



# Loss Control TIPS

## Technical Information Paper Series

*Innovative Safety and Health Solutions<sup>SM</sup>*

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# Understanding Silica: Health Hazards, Standards, and Sampling Issues

## Sources, Properties, and Uses

Any discussion of “silica” has to start with a few definitions. Silica can take several different forms, and the term is applied (and sometimes misapplied) to very different materials. Free silica ( $\text{SiO}_2$ ) and silicates, or combined silica ( $\text{SiO}_3$ ), have substantially different chemical compositions and present different health hazards.

Free silica ( $\text{SiO}_2$ ) can take two separate forms: *crystalline* and *amorphous*. Both represent significantly different health concerns. Silicates can include many relatively nontoxic compounds, including sodium silicate (water glass), calcium metasilicate, portland cement, kaolin clay, or perlite. On the other hand, some silicates such as mica, talc, asbestos, feldspar, and soapstone have potentially toxic properties. Not all forms of silica exhibit the same degree of toxicity, so it is essential to understand the type of silica present in order to determine its degree of hazard. For further information, refer to the *Threshold Limit Values (TLV)* published by the American Conference of Governmental Industrial Hygienists or other reliable references.

*Amorphous forms of silica do not present the serious health hazard associated with the crystalline forms.* Examples of amorphous silica include glass, diatomaceous earth (uncalcined), precipitated silica, and silica gel.

Silica or silicates can occur naturally and are also manufactured. *It is reasonable to expect crystalline silica content in almost any naturally-occurring mineral or other substance which has been removed from the ground.* Dust from sand, coal, graphite, slate, clay, sandstone, shale, pumice, flint, diatomite or glacial deposits are all possible candidates for crystalline silica exposures.

The terms *crystalline* and *amorphous* silica apply to the chemical silicon dioxide ( $\text{SiO}_2$ ). Crystalline silica exists in several different mineral forms, including quartz, cristobalite, and tridymite. Other materials that may contain appreciable amounts of quartz include fused silica, silica flour, and tripoli.

The primary source of crystalline silica is *quartz*, a mineral found in nearly all mineral deposits; it is an important component of common rocks such as granite and sandstone.



Sand contains large amounts of quartz and is used in the glass and pottery industry as well as in production of brick, mortar, and abrasives (for example, concrete, sand paper, sand blasting). In its finely divided form (silica flour), it is added to soaps, paints, and porcelains.

The two minerals known as *cristobalite* and *tridymite* usually occur together, most commonly in volcanic rock in California, Colorado, and Mexico. These two minerals can also be manufactured by heating silica (either crystalline or amorphous) to high temperatures. This process occurs in calcining diatomaceous earth; the resulting products are used in insulation, filters, and furnace linings.

Industries and products which use crystalline silica include abrasives, abrasive blasting, boiler scaling, cement production, ceramics, coal mining and milling, fillers (paints, rubber, etc), foundry work, glass manufacture, insulation production, metal mining and milling, mining, quarrying, tunneling, nonmetallic mining and milling, plastic manufacturing (as a filler), pottery making, refractories, road working, rubber manufacturing (as a filler), sandblasting, scouring powder, tile and clay production, and vitreous enameling.

## Health Hazards

It is impossible to generalize about the health hazard potential of any dust of unknown composition. References in Material Safety Data Sheets may give hints as to whether the material in question is silica or a silicate, or whether it is crystalline or amorphous silica, or none of the above. Because some silicates are harmless and others are not, explore this aspect fully.

Crystalline silica can damage the lungs. Of primary concern are *respirable* silica dust particles (those that are sufficiently small to penetrate into the deep recesses of the lung). Health hazards associated with excessive exposure to respirable crystalline silica include silicosis and lung cancer. Employees who develop silicosis are also at increased risk of developing tuberculosis, although tuberculosis is not directly caused by exposure to silica. The rate of tuberculosis has long been known to be higher among those who have silicosis, and may occur at any stage of the disease. There are also case studies of short but profound exposures to very fine forms of crystalline silica producing a condition known as "acute silicosis."

Silicosis symptoms are often not initially apparent; a victim's exposure may continue for decades before he or she experiences respiratory difficulties. By then, significant damage may have occurred, including classic silicosis or progressive massive fibrosis. Several agencies, including the International Agency for Research on Cancer, the German MAK Commission, and the American Conference of Governmental Industrial Hygienists, have concluded that respirable crystalline silica dust exposures and the development of silicosis are associated with an increased risk of lung cancer, tuberculosis, or both.

## Standards

The United States Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have established different standards for respirable crystalline silica.

The current ACGIH standard, or Threshold Limit Value (TLV), for respirable quartz is the more conservative of the two, at 0.1 milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ). (In 1999, ACGIH published a Notice of Intended Change for quartz to reduce the TLV to  $0.05 \text{ mg}/\text{m}^3$ .)

OSHA's Permissible Exposure Limit (PEL) uses a different method; it requires the following formula to determine the PEL *for each sample taken*, the PEL is different for each sample. The respirable dust concentration (in mg/m<sup>3</sup>) is then compared to the individual PEL for each sample to determine exposure.

$$\text{PEL Respirable Silica} = \frac{10 \text{ mg/m}^3}{\% \text{ Quartz} + 2}$$

As a practical matter, the OSHA PEL and the ACGIH TLV are identical when the material being sampled is 100% quartz. Both are twice as high as the proposed TLV.

Note that the permissible exposure limit and TLVs for silica (other than quartz) such as cristobalite and tridymite are 0.05 milligrams per cubic meter, half the quartz value. At this time, there is no proposal to lower the TLVs for either cristobalite or tridymite.

If the material being used contains less than 1% silica, or if it is amorphous silica, then ACGIH's Particulate Not Otherwise Classified (PNOC) standard applies.

Because of the significance of the health effects, The Hartford recommends adherence to the proposed ACGIH Threshold Limit Value of 0.05 mg/m<sup>3</sup> for respirable quartz dust and the existing TLV of 0.05 mg/m<sup>3</sup> for respirable dust of cristobalite or tridymite.

## Sampling Issues

Respirable dust measurements are more practical than total dust measurements in making a meaningful estimate of the health hazard potential associated with exposure to silica. The standard sampling methodology for total dust collects particles of all sizes, which can bias sample results (both negatively and positively) during measurement of silica concentrations.

To collect respirable dust samples, use a size-selective collection device, usually a cyclone separator. This device separates particles larger than 10 microns (not considered respirable) from those fewer than 10 microns (as defined by OSHA under 29 CFR 1910.1001, Table Z3, footnote e.) It is essential that the collection device be operated at the flow rate stipulated by the manufacturer. Higher or lower flow rates will directly impact the efficiency of the device. (The Hartford uses two types of cyclone separators, but most often the MSA 10-millimeter nylon cyclone, which requires a flow rate of 1.7 liters/minute.) Samples are collected on pre-weighed 5 micron PVC filters in a 2-piece, 37-millimeter cassette.

In some limited situations, a major drawback to the analytical procedure employed by some laboratories is the inability to differentiate among the various types of silica. Some methods cannot distinguish quartz from cristobalite or tridymite, nor can they distinguish quartz from amorphous silica. In short, with some methods, *all silica* (silicon dioxide) *is reported regardless of its form or structure. In order to identify combinations of silica or to assess unknown material, conduct an x-ray diffraction.* But be aware that x-ray diffraction alone cannot distinguish quartz from amorphous silica.

Because the TLV and PEL differ, it is *imperative* that you know which standard is going to be applied *prior to requesting laboratory analysis.*

## Sampling Methodology

In most sampling methods, a pre-weighed, PVC, 5 micron filter is placed into a cyclone apparatus face down, so that the ribbed outlet side is facing up and towards the tubing leading to the pump. Adjust the flow rate to the manufacturer's specification and check it at least once each hour. Re-adjust the flow only if it appears that the flow rate has increased or decreased more than 10%.

Since only the respirable dust is being collected, it will be necessary to take samples for a longer time to ensure that sufficient material is obtained for analysis. To obtain meaningful results from the chosen laboratory, *collect respirable dust samples for a minimum of five hours*, and preferably during the entire shift. Obviously, if conditions are such that dust loadings appear high, shorter collection times are permitted, but sampling for at least five hours should be the goal.

## Control Options

If the exposure approaches levels of respirable silica dust at or in excess of the TLV/PEL, consider control options. Fundamental principles of industrial hygiene indicate that the most effective measures are likely to be substitution of a less hazardous material for silica or the use of engineering controls to remove respirable silica dust from the air.

Where possible, use effective engineering controls or other dust suppression methods to bring the airborne levels of respirable crystalline silica below an acceptable exposure level, such as the proposed TLV of 0.05 mg/m<sup>3</sup>.

In circumstances where, despite using the best technology, airborne levels of respirable crystalline silica dust cannot be brought into compliance with the exposure limit, worker(s) must be protected adequately, either through isolation of the employee(s) or through administrative controls. As a last resort, and as an interim method to protect employee health, an appropriate respiratory protection program should be implemented. Note that respirator users must comply with OSHA's Respiratory Protection Standard (29 CFR 1910.134).

Exposed workers also need to receive regular medical evaluations to determine whether they are developing adverse health effects. These examinations should include initial and periodic chest x-rays, pulmonary function tests, and a complete physical examination. If medically warranted, it may be necessary to remove a worker from the hazardous environment.

Eliminating the use of silica is possible in some industrial processes where a suitable, less toxic material exists. The use of sand in abrasive blasting is one example of a process for which a number of substitutes are available. Commercially available abrasives (such as Zeolite and "black beauty") may be good substitutes for sand. Substitutes should also be considered for the production and commercial use of silica flour, the very finely divided, highly purified form of crystalline silica. Silica flour is often used as an abrasive where other less toxic substitutes exist. In some instances, cristobalite can be replaced by similar refractory materials that are less toxic.

In hard rock mining, quarrying, stone crushing, and heavy construction, workers are exposed to dusts generated from naturally occurring quartz. In these circumstances, more stringent preventive measures (e.g., wet methods, ventilation) are needed to minimize exposures and reduce the risk of silicosis.

## References

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