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Dawn Than Column Editor , David M. Lipton , Romie L. Herring & Marilyn Parker

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Respirable Crystalline Silica Dust Exposure During Abrasive Blast Cleaning of Bridge Deck Surfaces

Dawn Tharr, Column Editor

Reported by David M. Lipton, Romie L. Herring, and Marilyn Parker

Introduction

A study of respirable crystalline silica dust exposures during abrasive blasting operations was conducted by the North Carolina Department of Environment Health and Natural Resources (NCDEHNR), Occupational Health Section (OHS). NCDEHNR received a grant from the National Institute for Occupational Safety and Health (NIOSH) through its Sentinel Event Notification System for Occupational Risk (SENSOR) program. A portion of the grant funds was directed toward characterizing exposures during abrasive blast cleaning of bridges. This report outlines background information, exposure data, and other workplace observations gathered during monitoring and evaluation of respirable silica dust exposures during the summer of 1994.

The North Carolina Department of Transportation (NCDOT) Bridge Maintenance Unit employs nearly 380 workers in 58 crews responsible for the upkeep of bridges on roads in North Carolina. The NCDOT Safety Office estimated that 977 days of abrasive blasting were performed in 1994, or an average of nearly 17 days per crew.[1] In this study we monitored respirable silica dust concentrations of three NCDOT bridge maintenance crews (at three separate locations) that were removing deteriorating epoxy protective coatings from bridge deck surfaces.

Background

Exposure to respirable silica dust during abrasive blasting operations where silica sand is used as the blasting agent (sandblasting) continues to be a significant health risk for workers in the United States. NIOSH estimates that approximately 100,000 sandblasters are at risk, with the majority employed in the construction and specialty trades industries.[2] The risk to sandblasters for the development of acute silicosis is well documented and has been recently demonstrated by SENSOR case reports in Ohio.[3]

The American Conference of Governmental Industrial Hygienists (ACGIH) current threshold limit value (TLV™) for respirable silica dust is 0.1 mg/m^3.[4] In 1975 NIOSH adopted a recommended exposure limit (REL) of 0.05 mg/m^3. Simultaneously, NIOSH recommended banning the use of silica as an abrasive in blasting operations.[5]

Open-air sandblasting, using nonenclosed, portable, hand-operated blasting equipment, typically produces large quantities of respirable dust; poorly protected sandblasters and nearby workers have been shown to be exposed to hazardous dust concentrations. In a 1974 study, NIOSH found that when silica was used as the abrasive, dust concentrations around protected and unprotected blast operators, as well as nearby workers, frequently exceeded Occupational Safety and Health Administration (OSHA) limits and ACGIH TLVs that were in effect at the time. Dust concentrations 75 to 100 ft downwind of a sandblasting operation were found to exceed the TLV.[6]

Until 1989, the OSHA permissible exposure limit (PEL) for respirable silica-containing dust used the following formulas: 10 mg/m^3/(%SiO_2 + 2) for general industry and 250 mppcf/(%SiO_2 +5) for construction.[7,8] The 1989 revisions to the PELs changed the limit to be equivalent to the TLV for general industry, but did not change the limit for construction.[9] However, since the revised limits were vacated by the 11th Circuit Court, the 1970 limits remain in effect. In North Carolina the state OSHA program adopted the 0.1 mg/m^3 limit for general industry, but did not change the limit for construction.[10]

Both NIOSH and OSHA have recognized that blast operators must use supplied-air respirators during open-air blasting. Furthermore, nearby workers may also need respiratory protection. Both agencies have emphasized that employers must develop and implement respiratory protection programs to ensure effective respirator use during sandblasting operations, including providing Grade D breathing air for supplied-air respirators.[11–14]

Process and Exposure Assessment

Bridge deck surfaces on roads in the mountains of North Carolina are coated with epoxy for corrosion protection. Periodically, worn coatings must be removed and the deck re-coated. The epoxy surface coatings are removed using hand-held, open-air, portable abrasive blasting units. In addition to the abrasive blaster, other employees are present to help with auxiliary duties. Job tasks include: abrasive blaster, hopper loader, traffic controller, and flagger. A typical crew includes one blaster, one or two traffic controllers, two hopper loaders, and one flagger.

The workday for the bridge maintenance crew included activities at the maintenance yard, travel to and from the job site, setup/take-down of traffic controls, and duties relative to abrasive blasting. These nonblasting activities did not contribute to silica exposures, but were significant portions of these employees' normal workdays. The typical daily duration of abrasive blasting operations was between 4.5 and 5.5 hours.

Upon arrival at the bridge, traffic control measures such as cones, signs, and barricades were put in place. Once employees were fitted with the sampling equipment and the sand hopper was filled, the abrasive blasting began. At each site the blasting agent was the same type of commercial sand from the same mine site. The abrasive blaster was the worker who operated the blasting nozzle. Traffic controllers worked on the road surface near the abrasive blaster moving air hoses, shoveling spent sand, and acting as traffic lookouts for the blaster. Hopper loaders were located on the beds of work trucks between 20 and 50 feet from the blasting operation. Their primary task was to keep the sand hopper filled by manually pouring 50-lb bags of sand into the blasting pot. Flaggers warned oncoming traffic of the work zone. NCDOT procedures specify the flaggers' distance from the work based on factors such as the type of road and speed limit. At all sites in the study the flagger was at least 200 ft from the work zone. Spent sand remaining on the road at the end of the workday was blown off the road surface with a compressed-air wand. This task had a typical duration of 15 to 30 minutes and created a large visible dust cloud.

At each job site a diesel compressor supplied air for both the blasting unit and a Clemco™ continuous positive-pressure, air-supplied respirator. The compressor did not have a high temperature alarm. The Clemco helmet was provided with an in-line cartridge air filter. The abrasive blaster always wore this type of supplied-air respirator; however, there was variability in the use of respirators by other workers. At site A none of the other employees on the crew used respiratory protection. At site B a hopper loader wore a half-mask air-purifying respirator with high efficiency particulate air filters; traffic controllers wore disposable dust/mist respirators. At site C a hopper loader and a traffic controller wore disposable dust/mist respirators.

Personal samples were collected using precalibrated and postcalibrated Gilian Hi Flow samplers at a flow rate of 1.7 L/min with MSA and Bendix 10-mm nylon cyclones and tared polyvinylchloride filter assemblies. All samples were collected in the employees' breathing zones. Workers operating the abrasive blasting unit wore the cyclone/filter assembly inside the abrasive blasting respirator helmet. It was not unusual for employees to rotate jobs during the day. At sites A and B personal filters were changed when employees switched job duties. Even though employees at site C rotated jobs, the filter for the blaster remained inside the helmet to simulate one person's exposure if she/he performed all the blasting on that day.

Gravimetric determination (NIOSH Analytical Method 0600) was conducted by the NCDEHNR's American Industrial Hygiene Association (AIHA)-accredited laboratory.(15) Subsequent analysis for crystalline silica was conducted in accordance with NIOSH Analytical Method 7500 (X-ray diffraction) by a private AIHA-accredited laboratory through a contract with OHS.(16)

TABLE 1. Respirable Silica Exposures to Abrasive Blasters

Site	Employee	Concentration (mg/m^3)	Exposure Time (minutes)
A	1	0.05	91
A	2	0.02	102
A	3	ND	137
B	1	0.20	94
B	2	0.16	168
C	1	ND	62
C	2	ND	211

ND = none detected above detection limit of 0.020 mg/filter.
The current ACGIH TLV for respirable dust containing more than 1 percent crystalline silica is 0.1 mg/m^3 as an 8-hour TWA concentration.

Results

The silica content (percent by weight) of the respirable dust at the three job sites ranged from 7.1 to 37.5 percent. Tables 1 to 4 show the respirable silica dust exposure data for the job classifications of abrasive blaster, hopper loader, traffic controller, and flagger, respectively, within and between sites. All concentrations reported are actual time-weighted average (TWA) exposures due to relatively short sample periods.

Although all the abrasive blasters wore an identical brand and type of air-supplied helmet, we found a high degree of variability in the blasters' exposures between sites. Concentrations ranged from nondetectable to 0.2 mg/m^3. These data may be an indication of inconsistent and/or ineffective use and maintenance of air-supplied respirators.

Traffic controllers had the highest exposures of any job classification. This was expected because these workers were on the bridge surface, near the blasting process, and in the dust cloud.

Hopper loaders also had significant exposures, but less than traffic controllers. Sources could include the dust cloud generated by the blasting operation and cleaning of the road surface with compressed air; dust generated by vehicles passing over spent sand on the road surface; and dust generated as a result of opening and pouring sand into the hoppers and disposing of empty sand bags.

Flaggers had the lowest exposures of any job classification. Again this was anticipated, as these workers were stationed at the greatest distance from any potential sources.

Based on the data gathered at the three sites, it is apparent that all the blast crews had the potential for exposure to significant concentrations of respirable silica dust. The data indicate that at each job site, in each job classification, workers received significant 8-hour TWA exposures, and in some cases overexposures, when compared with the TLV and REL. Considerable variation was found among exposures within a job site for each job

TABLE 2. Respirable Silica Exposures to Traffic Controllers

Site	Employee	Concentration (mg/m^3)	Exposure Time (minutes)
A	1	0.06	129
A	2	0.05	299
A	3	0.04	273
B	1	0.09	183
C	1	0.53	79
C	2	0.34	208

ND = none detected above detection limit of 0.020 mg/filter.
The current ACGIH TLV for respirable dust containing more than 1 percent crystalline silica is 0.1 mg/m^3 as an 8-hour TWA concentration.

TABLE 3. Respirable Silica Exposures to Hopper Loaders

Site	Employee	Concentration (mg/m^3)	Exposure Time (minutes)
A	1	0.05	221
A	2	0.04	100
A	3	0.04	122
A	4	0.06	254
B	1	0.08	308
B	2	0.16	187
C	1	0.24	83
C	2	0.35	212
C	3	0.20	134

ND = none detected above detection limit of 0.020 mg/filter.
The current ACGIH TLV for respirable dust containing more than 1 percent crystalline silica is 0.1 mg/m^3 as an 8-hour TWA concentration.

TABLE 4. Respirable Silica Exposures to Flaggers

Site	Employee	Concentration (mg/m^3)	Exposure Time (minutes)
A	1	0.02	243
A	2	0.02	283
B	ND	ND	327

ND = none detected above detection limit of 0.020 mg/filter.
The current ACGIH TLV for respirable dust containing more than 1 percent crystalline silica is 0.1 mg/m^3 as an 8-hour TWA concentration.

classification monitored. There was also considerable variation between sites. Factors that affect the exposure risk and variability may include crew work practices, job duties (loading sand hoppers), worker experience, proximity to the blasting operation, cleanup methods, wind direction (with regard to blasting, the employee, and the compressor intake), and traffic patterns.

Recommendations

All employees should be required to participate in a respiratory protection program and to wear respirators when involved in abrasive blasting operations using silica sand. Real-time monitoring of respirable silica dust, performed periodically throughout the work shift at a specific work station, may be an acceptable alternative for all blast crew members wearing respirators. There is also concern that at small mobile locations such as these, where part-time blaster operators are used, the air-supplied, abrasive blasting helmets may not be properly used (no air supplied) and the supplied air may not meet Grade D specifications. Substitution of a nonsilica blasting agent should be considered.

Conclusion

This small study does not reveal any new or surprising data, and this was not its intent. Instead, the purpose is to reopen our eyes to the old problem of using silica sand as an abrasive blasting agent. As industrial hygienists working with abrasive blasting operations, we should to be aware that abrasive blasters need proper equipment and training in the use of supplied-air respirators, and that nearby workers can have significant exposure to respirable silica dust. Our biggest challenge is to educate employees and employers about the hazards of respirable silica dust and to assist in finding alternatives to silica sand for abrasive blasting.

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Editorial Note: David Lipton, Romie Herring, and C. Marilyn Parker are with the North Carolina Department of Environmental Health and Natural Resources, Occupational and Environmental Epidemiology Section. They may be contacted at P.O. Box 27687, Raleigh, North Carolina 27611-7687; telephone: (919) 715-3506.