IT'S NOT JUST DUST ... It's Silica!

What you should know about silicosis in the ready mix industry

Illinois Onsite Safety & Health Consultation Program

dceo
Illinois Department of Commerce and Economic Opportunity

Introduction

Introduction

Silicosis is an occupational disease caused by exposure to dust from crystalline silica, one of the most common minerals on our planet.

Silicosis isn't curable! Workers are still dying from the disease. **This condition is preventable.** The keys to prevention are straightforward:

❖identify workplace activities that produce crystalline silica dust and then

❖eliminate the dust or control it so that workers aren't exposed.

In the ready mix industry, you often use products or materials that contain crystalline silica and should be concerned about silicosis and crystalline silica hazards.

This workbook will inform you about the hazards in your industry so that you can control them.

About crystalline silica

What is it?

Crystalline silica is the scientific name for a group of *minerals* containing silicon and oxygen. *Crystalline* means that the oxygen and silicon atoms are arranged in a specific pattern.

Forms of crystalline silica

Crystalline silica exists in several forms, including *quartz*, *cristobalite*, and *tridymite*. Tridymite is the most potent, but least common form. Cristobalite, which occurs naturally in volcanic rock, is often found with quartz in the Pacific Northwest. Of these forms, quartz is the most common; in fact, it's the second most common mineral on the planet. (Feldspar is the most common.)

The cause of silicosis is linked to cancer

Crystalline silica causes silicosis, but it has also been linked to cancer. Any material that contains more than 0.1 percent crystalline silica must meet the labeling, information, and training requirements of the *Hazard Communication Standard, 29 CFR* 1910.1200).

Concern

Who should be concerned?

Any worker exposed to dust containing crystalline silica — dust from crushed rock, soil, dirt, gravel, or sand, for example — should be concerned about silicosis.

Because crystalline silica is such a common mineral — so prominent in the products that we make and use — you should be concerned about working with any material that contains more than 0.1 percent crystalline silica.

Chronic silicosis

Silicosis can affect you in three ways. Most workers who get silicosis don't show any symptoms for 10 or more years. That's because their exposures to crystalline silica are fairly low, but frequent. They develop a condition called chronic silicosis.

Accelerated silicosis

As exposure levels increase, however, silicosis symptoms can appear much earlier. For example, those diagnosed with accelerated silicosis show symptoms within five to 10 years.

Acute silicosis

Workers exposed to extremely high levels of crystalline silica dust may develop acute silicosis, a condition that can show symptoms within only a few weeks of an initial exposure. Acute silicosis is most common among sand blasters because of the high levels of silica dust they breathe.

Work Activities

How do you determine if you have a problem?

Do you know what activities at your workplace expose workers to crystalline silica dust? Suspect any activity that produces dust from rock, soil, dirt, gravel, sand, or any product made from these materials. Obtain a material safety data sheet for the products you use to determine if they contain crystalline silicia. In ready mix operations, the employee who chips out the truck is usually at risk.

Material Safety Data Sheets

These sheets contain data for all materials or products containing hazardous substances that are used at a business in quantities greater than what a consumer would use.

If a material or product contains crystalline silica in quantities greater than 0.1%, there must be a safety data sheet for it.

Manufacturer's responsibility: obtain or develop a safety data sheet for each hazardous chemical they produce or import.

Employer's responsibility: ensure access to safety data sheets for all hazardous materials at the workplace.

Now that you suspect silica is being used and that it may be in the air, you need to know just how much is there.

An industrial hygienist can help you make that determination by sampling the air workers breathe and calculating a Permissible Exposure Limit (PEL).

Determining the PEL for crystalline silica quartz—an example

A key term
The Permissible Exposure Limit (PEL) is the maximum average amount of airborne crystalline silica dust that one can be exposed to during a full work shift.

This example highlights the calculations an industrial hygienist might use to determine if a worker was exposed to unsafe levels of crystalline silica quartz dust. The permissible exposure limit (PEL) for respirable crystalline silica quartz is based on the following equation and is expressed in milligrams per cubic meter (mg/m3).

$$\text{PEL} = \frac{10\ \text{mg/m3}}{[\%\ \text{Silica}] + 2}$$

Assume the hygienist sampled air in the employees breathing zone during a chipping operation. She had a laboratory analyze the sample to determine the weight of respirable dust and the percentage of free silica quartz. The laboratory reported the following results:

Lab Report

What was sampled	Value
Weight of respirable silica dust	0.45 mg/m3
Percentage of free silica quartz	**25.00%**

She plugged 25 percent into the PEL equation and calculated a value of 0.37 mg/m3, as shown below.

$$\text{PEL} = \frac{10\ \text{mg/m3}}{25 + 2} = 0.37\ \text{mg/m3}$$

Results

The weight of airborne respirable dust in the sample = 0.45 mg/m3
The calculated PEL value = 0.37 mg/m3
0.45 mg/m3 is greater than 0.37 mg/m3
Therefore, the worker is overexposed.

Because the weight of the airborne breathable dust in the sample (0.45 mg/m3) is greater than the calculated PEL value (0.37 mg/m3), the hygienist concludes that the worker is overexposed.

Industrial Hygiene Study

IRMCA Industrial Hygiene Study

In 1997, the Occupational Safety and Health Administration (OSHA) implemented a special emphasis program (SEP) which focused on employee exposure to silica in general industry and in the construction industry. The SEP involved increased OSHA compliance inspections at facilities that had potential employee exposure to silica. The SEP was intended to address concerns regarding health problems associated with the lung disease silicosis, as identified by the Center for Disease Control (CDC).

In response to the OSHA special emphasis program on silica, the Illinois Ready-Mixed Concrete Association (IRMCA) took a proactive approach by requesting the assistance of the Illinois OnSite Consultation Program to evaluate employee exposure to silica in ready-mixed concrete facilities. This study covered the time period October 1997 through June 1999.

Workstations at five separate ready-mixed concrete companies were evaluated to determine employee exposure to silica:

Yardman	This employee moves material around the facility usually in material handling equipment with an enclosed cab.
Driver	In addition to driving the concrete truck, the driver also periodically removes dried concrete from inside the concrete truck mixer drum using a hammer and a pneumatic chipper.
Batch loader	This employee's workstation is usually inside a booth or office. They monitor the material as it is being mixed and/or dispensed into the trucks.

CONCLUSIONS

Sampling results indicated that the yardman and batch loader were not over exposed to silica. Silica concentrations were either undetectable or well below the OSHA Permissible Exposure Limits (PEL).

In contrast, **drivers were found to be exposed to levels of silica which exceeded the OSHA PELs** when chipping out dried concrete from the truck drum mixer.

In addition to silica exposures, employee exposures to calcium hydroxide and to noise were evaluated during truck drum cleaning. Employee exposures to calcium hydroxide did not exceed the OSHA PEL. Employee exposures to noise exceed the OSHA PEL.

Controls

Engineering Controls

A. Methods/procedures to minimize dried concrete buildup in mixers

Employee exposure to higher concentrations of silica occurred due to heavy build-up of concrete inside the drum mixer. Rinsing the drum mixer with water immediately after each load will minimize dust exposure.

The amount of build-up of concrete depends on the rinse procedure used by the driver. Some drivers who practice good rinsing procedures have minimal build-up of dried concrete in their trucks. Other drivers with poor rinsing procedures have significant build-up of dried concrete.

Good drum rinsing procedures included a rinse after each load is delivered and a triple rinse at the end of each work shift.

When a driver has a slower pour which can result in excess concrete build-up in the drum, a load of ¾ inch aggregate can be loaded into the drum and rotated for 30 minutes to scour the drying concrete from the inner surface of the drum.

Employees must be trained on the importance of monitoring the dust level generated during chipping.

If dust levels begin to increase, rewet the entire surface, ensure water is continuously spraying while chipping at the point where the chisel meets material.

It is also important for supervisors to ensure proper procedures are followed throughout the chipping process.

B. Methods/procedures to follow to maintain employee exposure to silica below the OSHA Permissible Exposure Limit (PEL) while chipping out a drum.

1. Hatch open
2. Place box fan horizontally in hopper
3. Set on high speed and exhaust the air flow out of the drum
4. Use chipping hammer equipped with water spray nozzle
5. Initially spray the entire inner surface of the drum with water
6. Adjust the water spray so that it is aimed at the point of the chisel
7. Ensure water sprays at all times when the chipper is in operation
8. If during the cleaning procedure, concrete surfaces dry to the point that dust is being generated while chipping, the surface should be re-sprayed with water.

Noise Results

Noise

Personal noise monitoring was conducted on employees during the truck drum cleaning process. Employees wore Quest Micro 15 noise dosimeters to determine average noise exposures during the cleaning procedure. Exposure to an eight hour time weighted average noise level of 90 decibels on the "A" scale (dBA) can result in hearing loss.

The average noise level readings during the cleaning procedure ranged from 113 dBA to 115 dBA. Exposure to noise at this level exceeds the OSHA PEL and requires employees to be included in a hearing conservation program. Additionally, adequate hearing protection must be worn at all times during the drum cleaning process. Adequate hearing protection at these noise levels requires the use of double hearing protection. That is the use of ear plugs in addition to muffs such that the combined effectiveness of the hearing protection is adequate to reduce the employee's noise exposure below 90 dBA.

Essential elements of a hearing conservation program include conducting annual hearing tests for all employees involved in the truck drum cleaning process, instructing them on when to use hearing protection and the proper use and care of the hearing protection, and training on the effects of noise on the ear.

OSHA mandates that employers look for economically feasible engineering controls to reduce employee exposure to occupational noise. There does not appear to be much on the market in terms of adequate control measures to reduce noise levels while chipping inside drum mixers. An investigation into silencers for the pneumatic chippers used during the drum cleaning process did not identify any products that would make a significant impact on reducing noise levels during the process.

One control measure that was used to reduce noise levels outside the drum during the cleaning process was a polypropylene tarp typically used to protect wet concrete from weather related elements. It was draped over the entire exterior surface of the mixer drum. This reduced noise levels outside of the drum by as much as 10 decibels. This control measure could be used to reduce noise exposures for employees working in the near vicinity to the truck during the cleaning process and could be a reasonable method to reduce noise levels that cross the facility's property line in residential neighborhoods.

F	Hatch open, pedestal fan outside hatch blowing air into drum and box fan at hopper exhausting air out from drum	A pedestal fan was placed at the hatch opening, blowing air into the drum through the hatch. A box fan was positioned at the hopper end allowing air to be exhausted out from the drum. Most of the cleaning occurred at the hatch end. Exposure to total particulates containing silica was very high. We believe that the elevated exposures were the result of dust blowing into the employee's breathing zone during the cleaning process. The mixer fins move the air in a cyclonic turbulence that significantly contributes to the amount of dust being blown into the employee's breathing zone.
G	Combination (1) Hatch open and box fan at hopper end blowing air through the hatch and into the drum when the employee was working in the front and middle sections of the drum. (2) Hatch open and box fan at hopper end exhausting air out of drum when worker at hopper end of drum	(1) This sample produced much higher results above OSHA's PEL than any other method conducted excluding the method where the fan was placed at the hopper and exhausting air out of the drum mixer. Again, part of the reason is the cyclonic turbulence described in Section F. In addition, it was discovered during this sampling period that a lot of the dust was coming from the core of the concrete rather than the surface of the material. As the driver chipped into the core of the concrete, the dust would shoot back into the employee's breathing zone, thus increasing the likelihood of exposure to silica above the PEL. (2) Concentrations of respirable silica were not detected during this sampling. This truck had minimal build-up of concrete residue unlike the first truck. This could very well explain why the concentration of respirable silica was undetectable. However, concentrations of total particulates with silica exceeded the OSHA PEL. One possible reason these results were much higher may have been related to a larger water tank on this truck as opposed to a much smaller water tank used on the first truck. The larger water tank may facilitate more effective rinsing of the drum by the driver after a load is delivered. Additionally, the exhaust being pulled through the truck mixer via fan at the hatch could have been overpowered by strong winds on that day, resulting in minimal exhaust of dust from the mixer.
H	Same as G. but interior of drum sprayed with water prior to chipping	To reduce the generation of dust from the surface of the dried concrete in the drum during chipping, the interior of the drum was sprayed with water and allowed to soak. There was little effect in reduction of silica dust exposures. When the chipper would chip a hole in the dried concrete, the dust was blown out of the hole and into the employee's breathing zone.

IRMCA Study

Data Tables from Original Study October 1997 through June 1999

Silica and the Ready Mix Industry

IRMCA DRUM CLEANING AIR SAMPLING SUMMARY DATA

	RESPIRABLE PARTICULATES						TOTAL PARTICULATES									
TEST	SAMPLE CONC	SILICA (QUARTZ)	EXP TIME	TWA*	% SILICA	RESPIRABLE % OF PEL	SAMPLE CONC.	SILICA (QUARTZ)	% SILICA	% OF PEL	HATCH	FAN IN	FAN OUT	EXH. DUCT	WATER	COMMENT
1?	[illegible]	0.741?	[illegible]	2 HRS	7.1	241	2.37?	0.494?	[illegible]	37	open	hatch	hopper	-	-	Six WT/wk at hatch end/sign [illegible]
2B	[illegible]	N.D.	160	2 HRS		5	41.5	1.54	3.7	197	open		hopper			[illegible] hopper end/2nd [illegible]
3B	5.?	[illegible]	68	2 HRS	6.?	116	44.6	1.76	3.?	219	open	hopper			partial	all sfc wetted initially then periodically during chipping
4B	[illegible]	0.355?	68	2 HRS	6.6	292	85.?	[illegible]	[illegible]	307?	open		hopper		partial	all sfc wetted initially then periodically during chipping wk at hopper end
5?	1.02	0.107?	237	3 HRS	11	93	16	0.75?	4.7	89	open	hopper	-			
6?	10.?	1	194	2 HRS	9.2	4?6	1?6	1.90	1	455?	open		hopper			Different employee and truck than 5?
7?	5.27	0.741	90	2 HRS	14	210	45.1	3.51?	6.8	353	open	hopper			partial	Drum presoaked, all sfc wetted initially and periodically during chipping
8?	1.9?	0.176	12?	2 HRS	9.9	63	34	4.40	13	475	open	hatch	hopper			Most of work at hatch end
9?	2.69?	0.455	9?	2 HRS	22	124	67.8	3.64	4.?	445	open	hatch	hopper			Most work at hatch end
10C	12.9	1.97	56	2 HRS	15	548	121	9.45	7.8	988	open	hopper				Work at hatch end
11C	11.?	1.7	64	2 HRS	15	450	161	11.7	7.3	1246	open	-	hopper/hatch?	-		Working in center of truck. Operator commented that dust conc. was greater
12?	0.58?	0.045	130	2 HRS	7.8	14	9.8?	N.D.	0.7	13	open	hopper			yes	All sfc prewetted and water used during all jack hammer use at chisel pt
13V	0.04?	N.D.	9?	2 HRS	10	19	5.54	0.72	13	69	closed		hopper			
14V	1.40	0.109	117	2 HRS	7.8	34	20.5	0.76	3.?	97	closed		-			
15V	2.14	N.D.	122	2 HRS	1.6	19	15	0.54	3.6	70	open					
16V	2.6?	0.09?	26?	2 HRS	4.5	3?	32.4	0.6?	1.3	105	closed	-	-	yes	-	Flexible exhaust duct 1/3 hp RAM FAN
17P	1.99	0.165	96	2 HRS	8.8	51	12.3	0.9??	7.6	99	open	-	-	yes		Manual (Unpowered) 12" duct w/RAM FAN
18V	1.12	N.D.?	90	2 HRS	5.8	2?	15.6	0.74	4.4	33	open	50% hopper 50% hatch				Wk at hatch end w/fan blwng in from hopper. Wk at hopper end w/fan blwng in from hatch.
19V	4.25	0.250?	1.3	2 HRS	6.1	54	12.1	0.468	4.1	38	open	hopper			yes	(For 18P [illegible])
20V	1.8?	0.079?	1.6	2 HRS	4.4	23	4.70	0.25?	5.4	24	open	hopper			yes	(For tests 19V, 20V and 21V, the modified chipper with water spray was used as in 12 [illegible])
21V	0.60?	0.120?	[illegible]	2 HRS	2?	42	6.01?	1.15?	[illegible]	63	open	hopper	-		yes	

* TWA exposure was calculated using sample concentration [illegible]
\# [illegible] based on estimated exposure time and remaining [illegible] hours of no exposure to silica

Ready Mix Truck Mixer Entry Procedures for CHIPPING or INSPECTION

Truck mixers are equipped with rotating drums for the mixing of concrete before and during delivery to construction sites. The rotating drums on the mixers are periodically entered for cleaning by chipping or inspection. Retrieval lines and harnesses generally required are impractical for use in truck mixers because the internal configuration and their interior baffles would prevent rescuers from pulling out workers.

The truck mixer meets OSHA's definition for permit-required confined space [PRCS]. While entry operations present many different hazards, the hazard that defines the truck mixer as "permit required" is the possibility of having the drum start turning while an employee is inside. This is a recognized hazard in the industry.

This space can be reclassified as a non-permit space as there are no actual or potential atmospheric hazards (note that silica is a chronic health hazard and as such is not covered under the Permit Entry Confined Space Standard) **and if all the other hazards within the space are eliminated without entry into the space**.

Entry can then be made without a permit, attendant or entry supervisor. ***A certification record must be completed prior to each and every entry.***

Entry & Lockout Procedures

Step	Hazard	Procedure/Protection
Preparation for Mixer Entry	Mechanical hazards (struck or caught by) may exist during entry into the mixing drums for maintenance operations, including truck movement, rotation of the drum and injuries from the use of tools and other equipment.	Move truck to a safe location. Prior to entry, implement full lockout/tagout procedures to ensure control of hazardous energy sources such as electrical (remove key), hydraulic or pneumatic (bleed if applicable) and kinetic (block and secure).

Step	Hazared	Procedure/Protection
Mixer Entry	Slips and falls when entering	◆ Inspect ladder for defects prior to use. ◆ Use three points of contact when climbing. ◆ Secure portable ladders.
Chipping	Falling Material	◆ Wear Class A hard hat (ANSI Z89.1-1986 or later.) ◆ Wear safety shoes (ANSI Z Z41-1991 or later.) ◆ Arm Protection
	Eye and face injury from flying and falling materials	◆ Wear eye protection with side shields suitable for industrial use (ANSI Z87-1989 or later.) **AND** ◆ Wear full face shield over the eye wear. Note: Wearing a face shield does not eliminate the need
	Inhalation of airborne silica created from chipping operations	Use wet methods 1. Open hatch. 2. Place box fan horizontally in hopper 3. Set on high speed and exhaust the air flow out of the drum 4. Use chipping hammer equipped with water spray nozzle 5. Initially spray the entire inner surface of the drum with water 6. Adjust the water spray so that it is aimed at the point of the chisel 7. Ensure water sprays at all times when the chipper is in operation 8. If during the cleaning procedure, concrete surfaces dry to the point that dust is being generated while chipping, the surface should be re-sprayed with water.

Note: If employee has to work at hopper end and needs to face toward hopper, the fan should be turned over to exhaust air out of the mixer. Wear respiratory protection such as two strap disposable respirator for dust (N95) or half-mask respirator with HEPA filters

Help

Getting Help

Consultation Program – this is a free consultation service largely funded by OSHA where employers can: find out about potential hazards at their worksites; improve their occupational safety and health management systems; and even qualify for a one-year exemption from routine OSHA inspections.

The service is delivered by state governments using well-trained professional staff. Most consultations take place on-site, though limited services away from the worksite are available. The program is primarily targeted for smaller businesses and is completely separate from the OSHA inspection effort. In addition, no citations are issued or penalties proposed. Your name, your firm's name, and any information you provide about your workplace, plus any unsafe or unhealthful working conditions that the consultant uncovers, will not be reported routinely to the OSHA inspection staff. Your only obligation will be to commit yourself to correcting serious job safety and health hazards -- a commitment which you are expected to make prior to the actual visit and carry out in a timely manner. Because consultation is a voluntary activity, you must request it. Your telephone call or letter sets the consulting machinery in motion.

In Illinois, call 1-800-972-4216

For other states, find the consultation project near you by going to the OSHA website at www.OSHA.gov. In the right hand margin, under "Cooperative Programs", click on "consultation".

Portland Cement Association

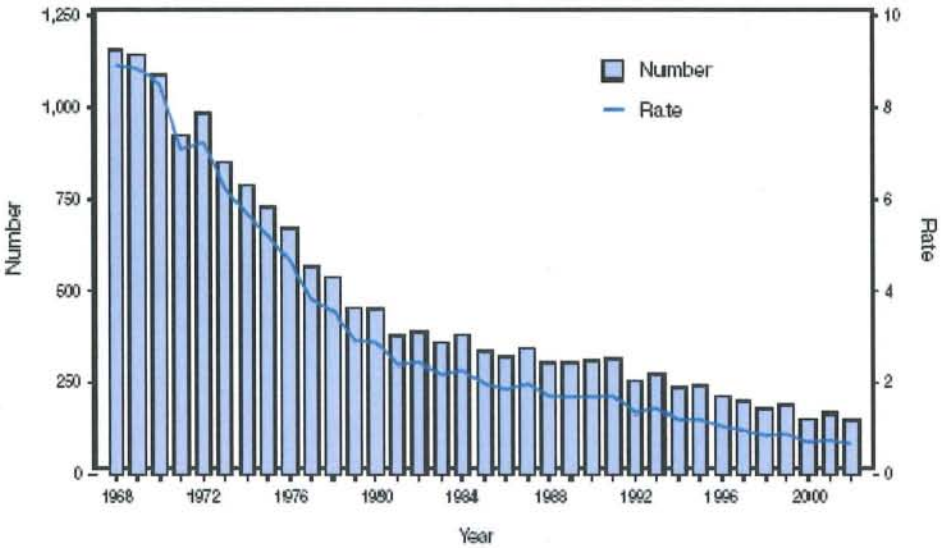
PCI

NRMCA
NATIONAL READY MIXED CONCRETE ASSOCIATION

Issues of Concern to the Cement and Concrete Industries Regarding the OSHA Crystalline Silica Proposal

- Reduction in the permissible exposure limit for crystalline silica exposure. Since 1968, there has been a steady reduction in mortality rates from silicosis. The reason for the reduction is better industrial controls, including the use of dust masks. Figure 1 below from the National Institute for Occupational Safety and Health illustrates the decrease in silicosis.

FIGURE 1. Number of silicosis deaths and age-adjusted mortality rate*, by year — National Occupational Respiratory Mortality System, United States, 1968–2002



* Per million persons aged ≥15 years.

- Costs associated with the ancillary provisions in the rule. The rule likely includes exposure monitoring and medical surveillance, regulated areas and hygiene facilities, hazard communication and training requirements with recordkeeping and reporting requirements. These costs are unnecessary for facilities where there are very few exposures above the threshold PEL. The rule should allow accommodations to minimize unnecessary costs.

- Dust masks are effective in limiting individual exposures to silica dust, but the rule does not allow PPE to be used for compliance until all feasible engineering controls have been put in place. This greatly increases the costs of compliance unnecessarily.

- Unemployment is at historic highs in the construction sector, almost 20% nationally. During the recession, tens of thousands of employees in the cement and concrete manufacturing sectors have been furloughed. The timing for the release of this rule could not be worse.

NATIONAL CONCRETE MASONRY ASSOCIATION
Sustainable Concrete Products for Structures and Hardscapes

American Concrete Pipe Association

PREVENTION OF SILICOSIS AND COMPLIANCE WITH ENVIRONMENTAL REGULATIONS

The International Agency for Research on Cancer has concluded that the scientific literature on crystalline silica is sufficient to conclude that exposures from occupational sources are casually related to an increase in lung cancer. This determination has resulted in reclassifying crystalline silica as carcinogenic to humans. Additionally, the Occupational Safety and Health Administration (OSHA) has implemented a Special Emphasis Program (SEP) to reduce and eliminate the workplace incidence of silicosis from exposure to crystalline silica. This program includes increased enforcement and an outreach educational assistance program.

Potential Impact of SEP

❶ Rulemaking by OSHA will occur for crystalline silica involving a comprehensive standard possibly to include: reduced exposure limits; action levels; dust monitoring; medical surveillance; medical removal and pay protection; methods of compliance; worker training; engineering controls; respirators; and record keeping. Proposed standards are expected to include risk assessment for carcinogenicity, silicosis, and chronic obstructive pulmonary disease (COPD).

❷ Examination by EPA of the cancer risk posed to the general population by silica with possible impact on its regulations for air emissions, operating permits, control devices, and community warnings.

❸ Increased opposition in local land use permitting based on crystalline silica being carcinogenic to humans.

❹ Changes to Material Safety Data Sheets as well as product labeling. (There is a stay on 1926.59/1910.120 (f) (ii) and OSHA cannot enforce the requirement to update labels.)

❺ Increased product substitution for silica and silica-containing products, with potential market loss for some uses.

❻ Increase in worker's compensation and product liability litigation for lung cancer in silica-exposed workers (estimated by Department of Labor at 2 million workers).

In precast concrete operations, activities such as concrete batching and mixing, abrasive blasting, concrete drilling or sawing, dry sweeping or pressurized air blowing of concrete coarse and fine aggregate dust are associated with potential exposure to crystalline silica dust. Precasters should make a commitment to prevent silicosis at their plants. They should recognize when silica dust may be generated and plan ahead to eliminate or control the dust at the source. Awareness and planning are keys to prevention of silicosis.

OSHA compliance officers will be focusing their inspection on sites where silica is not controlled effectively, and will limit their inspections at sites where effective silicosis prevention programs have been implemented.

Table 1 lists OSHA standards that may under appropriate inspection conditions be cited for crystalline silica overexposure. The standards listed in Table 1 are for general industry and construction.

The following is a list of elements, which may be included in an effective program:

- ongoing personal air monitoring program*
- ongoing medical surveillance program
- training and information on crystalline silica provided to workers*
- availability of air and medical surveillance data to workers*
- an effective respiratory protection program*
- hygiene facilitates and clothing change areas are provided
- appropriate recordkeeping*
- personal exposures below the permitted exposure limit

* Note: Required by specific OSHA standards if an overexposure to crystalline silica exists. All of the elements are not necessarily required for a program to be effective.

concrete surface. Where fragmentable abrasives such as sand is used, or where a concrete surface is blasted, the airborne dust generated will vary in particle size and chemical composition.

Abrasive blasting creates clouds of tiny, sometimes invisible dust particles that can hang in the air long after blasting has stopped. To cause silicosis, the silica particles must be respirable and able to reach the smallest airways and air sacs in the lungs. This means the particles must be around three to five microns in diameter. When a respirable dust sample is collected, a device (cyclone) is used prior to the collection filter to separate and remove particles that are too large to be taken into the lungs. The cut-off point is 10 microns, or about 1/50th the size of the period at the end of this sentence. These are very small particles -- particles the human eye cannot see.

Even though the particles of concern are not visible, it goes without saying that when you see a dust cloud in your operation, there will be particles in that dust cloud that are of respirable size.

The current OSHA Permissible Exposure Limit (PEL) for respirable dust containing crystalline silica (quartz) for general industry is an 8-hour time-weighted average (TWA) [29 CFR 1910.1000] as follows:

$$\text{PEL (mg/m}^3\text{)} = \frac{10 \text{ mg SiO}_2\text{/m}^3}{\%\ \text{SiO}_2 + 2}$$

where:

$\text{mg SiO}_2\text{/m}^3$ = milligrams of silica per cubic meter of air

$\%\ \text{SiO}_2$ = the percentage of silica in the respirable dust

$$\text{For total silica (quartz) dust the PEL} = \frac{30 \text{ mg/m}^3}{\%\ \text{SiO2} + 2}$$

Silicosis prevention measures should be based on the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of 0.05 mg/m³ respirable crystalline silica as a TWA for up to 10 hrs/day during a 40-hr workweek, since the OSHA PEL is outdated and not protective.

Sampling

Exposure monitoring should cover conditions throughout a full work shift as activities in the work area vary during the shift and change the hazard intensity. Preferably, the air in the work area should be sampled in the workers' breathing zones.

A respirable sample is collected by drawing air at approximately 1.7 liter per minute (± 0.2 liters/min.) through a 10-mm nylon Dorr-Oliver cyclone attached to a 5 micron pore size, 37-mm diameter polyvinyl chloride (PVC) filter cassette. The 5-micron pore size filters reduce problems associated with sample loading and backpressure. This is important to maintaining a constant sampling rate in dusty work environments. Sample air volumes of 408 to 816 liters are recommended.

Care needs to be taken to assure that the cyclones are not inadvertently inverted. Pumps should be checked on at least an hourly basis, if possible, and the flow rates noted, and what the worker was doing at the time of the check documented. If filter overloading is suspected or workers change to another job or procedure, the sampling filter should be replaced with a new filter and the time of changes documented.

Assessments of exposure should be made by a certified industrial hygienist (CIH) or by persons who by virtue of special studies and training have acquired competence in industrial hygiene. The choice of the laboratory to analyze the silica sample is also very important. Only labs certified to do silica analyses by the American Industrial Hygiene Association should be used. (American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031, InfoFax: (703) 641-4636, Internet: http://www.aiha.org.

The average cost of a silica sample analysis by X-ray diffraction (XRD) is in the range of $55 to $85. In 1996, the average cost for a CIH was $75 to $125 per hour depending upon the geographical region. The average cost for an industrial hygiene technician was $45 to $75 per hour, again depending upon the geographical region.

How do you go about setting up a sampling program? You can choose to use consultants, your insurance carrier, or do it yourself. The American Industrial Hygiene Association offers a listing of industrial hygiene consultants. Many safety equipment suppliers will know consultants in your area. Employers can contact their local OSHA consultation service for free guidance and assistance. Primarily developed for smaller employers with more hazardous operations, the consultation service is delivered by state government agencies or universities employing professional safety consultants and health consultants. Comprehensive exposure. The medical examination should be repeated more frequently if respiratory symptoms develop or upon the recommendation of the examining physician.

❷ A baseline chest x-ray should be obtained prior to employment with a follow-up every 5 years if under 20 years of exposure and every 2 years if over 20 years of exposure. A chest x-ray may be required more frequently if determined by the examining physician.

❸ Pulmonary Function Tests (PFT) (spirometry): Should include FEV1 (forced expiratory volume in 1 second), FVC (forced vital capacity) and DLCO (diffusion lung capacity.) PFTs should be obtained for a baseline examination with PFTs repeated every 5 years if under 20 years of exposure and every 2 years if over 20 years of exposure. PFTs may be required more frequently if respirable symptoms develop or if recommended by the examining physician. PFTs are designed to assess the elasticity and proper functioning of the lungs. Many lung diseases affect the PFT results. Typically, smoking causes an obstructive type of abnormality, while pneumoconiosis causes a restrictive abnormality. Combinations of the two abnormalities can also occur.

❹ A chest x-ray should be obtained on employment termination.

The chest x-ray should be chest roentgenogram (posteroanterior 14" x 17" or 14" x 14") classified according to the 1980 ILO International Classification of Radiographs of Pneumoconiosis by a certified class "B reader." A "B-reader" is a radiologist or physician that is trained and certified by NIOSH to read and interpret chest X-rays in a systematic way with special emphasis on detecting lung abnormalities caused by the inhalation of dusts.

The medical follow-up should include the following procedures:

❶ With a positive chest x-ray (1/0 or greater), the employee should be placed in mandatory respiratory protection, or if already wearing a respirator, the program should be reevaluated to assure proper fit and the elements of OSHA's Respiratory Protection Standard, 29 CFR 1910.134 are being met.

❷ The employee should be referred to a physician specialized in lung diseases for a medical evaluation and medical monitoring as warranted by the examining physician. A written opinion from the examining physician as to whether the employee has any detected condition that would place the worker at an increased risk should be provided to the employer and employee, if the chest x-ray is positive (1/0 or greater) while specific medical findings remain confidential. Procedures should be developed for reducing exposures of employees whose X-rays show changes consistent with silicosis.

❸ All medical test results should be discussed with the employee by the physician. If clinically significant non-occupational abnormalities are identified, the employee should be urged to seek treatment.

❹ In accordance with 29 CFR 1910.1020, medical records shall be maintained for at least 30 years following the employee's termination of employment, unless the employee is employed for less than one year and the records are provided to the employee upon termination. This is necessary because of the chronic nature and long latency of silicosis.

Training

Employees should receive training [29 CFR 1926.21] that includes the following:

- Information about the potential adverse health effects of exposure to respirable crystalline silica. Make sure they know what operations and materials present a silica hazard. Advise employees of increased risk of impaired health due to the combination of smoking and silica dust exposure.
- Material safety data sheets for silica, alternative abrasives, or other hazardous materials [29 CFR 1926.59].
- Instruction about the purpose and set-up of regulated areas marking the boundaries of work areas containing crystalline silica.
- Information about safe handling, labeling, and storage of toxic materials [30 CFR 56.20012, 56.16004, 57.20012, 77.208].
- Discussion about the importance of engineering controls, personal hygiene, and work practices in reducing crystalline silica exposure.
- Instruction about the purpose, proper use and care of appropriate protective equipment (including protective clothing and respiratory protection).
- Monitoring, monitoring results and medical surveillance.

Engineering Controls

A plant should evaluate the circumstances leading to exposure to crystalline silica, and the use of effective controls. Proven methods of control include area clean-up and bag house maintenance. This is necessary to select the proper respirator assigned protection factor (APF) and ensure that workers are not overexposed (i.e., measured silica dust concentration is less than the exposure limit multiplied by the respirator APF).

- Regular training of personnel in proper use of respirator, and its limitations.
- Selection of proper NIOSH-approved respirators. If silica sand is used as an abrasive, despite its much greater hazard relative to other abrasive agents, only the highest level protection respirators (i.e., respirators certified by NIOSH for blasting: Type CE pressure-demand or positive pressure and with NIOSH recommended APFs of 1000 or 2000) should be used. Anytime environmental conditions, airborne contaminants, or their concentrations are highly variable or poorly defined, high level respiratory protection should be used, even if silica is not the abrasive agent.
- A medical evaluation of the worker's ability to perform the work while wearing a respirator. No one should be assigned a task requiring use of respirators unless found physically able by a physician or other licensed healthcare professional to do the work while wearing the respirator.
- Respirator fit testing. Determination of face piece fit should involve both qualitative (QLFT) and quantitative (QNFT) tests. A qualitative test relies on the wearer's subjective response to the introduction of an aerosol challenge agent, such as irritant fume, denatonium benzoate, or saccharin, into the area around the face of the respirator wearer. A quantitative test uses some actual measurement of a challenge agent (e.g., corn oil) in a test chamber divided by the concentration of the agent in the respirator.
- Maintenance, inspection, cleaning, repair, and storage of respiratory protection equipment. Respirators will only provide a satisfactory level of protection when they are selected, fitted, used, and maintained according to the manufacturer's written instructions, NIOSH approval limitations and guidelines, and OSHA regulatory requirements.

  Respirators should be assigned to individual workers for their exclusive use. Respirators should be cleaned and disinfected after each day's use. Respirators must be inspected during cleaning. Worn or deteriorated parts must be replaced. Damaged or altered respirators must not be used. All respirators must be stored in a convenient, clean and sanitary location.
- The respiratory protection program should be evaluated regularly (at least annually) by the employer to determine its continued effectiveness.

Many sandblasters in the precast concrete industry work with adequate respiratory protection, however, workers near the sandblaster generally wear no protection at all. Care should be taken to prevent the dust cloud from spreading to other work areas.

OSHA 1910.94 (a)(1)(ii) defines an abrasive-blast respirator as a continuous-flow air-line respirator constructed to protect the user's head, neck, and shoulders from rebounding abrasives. This was the only available equipment at the time the regulation was implemented. Positive-pressure Type CE, abrasive-blast respirators (APF of 1000 or 2000) are now available, and NIOSH recommends their use when crystalline silica is generated in abrasive blasting.

Currently, four Type CE abrasive-blasting respirators are certified by NIOSH. These four kinds of respirators and the NIOSH recommended assigned protection factors* (APF) are:

❶ A continuous-flow respirator with a loose-fitting hood and an APF of 25 is most commonly used, Fig. 1.

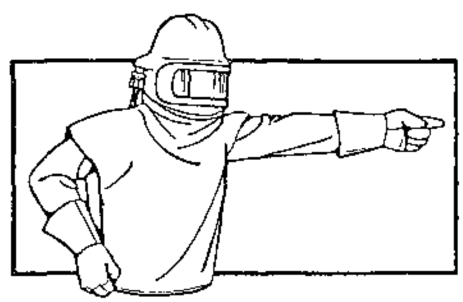


Fig. 1. Supplied air respirator, hood style, Type CE.

❷ A continuous-flow respirator with a tight-fitting facepiece and an APF of 50.

Continuous-flow, Type CE, abrasive-blast supplied-air respirators (SAR) should only be used if (a) silica sand is NOT used as the blasting agent AND (b) workplace monitoring indicates that the level of contaminant in the ambient air does not exceed 25 or 50 times the recommended exposure limit, respectively. The

* Note: OSHA has no APFs for silica therefore employers should use NIOSH selection criteria for guidance. Air purifying and powered-air purifying respirators are not recommended for abrasive blasting operations, but may be suitable for auxiliary work such as outside clean-up operations.

TABLE 2. Alternative Abrasive Materials

ABRASIVE	PRICE*	SPECIAL EQUIPMENT AND PROPERTIES
ALUMINUM OXIDE	$660/Ton	Closely Sized, Very Hard (MOH 8.5-9)
BAKING SODA (Sodium Bicarbonate) or Trona (Natural Sodium Carbonate/Sodium Bicarbonate)	$900/Ton	Special Equipment Required (Meters Less Product/Min and Dries Air), Low Nozzle Pressures (35-90 PSI), Less than 1% Free Silica, Water Soluble/Less Cleanup, Non-Sparking, Non-Flammable
COAL SLAG	$44/Ton 100-150	May Contain Toxic Metals, Less Than 0.1% Free Silica, Inert, Fast Cutting, Hard (MOH 6-7), Angular, Uniform Density, Low Friability
COPPER SLAG	$50/Ton	May Contain Toxic Metals, Blocky, Hard (MOH 7-8), Sharp Edged
CORN COB GRANULES	$350/Ton	Special Ventilation May Be Required in Enclosed Areas to Control Combustion, Medium Hardness (MOH 4.5), Non-Sparking, Low Dust Levels, Biodegradable
DRY ICE (Carbon Dioxide)	$60-80/Ton	Dry Air Required, No Residue Remains, Natural Gas in Solid State, Minimal Cleanup
GARNET	$325/Ton	Low Dust Levels, Fast Blasting Rates, Low Free Silica <0.5%, Very Hard (MOH 7.5 to 8), Very Heavy (S.G. 4.1), Subangular, Low Nozzle Pressures (60-70 PSI)
GLASS BEADS	$500/Ton	Manufactured of Soda Lime, Uniform Size and Shape
NICKEL SLAG	$70/Ton	Very Hard (MOH 7-8), Blocky, Sharp Edged, Poor Visibility, May Contain Toxic Materials
NUT SHELLS	$360/Ton	Special Ventilation May Be Required in Enclosed Areas to Control Combustion, Soft, Non-Sparking
OLIVINE	$76/Ton	Natural Mineral, Hard (MOH 6.5-7), High Specific Gravity, Angular
PLASTIC MEDIA (Polyester, Urea, Melamine Varieties)	$3000-4000/Ton	Soft, Non-Abrasive, Inert, Low Nozzle Pressures (20-40 PSI)
STAUROLITE	$75-140/Ton	May Contain Up to 5% Free Silica, Rounded to Subangular Grains, Hard (MOH 6.5-7.5), Irregular Shape, Low Dust Levels
STEEL GRIT & SHOT	$425-475/Ton	Uniform Size, Uniform Hardness, Creates Anchor Profile, Low Dust Levels, Superior Visibility

* Prices are estimates based on 1994 data.

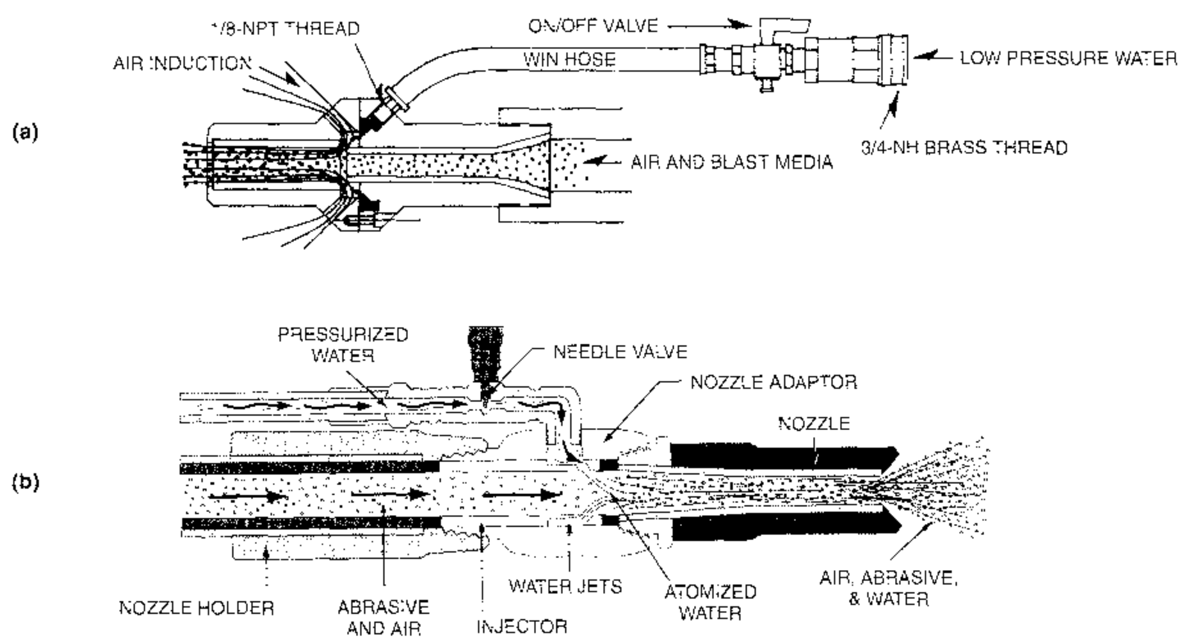


Fig. 3. (a) Water Induction Nozzle available from Fister Quarries Group and (b) Wetblast Injector System available from Clemco Industries Corp.

For greater dust suppression, another type of attachment can be installed just behind the nozzle (see Fig. 3). These systems inject water into the air and abrasive stream, more thoroughly wetting the abrasive.

A different type of wet blasting equipment is also available. This system uses 80% abrasive and 20% water mixed in a pressure vessel. Water pressure from an onboard pump forces the mixture from the vessel into a compressed airstream, where it is accelerated to the nozzle. Although to the best of our knowledge this is not used in the industry, possibly because of a thick film being deposited on the concrete surface.

If wet blasting is employed, an airborne dust hazard from the concrete surface and abrasive residue may exist after evaporation of water.

Dust should not be permitted to accumulate on the floor or on ledges outside of an abrasive-blasting area, and abrasive blast residue should be cleaned up promptly. This is particularly critical, if dispersed the dust would result in airborne concentrations in excess of the permissible exposure limit. Also, the abrasive blasting residue is a significant source of pollutant loading to stormwater. Minimize dust by following good work practices, such as removing dust with a water hose (wet sweeping instead of dry sweeping) or vacuum with a high-efficiency particulate air (HEPA) filter rather than blowing it clean with compressed air.

Air monitoring data have revealed that the dust exposure problems in yards is typically a total dust problem and not a respirable dust problem. Except in extreme cases, silica exposures are not expected to be a problem although the exposures usually exceed the OSHA limits for total dust. Over months and years the amount of dust which settles on the yard accumulates and soon enough, passing mobile equipment or gusts of wind billow up a perpetual dust cloud which eventually settles, only to be continually re-used in future dust clouds. This dust becomes pulverized, by foot traffic or heavy mobile equipment, which reduces the dust particle size, which in turn may create a future silica exposure problem. The plant should carefully evaluate the type and quantity of dust control agents being used on the yard and roads. Many forestry product dust control agents, such as lignin, are excellent for dust control but they will runoff and increase the Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) loading of stormwater runoff. An acceptable product is Coherex dust retardant which is a virgin petroleum oil with an emulsifier made by Golden Bear Oil Specialties, Chandler, AZ, (602) 963-2267.

several more years before many regions have to comply. EPA estimates that about 150 counties will be out of compliance with the PM-2.5 standards. Under current standards, 41 counties exceed limits for particulate matter (PM-10).

Many plants would be surprised to learn that the activities or equipment in their facilities could label them as "major sources" of air pollution under the Clean Air Act (CAA) Amendments of 1990. Even more surprising might be the realization that some chemicals routinely released from their sites for decades are now classified as hazardous, or toxic, air pollutants that need state or federal emission permits. Plants located in unacceptably high pollution zones or non-attainment areas are especially likely to warrant an examination of their status relative to regulations emerging as a direct result of the CAA. As a result, many plants should anticipate costs associated with inventorying, permitting and controlling their air pollution sources.

The maximum opacity of visible particulate emissions is controlled by the states or counties. Areas with ambient air quality problems often have tighter visible emissions limits than other areas. In order to determine potential emission limits for abrasive blasting, or for emissions from roadways or material storage piles, a plant needs to contact their state EPA. The plant should have the average opacity of the emissions from any fugitive dust source determined to ensure compliance. Plant personnel may receive certification as a qualified observer by meeting the requirements of U.S. EPA Method 9 Visual "Determination of the Opacity of Emissions from Stationary Sources."

CAA and Title V. With the changes to the Clean Air Act (CAA) in 1990, the very nature of permitting for air pollution sources was overhauled. Under the new requirements spelled out in Title V (Permits) of the CAA, states must develop a comprehensive operating permit system for sources.

At the federal level, these clean air compliance laws have been codified by the U.S. Environmental Protection Agency regulations contained primarily in 40 Code of Federal Regulations (CFR) Parts 52, 60, 61, 63, and 70. Most State Implementation Plans (SIPs) are based on these regulations, although critical differences can and do exist. Depending on the state, additional permitting requirements may also apply.

All stationary point sources, all fugitive emissions, all air pollution control equipment, most mobile sources and many work practices should be evaluated for inclusion in an emissions inventory. Many sources may ultimately be considered insignificant or "de minimis" and therefore exempt from Title V reporting – depending on the language of the state's own program rules – but all should be included in at least an initial emissions listing.

Air emissions permits are required for almost all existing plants, modifications to existing pants and for new concrete production plants. It is impossible within the scope of this article to do more than mention key aspects of the Clean Air Act that should be considered in trying to ascertain if a Title V permit is required. Some of the more important questions to be answered are:

- Does the sum of all the sources of all air pollutants at the site constitute a major source (i.e., in an attainment area, does the operation have the potential to emit 100 tons per year for attainment areas (areas which meet national ambient air quality standards), or 25 tons per year for non-attainment areas, of any criteria air pollutant, or 10 tons per year of any of 188 listed "hazardous" air pollutants)? These levels exceed most precast concrete plant emissions rates which will typically vary from 3 to 20 tons per year. However, if plant is in a severe particulate or ozone non-attainment area, thresholds will vary (see 40 CFR Part 70.3).
- Is the facility located in a non-attainment area for one or more specific air pollutants (e.g., ozone or carbon monoxide)? Different timelines and control technologies (e.g., maximum achievable control technology versus best available control technology or reasonably available control technology) are in effect for attainment versus non-attainment areas, with lower emission limits requiring permits being applicable in non-attainment areas.
- If in a non-attainment area, what is the non-attainment areas classification: "marginal," "moderate," "serious," "severe" or "extreme." And are changes to the current attainment status pending with the EPA? Depending on the classification, different emission limits for compliance exist.
- What governmental entity is responsible for CAA compliance, and what is the status of implementation plans? In some states, responsibility for CAA compliance rests with a county governmental office or specially designated airshed district. Some state implementation plans have elected to defer for the maximum five years any regulation of nonmajor sources.

in 5 of 12 bulk samples analyzed by NIOSH. Manganese in the range of 100-700 µg/gm was found in all 4 bulks used for elemental analysis. 50-60% of garnet is composed of iron oxide and aluminum oxide, which were classified earlier by ACIGH, NRC, and IARC as being nonfibrogenic and noncarcinogenic.

Staurolite

Staurolite is composed of 29% silicon dioxide, and according to suppliers, less than 2% quartz. About 1.0% quartz was found in 2 of 4 bulk samples analyzed by NIOSH. 59% of staurolite is composed of aluminum oxide and iron oxide, which were classified earlier by ACIGH, NRC, and IARC as being nonfibrogenic and noncarcinogenic.

Coal Slag

Coal slag is composed of 45-50% silicon dioxide and no quartz. The gamma range is 15-20 pCi/g. Eighteen bulk samples analyzed for 28 elements contained the following: arsenic in 8, beryllium in 12, chromium in 9, nickel in 14, manganese in 12. Three NIOSH studies by Stettler indicated coal slag to cause moderate pulmonary fibrosis, but much less fibrogenic potential than silica sand [Stettler 1981,1982, 1988].

Copper Slag

Copper slag is composed of 45% silicon dioxide and no quartz. Seven bulk samples analyzed for 28 elements contained the following: arsenic in 3 (up to 1450 µg/gm), beryllium in 2 (up to 180 µg/gm), chromium in 5 (up to 2400 µg/gm), nickel in 4 (up to 2240 µg/gm), manganese in 6 (up to 2900 µg/gm), lead in 6 (up to 8900 µg/gm), and copper in 7 (up to 6400 µg/gm). Three NIOSH studies by Stettler indicated copper slag to cause minimal pulmonary fibrosis, with much less fibrogenic potential than silica sand [Stettler 1981, 1982, 1988]. However, copper slag was suggested to be carcinogenic to rats [Stettler 1981, 1982, 1988]. The NIOSH DBBS in vivo assays by Stettler were the only toxicity studies regarding copper slag.

Nickel Slag

Nickel slag is composed of 37-50% silicon dioxide and no quartz. Three bulk samples analyzed for 28 elements contained the following: arsenic in 2 (up to 180 µg/gm), chromium in all 3 (up to 3700 µg/gm), nickel in all 3 (up to 2400 µg/gm), manganese in all 3 (up to 1100 µg/gm) and lead in 2 (up to 700 µg/gm). Two NIOSH studies by Stettler indicated nickel slag to cause minimal pulmonary fibrosis, with much less fibrogenic potential than silica sand [Stettler 1981, 1982, 1988]. Nickel slag was suggested to be noncarcinogenic to rats [Stettler 1981, 1982, 1988]. The NIOSH DBBS in vivo assays by Stettler were the only toxicity studies regarding nickel slag.

Steel Grit

Steel grit is composed of 95-99% iron oxide. Therefore, one may refer to specular hematite for the toxicity of steel grit. Steel grit contains no quartz.

Aluminum Oxide

Aluminum oxide is composed of 92-97% aluminum oxide. Aluminum oxide contains no quartz, and is classified to be inert and nonfibrogenic by NRC and ACGIH and not classified as a human carcinogen by IARC and ACGIH [National Research Council 1979, IARC 1987a, b, c]. These classifications are supported by numerous studies. Over 20 toxicity studies (references) suggest the potential of neurotoxicity due to aluminum oxide exposure. Aluminum oxide is often not considered a potential substitute for silica sand in abrasive blasting since it's hardness of 10 MOHS often makes it too aggressive for many blasting tasks (it can erode expensive tungsten carbide nozzles out quickly) and the initial per ton price range of $600 to $800 dollars often makes it economically noncompetitive with silica sand.

Olivine

Olivine is composted of 39-46% silicon dioxide, but no quartz, Ten toxicity studies (references) suggest olivine to be inert and nonfibrogenic. Three toxicity studies (references) suggest olivine to be noncarcinogenic. The synthetic olivine marketed as an abrasive blasting agent out of Quebec, Canada has been found to contain little to no asbestos fibers. Asbestos fibers have been found in natural olivine as suggested by three references.

* * *

PRECAST/PRESTRESSED CONCRETE INSTITUTE

TECHNOTE

TN-1

RESULTS OF SANDBLASTING — ENVIRONMENTAL POLLUTION SURVEY

A number of producers have been cited for air pollution caused by sandblasting. In an attempt to determine current practices (1990), problems and solutions regarding sandblasting, all producers, both structural and architectural precast concrete, were surveyed in 1990.

Dust concentrations in areas adjacent to sandblast operations can be excessive as far as 75 ft from the operator, even with only a light wind. Silica particles sand remain airborne for up to 20 minutes.

- The frequency of blasting of the responding plants was: daily – 52; and occasionally – 33.
- Percent of production which is sandblasted is shown in Table 1.
- Material used for blasting (by number of producers) is:
  Silica Sand: 58
  Natural Sand: 21
  Blasting Grits (ie. Black Beauty): 20
  Ground Shells or Corn Cobs: 1
  Slag: 1

Note: Silica sand does not break down as readily as bank or river sand, thus much less fine-sized dust is formed. Hardness of abrasive should be checked.

- No producer was recycling abrasive. One producer had a hauler who rescreened and resold sand to others.
- A retarder was used as a blasting aid by 65% of plants. Initially a larger plume of dust results, however, the total time involved in blasting is significantly decreased when a retarder is used, thereby reducing the total air pollution.

One plant reported that in order to avoid a dust plume they have gone to using a light retarder and high pressure water washing and then blasting with slag to dull the surface. They report slag is clean and does not produce dust.

- The reported pressure at the nozzle ranged from 60 to 150 psi (average 101 psi). Three producers exceeded manufacturers' maximum working pressure of 125 psi. However, they may have been reading it on the compressor and/or on the sandblast machine, while these are indicators of the pressure at that point, they do not indicate the pressure that exists at the nozzle. To determine the pressure at the nozzle, it is necessary to use a hypodermic needle gauge inserted into the sandblast hose (while operating).

  The compressor size used varied from 30 to 250 H.P. (average 109 H.P.) with the air volume varying from 100 to 1500 cfm. (average 428 cfm). The number of pots used per compressor varied from ½ to 8 (average 1½ pots) with 62% of respondents using 1 pot per compressor.
- The nozzle orifice size used by various plants is shown in Table 2.
- 14 out of 85 plants were blasting wet. PCI is aware of 9 plants not responding that also have used wet blasting. Several plants stated that EPA has stopped the use of dry blasting due to plumes of dust.
- The most popular method of water blasting was using the water ring at the nozzle (12 responses).

TABLE 2 Nozzle Orifice Size (in.)

	1/8	1/4	5/16	3/8	7/16	1/2	5/8
No. of Plants	1	9	14	24	3	8	4

TABLE 1 Percent of Production Sandblasted

	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
No. of Plants	16	18	12	4	10	2	6	7	7	3