PDHonline Course G367 (2 PDH)

Silica Exposure in Sandblasting, Construction and Other Occupations

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by

Mark P. Rossow

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Figure 1. Photo collage of work environments where silica can be found: clay mold operations, foundry operations, work environment with local exhaust ventilation, and payloader moving quartz sand.

Discussion: Crystalline silica, also called free silica, is an odorless crystalline solid that is found as a dusty air contaminant in many industrial processes. It is the cause of the lung disease silicosis.

Figure 2. Common forms of crystalline silica

Discussion: The three most common forms of crystalline silica found in industry are quartz, tridymite and cristobalite. These three materials differ in the structure, or arrangement of the silicon and oxygen, in their crystals. They have the same chemical formula.

Figure 3. Stacked bags of amorphous silica.

Discussion: Another type of silica which has the same chemical formula as crystalline silica is called amorphous silica. Amorphous silica is not crystalline in nature and does not cause silicosis, although it may be associated with other kinds of lung problems. However, where sufficient heat and/or pressure is applied to amorphous silica, as in calcining or mining, crystals may be formed. This is one way in which workers may unknowingly be exposed to crystalline silica.

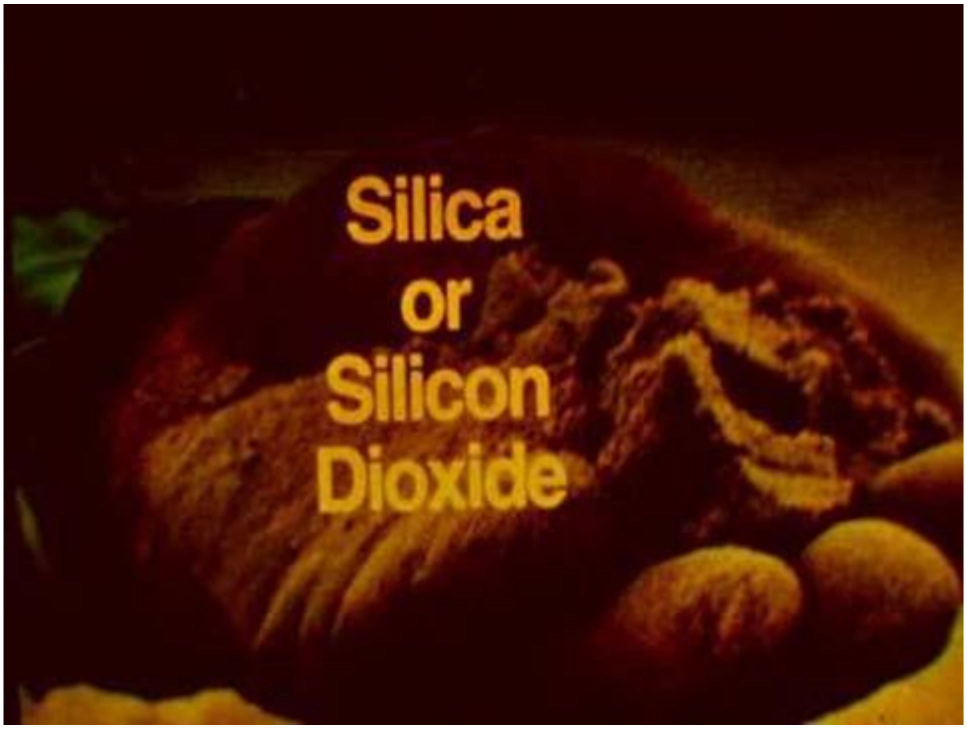

Figure 4. Chemical name for silica: silicon dioxide

Discussion: Crystalline silica is composed of silicon and oxygen, both of which are abundant in the earth's crust. Its chemical formal, or the ratio of the amounts of these two elements, is SiO_2. Crystalline silica is a naturally occurring component of many minerals, such as granite and feldspar. It is a principal component of sand and occurs in soils.

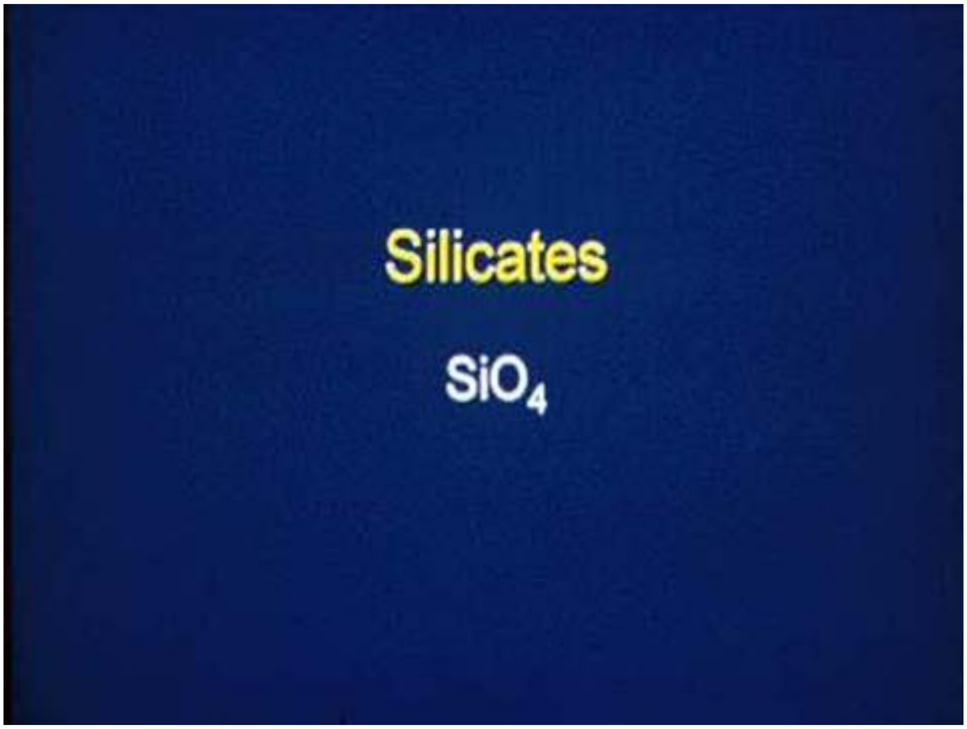

Figure 5. A different class of silicon minerals: silicates (SiO_4)

Discussion: A different class of minerals which contain the same amount of silicon are the silicates. Silicates have a basic chemical unit of one silicon atom associated with four oxygen atoms (SiO_4) in a tetrahedron-shaped group. Silicates also can contain other elements such as aluminum, magnesium, or lead. Examples of silicates are mica, soapstone, talc, portland cement, fiberglass, mineral wools, refractive ceramic fibers, and asbestos. This present document will not deal with silicates.

Figure 6. Area where silicon is packaged for shipment

Discussion: After silica has been mined, it can be milled and packaged for shipment. Silica-containing products are not always labeled as containing silica. They may sometimes be labeled incorrectly as containing amorphous silica, rather than crystalline silica.

Figure 7. Cleaners, powders and polishes containing silica

Discussion: Silica is used in industry as an abrasive cleaner and as an inert filler. It can be found in scouring powder and metal polish. It is used as an extender in paint, as wood filler, in concrete, and as a component in road-surfacing mixtures.

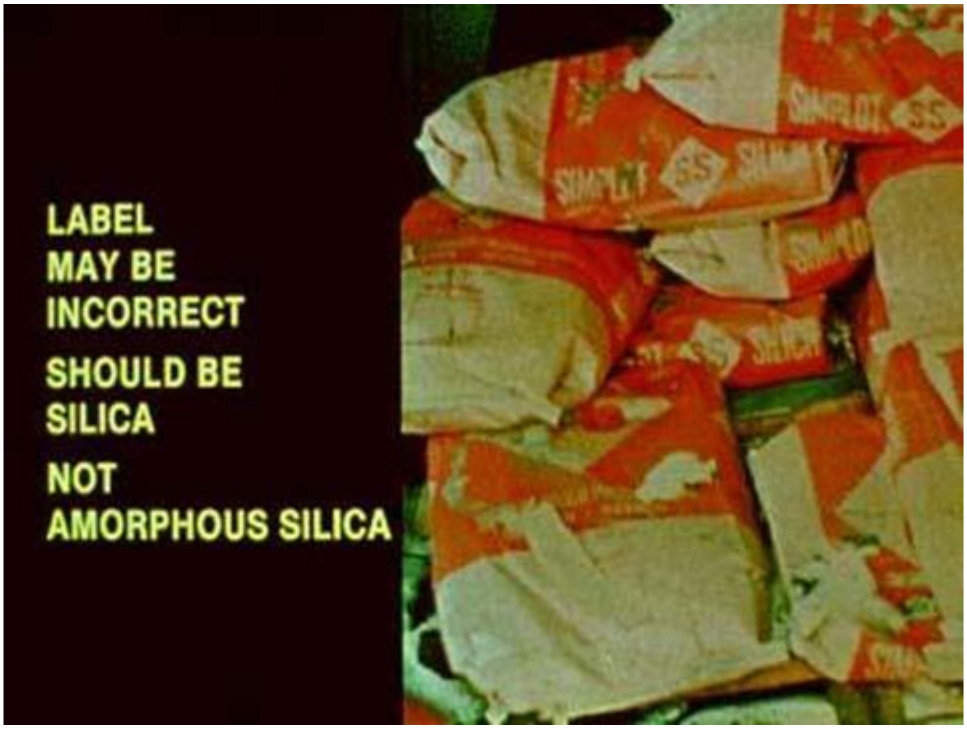

Figure 8. Bags of silica.

Discussion: Workers who must handle silica may be unaware of the fact that it is a hazardous material because it may not be labeled.

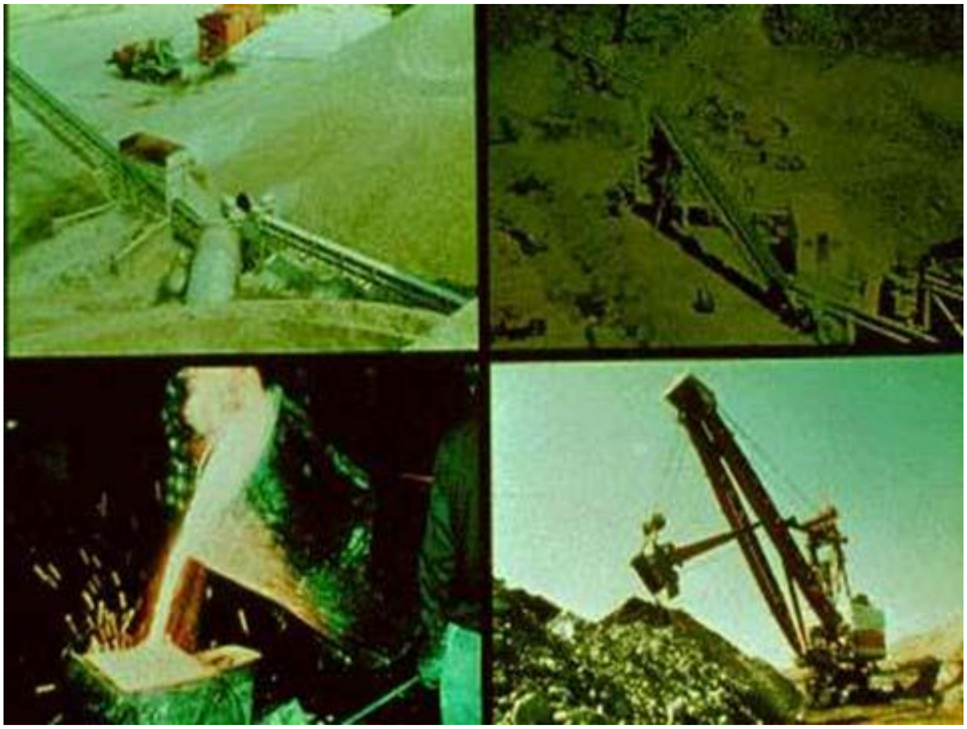

Figure 9. Photo collage of places where sand and gravel containing silica is used: foundry operations and mining of coal, metals, and clay

Discussion: Silica is found widely in sand and granite. Besides construction operations, it may be present in pottery and foundry operations and in the mining of coal, metals, clay and so forth.

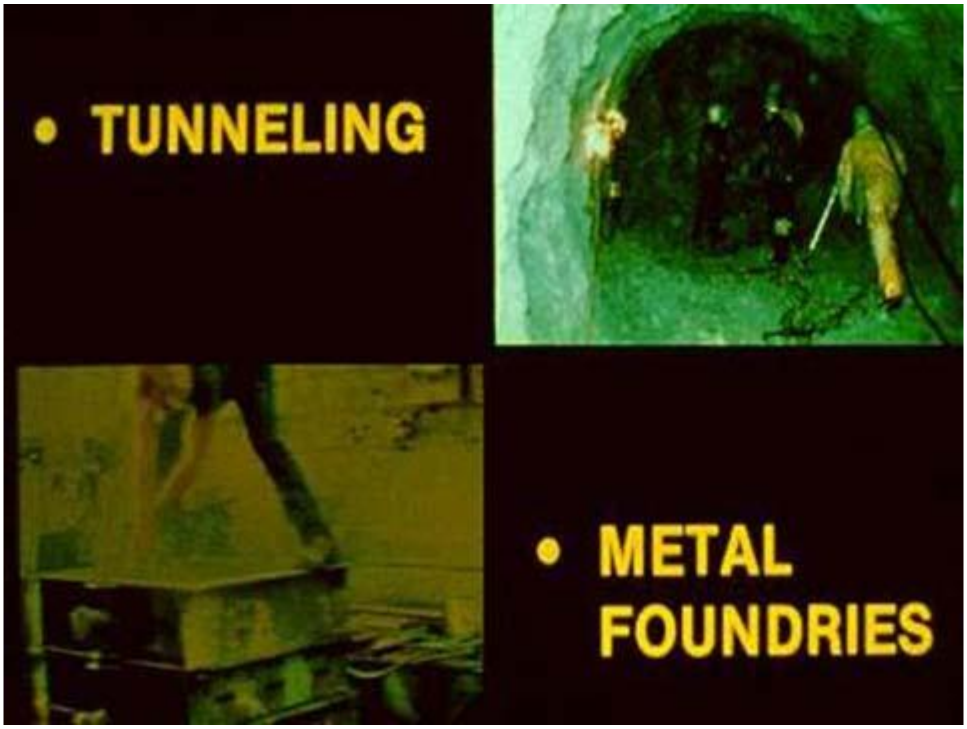

Figure 10. Photo collage of industrial operations involving silica: tunneling and metal foundry work.

Discussion: Worker exposure to silica dust can occur in tunneling and metal foundries.

Figure 11. Sandblasting and stacks of bags of clay.

Discussion: Potential silicon exposure occurs in abrasive cleaning or sandblasting, and in stone, clay and glass production.

Figure 12. Worker cutting material with saw.

Discussion: Other processes that may involve silica exposure are portland cement production and use, paint manufacturing, plastics production, and soap and detergent manufacturing.

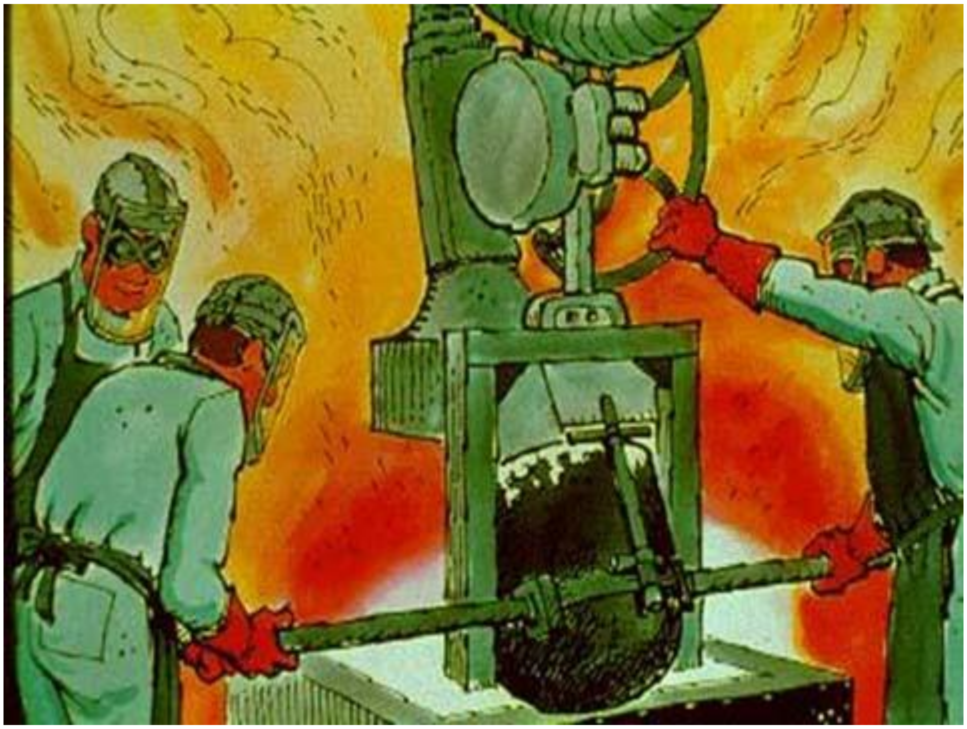

Figure 13. Workers pouring molten metal into molds.

Discussion: In the foundry environment, sand is used to make molds into which molten metal is poured. In addition, molds may be coated with flint and silica to prevent the sand from adhering to the poured forms. Materials are poured into these molds in the molten state. The heat released during cooling of the metal dries the sand, which can release large amounts of dust when the forms are separated from the molds during shake-out or knockouts. Other processes in foundries, including sand screening, sand recovery, conveying and grinding, also create exposures to silica dust.

Figure 14. Raw material in the pottery industry

Discussion: Silica in the form of flint is used in the pottery industry. Exposure to silica dust begins with the initial handling of the raw material and continues through the drying, crushing, grinding, and finishing processes.

Figure 15. Payloader moving quartz sand.

Discussion: Quartz sand is the major ingredient in the manufacture of glass. Exposure to silica dust can occur when the sand is being loaded and unloaded from boxcars and storage areas. Exposure may also occur during the actual manufacturing process, especially during heating when air currents caused by thermal drafts circulate the silica dust throughout the workplace.

Figure 16. Portland cement operations.

Discussion: The manufacture of portland cement and bricks requires that the raw material used, including silica, be reduced in size. The raw materials are crushed into small stones, then ground into a fine powder. The result is that a great amount of silica dust is created and becomes airborne. Exposure to the dust continues during further handling and processing of the material.

Figure 17. Abrasive blasting.

Discussion: Abrasive blasting, specifically sandblasting, is used to remove paint, oils, rust or dirt from objects. The particles of sand break down into dust when they hit the object being cleaned—the source of silica exposure in abrasive blasting.

Figure 18. Sources of dust

Discussion: Dust consists of solid particles generated by work processes that involve the degeneration of material in some way, such as through pulvation, grinding, blasting, drilling, crushing and so on of organic or inorganic materials, such as rock, ore, metal, coal, wood, and grain. Dust particles do not tend to flocculate, except under electrostatic forces; they do not diffuse in air but settle under the influence of gravity. The particles may be as small as 0.1 micrometer in size, well below the visible range.

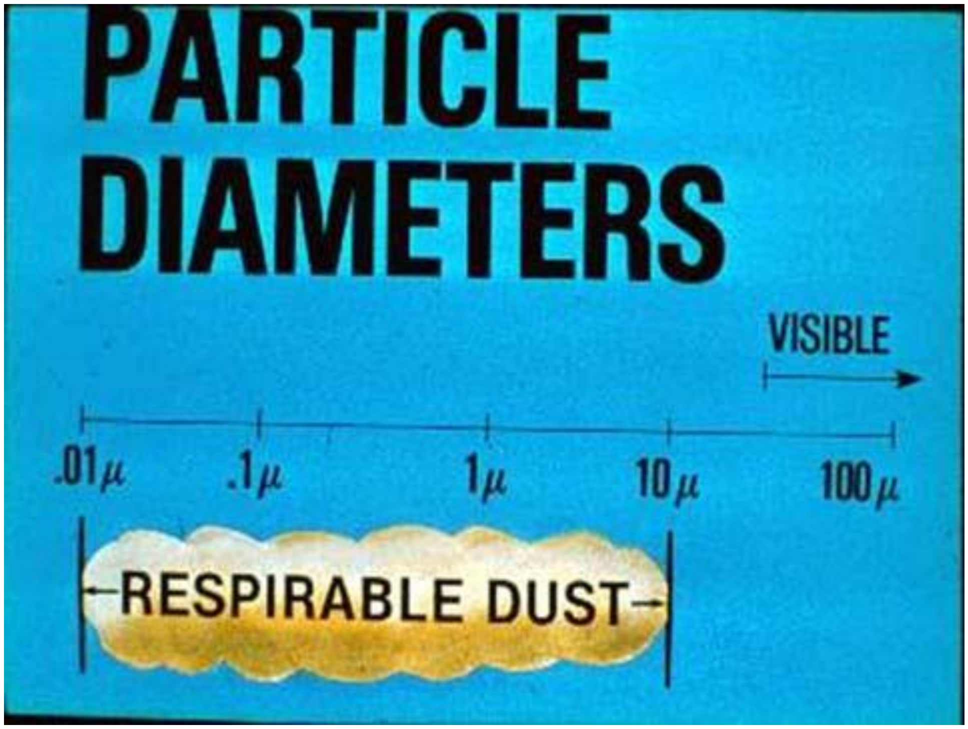

Figure 19. Range of size of dust particles

Discussion: Dust that is in the non-visible size range is also in the respirable range, which means that it is the most hazardous. Most dusts consist of particles of various sizes. Generally, dust particles smaller than 10 micrometers in size are considered respirable and can penetrate into the lung cavity.

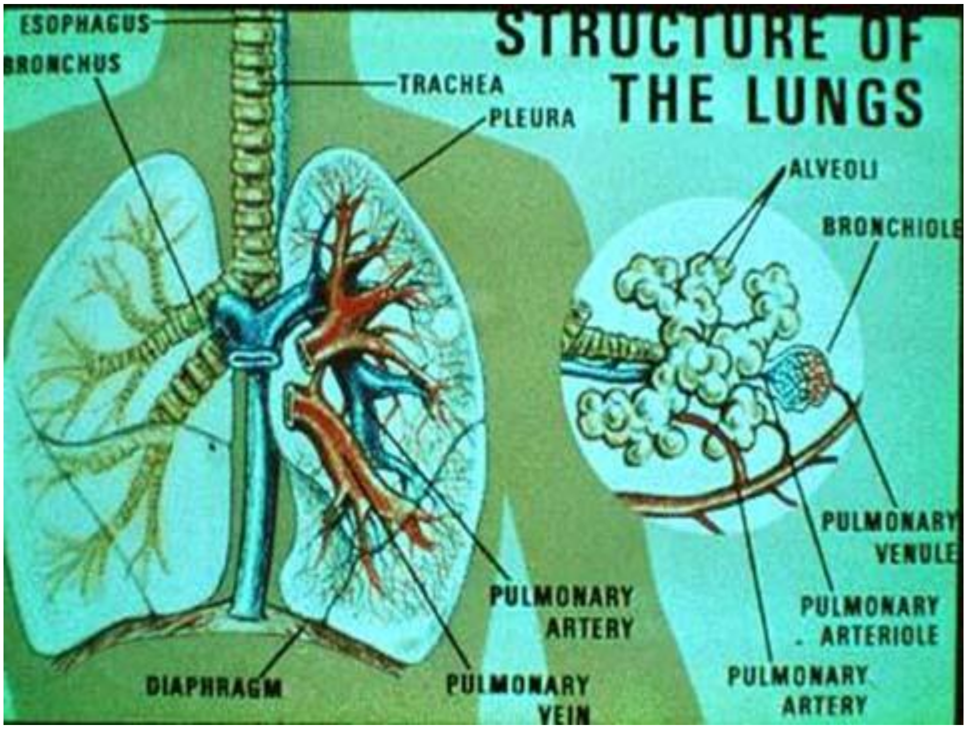

Figure 20. Air passage-ways and lungs of a human being

Discussion: Almost any type of dust may become a hazard when it becomes airborne. Once inhaled into the lungs, small particles of the dust can become trapped in the small air passages and air sacs (called the alveoli). Usually, the dust particles must be very small -- less than five micrometers -- in order to travel this far.

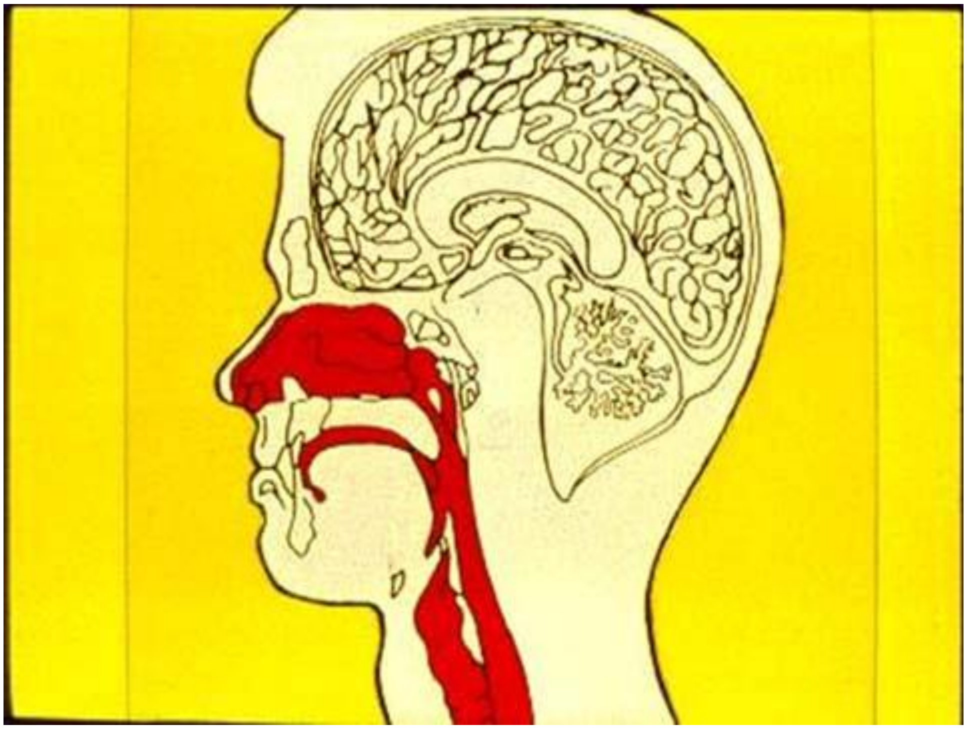

Figure 21. Air passage-way (identified in red) of a human being

Discussion: The larger particles become lodged in the nasal passages, throat, trachea, larynx, and larger passages of the lung (the bronchi). From there, these larger particles are picked up by mucous and removed from the respiratory tract as an expectorant or as material which is swallowed. However, if there is enough dust in the air, the mucous transport system can stop functioning.

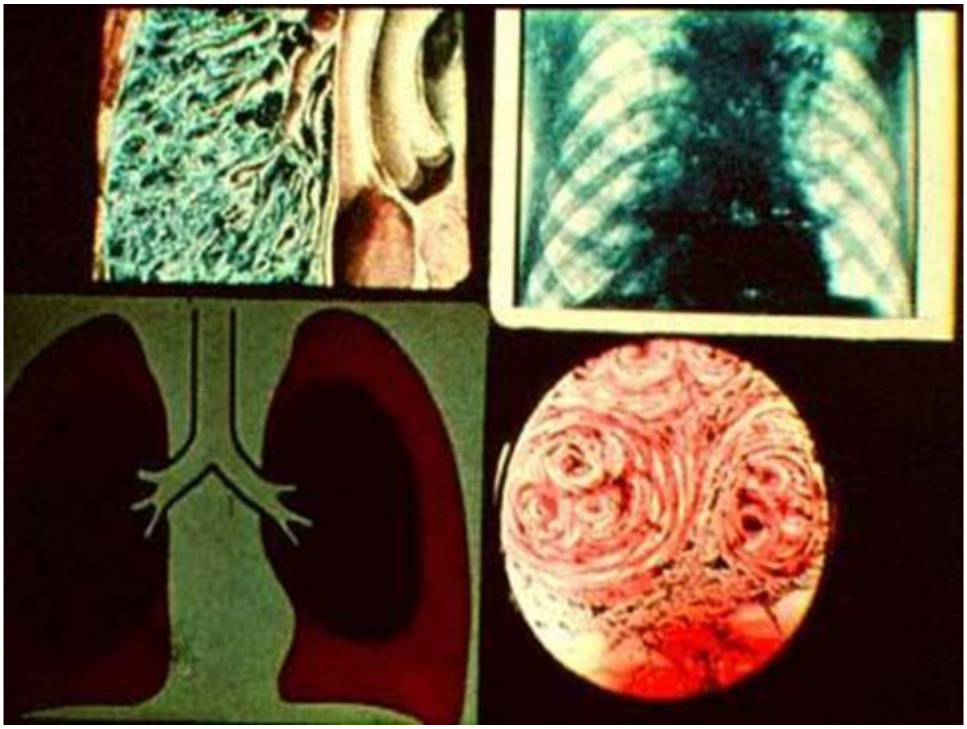

Figure 22. Photo collage of bronchioli and alveoli showing particle deposits, an x-ray of affected lungs, an illustration of affected lungs, and an enlargement of diseased lung tissue.

Discussion: The finer dust particles, those smaller than ten micrometers, are inhaled along with a breath of air and are carried into the lungs. Some of the particles are deposited into the lungs. Some of the particles are deposited in the bronchioli and alveoli; the rest are carried back out of the lungs during exhalation.

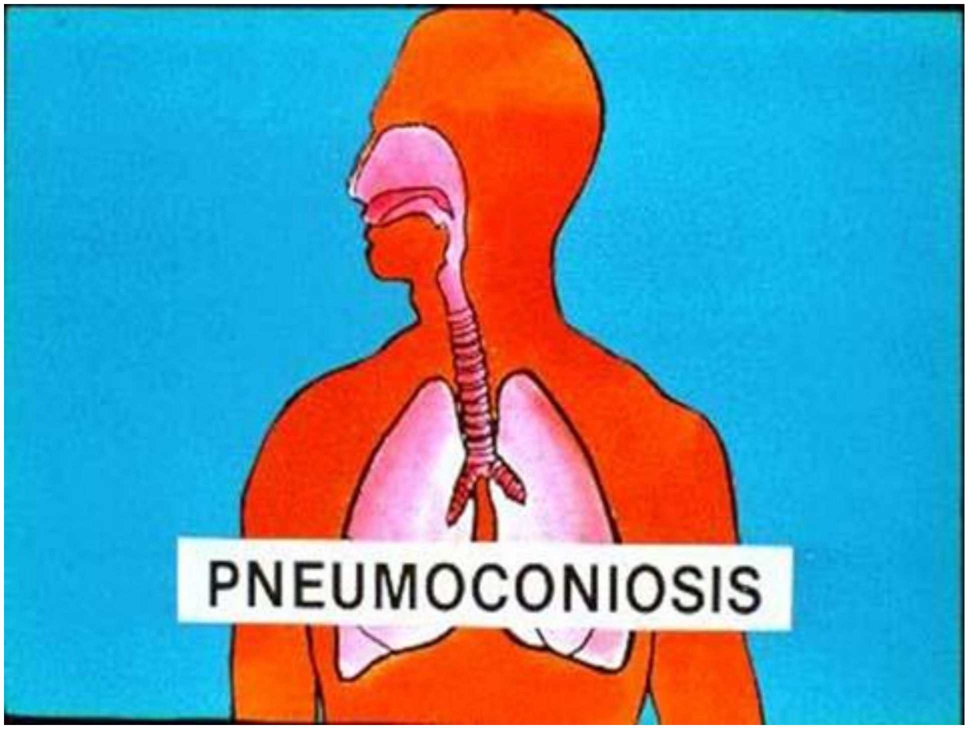

Figure 23. Pneumoconiosis involvement of air passage-way of a human being

Discussion: In extremely dusty conditions, or even moderately dusty conditions, a disease called pneumoconiosis may occur. Pneumoconiosis is a fibrosis (hardening, scarring, or stiffening) of the lungs due to irritation caused by the inhalation of dust. In very severe cases, the dust may actually cause physical blockage of the air passages resulting in difficult or labored breathing (dyspnea) and ultimately suffocation.

Figure 24. Sandblasting.

Discussion: Exposure to other toxic substances may also occur during sandblasting. For example, sandblasting lead-containing paints will generate large quantities of lead dust. Other hazardous materials that may be released include arsenic, chromium, magnesium, manganese, nickel and iron oxide.

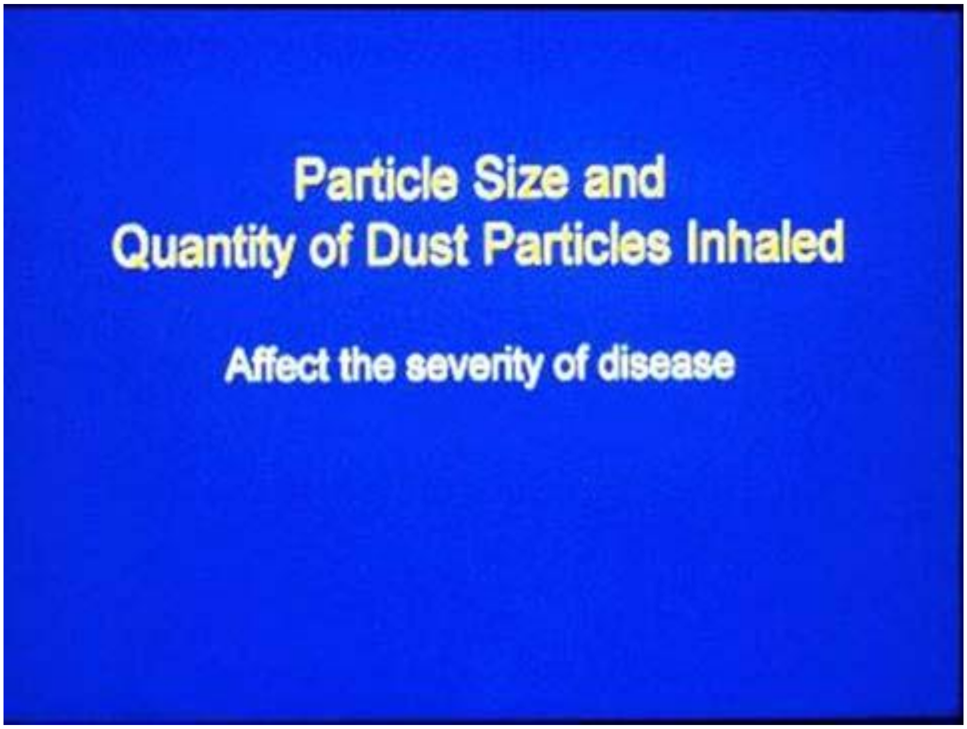

Figure 25. Effect of particle size and quantity

Discussion: The size and quantity of dust particles inhaled also have an effect on the severity of the disease.

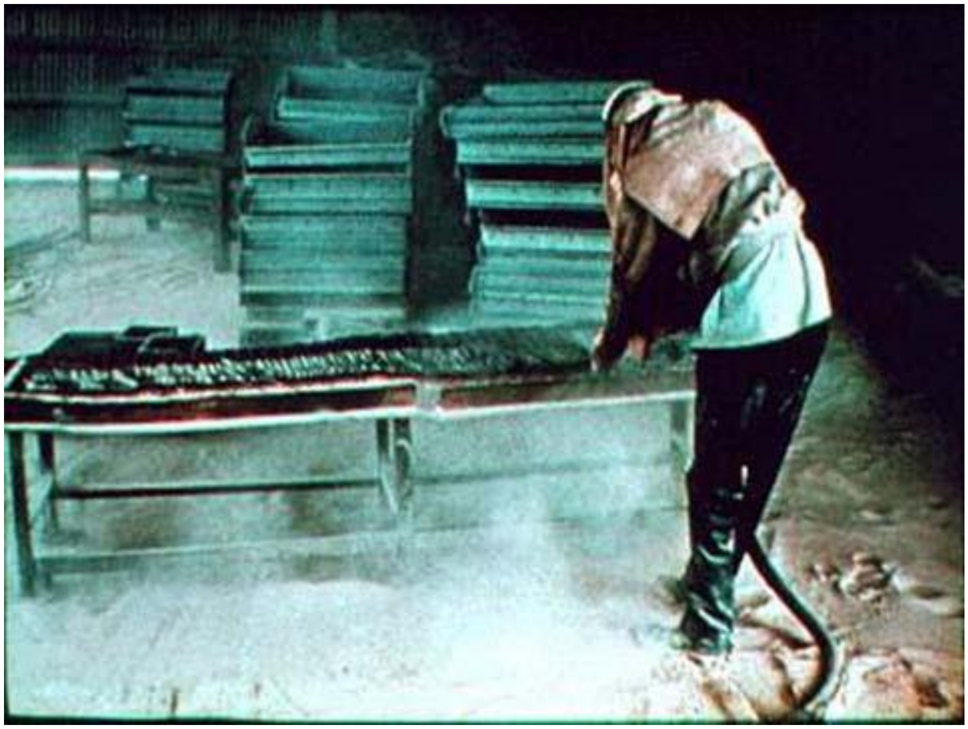

Figure 26. Work involving exposures to high concentrations of silica

Discussion: Acute exposures involve a single exposure or multiple exposures within a short period of time, 24 hours of less. Acute exposures to very high concentrations of silica may occur in some occupations such as sandblasting or in foundries and may result in rapidly developing cases of silicosis with the above symptoms appearing early in a worker's career.

Figure 27. Worker shoveling dusty material while wearing a respirator.

Speaker Note: Chronic exposures are experienced by workers who work in dusty conditions on an almost daily basis for extended periods of time. Symptoms from this type of exposure may develop slowly during one's career, often taking 15 to 20 or more years to appear.

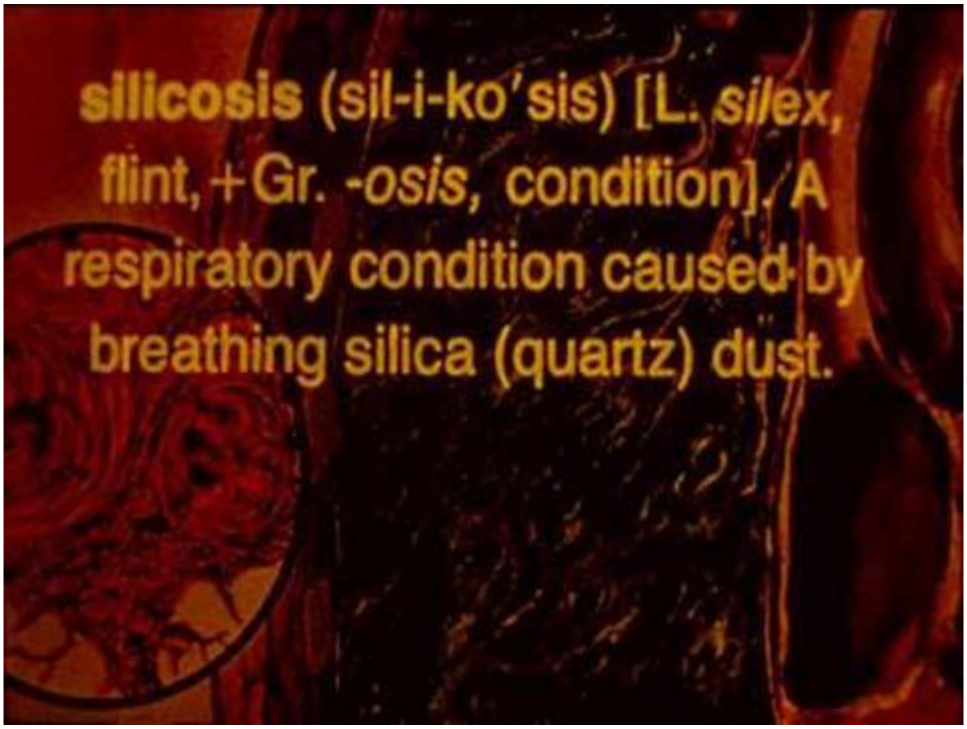

Figure 28. Definition of silicosis

Discussion: Long-term exposure to free silica dust may result in silicosis, a form of disabling, progressive, and sometimes fatal pulmonary fibrosis. It is believed that silicosis has claimed more lives than any of the other kinds of pneumoconiosis. It has been known by such common names as dust consumption, grinder's rot, stonemasons' disease, miners' asthma and potters' rot.

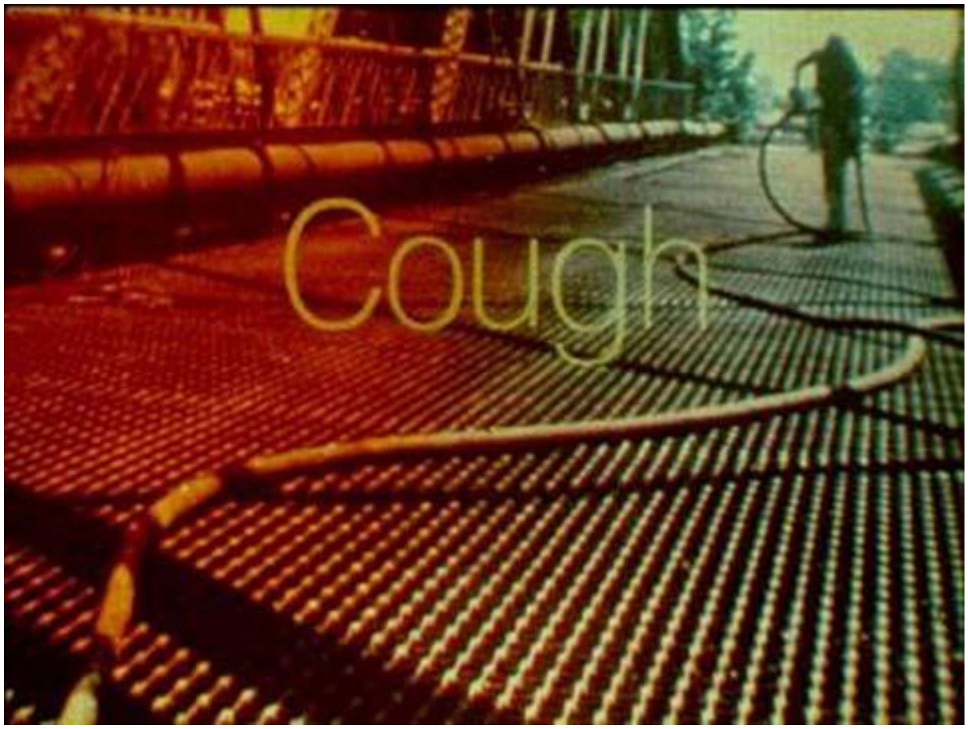

Figure 29. Coughing as a symptom

Discussion: The symptoms of silicosis include coughing, dyspnea, wheezing and chest pain. The elasticity of the lung, which is its ability to expand and contract, can decrease as the disease progresses. Persons with silicosis appear to be more susceptible to contracting tuberculosis. Some studies have also indicated an association between silicosis and lung cancer.

Figure 30. Factors affecting the severity of the disease

Discussion: The severity of the disease is dependent upon the dust concentration, the amount of (percent) free silica in a given dust exposure, the duration of the exposure, and possibly the size of the particles.

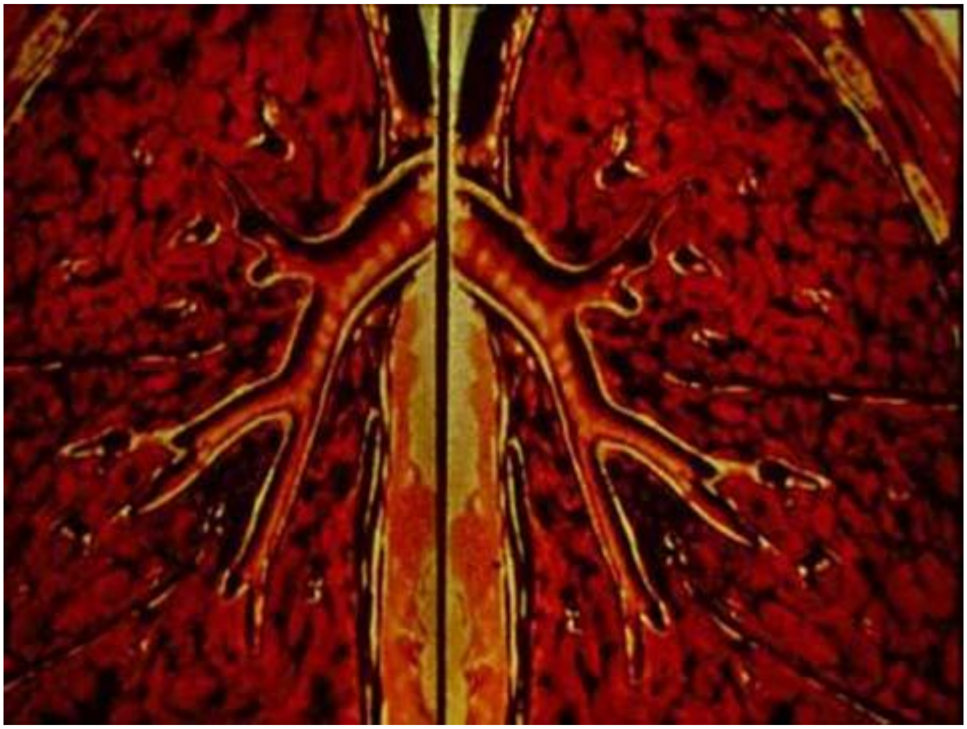

Figure 31. Lung tissue affected by inhaled silica dust.

Discussion: Inhaled silica dust is deposited in the bronchioles and alveoli. It then causes the lung tissue to form nodules. The earliest symptom of silicosis is shortness of breath.

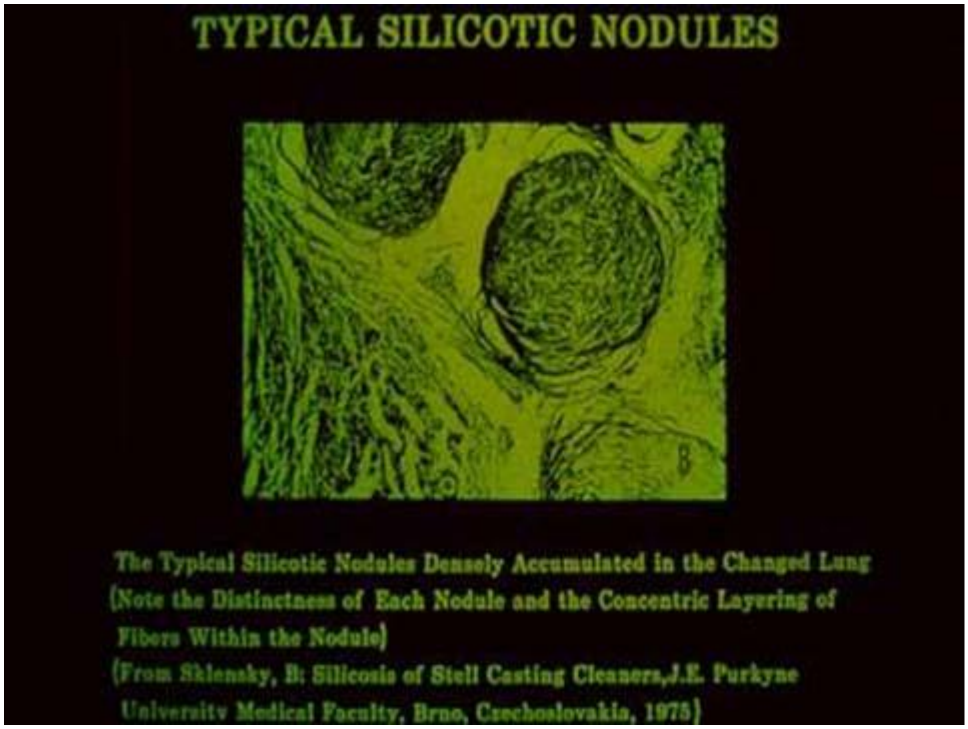

Figure 32. Typical silicotic nodules densely accumulated in the changed lung (Note the distinctness of each nodule and the concentric layering of fibers within the nodule). From Sklensky, B: Silicosis of Stell Casting Cleaners, J. E. Purkyne University Medical Facility, Brno, Czechoslovakia, 1975.

Discussion: As the disease progresses, the silicotic nodules coalesce and form a continuous mass of fibrotic tissue, called progressive massive fibrosis.

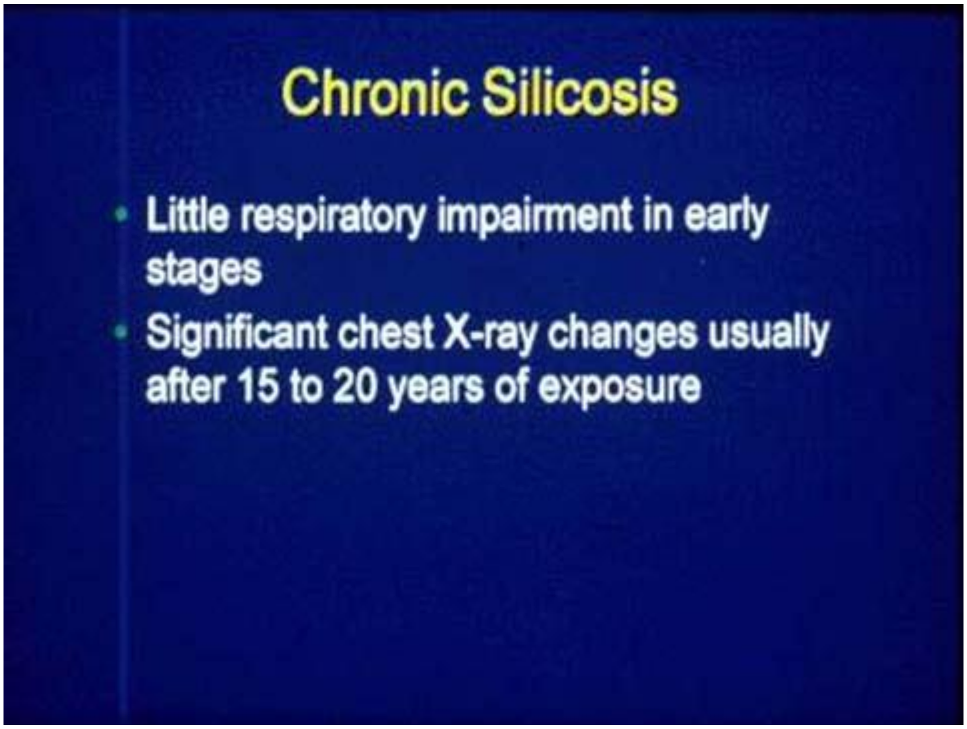

Figure 33. Characteristics of chronic silicosis

Discussion: Three forms of the disease have been described. Chronic silicosis usually takes 20 to 45 years to develop. Dust concentrations of 10% silica or even less are often capable of producing silicosis. Usually the early stages of chronic, or simple, silicosis produce little or no respiratory impairment. Although early chest X-rays changes may sometimes be noted, significant changes may not be seen until after 15 to 20 years of exposure.

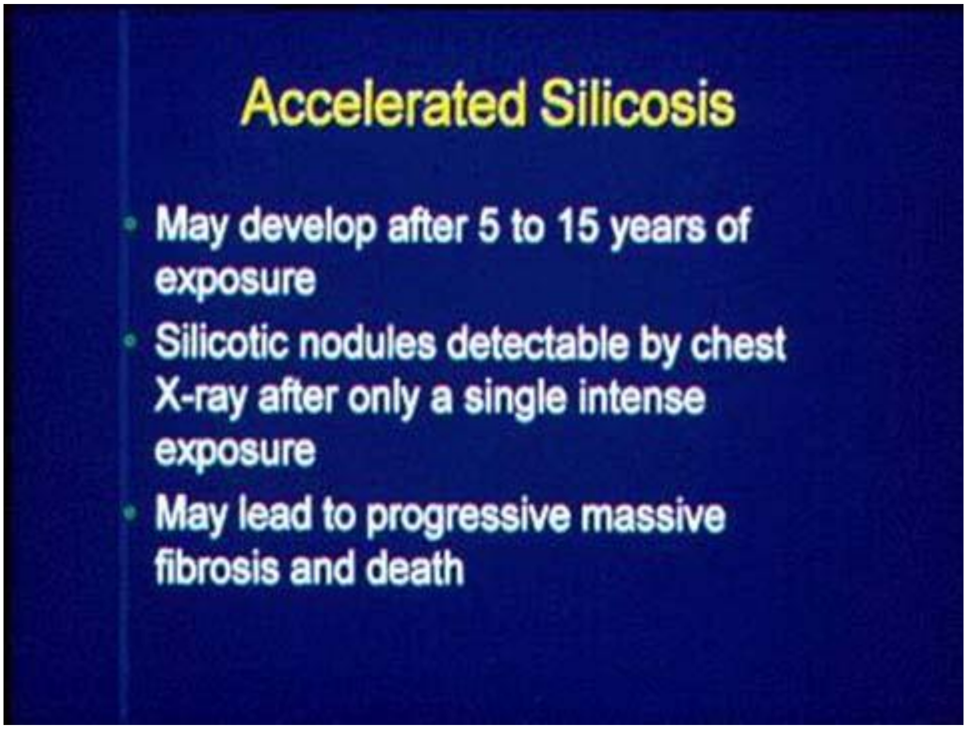

Figure 34. Characteristics of accelerated silicosis

Discussion: Accelerated and acute silicosis result from shorter exposures at higher concentration. The accelerated form, which requires only 5 to 15 years to develop differs from the simple form in that silicotic nodules are detectable by chest X-rays after only a single intense exposure. Accelerated silicosis may lead to progressive massive fibrosis and death. Extremely small sized particles may contribute to the development of accelerated silicosis.

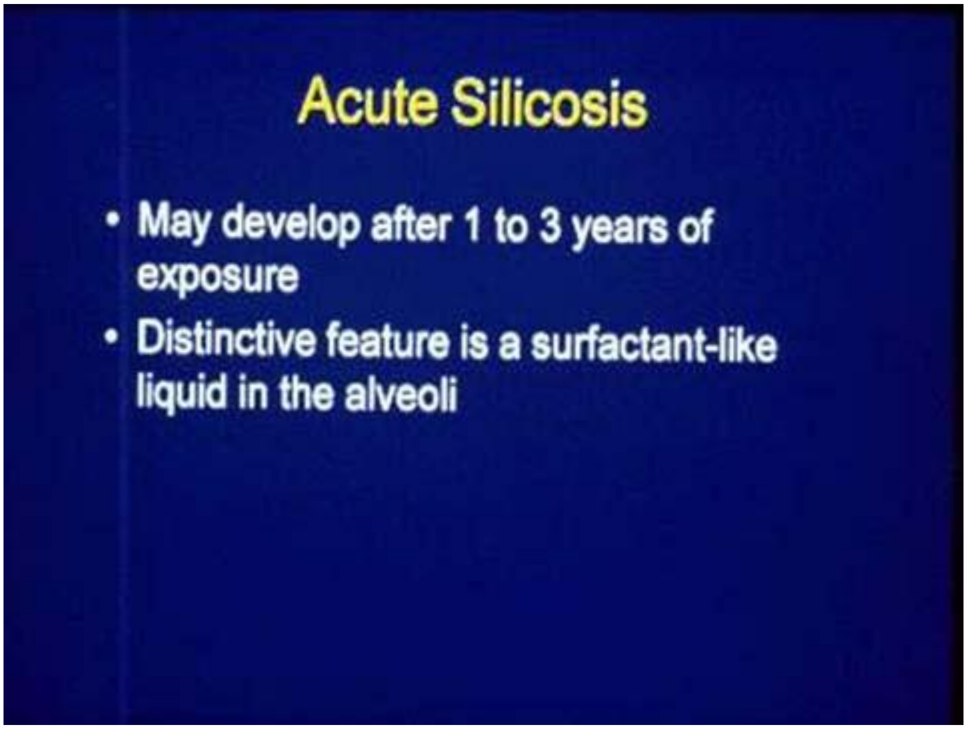

Figure 35. Characteristics of acute silicosis

Discussion: Acute silicosis may develop after only 1 to 3 years of exposure, progressing even more quickly than accelerated silicosis. A distinctive feature of acute silicosis is the presence of a surfactant-like liquid in the alveoli. However, chest X-rays reveal few silicotic nodules. Acute silicosis is rapidly fatal.

Figure 36. Barrels of fluorine, chlorine trifluoride, manganese trioxide, and oxygen difluoride stored next to a pile of silica

Discussion: Silica should not be allowed to come in contact with powerful oxidizing agents such as fluorine, chlorine trifluoride, manganese trioxide, and oxygen difluoride.

Figure 37. Silica pile on fire next to chemical barrels.

Discussion: Contact with these agents may result in a fire. By itself, silica is not combustible.

Figure 38. Permissible Exposure Limit for crystalline quartz

Discussion: The Permissible Exposure Limit for respirable dusts containing the quartz form of silica is 10 mg/M^3 divided by (%SiO_2 +2), where %SiO_2 is entered as a percentage, rather than a decimal, for example, 2 rather than 0.02 when %SiO_2 = 2%.

Figure 39. Using checklist to inspect work area.

Discussion: A silica control program should begin with a general inspection of the work area and review of material safety data sheets to determine the most likely sources of silica dust. Worker's exposure levels should be monitored using respirable personal dust monitoring.

Figure 40. Abrasive blasting cabinet

Discussion: Work processes that produce silica dust should be isolated whenever possible, for example, by performing sandblasting within an enclosed cabinet rather than in the open air. Isolated areas should be provided with engineering controls to reduce the hazard.

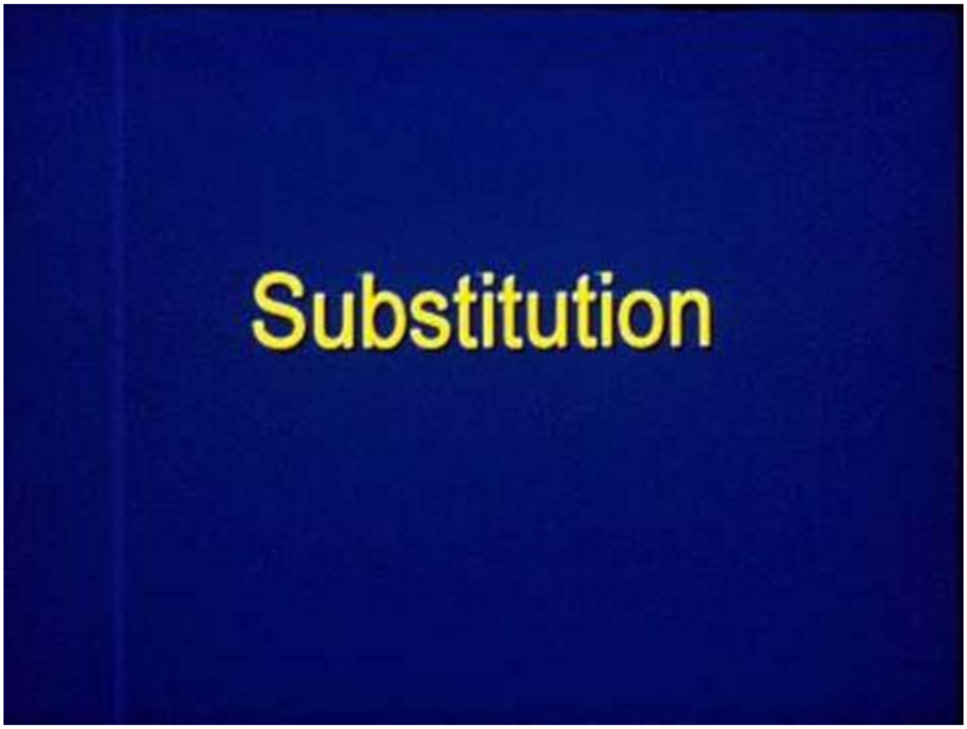

Figure 41. Avoiding exposure through substitution

Discussion: Sometime other materials can be substituted for silica. In abrasive blasting, for example, steel shot or "Black Beauty" may be used as an abrasive instead of sand.

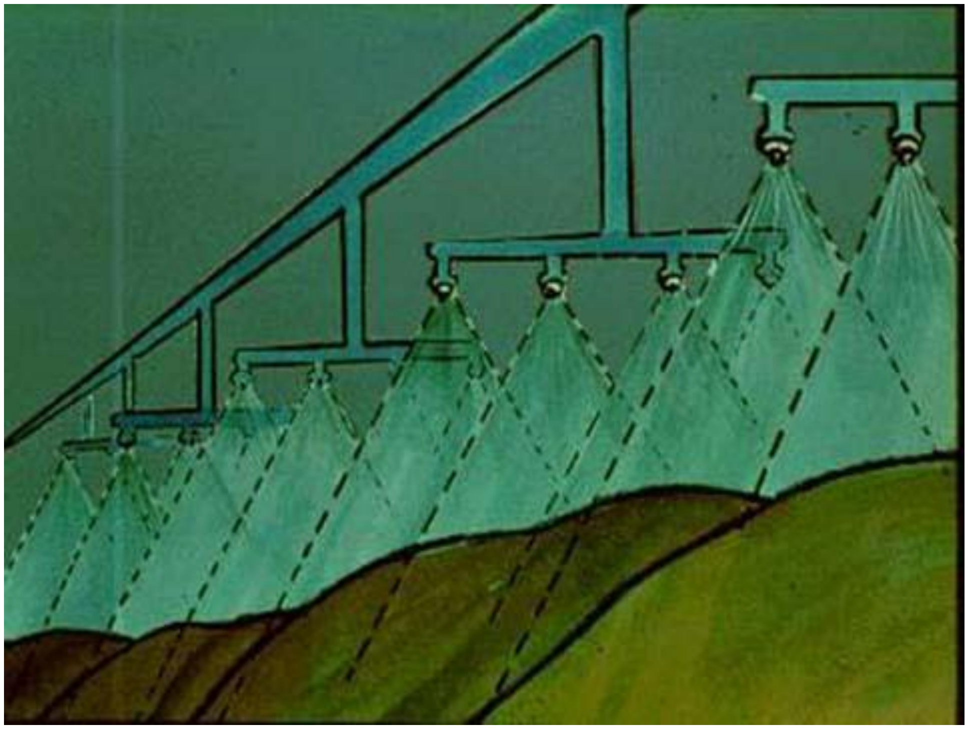

Figure 42. Dust piles being sprayed.

Discussion: Dust can sometimes be suppressed with the application of moisture to the dust sources or by installing sprays to remove airborne dust at the source.

Figure 43. Workers performing operations with local exhaust systems installed.

Discussion: Existing ventilation systems that rely on dilution of the silica dust to a safe concentration, are often not adequate, as they sometimes recirculate dust into the building. Some sources may need properly designed local exhaust systems to remove the dust at the emission source. Where employees are close to the emission source, local exhaust is usually superior to dilution.

The most effective control of silica in the air is by the use of local enclosed exhaust ventilation. When a process of operation is enclosed, and the system is properly designed, a slight vacuum, creating a negative pressure, ensures that any leakage will result in the flow of outside air into the enclosure. A well-designed local exhaust system that encloses the process on all sides is best.

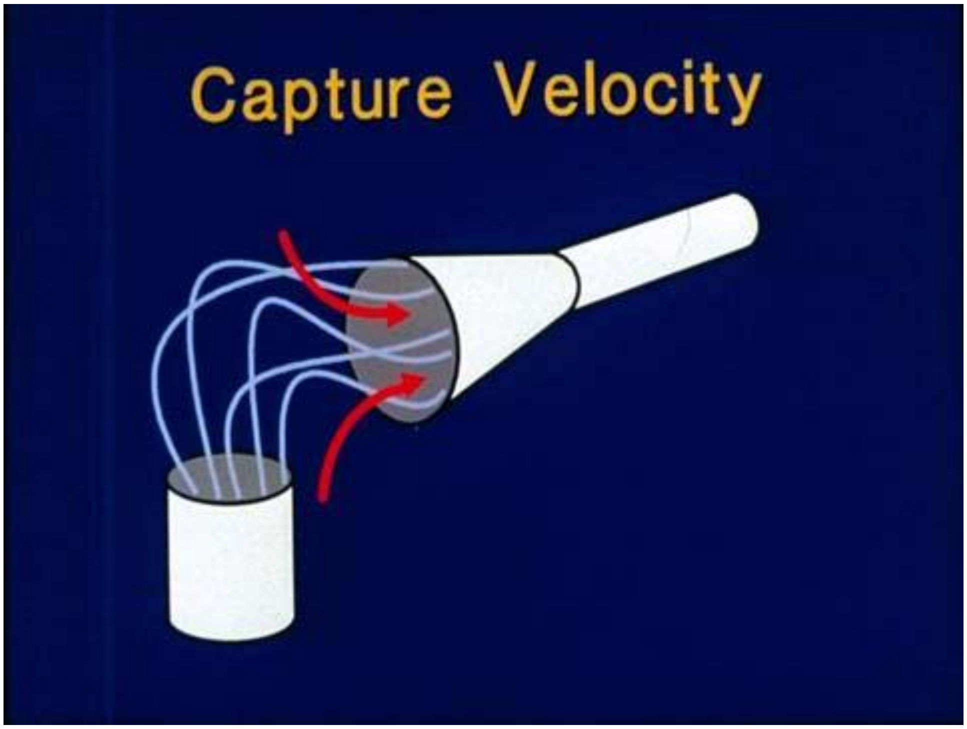

Figure 44. Capture velocity in motion.

Discussion: Sufficient capture velocity will keep the contaminant from entering the work atmosphere. Capture velocity is that amount of air movement required to capture the contaminant from the airspace in front of the exhaust hood and cause it to flow into the hood.

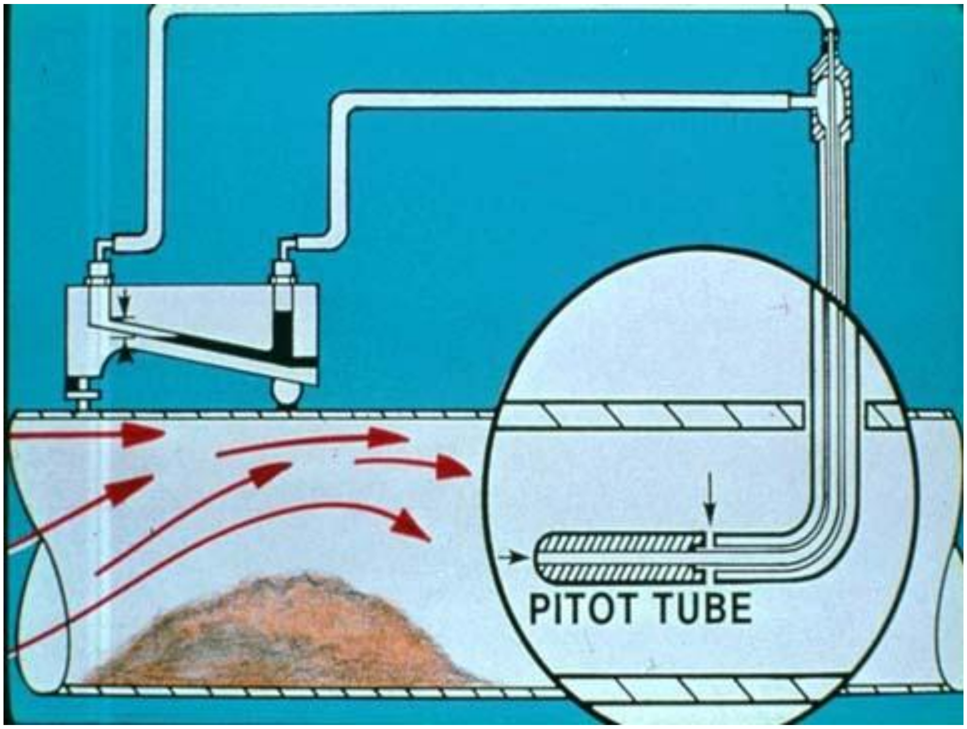

Figure 45. Ventilation system where material has collected within the system and a pitot tube has been added for monitoring purposes.

Discussion: The National Institute for Occupational Safety and Health (NIOSH) recommends that ventilation equipment be checked once every three months.

Figure 46. Maintenance of ventilation equipment

Discussion: In addition to regularly scheduled inspections ventilation equipment should be checked after any change in production, process or control that might result in significant increases in airborne silica.

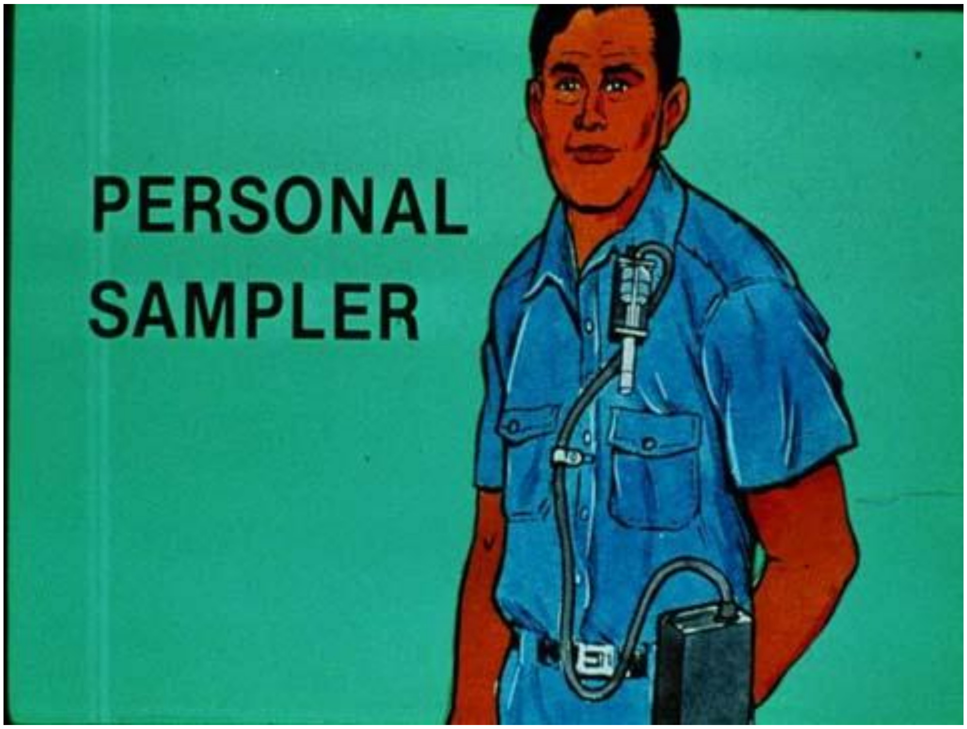

Figure 47. Worker wearing personal sampler.

Discussion: Surveys should be made by industrial hygiene and engineering personnel to determine worker exposure and the effectiveness of engineering controls.

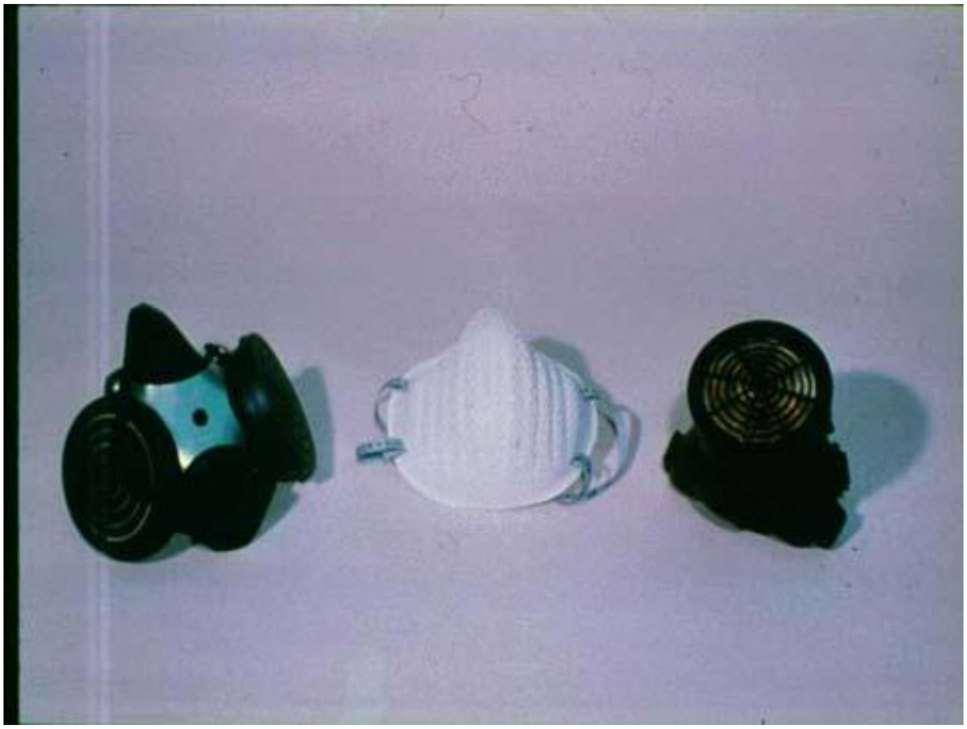

Figure 48. Masks and respirators.

Discussion: When effective engineering controls are not feasible, or while they are being installed, approved respirators shall be used pursuant to the requirements of OSHA's respiratory protection standard.

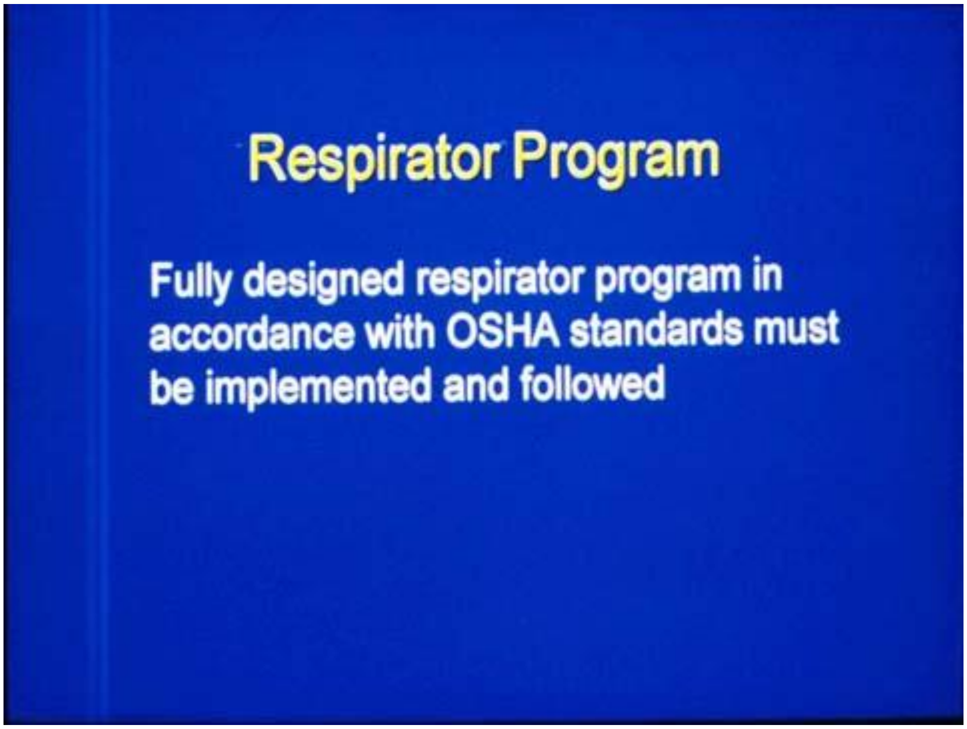

Figure 49. Requirement for respirator program

Discussion: However, it must always be remembered that such protective equipment has a major limitation: it can create a false sense of security, because it does nothing to control the hazard itself. Therefore, should a protective device fail or be used improperly, the wearer is exposed immediately to the hazard. That is why a fully designed respirator program in accordance with OSHA's respiratory protection standard must be implemented and followed.

Figure 50. Worker in dusty environment with personal protective equipment including respirator.

Discussion: One further situation requiring the use of personal protective equipment is in the case of an emergency, when the hazard is suddenly very great. This type of situation should be only temporary.

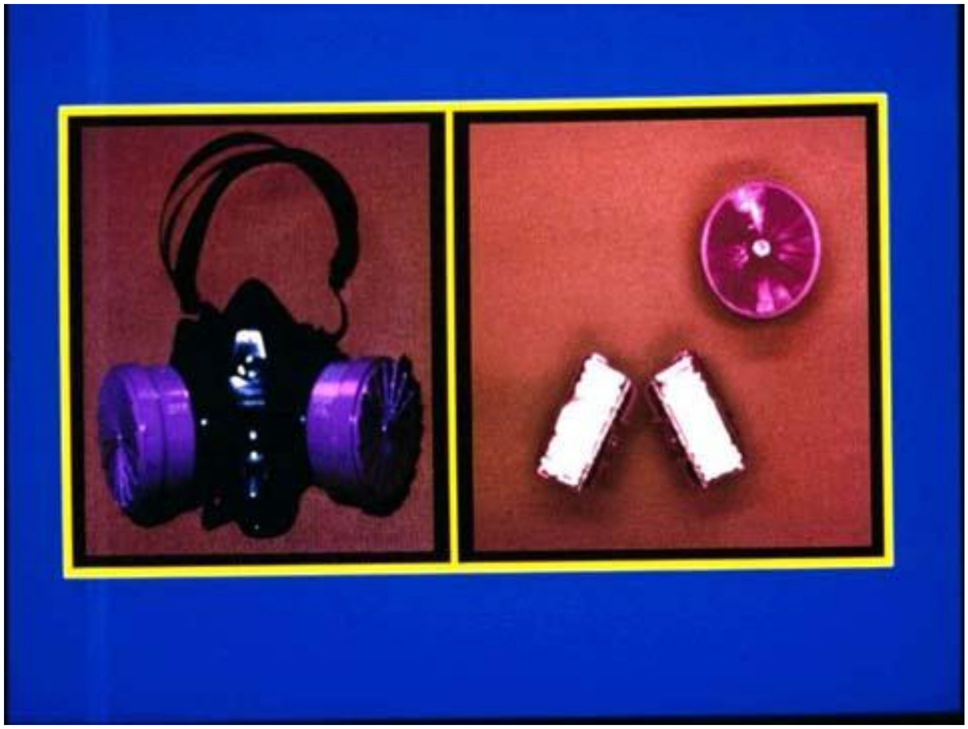

Figure 51. Respirators and filters

Discussion: When concentrations of airborne silica are equal to or less than ten times the Permissible Exposure Limit, an air-purifying particulate filter respirator may be used. All tight-fitting respirators must be fit-tested either qualitatively or quantitatively, in accordance with the respiratory protection standard.

Figure 52. Type C supplied-air respirator.

Discussion: At higher concentrations, a type C supplied-air respirator of the pressure demand or continuous flow type, with a full facepiece, hood, or helmet will be needed.

Figure 53. Airway with silica dust exposure.

Discussion: Unfortunately, there is no first aid for the inhalation of silica dust. Prevention of silicosis depends entirely on the prevention of inhalation.

Figure 54. Non-responsive worker being attended to.

Discussion: If an acute exposure to silica dust occurs through inhalation of large amounts of the dust, the workers should be moved to fresh air at once.

Figure 55. Eye wash station.

Discussion: If silica dust should contact the eyes, do not rub the eyes; instead flush immediately with large amounts of water.

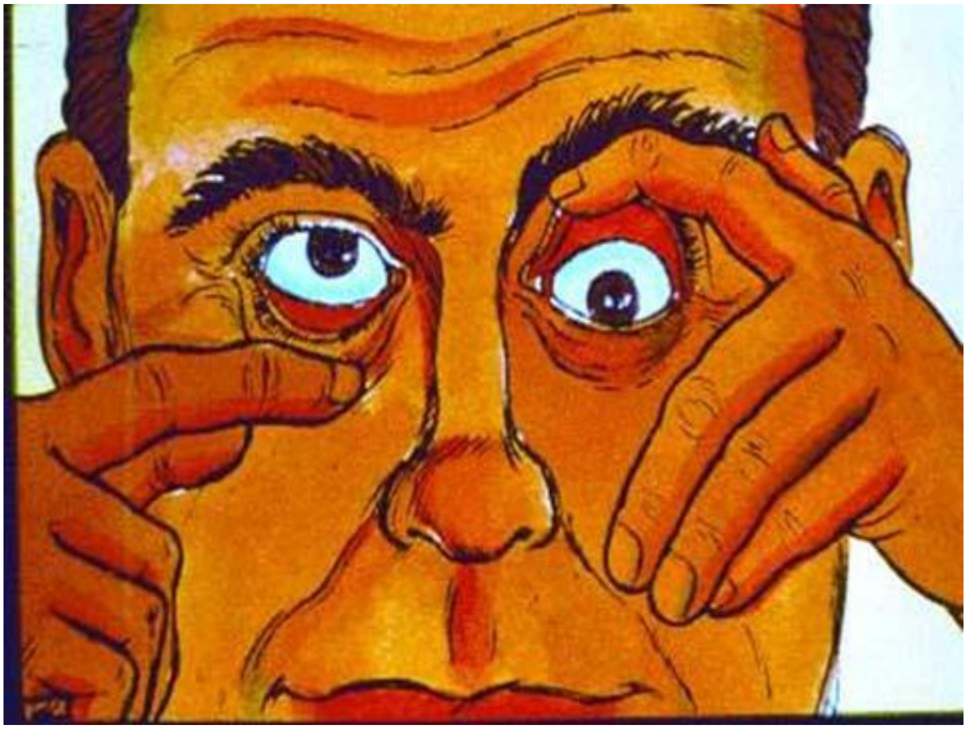

Figure 56. How to move eyelids when rinsing.

Discussion: The upper and lower lids should be lifted occasionally to make certain that the water is rinsing the eye completely and that no silica is collecting in the corners of the eye. If an irritation develops after the eyes are rinsed, a physician should be contacted immediately.

Figure 57. Office work environment

Discussion: All employees, including office workers, who are exposed to silica dust in concentrations above the PEL, should be included in a medical surveillance program.

Figure 58. Reviewing medical x-ray with patient.

Discussion: A medical examination should be made and should include a medical history and physical examination, chest X-ray, and pulmonary function tests for each employee exposed to silica in excess of the Permissible Exposure Limit. The frequency of this surveillance should be upon hire and subsequently a function of the years of exposure.

Figure 59. Showering after silica exposure.

Discussion: Workers should be aware of correct personal hygiene practices as a way of reducing their risk of exposure to silica dust.

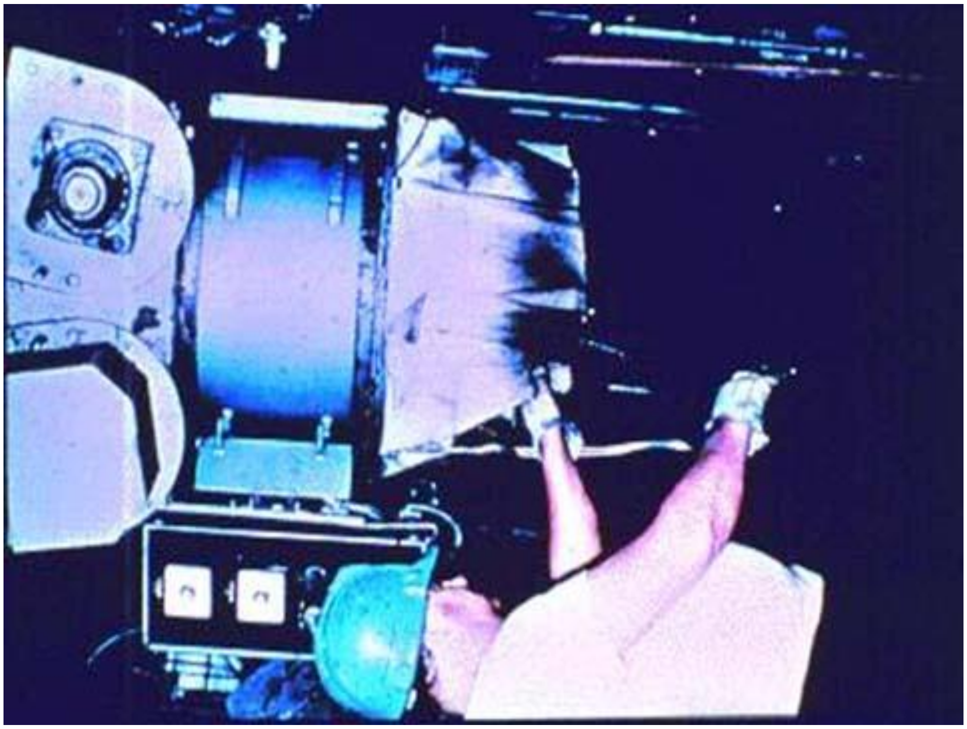

Figure 60. Using silica in hopper

Discussion: Silica kept in large quantities should be stored in tight bins or hoppers. Any silica that becomes caked should be freed by vibrating mechanisms attached to the outside of the storage vessel.

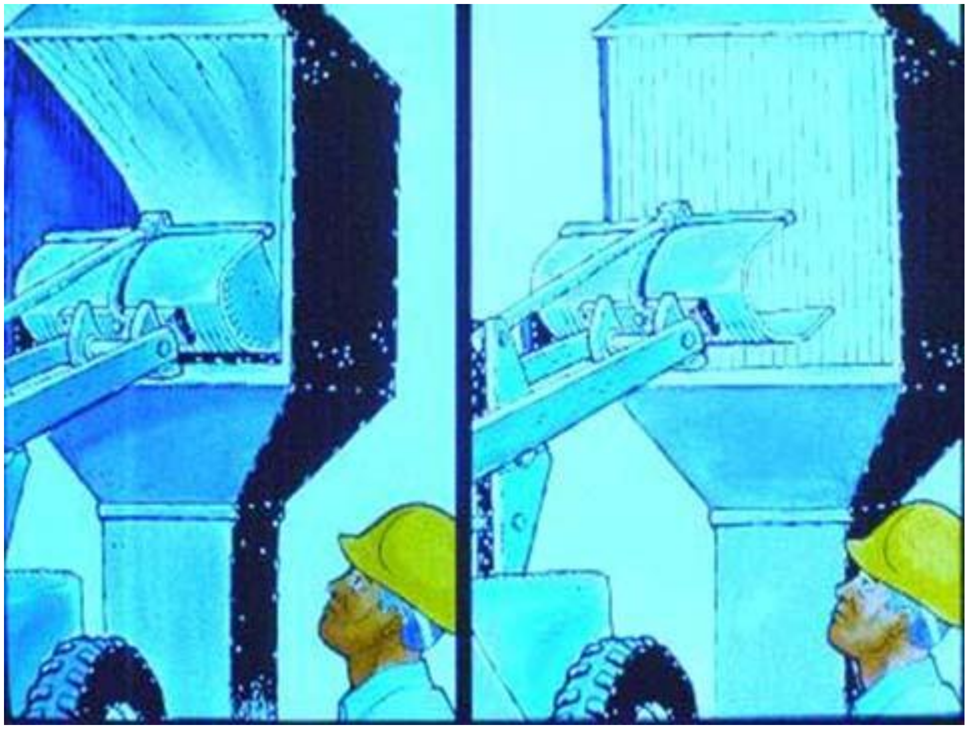

Figure 61. Workers reviewing material being dumped with and without exhaust ventilation

Discussion: If bins cannot be kept dust-tight, suction ventilation should be proved to carry off the dust

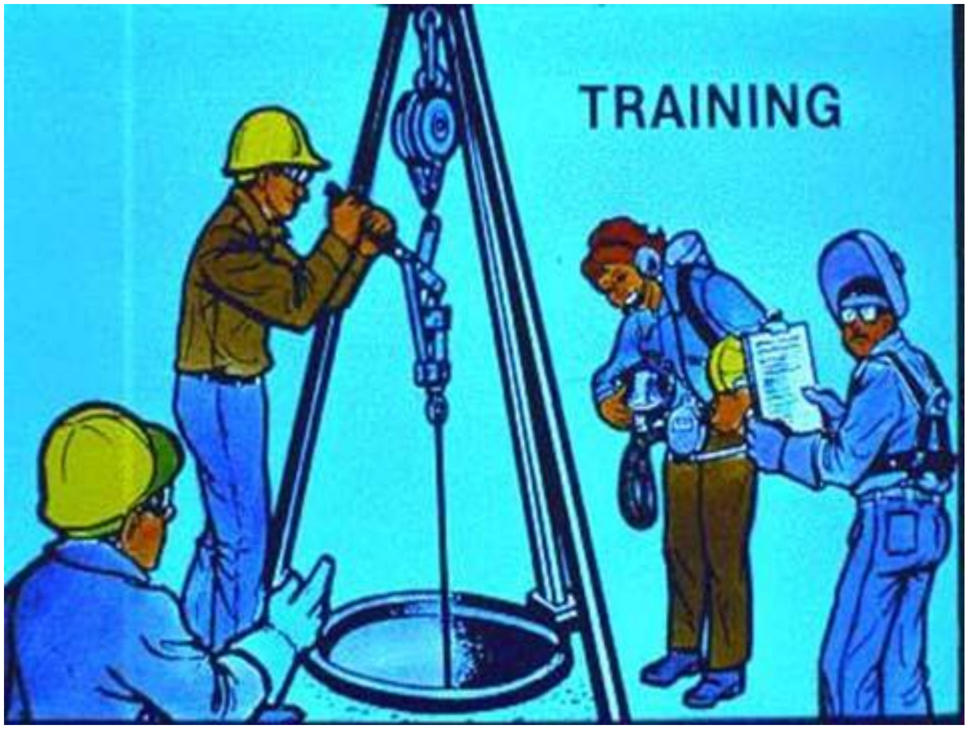

Figure 62. Training for working in a confined space where monitoring and evaluation is being conducted

Discussion: Workers entering hoppers or bins must be properly trained in confined space entry procedures and the proper protective equipment.

Figure 63. Training new employee.

Discussion: One method of reducing dust levels in the work areas is by effective worker training. Workers should be made aware of the dangers of breathing silica dust. Often, work habits can be modified to reduce dust levels.

Figure 64. Using vacuum system to collect dust.

Discussion: Good housekeeping should be stressed as a way to reduce airborne dust levels. When possible, use vacuum systems for dust removal. Never allow the use of compressed air for cleaning work areas or clothing. This simply blows the dust into the air where it can be inhaled.

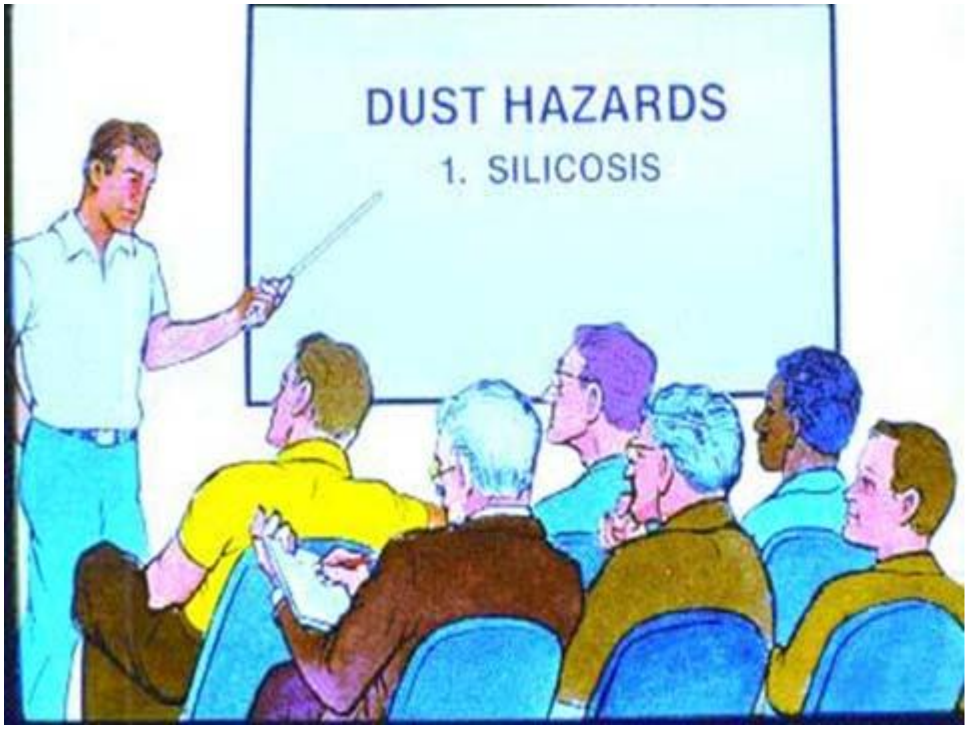

Figure 65. Teaching class about dust hazards and silicosis.

Discussion: Educate the workers as to how dusts are produced and introduced into the air. Tell them about the symptoms of dust-related illnesses and have them notify you should they develop any of these symptoms.

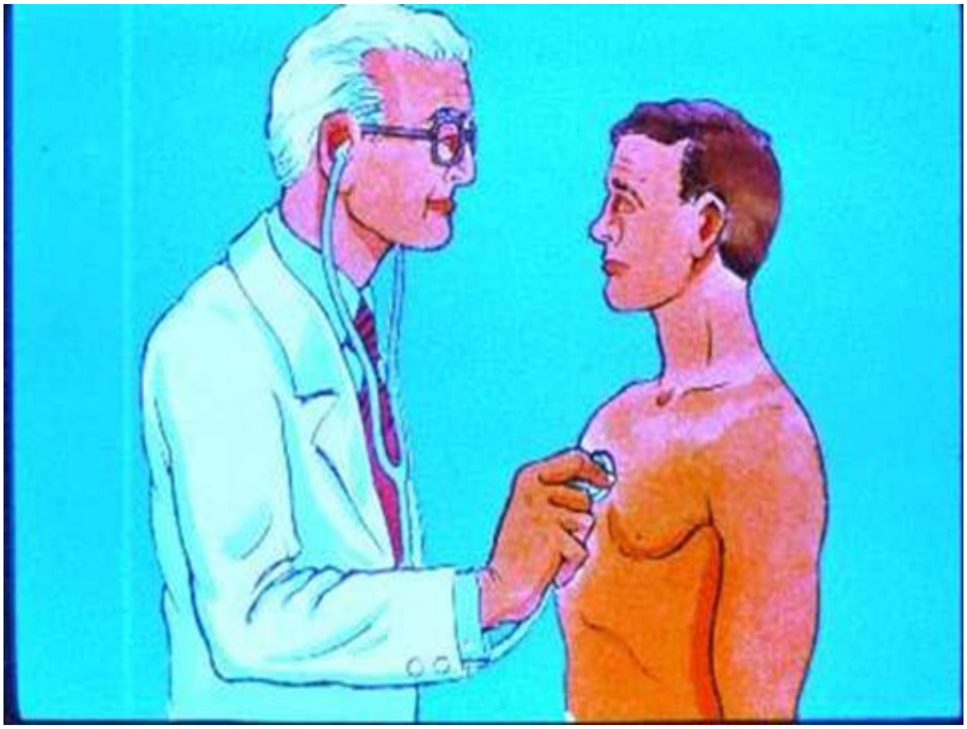

Figure 66. Examining worker.

Discussion: If workers show signs of prolonged exposure to silica or other dust, have them visit a doctor.

Figure 67. Reviewing medical surveillance program.

Discussion: Discuss the importance of the medical surveillance program. Finding the symptoms early in the development of silicosis may lead to control of the disease.

Figure 68. Smoking

Discussion: Warn your workers that smoking greatly increases the risk of their developing respiratory problems, especially with the added effect of silica exposures.

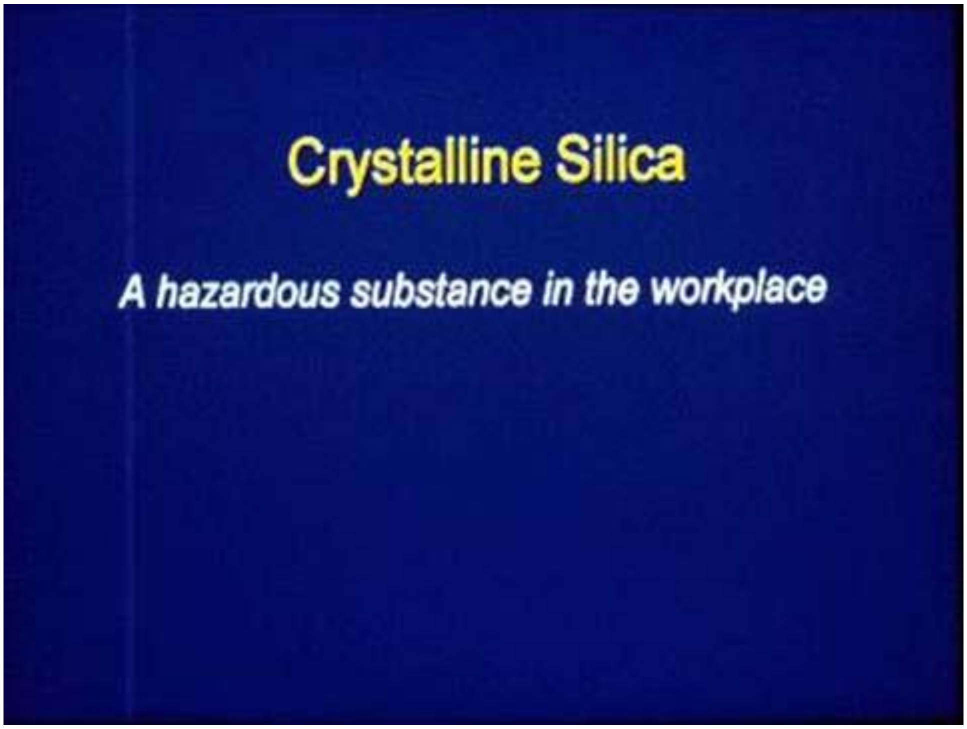

Figure 69. Characteristic of crystalline silica

Discussion: As we have seen, silica can be an extremely hazardous substance to work with. Not only does it have the potential to cause an incurable respiratory disease, silicosis, it also produces its effects insidiously, sometimes taking years of symptoms to appear.

Figure 70. Containing the hazard through engineering control

Discussion: However, with conscientious use of ventilation, monitoring, and proper storage and handling, the hazard can be reduced.

Figure 71. Vacuuming and showering afterwards

Discussion: Other controls, including proper personal hygiene, will help reduce the hazard further. Workers should be trained in personal hygiene such as vacuuming work clothes before removing and showering to remove contaminants from their skin before putting on street clothes.

Figure 72. Photo collage of means of reducing exposure through washing hands, eating sandwich, smoking and putting on cosmetics.

Discussion: Washing hands before eating and not bringing food, beverages, cigarettes, or cosmetics into the work place, will reduce the exposures even further.

Figure 73. Training on respiratory protection.

Discussion: The workers must be trained in the proper selection, use and care of respiratory protection for their health and safety.

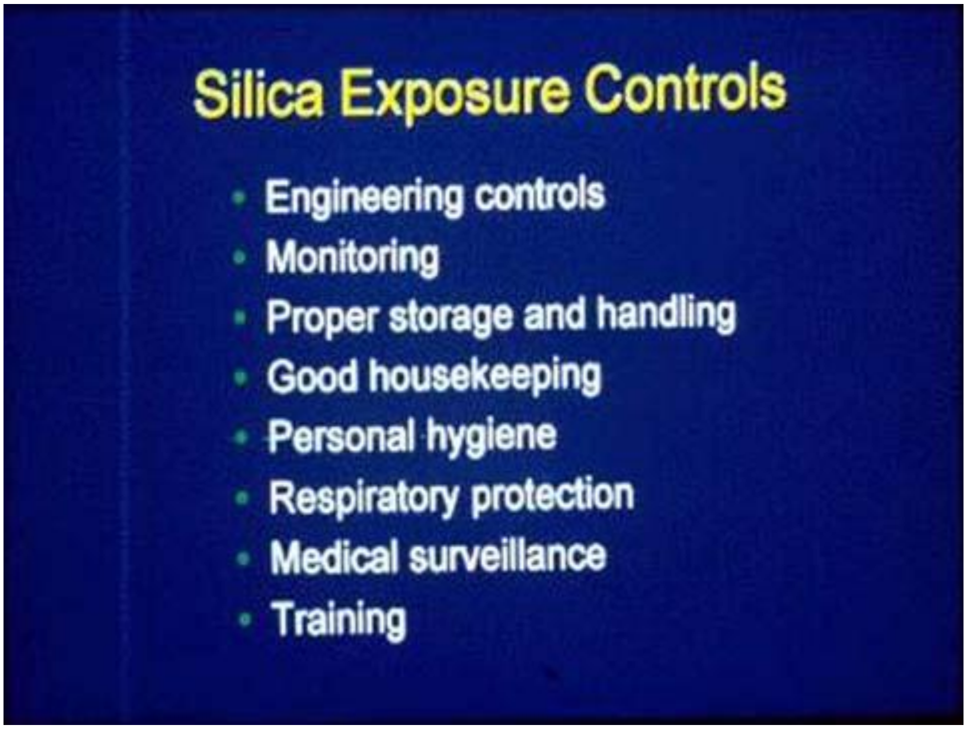

Figure 74. Types of silica exposure controls

Discussion: In order to prevent silicosis, exposure to silica dust must be kept to a minimum, by implementing the measures discussed in this program.