silica fume, generally regarded as amorphous silica, has been associated with the development of fibrotic effects in exposed individuals. If microcrystalline phases were present, this might lead to the development of silicosis. Microcrystalline phases are however difficult to detect with routine X-ray diffraction in the ultrafine matrix. Silica fume that appears to be amorphous in routine occupational hygiene surveys might therefore have the potential to cause silicosis because it contains a small proportion of crystalline silica.

Occupational exposure to amorphous silica generally does not show a silicotic effect. When silicosis does occur, exposures are usually mixed, with both amorphous and crystalline silica being present. A major limitation in most of these studies is the uncertain crystalline content. However, even small amounts of crystalline silica in the order of 0.1 per cent of the total amorphous content, are known to result in fibrotic effects.

Recent work on ultrafine particles has shown that their respiratory effects include inflammatory responses, while amorphous silica exposure can result in lung fibrosis. It is possible that co-exposure to ultrafine particles might sensitise the lung to silicotic effects by stimulating recruitment and activation of inflammatory cells and the amplified release of fibrogenic factors, enabling low concentrations of crystalline particles to trigger a silicotic effect. The dose-effect relationship for the development of silicosis under such conditions is not known, and it is therefore difficult to estimate an appropriate occupational exposure threshold level.

This SIMRAC study was initiated to investigate whether crystalline phases were present in silica fume and, if so, at what levels. The role of the ultrafine nature of silica fume in its overall toxicity also required clarification. Samples of airborne silica fume were collected at various locations in a typical silicon smelter plant. Transmission electron microscopy (TEM) was used to analyse the particle size, crystallinity and composition of

crystalline phases present. The TEM techniques were bright field (to count particles), conical dark field (to determine the crystallinity of the particles) and EDS (energy dispersive spectroscopy) to evaluate the composition of the crystalline particles.

The TEM evidence leaves no doubt that crystalline particles are present in silica fume that forms when oxygen is bubbled through molten silicon. Less than 1 per cent of silica particles were crystalline, but its potential impact on the development of lung fibrosis should not be dismissed. The needle-shaped crystalline particles were approximately 200 nm and less in length and approximately 20 nm wide. Amorphous silica particles in all samples were smoothly spherical in shape with a diameter in the order of 100 nm and less. Silica fume can therefore be classified as ultrafine.

It has now been confirmed unambiguously that small concentrations of crystalline silica can be present in amorphous silica under certain process conditions. This should affect the overall interpretation of the association between exposure to silica fume and the potential for development of silicosis.

The fibrogenic effects associated with exposure to amorphous silica fume may be transient, but remain adverse. Irrespective of the potential for development of silicosis, these facts suggest a re-assessment of exposure guidelines. In the U.S., the occupational regulating agencies (NIOSH and OSHA) have set guidelines for various amorphous forms of silica, but not for silica fume *per se*. The U.S. ACGIH occupational exposure guideline value for silica fume is 2 mg/m³, but has been questioned. The German regulating body has set a guideline (MAK) value of 0.3 mg/m³ fine dust for several forms of amorphous silica grouped together.

The South African guideline for respirable amorphous SiO₂ is 3 mg/m³, which corresponds with the ACGIH TLV for diatomaceous earth. There appears to be insufficient justification to retain this guideline in view of the available evidence on adverse health effects of ultrafine silica fume. It is therefore apparent from this SIMRAC study that the occupational exposure guideline for amorphous silica fume should be reassessed.