Crystalline silica in High Temperature Insulation Wool (HTIW) products after use in high temperature applications

In our everyday lives we are all exposed to dusts containing crystalline silica (CS). While this rarely causes any harm, occupational exposures to CS particles that are fine enough to enter the lung (respirable CS), typically during mining, quarrying, stone masonry and sand blasting activities, can cause disease in exposed workers – possibly including lung cancer.

The high temperature insulation industry has long been concerned with any possible effects of exposure to dusts from their products that may occur during maintenance or wrecking of used furnaces. Such dusts can contain respirable CS. Numerous studies have been undertaken, independently or commissioned by the industry, to study this possibility and the results of these are described below. Overall, the available data indicate that exposure to CS in after-use HTIW products, as may occur during furnace maintenance and wrecking, is unlikely to cause disease.

Background

Refractory materials, including bricks, castables and man made mineral fibre products, are usually composed of silicates – silicon in various combinations with oxygen and other elements. Most high temperature insulation wools consist of amorphous glass fibres, composed of either alkaline earth silicates (AES) or alumino silicates (refractory ceramic fibres; ASW/RCF). A third group are the polycrystalline wools (PCW). Although types of silica may be used in their manufacture, none of these materials contain free crystalline silica in the product as sold and installed. However, it is now known that AES and ASW/RCF may transform into a mixture of crystalline phases, including CS, following prolonged heating. PCW, though, does not contain CS even after use.

Amorphous HTIW products are produced from a molten glass stream which is aerosolised by a jet of high pressure air or by letting the stream impinge onto spinning wheels. The droplets are drawn into fibres; the mass of both fibres and remaining droplets cool very rapidly so that no crystalline phases form.

When amorphous HTIW products are installed and used in high temperature applications, such as industrial furnaces, at least one face (the hot face) may be exposed to conditions causing the fibres to partially devitrify. Depending on the chemical composition of the fibres and the time and temperature to which the materials are exposed, different stable crystalline phases may form.

Devitrification involves separation within the glass of phases with similar compositions to those of stable silicate minerals such as mullite, enstatite and wollastonite or diopside. These phases crystallise within a matrix of silica-rich glass from which, in turn, silica also crystallises, predominantly in the form of cristobalite.

Regulation and classification of dusts containing respirable crystalline silica dust

In 1997 IARC \(^1\) reviewed the available literature on crystalline silica exposure and concluded that there was sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources; IARC therefore classified crystalline silica in these situations as a Group 1 carcinogen.

In making their overall evaluation, the IARC Working Group noted that carcinogenicity in humans was not detected in all industrial circumstances. Carcinogenicity may be dependent on inherent characteristics of the crystalline silica or on external factors affecting its biological activity or distribution of its polymorphs.

In Europe, as of December 2010, suppliers of materials have to classify, label and package hazardous substances according to the Classification, Labelling and Packaging Regulation (EC) 1272/2008. As a consequence, mixtures and substances containing CS (fine fraction) above 1% are classified as hazardous and must be appropriately labelled. In addition, various national regulations exist in almost all EU member States. Such regulations entail various controls including regulatory limit values fixing the maximum allowed exposures to respirable airborne crystalline silica.

---

2. ASW/RCF stands for Alumino Silicate Wool, also called Refractory Ceramic Fibre (RCF).
Summary of scientific information available for CS in after-service ASW/RCF and AES

When, in the 1980’s, RCF’s were tested in a series of animal inhalation experiments (the so-called RCC studies), the samples tested included a specimen of heated (devitrified or crystallised) ASW/RCF estimated as containing 27% cristobalite, to simulate after-use fibres. This sample caused less lung effects than any other sample tested and no excess of tumours.

Further studies at the IOM in Edinburgh also found this sample to be inert when injected into the peritoneum of rats. These early results with ASW/RCF already gave an indication that after-use (devitrified) fibres do not constitute a health hazard.

Some forms of CS can accumulate in the lungs causing inflammation, tissue damage and silicosis. This is especially true of freshly-cleaved CS which is toxic to the cells (macrophages) that normally clear dusts from the lungs. This prevents the silica from being removed. The damaged cells release substances that attract more macrophages and inflammatory cells, and a cascade of deleterious effects ensues.

The ease with which macrophages may be kept alive (cultured) in the laboratory - whilst retaining their ability to ingest particles - has enabled their interaction with silica to be studied extensively in so-called in vitro experiments. Forms of silica that are toxic to macrophages in vitro also cause disease in animals. As there are ethical and other reasons for trying to avoid animal experiments, heated AES fibres have been tested in vitro using cultured macrophages. As with heated ASW/RCF’s, AES fibres were not toxic to these cells even after complete devitrification.

More recently at the Fraunhofer Institute for Toxicology and Experimental Medicine, four samples of AES (three calcium-magnesium-silicate wools and one magnesium silicate wool), with classification temperatures between 1100°C and 1300°C, were heated for different durations to their classification temperature and/or their normal maximum continuous use temperature (approx 150°C below their classification temperature). These heated samples contained between 0.3 and 32% CS (see table).

Unheated and heated fibres were then tested in cultures of macrophages. Two measures of toxic activity were used. Firstly the ability of the fibres to cause the cells to leak was determined by measuring the amount of an enzyme (lactate dehydrogenase; LDH) normally found inside the cells that had leaked into the medium outside. Secondly the amount of DNA damage was measured using the Comet assay in which the level of DNA strand breakage is quantified in individual cells.

The control quartz sample (DQ12) was clearly positive in both these assays. However none of the heated or unheated fibres showed significant activity. The cytotoxicity results for all four types of AES wools are illustrated in the chart. The authors of this study concluded that heating AES wools mediates changes in CS content and in fibre length/shape, with heated fibres containing varying amounts of CS (principally in the form of cristobalite) and generally being more particulate in nature than the original unheated forms. While the changes in fibre morphology did impact biological activity, with the heated material showing less activity, CS content had little or no bearing on the measured cellular responses to heated AES wools.

ECFIA has developed, as part of its Product Stewardship Programme, the so-called CARE Programme (Control and Reduced Exposure) as described elsewhere. CARE occupational hygienists have had the opportunity to collect about 190 samples during after-service operations where HTIW insulation materials were being repaired or removed. In only six samples was cristobalite detected, and only one sample showed a level of respirable airborne cristobalite above 0.05 mg/m³, the occupational limit recommended by the EU Scientific Committee for Occupational Exposure Limits (SCOEL). This confirms that, in most cases, respirable CS is not detectable and even more rarely is it above occupational limit values.

Why is CS in after-service HTIW not a health concern?

Silica related fibrosis and cancer in humans have most clearly been observed following exposures to freshly cleaved respirable silica dust. In after-use HTIW, crystalline silica crystals are embedded in a matrix composed of other crystals and glasses and do not seem to be biologically available or capable of damaging the lung. It has been suggested that there is a possibility that such “passivated” silica...
could be attacked in the body and any coating eventually removed, thus re-activating the potential for the deposited dust to do harm. However, silica particles that do not damage macrophages would be cleared by the normal processes and therefore would not accumulate in the lungs.

Most effects of inhaled or injected fibres are not due to the silica content but to their fibrous shape and size. The absence of effects from devitrified fibres in animal experiments is probably due to the brittle nature of the heated fibres. They readily fragment into shorter pieces which are then easily and rapidly cleared from the lung. A recent extensive review of the literature on crystalline silica in heated man-made vitreous fibres has confirmed that the formation of CS in heated HTIW does not render them more toxic but that concomitant alterations to their fibrous shape actually serve to reduce their biological activity.

Overall, therefore, experimental studies on the biological activity of after-use HTIW have not demonstrated any hazardous activity that could be related to any form of silica they may contain. This, coupled with the inability to detect airborne CS during most after-use activities, means that there is unlikely to be any risk of CS related disease from employment in furnace maintenance or wrecking. However, worker protection measures that comply with regulations must be applied. Where no regulation or code of practice is available, ECFIA recommends that you consult its handling advice available at www.ecfia.eu.

Note: This publication is for information only and does not claim to be comprehensive and ECFIA shall not incur any liability for its use. For more information on the subjects mentioned in this issue, please contact ECFIA (3 rue du colonel Moll, 75017 Paris) or connect to its website: www.ecfia.eu