
OSHA®
Occupational Safety
and Health Administration

Crystalline Silica

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OSHA® Occupational Safety and Health Administration

What is Silica?

- Mineral found commonly in nature as quartz and sand
- Has chemical formula SiO_2
- Occurs in several different forms called polymorphs
- Has many industrial uses

Polymorphs of Silica:

Polymorph: an organism or inorganic object or material that takes various forms

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

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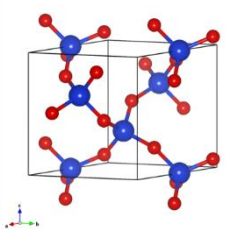
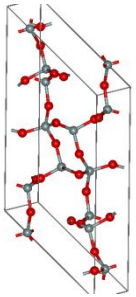
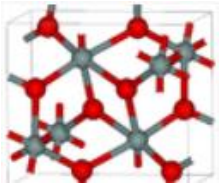
Polymorphs of Silica:



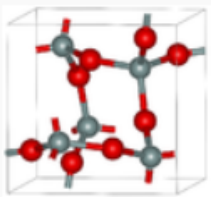
Quartz



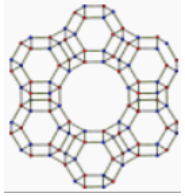
Moganite



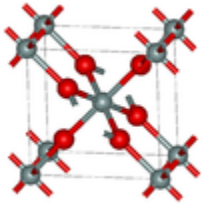
Seifertite



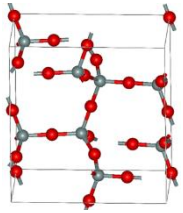
Cristobalite



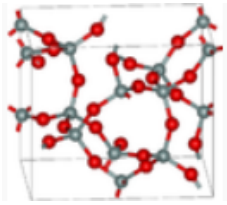
Faujasite



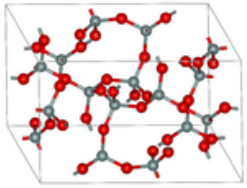
Stishovite



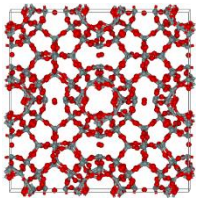
Tridymite



Keatite



Coesite



Melanophlogite

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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^{o} C
- Common in volcanic rocks
- Chemical formula is SiO_2
- Has different structure than silica
- Known carcinogen

Tridymite

- Forms naturally between 870 ^{o}C and 1470 ^{o}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

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Most Common Industries for Silica Exposure

Construction Industry

- Abrasive blasting
- Jackhammering
- Rock/well drilling
- Concrete mixing and drilling
- Brick and concrete cutting
- Quarry work and tunneling

General Industry

- Abrasive blasting
- Cement and brick manufacturing
- Asphalt/pavement manufacturing
- China and ceramic manufacturing
- Steel and foundry industries

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Hazards of Crystalline Silica

- Silica exposure is a serious threat to nearly 2 million works 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

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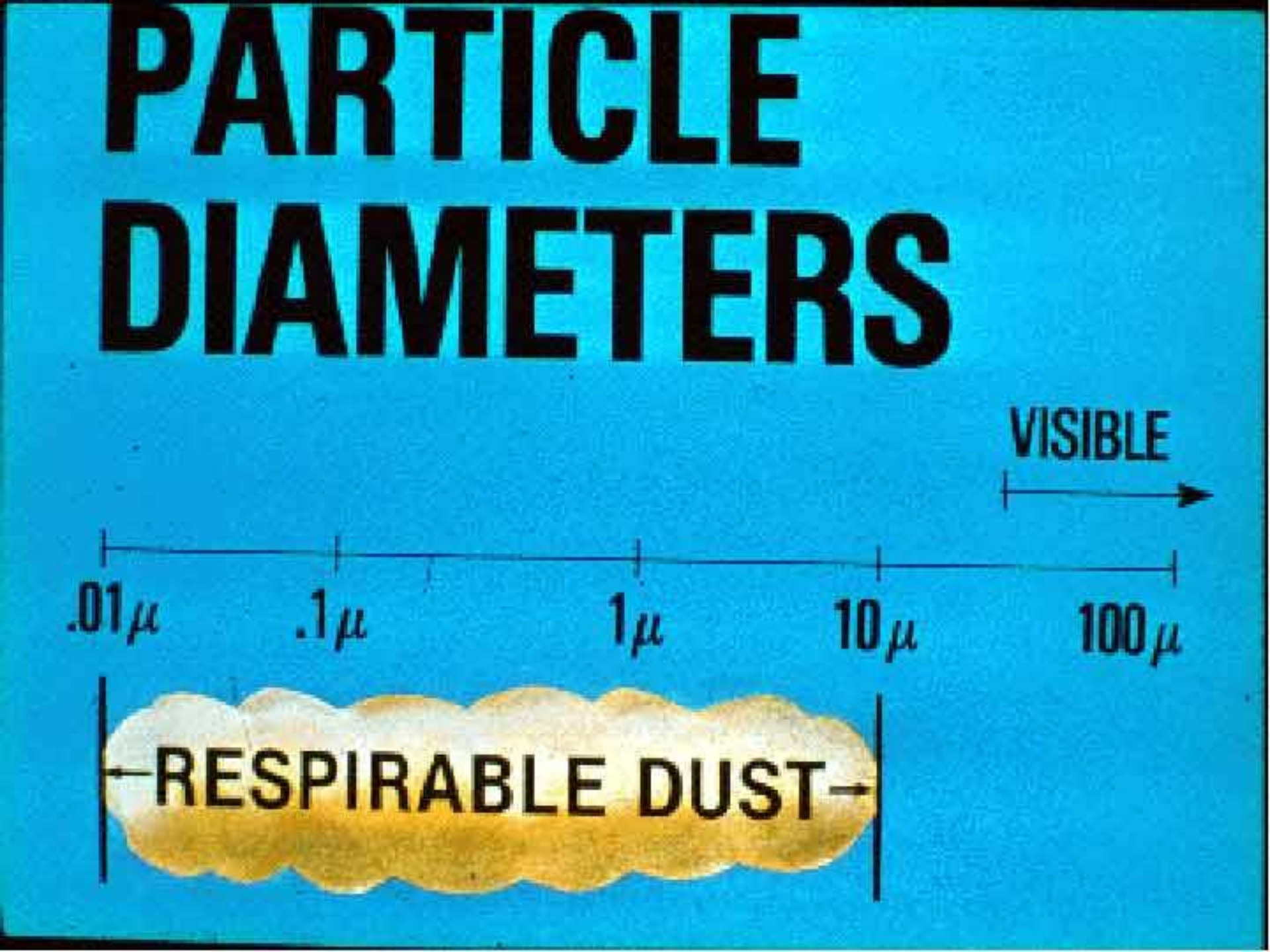
PARTICLE DIAMETERS



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

- 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

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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

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Number of Workers Exposed to Respirable Crystalline Silica in Selected General Industry/Maritime Sectors

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

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

Years	Total number of Silicosis Deaths	Percent Change (Reduction)
1970-1974	4,263	
1975-1979	2,711	36%
1980-1984	1,958	28%
1985-1989	1,601	22%
1990-1994	1,389	13%
1995-1999	1,018	27%
2000-2004	809	20%
*NORMS database (http://webappa.cdc.gov/ords/norms.html)		

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Most frequently recorded industries on death certificate

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

CIC – Census Industry Code n.e.c. – 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

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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)

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Lab Analysis

- 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

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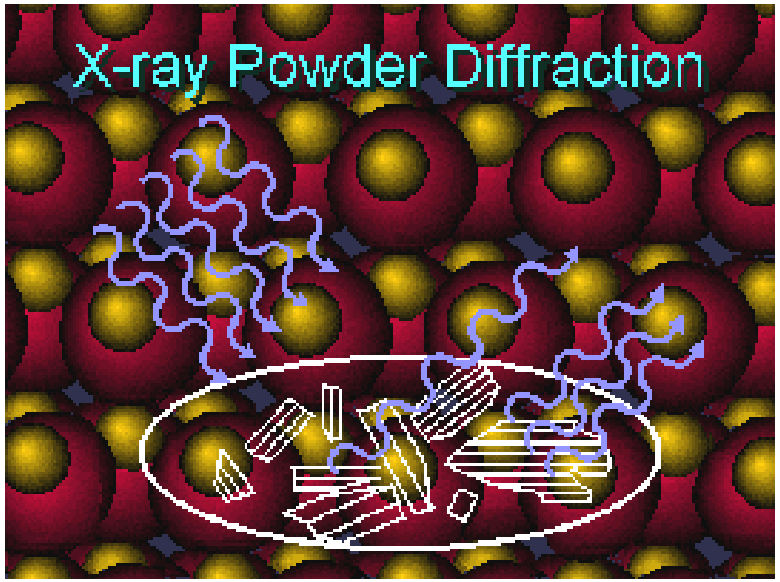
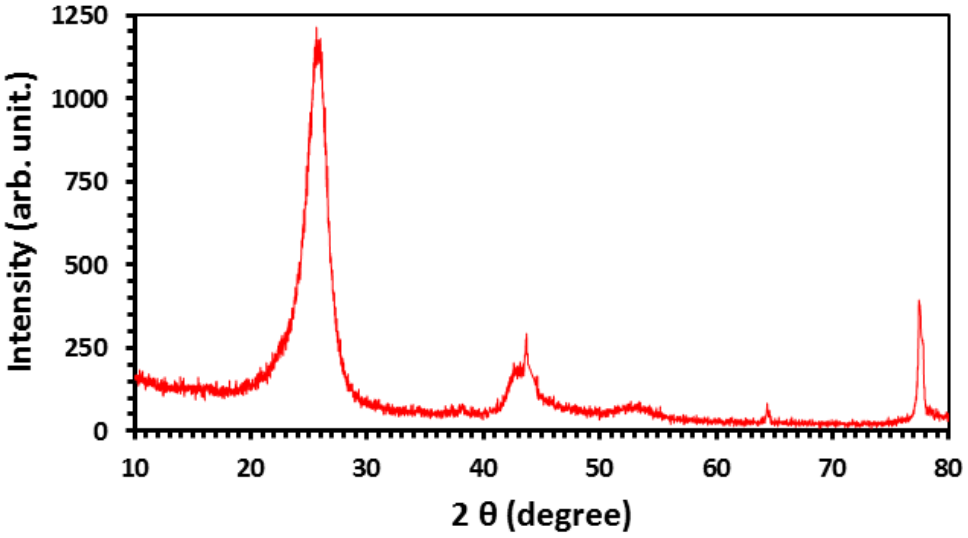
X-Ray Diffraction





Current Silica PEL

- 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

$$PEL\ (\frac{mg}{m^3}) = \frac{10(\frac{mg}{m^3})}{\%\ silica + 2}$$

- Step 2: Calculate 8 hour TWA

$$8\ hour\ TWA = \frac{(concentration\ (\frac{mg}{m^3}))(sample\ time)}{480\ minutes}$$

- Step 3: Calculate severity

$$Severity = \frac{8\ hour\ TWA}{PEL}$$

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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

$$\textbf{Construction PEL} = \frac{250}{5 + \%\ \textbf{silica}}$$

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

$$\textbf{mppcf} = \frac{\textbf{sample}\ \frac{\textbf{mg}}{\textbf{m}^3}}{0.1}$$

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

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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

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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?