Crystalline Silica

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What is Silica?

- Mineral found commonly in nature as quartz and sand
- Has chemical formula SiO₂
- Occurs in several different forms called polymorphs
- Has many industrial uses
Polymorphs of Silica:

- Quartz
- Caffobalite
- Tridymite
- Coesite
- Seifertite
- Stishovite
- Melanophlogit
- Moganite
- Keatite
- Faujasite

**Polymorph**: an organism or inorganic object or material that takes various forms
Polymorphs of Silica:

- Tridymite
- Cristobalite
- Coesite
- Moganite
- Stishovite
- Melanophlogite
- Seifertite
- Keatite
- Faujasite
Quartz

- Most common form of crystalline silica
- Second most abundant mineral in Earth’s crust
- Found in granite, sandstone, shale, and carbonate rocks
- Highly organized structure
- Chemical formula is SiO$_2$
- Known carcinogen
Cristobalite

- Forms naturally above 1470°C
- Common in volcanic rocks
- Chemical formula is SiO₂
- Has different structure than silica
- Known carcinogen
Tridymite

- Forms naturally between 870 °C and 1470 °C
- Common in volcanic rock
- Has chemical formula SiO$_2$
- Has different structure than silica and cristobalite
- Known carcinogen
- Rarely used in industrial environments
Industrial Uses of Silica

- Glass and porcelain
- Optical fibers for telecommunications
- Production of elemental silicon used in electronics
- Sand casting for manufacturing of metallic components
- Food additive
- Concrete and mortar
- Polishing and cutting
- Sandblasting
- Electrical insulators
- Toothpaste
- High-temperature thermal protection fabric
# Most Common Industries for Silica Exposure

<table>
<thead>
<tr>
<th><strong>Construction Industry</strong></th>
<th><strong>General Industry</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasive blasting</td>
<td>Abrasive blasting</td>
</tr>
<tr>
<td>Jackhammering</td>
<td>Cement and brick manufacturing</td>
</tr>
<tr>
<td>Rock/well drilling</td>
<td>Asphalt/pavement manufacturing</td>
</tr>
<tr>
<td>Concrete mixing and drilling</td>
<td>China and ceramic manufacturing</td>
</tr>
<tr>
<td>Brick and concrete cutting</td>
<td>Steel and foundry industries</td>
</tr>
<tr>
<td>Quarry work and tunneling</td>
<td></td>
</tr>
</tbody>
</table>
Hazards of Crystalline Silica

- Silica exposure is a serious threat to nearly 2 million workers in the U.S.A.
- Blasting, cutting, chipping, drilling, or grinding materials that contain crystalline silica can result in particles of silica that are considered respirable.
- Respirable particles are smaller than 10 microns.
- Respirable particles are small enough to penetrate deep into the lungs, beyond the body’s natural clearance mechanisms.
- Crystalline silica has been classified as a lung carcinogen.
PARTICLE DIAMETERS

.01μ .1μ 1μ 10μ 100μ

VISIBLE

- RESPIRABLE DUST -
Health Effects of Exposure to Crystalline Silica

- Silicosis
- Lung cancer
- Tuberculosis and other lung infections
- Chronic obstructive pulmonary disease (COPD)
- Renal disease
- Other forms of cancer
Silicosis is inflammation and scarring of the lungs.

Symptoms include:
- Shortness of breath
- Cough
- Fever
- Cyanosis (bluish skin)

No cure

More susceptible to tuberculosis and other lung infections
Severity of Silicosis

- Dust concentration
- Percent of free silica
- Duration of exposure
- Size of the particles
Types of Silicosis

**Chronic/Classic**
- Most common
- 15-20 years of moderate to low exposure
- Symptoms:
  - Shortness of breath
  - Fatigue
  - Low oxygen levels
  - Chest pain
  - Respiratory failure

**Accelerated**
- 5-10 years of high exposure
- Symptoms:
  - Shortness of breath
  - Weakness
  - Weight loss

**Acute**
- Few as 2 years after exposure to high concentrations
- Symptoms:
  - Disabling shortness of breath
  - Weakness
  - Weight loss
  - Death
### Number of Workers Exposed to Respirable Crystalline Silica in Selected General Industry/Maritime Sectors

<table>
<thead>
<tr>
<th>Industry Sector</th>
<th>Number of Workers Currently Exposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Roofing Materials</td>
<td>4,395</td>
</tr>
<tr>
<td>Concrete Products</td>
<td>54,449</td>
</tr>
<tr>
<td>Cut Stone</td>
<td>12,085</td>
</tr>
<tr>
<td>Dental Laboratories</td>
<td>41,194</td>
</tr>
<tr>
<td>Foundries</td>
<td>48,223</td>
</tr>
<tr>
<td>Jewelry</td>
<td>40,508</td>
</tr>
<tr>
<td>Porcelain Enameling</td>
<td>5,454</td>
</tr>
<tr>
<td>Pottery</td>
<td>10,148</td>
</tr>
<tr>
<td>Railroads</td>
<td>16,895</td>
</tr>
<tr>
<td>Ready-Mix Concrete</td>
<td>43,920</td>
</tr>
<tr>
<td>Shipyards</td>
<td>4,500</td>
</tr>
<tr>
<td>Structural Clay products</td>
<td>8,435</td>
</tr>
<tr>
<td>Support Activities for Oil and Gas Operations</td>
<td>25,440</td>
</tr>
</tbody>
</table>
Statistics:

- From 1968-2002 silicosis was recorded as the underlying cause of death for approximately 74 million U.S. workers
- An estimated 2 million employees were exposed to silica in 2007
- It is estimated that 1,600 new cases of silicosis occur each year in the United States
Statistics:

Total number of death with Silicosis mentioned on death certificate 1970-2004

<table>
<thead>
<tr>
<th>Years</th>
<th>Total number of Silicosis Deaths</th>
<th>Percent Change (Reduction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-1974</td>
<td>4,263</td>
<td></td>
</tr>
<tr>
<td>1975-1979</td>
<td>2,711</td>
<td>36%</td>
</tr>
<tr>
<td>1980-1984</td>
<td>1,958</td>
<td>28%</td>
</tr>
<tr>
<td>1985-1989</td>
<td>1,601</td>
<td>22%</td>
</tr>
<tr>
<td>1990-1994</td>
<td>1,389</td>
<td>13%</td>
</tr>
<tr>
<td>1995-1999</td>
<td>1,018</td>
<td>27%</td>
</tr>
<tr>
<td>2000-2004</td>
<td>809</td>
<td>20%</td>
</tr>
</tbody>
</table>

*NORMS database [http://webappa.cdc.gov/ords/norms.html](http://webappa.cdc.gov/ords/norms.html)*
## Most frequently recorded industries on death certificate

<table>
<thead>
<tr>
<th>CIC</th>
<th>Industry</th>
<th>Number of Deaths</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>060</td>
<td>Construction</td>
<td>118</td>
<td>13.4</td>
</tr>
<tr>
<td>040</td>
<td>Metal mining</td>
<td>86</td>
<td>9.8</td>
</tr>
<tr>
<td>041</td>
<td>Coal mining</td>
<td>69</td>
<td>7.8</td>
</tr>
<tr>
<td>270</td>
<td>Blast furnaces, steelworks, rolling and finishing mills</td>
<td>51</td>
<td>5.8</td>
</tr>
<tr>
<td>050</td>
<td>Nonmetallic mining and quarrying, except fuel</td>
<td>48</td>
<td>5.5</td>
</tr>
<tr>
<td>271</td>
<td>Iron and steel foundries</td>
<td>48</td>
<td>5.5</td>
</tr>
<tr>
<td>262</td>
<td>Miscellaneous nonmetallic minerals and stone products</td>
<td>44</td>
<td>5.0</td>
</tr>
<tr>
<td>392</td>
<td>Not specified manufacturing industries</td>
<td>33</td>
<td>3.8</td>
</tr>
<tr>
<td>331</td>
<td>Machinery, except electrical, n.e.c.</td>
<td>23</td>
<td>2.6</td>
</tr>
<tr>
<td>252</td>
<td>Structural clay products</td>
<td>20</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>All other industries</td>
<td>317</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Industry not reported</td>
<td>23</td>
<td>2.6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>880</td>
<td>100</td>
</tr>
</tbody>
</table>

CIC – Census Industry Code  
N – not elsewhere classified  
Source: National Center for Health Statistics multiple cause of death data. NIOSH 2008c, Table 3-6, p. 62
How to Protect Works From Silica Exposure:

- Replace silica material with safer substitutes
- Provide engineering controls such as local exhaust
- Use work practice controls such as water
- Use appropriate respiratory protection
- Provide exposure and medical monitoring
- Conduct employee training
Silica Sampling

- Sample media is pre-weighed, low ash, 5-μm pore size, 37-mm diameter polyvinyl chloride
- 10-mm nylon Dorr-Oliver cyclone is used with a personal sampling pump
- Sampled with a flow rate 1.7 L/min for 480 minutes (8 hours)
Pre-weighed filters are first submitted for gravimetric analysis to determine sample weight
Filters are transferred to a flask
Tetrahydrofuran (THF) is added to dissolve the filter
The suspension is agitated and deposited onto silver membrane filters through a filtration process
The sample is fixed to the silver filter using parlodion, an organic glue
Lab Analysis
Lab Analysis

- Silver filters are analyzed using x-ray diffraction
- X-rays are shot into the sample
- X-rays interact with the crystal structure and refract at district angles
- Diffraction angles are viewed as peaks on paper
- Silica analysis uses 4 diffraction angles and yields 4 peaks
- Intensity of peaks correlated to the amount of silica present in sample
X-Ray Diffraction

X-ray Powder Diffraction

Intensity (arb. unit.)

2 θ (degree)
The current PEL is a sliding scale dependent on the percent of quartz in dust and the mass of the sample.

Current PEL is not for pure silica (or polymorph), but for dust containing silica.

PEL for construction and general industry are calculated differently.

The same is true for cristobalite and tridymite.
Current Silica PEL: General Industry

- **Step 1**: Calculate PEL

\[
PEL \left( \frac{mg}{m^3} \right) = \frac{10 \left( \frac{mg}{m^3} \right)}{\% \text{ silica} + 2}
\]

- **Step 2**: Calculate 8 hour TWA

\[
8 \text{ hour TWA} = \frac{(\text{concentration} \left( \frac{mg}{m^3} \right))(\text{sample time})}{480 \text{ minutes}}
\]

- **Step 3**: Calculate severity

\[
\text{Severity} = \frac{8 \text{ hour TWA}}{PEL}
\]
Current Silica PEL: Construction

- **Step 1:** Calculate PEL as per general industry
- **Step 2:** Calculate 8 hour TWA and severity
- **Step 3:** Determine possible over exposure, if not, STOP
- **Step 4:** Calculate construction PEL

\[
\text{Construction PEL} = \frac{250}{5 + \%\text{ silica}}
\]

- **Step 5:** Convert TWA \( \frac{mg}{m^3} \) to TWA (mppcf)-million particles per cubic foot

\[
mppcf = \frac{\text{sample} \frac{mg}{m^3}}{0.1}
\]

- **Step 6:** Compare the TWA (mppcf) with the construction PEL to determine over exposure

OSHA®
Proposed Silica Standard

- PEL of 50 $\frac{\mu g}{m^3}$ for 8 hours
- PEL would be the same for all industries and would not be variable
- Monitoring employee exposure
- Limit works’ access to areas of high exposure
- Provide effective methods to reduce exposure
- Require employees with high exposure to receive medical exams
- Require employee training
Effects of New Standard

- Estimated to save 700 lives per year
- Prevent 1,600 new cases of silicosis per year
- Reduce exposure for over 2.2 million workers
Questions?