SILICA IN THE REPAIR ENVIRONMENT: WHAT YOU NEED TO KNOW ABOUT THE ISSUES AND SOLUTIONS

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Every year, millions of workers in the U.S. are exposed to crystalline silica. Occupational exposure to crystalline silica dust causes or contributes to the development of silicosis, a potentially disabling disease.

Silica is a natural constituent of the earth's crust and is a major component of sand and granite. Crystalline silica, or free silica, is a term for the chemical compound silicon dioxide (SiO_2) when it occurs as a crystalline structure. Crystalline silica occurs naturally in many different forms, but the three most common forms are quartz, which is the most abundant; cristobalite; and tridymite. Exposure results from quartz in the form of respirable dust produced by chipping, grinding, sandblasting, and mixing operations. Activities such as jack hammering, rock drilling, concrete mixing, concrete drilling, brick and concrete block or slab cutting, and shotcreting are also associated with potential exposure to crystalline silica dust.[1]

WHAT IS DUST?

Dust is the general name for minute solid particles with a diameter of less than 500 micrometers. Dust is generated from a wide range of activities, both industrially and domestically. Activities such as mining, construction, demolition, and agriculture are industries that are large contributors to general atmospheric dust levels. Dust is produced in a very wide range of sizes. Larger, heavier particles tend to settle out of the air and onto surfaces; smaller, lighter particles have a tendency to hang indefinitely in the air.

Dust exposure is contingent on the amount of dust emitted and the physical characteristics of the material, in addition to the methods of handling of the material. Dust exposure generally occurs from, but is not limited to, coming in contact with dust from one or more of the following tasks:

- Abrasive blasting involving harmful materials;
- Demolition of concrete and masonry structures;
- Breakage or crushing of ore; and
- Release of previously generated dust through the loading or dumping of materials.

WHAT ARE THE HAZARDS OF DUST?

In construction, demolition, and renovation situations, dust is created from a variety of sources. In addition to being a potential health problem for workers, dust emissions, in some sectors, also create another threat by increasing the probability of fires or explosions.

Health risks occur when workers are exposed to excessive amounts of harmful dust. The harmfulness

of dust is based on the composition of the dust (chemical or mineralogical), the size and shape of the particle (fibrous or spherical), the concentration of the dust (either by weight or quantity of dust particles), and the exposure time.

For occupational health purposes, dust is categorized by its composition. There are two main categories of mineral dust that exist on concrete repair project sites. The first contains fibrogenic dust. Fibrogenic dust has fiber-like qualities. If retained in the lungs, fibrogenic dust can impair the lungs' ability to function properly. Examples of this kind of dust include asbestos dust and free-crystalline silica.

The second category is inert or nuisance dust, which is defined by OSHA as mineral, inorganic, or organic dust, not listed specifically by substance name in its Limits for Air Contaminant tables (1910.1000 Table Z-1 and Z-3). Inert dust is classified under the Particulates Not Otherwise Regulated (PNOR) limit in Table Z-1. Inert or nuisance dust is limited to 15 mg/m^3 total dust and 5 mg/m^3 respirable. Typically, health effects caused by inert dust are potentially reversible, as opposed to the potentially more permanent effects of fibrogenic dust. Inert dust, however, has the potential to obscure visibility, cause unpleasant deposits in exposed bodily orifices, and potentially injure mucous membranes or the skin through chemical action.

Additionally, dust is classified by size into three categories: respirable dust, inhalable dust, and total dust. *Respirable dust* is small enough to penetrate the lungs and bypasses the nose, throat, and upper respiratory tract. It is defined as being less than or equal to 5μm, which is about 1/12 the width of the average human hair. *Inhalable dust* has a median size of 10μm and, when inhaled, becomes trapped in the nose, throat, and upper respiratory tract. *Total dust* includes all airborne particles, without regard to size or composition.

Long-term exposure to certain harmful respirable dusts can cause a condition known as pneumoconiosis. Pneumoconiosis is a general name for dust-related respiratory diseases that are categorized by a tissue response to the buildup of mineral and/or metallic dust particles in the lungs.

SILICA

WHAT IS CRYSTALLINE SILICA?

Crystalline silica is a basic component of soil, sand, granite, and many other minerals. Quartz is the most common form of crystalline silica. Cristobalite and tridymite are two other forms of crystalline silica. All three forms may become respirable-sized dust particulate when workers chip, cut, drill, or grind objects containing crystalline silica.

WHAT ARE THE HAZARDS OF CRYSTALLINE SILICA?

Breathing crystalline silica dust can cause silicosis. The respirable silica dust enters the lungs and can cause the formation of scar tissue, thus reducing the lungs' ability to take in oxygen. Silicosis affects lung function and can increase susceptibility to lung infections like tuberculosis. In addition, smoking causes lung damage and may add to the damage caused by breathing silica dust.[2]

OHSA STANDARD FOR RESPIRABLE CRYSTALLINE SILICA

OSHA has an established Permissible Exposure Limit (PEL), which is the maximum amount of crystalline silica to which workers may be exposed during an 8-hour work shift, as specified in 29 CFR 1926.55 and 1910.1000. OSHA also requires hazard communication training for workers exposed to crystalline silica and requires a respirator protection program until engineering controls are implemented. Additionally, OSHA has a National Emphasis Program (NEP) for Crystalline Silica exposure to identify, reduce, and eliminate health hazards associated with occupational exposures.[3]

MITIGATION STRATEGIES

OSHA suggests employers and employees take measures to protect against exposure to crystalline silica, including:

- Replacing crystalline silica materials with safer substitutes, when possible;
- Recognizing when silica dust may be generated and plan ahead to eliminate or control dust at the source;
- Knowing how to protect against exposure to crystalline silica dust;
- Providing engineering or administrative controls, where feasible, such as local exhaust ventilation with dust collectors, blasting cabinets, and/or wet methods to prevent dust from becoming airborne;
- Using all available work practices to control dust exposures, such as water spray;
- Routinely maintaining dust control systems to keep them in good working condition;
- Wearing only a N95 (Filters at least 95% of airborne particles) National Institute for Occupational Safety and Health (NIOSH)-certified respirator, if respirator protection is required;
- Wearing only a Type-CE abrasive-blast supplied-air respirator for abrasive blasting;
- Wearing only disposable or washable work clothes and showering, if facilities are available;
- Vacuuming the dust from clothes or changing into clean clothing before leaving the work site;
- Participating in training, exposure monitoring, health screening, and surveillance programs to

monitor any adverse health effects caused by crystalline silica exposure;

- Providing workers with training that includes information on health effects, work practices, and protective equipment to protect against respirable crystalline silica;
- Being aware of the health hazards related to crystalline silica exposures and the additional lung damage that may occur from smoking;
- Refraining from eating, drinking, smoking, and/or applying cosmetics in areas where crystalline silica dust is present; taking care to wash hands and face outside of dusty areas before performing these activities; and
- Preventing dust from becoming airborne during cleanup by using water hoses or wet wiping rather than compressed air. Using vacuums with high-efficiency particulate air (HEPA) filters and wet sweeping rather than dry sweeping.[4]

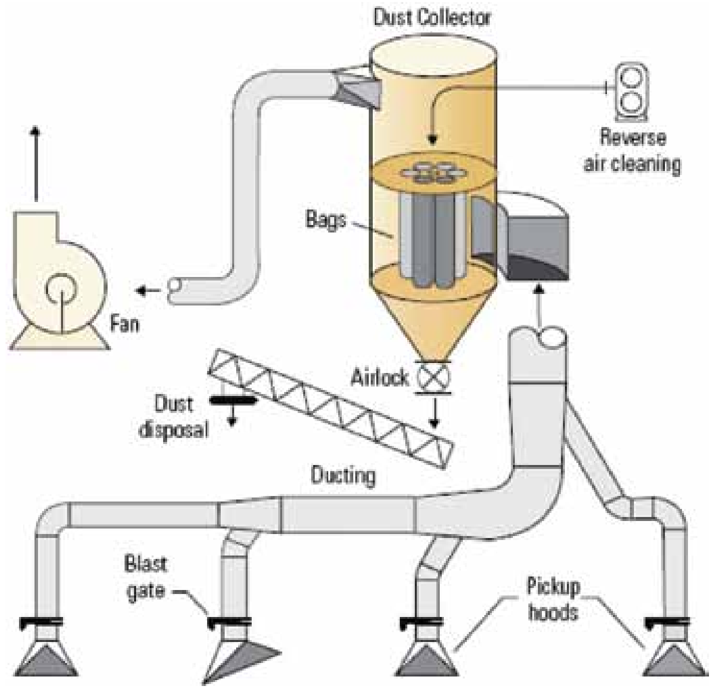
ENGINEERING CONTROLS

There are a number of engineering controls that may be installed and maintained in an effort to eliminate or reduce the amount of silica in the air and the buildup of dust on equipment and surfaces. Examples of these controls include exhaust ventilation and dust collection systems, water sprays, wet drilling, enclosed cabs, and drill platform skirts. The extreme abrasiveness of silica dust can damage the systems put in place; therefore, it is imperative that employers practice preventive maintenance.[5]

COLLECTION

Dust collection systems use ventilation principles to carry a dust-filled air stream through ductwork to a collection and isolation point. The system relies on four main components to effectively capture and collect the dust: an exhaust hood to capture dust emissions at their source, a system of ducts to transport the captured dust to the dust collector, a dust collector in which to store the removed dust, and a fan and motor system to provide the required suction for the system. Careful attention must be given to the selection and implementation of each component, as poor performance of one component will adversely affect the entire system.

Ventilation systems are often used in concrete repair and restoration projects to remove the respirable dust from the work area. These systems typically consist of fan and motor systems to direct the air flow from the work area to a containment system as described previously or to be exhausted from the work area to the exterior of the building. These systems may also use negative air machines with HEPA filters to clean the air prior to exhausting from the work area. These systems should be designed for a minimum of 20 air changes per hour. Should the silica be exhausted from the work area, it is important to consider the effects on the outside environment prior to designing such a system.



Dust collection system

Negative air machine

Masonry cutting with dust collection system

Equipment-mounted dust collection systems typically consist of a dust collecting hood and vacuum attachment that mounts to the cutting and drilling piece of equipment. During operation, dust and small particles are captured by a shroud and routed through a vacuum hose and into a dust collection system. These dust-controlling tools provide greater visibility when cutting. There are no dust clouds; and because these systems are designed to cut dry, there's no slurry produced that can block visibility.

CONTAINMENT

Dust control can also be accomplished by simply enclosing the dusty area inside a structure. The sides and sometimes the top of the structure may be closed to achieve complete dust control. Each work site is unique and therefore determines the size and location of the structure. Enclosures can be expensive to both build and to maintain and, due to their stationary nature, are semi-permanently fixed. Working inside a containment system requires proper respirator use designed for the environment in the containment. The containment can be used to capture the dust and is used in concert with a ventilation/collection system as described previously.

DUST SUPPRESSION

There are two different types of wet dust suppression—one wets the dust before it is airborne (surface wetting) and the other wets the dust after it becomes airborne.

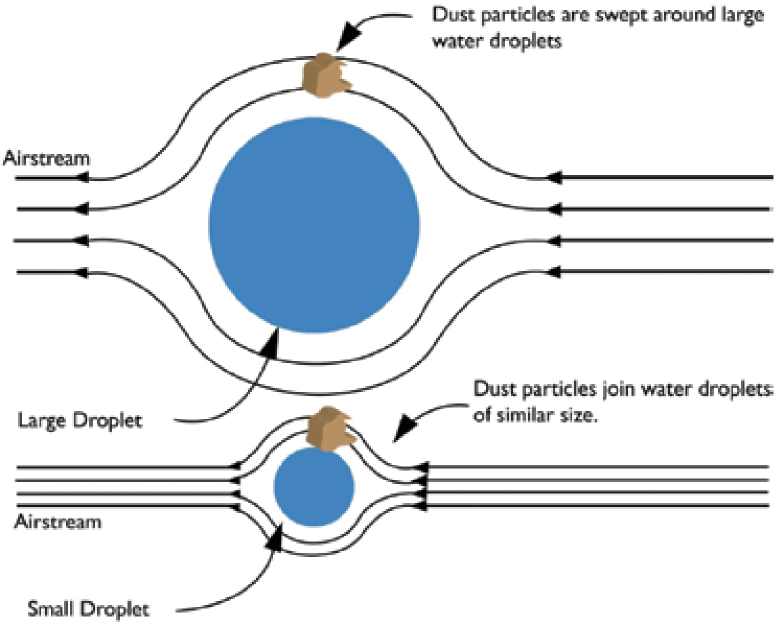
The principle behind surface wetting is to prevent dust from even forming and becoming airborne. This method is based on the effective wetting of the material, either through static spreading (wetting material while it is stationary) or dynamic spreading (wetting material while it is moving).

The principle of surface wetting is used in wet cutting and wet-blasting procedures. Wet cutting involves the use of water to suppress the airborne dust as the cutting process proceeds. Wet cutting is often associated with concrete and masonry cutting procedures.

Water spray/misting systems spray very small water droplets into airborne dust that collide with the airborne dust particles and cause them to stick to each other, falling out of the air onto the ground. This collision is optimized when the droplets of water and the dust particles are of similar sizes. When the water droplet size and the dust particle

Wet cutting hand-held saw

Walk behind concrete saw



Spray mist process

Spray misting equipment

size are not similar, the "slipstream effect" occurs (refer to diagram). In this scenario, the two never collide but are instead swept around each other, due to electrostatic force on the water droplets and the effect this has on the path of the dust particles. Just as with magnets, similarly charged particles repel each other. Thus, it is advantageous to have the particles either both neutrally charged (so that they neither repel nor attract one another) or oppositely charged (so that they attract one another) to increase the likelihood of a water and particle collision.

Hydrodemolition is another method to prevent worker exposure to crystalline silica-containing dusts that are created during impact methods of concrete surface preparation, removal, or sawing. By both eliminating mechanical impact and introducing water, hydrodemolition bypasses the only mode of entry and damage from silica by preventing the creation of respirable dusts. Once operations are completed, standardized wash down and disposal practices must be followed to prevent the drying of the demolition by-product into respirable dust and to avoid subsequent cement fines. Through the combination of hydrodemolition and good operational practices, employee exposure to silica dusts can be virtually eliminated.[6]

PERSONAL PROTECTIVE EQUIPMENT

Employers are required by the OSHA Standard 1910.132 to conduct a Personal Protective Equipment (PPE) Hazard Assessment and corresponding training of employees exposed to respiratory hazards. PPE is the last resort level of protection employers should rely on to protect against worker exposure to contaminants. If PPE fails, is not worn or is fitted improperly, or is of the wrong type, employees will be exposed. Documentation that PPE is effective is required, especially in the case of airborne contaminants such as silica dust.

Hydrodemolition equipment

When engineering controls cannot keep silica exposures below the NIOSH recommended exposure limit (REL) of 0.05 mg/m^3 (as a 10-hour time-weighted average),[7] proper respiratory protection should be used. Respirator use is predicated on environmental monitoring in accordance with OSHA 29 CFR Part 1910.134. Respirators should not be the primary method of protection, but they can be an important element in the defense against silicosis. Beards and mustaches can interfere with the fit of the respirator to the face, rendering most of them ineffective.

Respiratory Protection Programs must be established by employers when respirators are used. A comprehensive respiratory protection program is required by the OSHA standard "Respiratory Protection" and outlined in the "NIOSH Guide to Industrial Respiratory Protection." A respiratory program must be administered by a suitably trained individual and cover the following basic elements:

- Procedures for selecting respirators;
- Medical evaluations for users;
- Fit-testing procedures for tight-fitting respirators;
- Procedures for proper use during routine and emergency situations;
- Procedures for cleaning, storing, and disinfecting;
- Procedures to ensure adequate air quality and flow for atmosphere-supplying respirators;
- Training on respiratory hazards;
- Training on proper use, donning, and removal of the respirator; and
- Procedures for regularly evaluating the effectiveness of the program.

Records documenting each element of the program must be maintained.

RESPIRATORS

The following are various types of available respirators. Each respirator is assigned an applied protection factor (APF). The APF is defined as the minimum expected workplace level of respiratory protection that would be provided by a properly functioning respirator or a class of respirators, properly fit-tested, and trained users, and when all elements of an effective respiratory protection program are established and are being enforced.

Filtering face-piece respirators are half-mask, air-purifying respirators containing N-95 Type or higher filters to provide minimal protection (up to 0.5 mg/m^3). Dust masks are not respirators and do not offer protection against silica dusts. A typical NIOSH N-95 respirator has a NIOSH label and two straps. Note: Although acceptable by NIOSH, a N-95 filtering facepiece (disposable respirator) provides minimum protection. A tight-fitting half-mask air-purifying respirator is much more effective at protecting against silica exposure. The time use limitations for face piece respirators are listed in the manufacturers' fitting instructions that come with the respirators. An example from a respirator manufacturer states: "If respirator becomes damaged, soiled, or breathing becomes difficult, leave the contaminated area immediately and replace the respirator."

Disposable respirators (APF level 10)

Half- or full-mask respirators with replaceable filters provide better protection against respirable dust, up to 0.5 mg/m^3. These contain, at a minimum, N-95 filters that can be replaced.

Half-mask (APF level 10) and full-face (APF level 50 with N100, R100, or P100 filters) respirators[8]

Powered air-purifying respirators (PAPR) use a blower to pass ambient air through an air-purifying canister(s) to remove contaminants from the ambient air. They can provide respiratory protection up to 25 mg/m^3. These respirators have a face piece, helmet, or hood and must be used with HEPA filters. The length of canister or cartridge use time will depend on concentration of the hazardous substance, the temperature, relative humidity, and breathing.

Powered-air respirator[9] (APF level 25 with H.E. Filter)

Type CE abrasive-blasting respirators (SAR) are full-faced, hooded masks with draping that extends over the neck and shoulders. They operate in a pressure-demand or other positive pressure mode, and a tight-fitting mask must be worn under the blasting hood. These are the only respirators that should be worn during abrasive blasting.[9]

Abrasive blasting hood (APF level 1000)

The following list describes the NIOSH respirator recommendations for the varying levels of silica dust:

Up to 0.5 mg/m^3:
(APF = 10) Any particulate respirator equipped with an N95, R95, or P95 filter (including N95, R95, and P95 filtering face pieces) except quarter-mask respirators. The following filters may also be used: N99, R99, P99, N100, R100, and P100.

Up to 1.25 mg/m^3:
(APF = 25) Any powered, air-purifying respirator with a high-efficiency particulate filter

(APF = 25) Any supplied-air respirator operated in a continuous-flow mode

Up to 2.5 mg/m^3:
(APF = 50) Any air-purifying, full-face piece respirator with an N100, R100, or P100 filter

(APF = 50) Any powered, air-purifying respirator with a tight-fitting face piece and a high-efficiency particulate filter

Up to 25 mg/m^3:
(APF = 1000) Any supplied-air respirator operated in a pressure-demand or other positive-pressure mode

Emergency or planned entry into unknown concentrations or IDLH conditions:
(APF = 10,000) Any self-contained breathing apparatus that has a full face piece and is operated in a pressure-demand or other positive-pressure mode

(APF = 10,000) Any supplied-air respirator that has a full face piece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:
(APF = 50) Any air-purifying, full-face piece respirator with an N100, R100, or P100 filter.[7]

VACUUMING CLOTHING

Having workers engage in the practice of vacuuming clothing after exposure to silica-containing dust can further protect against inhaling residual dust that may cling to clothing garments. If this is not possible, it is advisable to wear disposable or washable clothes to the work site and shower, when possible, before changing into clean clothes prior to leaving the work site.

WASHING HANDS AND FACE

Workers who wash their hands and face before eating, drinking, smoking, or applying cosmetics may also reduce their risk of ingesting silica-containing dust.[3]

BLASTING MEDIUM SUBSTITUTION

Many blasting mediums, especially sand, quartz, and slag, used in abrasive blasting contain high levels of silica. Rocks and mineral sands containing less than 2% silica and some metal slags (based on content) could be substituted to reduce levels of exposure. Alternatively, non-silica blasting mediums are available and could reduce risks to workers even more.

NON-SILICA BLASTING MEDIUM

Alternative blasting mediums that do not contain silica, such as ilmenite, aluminum oxide, garnet, metal shot, steel grit, crushed glass, and sodium bicarbonate may additionally reduce exposure. It is imperative, however, that all environmental requirements are followed and protective equipment is used, even with the use of these safer blasting mediums.[10] Therefore, any abrasive blasting of concrete (regardless of abrasive used) should be treated as one that may release silica dust.

HOUSEKEEPING

Practicing general rules of work site cleanliness will help remediate silica dust on work sites, possibly preventing the dust from becoming airborne and potentially inhaled. Many of the strategies, such as avoiding the use of compressed air in cleaning, following guidelines for spill and debris cleanup, and using filters when vacuuming, are easy and inexpensive to follow.

AVOIDING COMPRESSED AIR FOR CLEANING

The use of compressed air when cleaning creates more respirable dust by stirring up latent dust and causing it to become airborne. Although this was at one time common practice, it is now advised against. Methods of removing dust, like wet hosing or wet wiping, are at least as effective at removing dust but also reduce inhalation hazards.

CLEANING UP SPILLS AND/OR DEBRIS

When dealing with spills and/or debris cleanup, it is best to avoid any type of activity that will stir up the dust and cause it to become airborne. The ideal methods for dealing with incidents involving silica-containing dust would incorporate the use of water. As with normal cleaning, wet hosing or wet wiping would be suitable, as would wet sweeping. For those individuals involved in the cleanup, the use of a respirator would also be advisable.

VACUUMING

Vacuums that are used on the work site, whether in cleanup or to remove dust from workers' clothing, should be equipped with HEPA filters. HEPA filters will capture the dust and prevent it from being recirculated into the air.[4]

CONTROLLING ACCESS TO THE WORK AREA

Silica dust exposure can be minimized by controlling access to work areas. By preventing unprotected and/or uninformed individuals from entering areas where dust is being generated, accidental exposures can be avoided.

WARNING SIGNS

Marking and posting the boundaries of work areas where exposure to airborne dust can occur will help alert individuals to the potential hazard. Warning signs should also be posted to mark areas contaminated with respirable crystalline silica.

LIMITED ACCESS

Cordoning off or fencing in areas where dust is present reduces the possibility of unnecessary exposure. The physical presence of a barrier is an even more effective tool in controlling which individuals can enter the work site.

EMPLOYEE TRAINING PROGRAMS

In addition to establishing workplace guidelines for employees to follow, employers should provide workers with training that includes information about health effects, work practices, and protective equipment for respirable crystalline silica. Training in the proper use, fit, care, cleaning and maintenance of respirators is also advisable.[11]

EMPLOYEE MONITORING PROGRAMS

Monitoring, performed as part of a respiratory program, not only measures dust exposure but also gauges the health of the employees. These steps will help ensure that workers are being protected by the controls that are in place and will determine if additional worker awareness, education, and/or training is necessary. Most importantly, annual health screening could prevent additional damage to the lungs of workers who may have already been exposed to silica dust.[11]

SUMMARY

The ICRI Environmental Safety and Health Committee was established in 2006 in response to the industry sponsored Vision 2020 initiative. The committee mission, as stated in the Vision 2020 documents, is to "Develop environmentally and worker friendly repair methods, equipment and materials that will greatly reduce the adverse effects on the workers, the public and the earth's ecosystem."

To support this goal, a number of strategies were developed. The first strategy was to create recommendations for minimizing the effects of hazardous airborne particulates on the workers, the public, and the environment. This paper provides the most current understanding of the hazards related to dust created in the concrete and masonry repair environment. It is important that the members of ICRI appreciate the severity of the hazards and implement mitigation and control strategies to ensure the safety and health of those exposed to the dust generating work. The primary recommended strategies are to use engineering controls to minimize the amount of dust generated and control and exhaust the dust that is produced. In addition to these controls, proper selection and use of personal protective equipment, including various forms and styles of respirators, are important strategies for protecting the workers.

It is the responsibility of our industry leadership to ensure that we are proactive in addressing these health hazards. In addition to this paper, the committee will soon be publishing a new guideline document, "Guideline and Recommendations for Safety in the Concrete Repair Industry." This guideline is an illustrative document that will be a useful tool for management and workers to better understand the hazards associated with concrete repair work and the strategies that are available to minimize the hazards and to provide a safer environment for all the stakeholders in the concrete repair project.

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REFERENCED STANDARDS AND REPORTS

New Jersey State Law
34:5-18 Dry Cutting, Grinding of Masonry, Certain Circumstances; Prohibited

Occupational Safety & Health Administration
29 CFR 1910.1000 Table Z-1 Limits for Air Contaminants
29 CFR 1910.1000 Table Z-3 Mineral Dusts
29 CFR 1910.132 Personal Protective Equipment
29 CFR 1910.134 Respiratory Protection
29 CFR 1926.55 Gases, Vapors, Fumes, Dusts, and Mists

The Goal of ICRI Committee 120, Environmental Health and Safety, is to develop and report information on environmental health and safety issues related to repair of concrete and masonry.

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