

Case Studies

Control Technology for Crystalline Silica Exposures in Construction: Wet Abrasive Blasting

This study was designed to document the effect that wet abrasive blasting has on reducing worker exposure to crystalline silica, which has been associated with silicosis and premature death. In this study, worker exposure to respirable crystalline silica was monitored during wet abrasive blasting on the exterior walls of a parking garage to remove surface concrete and expose the underlying aggregate. In this process a wet sand mix comprised of 80% dry sand and 20% water was used. Sampling and analysis revealed that the geometric mean respirable quartz concentration was 0.2 mg/m³ for workers conducting abrasive blasting and 0.06 mg/m³ for helpers. When abrasive blasting was conducted in areas that apparently had reduced natural ventilation, dust exposures appeared to increase. When compared with other published data, this case study suggests that wet abrasive blasting causes less exposure to crystalline silica than dry abrasive blasting.

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Abrasive blasting can generate a significant amount of dust that contains respirable crystalline silica. For example, respirable dust concentrations as high as 55 mg/m³ have been reported during abrasive blasting of a ship hull.⁽¹⁾ Abrasive blasting using sand can also lead to excessive exposure to respirable crystalline silica. In a steel fabrication yard respirable concentrations were reported to average 37 mg/m³ with mean silica content of 84%.⁽²⁾ In another steel fabrication yard respirable crystalline silica concentrations exceeded 0.1 mg/m³ as far as 200 ft downwind of an abrasive blasting operation.⁽³⁾ During abrasive blasting of steel structures and bridges, respirable crystalline silica concentrations of 200 µg/m³ were reported inside a positive pressure supplied air-blasting hood.

Premature death from silicosis still occurs. In 1998, two such deaths were reported. One was a 36-year-old sandblaster who had performed sandblasting for three years prior to being diagnosed with progressive massive fibrosis. He died 11 years after his initial exposure. The second worker died of respiratory failure in 1996 at age 30 as a consequence of silicosis after having been a sandblaster from 1986 to 1990. At autopsy the lungs from both of these workers were found to have extremely high silica contents.⁽⁴⁾ During the period between 1968 and 1992, about 10 workers between the ages of 15 and 44 died of silicosis each year. Each of these deaths was attributed to recent and intense exposure to crystalline silica. Other investigations have reported that dust masks and air-purifying respirators are used inappropriately for abrasive blasting.^(5,6) These respirators were used beyond the assigned protection factor and were frequently used without fit testing.

The Occupational Safety and Health Administration (OSHA) respirator standard [29 CFR 1910.134] requires the use of engineering control measures to reduce worker air contaminant exposure as much as possible by using accepted engineering control methods before the use of respirators is considered. One approach to minimizing dust

generation during abrasive blasting is to use water to suppress the generated dust. This case study describes the findings of a field trial conducted to evaluate a wet abrasive blasting method. One commercially available, wet abrasive blasting process is Torbo blasting (Keizer Technologies, Dallas, Texas). The dust exposures generated by using this process were evaluated during a field study that was conducted March 30–April 1, and April 14–15, 1999, in Irving, Texas.

EXPOSURE EVALUATION CRITERIA

To evaluate the hazards posed by workplace exposures, National Institute of Occupational Safety and Health (NIOSH) field staff use permissible and recommended exposure limits (PEL, REL) established by OSHA, NIOSH, or the threshold limit values (TLVs[®]), suggested by the American Conference of Governmental and Industrial Hygienists (ACGIH[®]), as criteria for assessment of a number of chemical and physical agents. Those criteria are intended to require (OSHA), recommend (NIOSH), or suggest (ACGIH) concentrations at which workers may be exposed for up to 10 hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects.

The NIOSH REL for respirable crystalline silica is 0.05 mg/m³, while the OSHA PEL varies based on the amount of quartz in dust. The current OSHA PEL is 15 mg/m³ for particulates not otherwise classified (respirable), and 5 mg/m³ for particulates which are inhalable. The OSHA PEL for respirable dust containing quartz (in mg/m³) is calculated from the following formula:

$$\text{PEL} = \frac{10}{\% \text{ silica} + 2} \quad (1)$$

SITE DESCRIPTION

The study site consisted of two three-story parking garages identified as the east and the west garages. The west garage was located closest to a highway. Each garage was 180 ft × 310 ft and had three levels of parking. On each level there was a 4-foot-high outside wall. The abrasive blasting was done to remove about 1/8" of the cured concrete to expose the underlying aggregate and improve the appearance of the building (see Figure 1).

Three workers performed this task. Two workers performed abrasive blasting and one worker tended the blasting machine. One worker performed abrasive blasting at ground level (Figure 1) and the second worker performed abrasive blasting on an elevated platform (Figure 2). The work practices were the same for both workers. However, because the platform needed to be moved from time to time, the duration of actual sandblasting on the platform was somewhat less than when it was performed on the ground. All the workers wore

an N95 disposable respirator (3M, model 8210, Minneapolis, Minn.).

A Torbo Wet Abrasive Blasting System (model 320, Keizer Technologies North America, Euless, Texas) was used. The mixing tank of the system was charged with 16 100-lb bags of Grade 3 sand (Texblast, Tex Minerals, Dallas, Texas), which was then filled with water to yield an 80/20% sand/water mix. The material safety data sheet for sand stated that the sand had been screened to remove fines. The feed rate for the water/sand mixture was 6 liters per minute (L/min). A metering system fed the wet sand and additional water into a fluidizing system. Additional water was not used during the testing on March 30 and 31. During the data collection on April 14 and 15, an additional 3 L/min of water was added to the wet sand mixture in an effort to reduce dust generation. During the data collection on April 1, the application rate of additional water was not consistently set at 3 L/min. Air pressure was used to transport the water and sand to the blasting nozzle that had a diameter of approximately 1.5 in.

METHODS

In addition to the typical industrial hygiene monitoring, the workers were also fitted with video exposure monitoring equipment to evaluate the extent to which work practices may have contributed to their exposures. Complete details of this field evaluation are available in a survey report.⁽⁷⁾

Worker exposure to respirable dust and respirable crystalline silica was measured. Air samples for determination of respirable dust were collected as described by NIOSH method 0600.⁽⁸⁾ This involved mounting two sampling trains on each worker. Total dust samples were collected by mounting a 37-mm closed-face cassette on the worker's shirt collar and using a calibrated battery-operated pump to draw a known volume of air through the cassettes. Respirable dust samples were collected by mounting a 10-mm cyclone on the worker. The outlet of the cyclone was attached to the inlet of a 37-mm filter holder. A calibrated sampling pump drew 1.7 L/min of air through the cyclone. These sample collectors were turned off during the daily 30 min lunch break.

At this job site there were two groups of workers—abrasive blasters and helpers. When one of the abrasive blasters was relieved by a helper, the workers traded sampling trains. Thus, the sample results reported here are task-based and not person-based. Abrasive blasting tasks and sampling were performed for periods between 205 to 483 min. Individual sampling times are listed in the survey report.⁽⁷⁾

At the end of the sampling period, the sampling time was recorded and the plugs were placed back into the cassettes. The samples were analyzed for total weight gain per NIOSH method 0600 and were analyzed for crystalline silica by X-ray diffraction using NIOSH method 7500⁽⁹⁾ with the following modifications: Filters were dissolved in tetrahydrofuran rather than being ashed in a furnace; and standards and samples



FIGURE 1. Abrasive blasting at ground level

were run concurrently and an external calibration curve was prepared from integrated intensities.

When an excessive amount of material was collected on the filter, the samples were treated as bulk samples. A 2-mg portion was removed from the material collected on each sample and the mass of crystalline silica in the 2-mg portion was measured. The percent of crystalline silica in this 2-mg bulk was reported. For these samples, the mass of crystalline silica was the product of the gravimetric analysis conducted under method 0600 and the fraction of crystalline silica in the bulk sample obtained from the filter cassette.

Video Exposure Monitoring

Video exposure monitoring was used to qualitatively evaluate how specific worker tasks may have affected dust exposure.⁽¹⁰⁾ An aerosol photometer (hand-held aerosol monitor (HAM), PPM Inc., Knoxville, Tenn.) was mounted on the worker's chest. Air is drawn through the sensing chamber of this instrument by a battery-operated pump at 2 L/min. The dust in the sensing chamber scatters light emitted from a light-emitting diode. The scattered light is then detected by a photomultiplier tube. The analog output of the aerosol photometer is proportional to the amount of light detected by the photomultiplier tube. In addition, the amount of light

scattered by the aerosol also varies with particle size and optical properties such as the refractive index. Thus, the analog output of the aerosol photometer is a measure of relative concentration. The HAM was set to have a 1-sec time constant; thus, after three time constants the instrument's response will be 95% complete. The HAM's analog output is a voltage that is proportional to concentration. This voltage was recorded with a data logger (Metrologger dl 3200, Metrosonics, Rochester, N.Y.). While the output of the HAM was recorded on the data logger, the worker's activities were simultaneously recorded on videotape. The video camera was located about 8 m from the worker to provide a view of their work practices.

RESULTS

The summary statistics for the respirable crystalline silica concentrations are in Table I.

During this study, there was a concern about what appeared visually to be excessive dust concentrations. During the April 1 visit, additional water was added at a rate of 3 L/min to the normal 80/20% sand/water mixture. Unfortunately, the workers often stopped the use of this more watery mixture during the day. Therefore, during the second sampling effort



FIGURE 2. Abrasive blasting from an elevated platform

in April, steps were taken to ensure that the additional water application rate was maintained at 3 L/min.

Analysis of variance (ANOVA) was used to evaluate whether the worker's task (listed in Table I), the application rate of additional water, and an interaction between additional water application rate and work task affected worker exposure to respirable crystalline silica.⁽¹¹⁾ The statistical analysis was performed on the logarithms of the concentrations. SAS General Linear Models procedure was used to perform the analysis of variance. The independent variables worker tasks listed in Table I and the application rate of additional water were treated as qualitative or categorical variables. The application rate of additional water had three levels: 0.0 L/min (March 30 and 31), 3 L/min (April 14 and 15), and "intermediate" value for

April 1. As described in the preceding paragraph, the use of 3 L/min during April 1 was inconsistent and the water application rate was assigned the categorical value "intermediate." The ANOVA revealed that worker task affected worker exposure ($p = 0.05$), but water application rate did not affect the respirable crystalline silica exposures ($p > 0.5$).

The effect of worker task on respirable dust concentrations and respirable crystalline silica concentrations are shown in Tables II and III. In the column labeled "Multiple Comparison Test," geometric means with different letter codes differ significantly. For example, in Table III the geometric mean respirable silica exposure for blasting on a platform does not differ significantly from values for the helper and blasting at ground level. The multiple comparison test (Tukey's Studentized Range)

TABLE I. Respirable Crystalline Silica Exposures—Summary Statistics

Description of Work	N	Geometric Mean (mg/m ³)	Geometric SD	Range (mg/m ³)
Abrasive blasting at ground level (see Figure 1)	7	0.22	1.59	0.12–0.43
Abrasive blasting from an elevated platform (see Figure 2)	9	0.13	2.25	0.04–0.41
Helper	8	0.06	2.08	Less than 0.02–0.12

TABLE II. Geometric Mean Respirable Dust Concentrations for Different Work Activities

Worker Activity	N	Geometric Mean (mg/m ³)	Multiple Comparison Test ^A
Blasting at ground level	7	0.93	a
Blasting on elevated platform	9	0.60	b
Helper	8	0.34	b

^AGeometric means with different letters differ significantly.

is used to evaluate the differences in the geometric means. Multiple comparison tests were conducted to an overall confidence level of 95%. This means there is a 5% chance of falsely declaring one or more differences between geometric means significant. The helpers were exposed to significantly less respirable dust and respirable crystalline silica than the workers who performed abrasive blasting at ground level.

Figures 3 and 4 present the HAM output from video exposure monitoring. None of the work practices appeared to affect exposure; however, wind and location did appear to have a noticeable impact on worker dust exposure. With the exception of three peaks, the worker's dust exposure in Figure 3 remains below 8 mg/m³. In Figure 4, abrasive blasting in areas that were isolated from the ambient wind appeared to cause noticeable exposure peaks that are above 20 mg/m³ when the worker was sandblasting below ground grade in a

TABLE III. Geometric Mean Respirable Quartz Concentrations at Different Work Activities

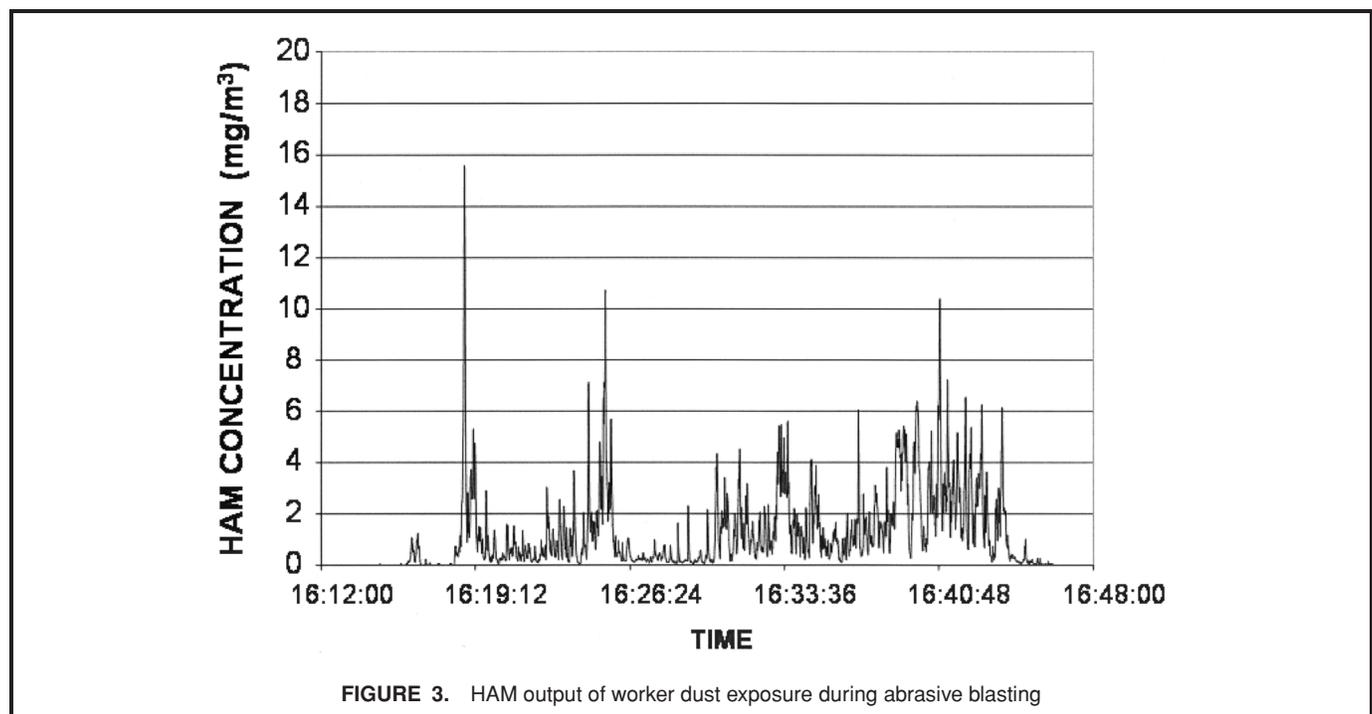
Worker Activity	N	Geometric Mean (mg/m ³)	Multiple Comparison Test ^A
Blasting at ground level	7	0.22	a
Blasting on elevated platform	9	0.13	a,b
Helper	8	0.06	b

^AGeometric means with different letters differ significantly.

poorly ventilated area on the leeward side of the building. Figure 4 is annotated to note when the worker was below the grade of the ground as shown in Figure 5.

DISCUSSION

The crystalline silica exposures found in this study for the workers performing abrasive blasting ranged from 0.04 to 0.4 mg/m³ with a geometric mean of 0.2 mg/m³. Although those exposures exceeded the NIOSH REL and the current OSHA PEL, they were less than exposures that have been reported by others. For example, other dry abrasive blasting operations reported in the literature demonstrated that worker exposures were as great as 25 mg/m³ outside of a supplied air respirator and exposures inside a supplied air blasting helmet were 0.2 mg/m³ respirable crystalline silica.⁽⁵⁾ In a review



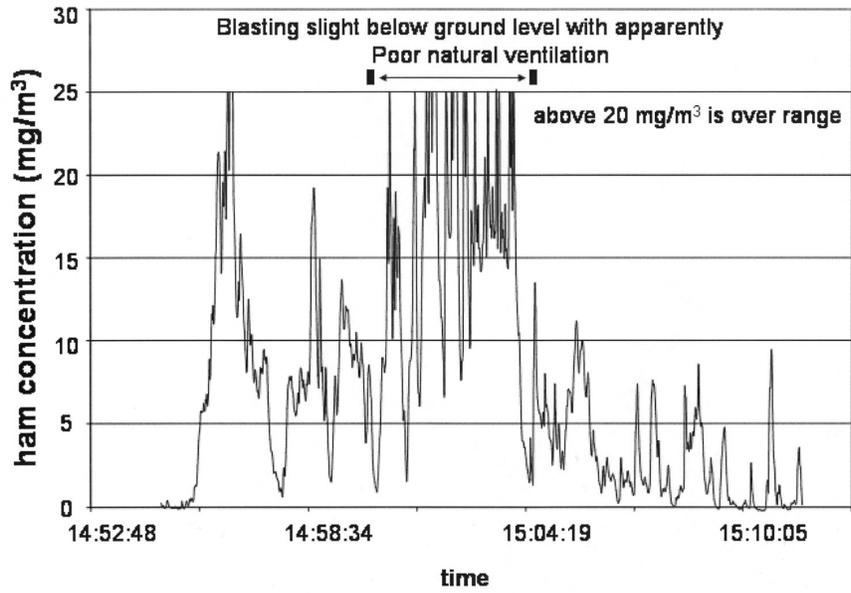


FIGURE 4. HAM output of worker dust exposure when isolated from ambient wind



FIGURE 5. Abrasive blasting below ground

of silica exposures among painters who spent part of their shift performing abrasive blasting, respirable crystalline silica exposures were between 0.26 and 26.2 mg/m³.⁽¹²⁾

With respect to respirator selection, the exposures found in this study were less than 5 times the OSHA PEL for crystalline silica and less than 10 times the NIOSH REL for crystalline silica. For that magnitude of exposure an air-purifying respirator with an assigned protection factor (APF) of 10 or better will provide appropriate exposure reduction. The filter facepiece respirators used at this site had a NIOSH APF of 5 or an American National Standards Institute (ANSI) APF of 10.⁽¹³⁾ In 2003, OSHA proposed an APF of 10 for half-facepiece respirators including filtering facepiece respirators.⁽¹⁴⁾

Review of the videotapes and the analog output of the HAMS indicates that work practices did not affect exposure. However, abrasive blasting in areas that were isolated from ambient air motion appeared to increase worker dust exposure.

The sand used for blasting appeared to be very coarse and it appeared to contain minimal fines that may also explain the relatively low respirable crystalline silica exposures. Based on the data obtained in this study, the extent to which the exposures were reduced by the presence of water or by the apparent absence of fine material in the sand could not be determined. It is also possible that the concrete substrate may have been the source of much of the crystalline silica exposure. Furthermore, the ratio of the respirable crystalline silica to respirable dust was 0.22 ± 0.04 . Typically, concrete aggregate is 20% silica.⁽¹¹⁾ This is consistent with the hypothesis that the substrate itself is the source of the crystalline silica exposures.

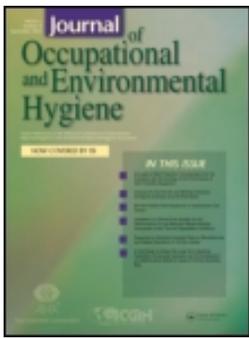
CONCLUSIONS

At the study site the wet abrasive blasting system, including the use of sand that had been screened to remove fines, resulted in respirable crystalline silica exposures that were sufficiently low that air-purifying respirators could be used to control worker exposure to crystalline silica. The extent to which the addition of water or the removal of fines reduced respirable silica exposure is unclear. However, the respirable

silica exposures reported in this case study are much less than the exposures reported elsewhere.

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