

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 but this does not usually cause disease. However, occupational exposures to silica fine enough to enter the lung (respirable crystalline silica) typically in mining, quarrying, stone masonry and sand blasting, could cause lung diseases possibly including lung cancer.

The high temperature insulation industry has long been concerned with any possible effects of exposures to dusts from their products during the maintenance or wrecking of used furnaces. Such dusts can contain respirable crystalline silica. Many 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 on health related effects of after-use HTIW products suggest that crystalline silica (CS) exposures during furnace maintenance and wrecking are 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: either alkaline earth silicate (AES¹) glass, or aluminosilicate glass (refractory ceramic fibres; ASW / RCF²). A third group are the polycrystalline alumina / silica wools (PCW). Although forms of silica may be used in their manufacture, none of these contain any free crystalline silica in the product as sold and installed. AES and ASW / RCF may transform into a mixture of crystalline phases,

including CS, following prolonged heating but PCW do not contain CS even after use.

Amorphous HTIW (ASW / RCF and AES) 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 are installed and used in high temperature applications such as industrial furnaces, at least one face may be exposed to conditions causing the fibres to partially devitrify. Depending on the chemical composition of the glassy fibre 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 silicates such as mullite, enstatite and wollastonite or diopside. These phases crystallise within a matrix of silica-rich glass from which, in turn, silica will also crystallise in the form of cristobalite.

Regulation and classification of dusts containing respirable crystalline silica dust

In 1997 IARC³ 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, rather than classifying CS as a CMR substance in the normal regulatory process a „Social Agreement“ was signed between industry and the European Commission describing measures to be followed when using and handling CS. For more detail please refer to the following Website: www.nepsi.eu.

However, notwithstanding this agreement, 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.

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 experiments (the so-called RCC studies), the samples tested included a specimen of heated (devitrified or crystallised) 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.

Details of the fibres tested in the Fraunhofer Institute cytotoxicity studies

- A number of commercially available AES fibres were tested including calcium magnesium silicate, calcium silicate and magnesium silicate.
- Fibres were heated to the indicated temperatures, representing both normal maximum continuous use conditions and classification temperature.
- Non heated samples were also tested.

Sample	Heating duration (Days)	Temperature (° C)	Crystalline silica content (Weight %)
AES 1	28	950	3
AES 1	7	1100	18
AES 2	28	1050	10
AES 2	7	1200	23
AES 3	28	1150	31
AES 3	7	1300	32
AES 4	1	1260	18

AES 1/2/3/4 describe samples of calcium-, calcium-magnesium- and magnesium-silicate wools, representing a wide range of commercially available AES products

1 AES stands for Alkaline-Earth silicate a type of wool exonerated from the carcinogen classification under Directive 97/69/EC and Regulation (EC) 1272/2008.

2 ASW/RCF stands for Aluminium Silicate Wool also called Refractory Ceramic Fibre (RCF)

3 IARC Monograph on the Evaluation of Carcinogenic Risk to Humans. Volume 68: Silica, some silicates, coal dust and para-aramid fibrils.

Further studies at the IOM in Edinburgh also found this sample to be inert when injected into the peritoneum of rats⁴. These early results with RCF already gave an indication that (devitrified) end of life fibres do not constitute a health hazard.

Some forms of CS can accumulate in the lung 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 cells and inflammation cascades.

These macrophages were the first type of cell to be studied *in vitro*, that is in cultures outside the body. The ease with which they may be kept alive and their ability to ingest particles has enabled their interaction with silica to be studied intensively. Forms of silica which are toxic to macrophages *in vitro* also cause disease in animals. As there are ethical and legal reasons for trying to avoid animal experiments, heated AES fibres were tested *in vitro* with cultured macrophages. As with heated RCF's, AES fibres were not toxic to these cells⁵ even after complete devitrification.

More recently at the Fraunhofer Institute for Toxicology and Experimental Medicine, four samples of AES with classification temperatures between 1100°C and 1300°C were heated to their classification temperature and normal maximum continuous use temperatures (approx 150°C below their classification temperatures). These heated samples contained between 3 and 32% of CS (see table on page 1).

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) 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.

ECFIA has developed, as part of its Product Stewardship Programme, the so called CARE Programme (Control and Reduced Exposure) as described elsewhere⁶. CARE occupational hygienists have had the opportunity to collect about 190 samples during after-service operations where HTIW insulations were maintained or removed. In only six samples cristobalite was detected, and only one sample showed respirable airborne cristobalite concentration above the level of 0.05 mg/m³. This confirms that in most cases respirable CS is not detectable and even more rarely is it above the limit value.

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 free 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 lung⁷. 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 silica 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 fragment easily into shorter pieces which are then easily and rapidly cleared from the lung.

Overall, experimental results on the biological activity of after-use HTIW has 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 employed. Where no regulation or code of practice are available, ECFIA recommends that you consult its handling advice available on www.ecfia.eu.

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4 Miller BG, Searl A, Davis JMG, Donaldson K, Cullen RT, Bolton RE, Buchanan D, Soutar CA 1999 Influence of fiber length, dissolution and biopersistence on the production of mesothelioma in the rat peritoneal cavity *Ann Occup Hyg*; 43:155-66
 5 Brown, R.C. [1999]. Regulation of Crystalline Silica: Where Next? *Indoor and Built Environment* 8: 113-120.
 6 Maxim LD, Allshouse JN, Deadman J, Kleck C, Kostka M, Webster D, Class P and Sébastien P. [1998]. CARE – A European programme for monitoring and reducing refractory ceramic fibre dust at the workplace: initial results. *Gefahrstoffe Reinhaltung der Luft*. 58(3):97-103.
 7 Techniques used to evaluate the level of crystalline silica at the workplace doesn't allow to differentiate between free CS and forms where CS is embedded within a particle of different nature. Most regulations apply therefore to all forms of CS whether available biologically or not, whether aged or freshly cleaved.

