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Case Studies

Control of Silica Exposure in Construction: Scabbling Concrete

Dawn Tharr, Column Editor

Reported by Alan Echt, William Sieber,
Aaron Jones, and Erica Jones

The following is the report of a project to investigate the reduction in respirable dust and crystalline silica exposures to construction workers that resulted from the use of a novel control that was conceived of and built by the site superintendent to suppress the dust generated from the use of a concrete scabbler. Scabbling concrete involves dressing the surface of the concrete to remove surface imperfections or surface coatings.

Background

In this evaluation, the scabbler was used to remove high spots and footprints from the surface of a parking deck under construction at an airport terminal. Figure 1 shows the scabbler (model SP8 G, Terex Bartell, Brampton, Ontario, Canada), a walk-behind gas-powered tool (also known as a surface grinder or scarifier) that uses a small

gasoline engine and belt drive to turn a horizontal shaft. As the shaft rotates, cutting tips on the shaft strike the concrete surface, removing material. The scabbler has an 8-inch cutting width, with a working depth of up to 1/8-inch per pass. The control evaluated was designed and built by the site superintendent. It consisted of a 15-inch spray bar made from 3/4-inch schedule 40 polyvinyl chloride pipe with 15 slots (spaced 3/4 to 1 inch apart) cut in it. The spray bar was attached to a lifting handle on the front of the scabbler with hose clamps and oriented with the slots facing downward, toward the work surface. An elbow connected the spray bar to a length of flexible hose mounted on the upright of the handle of the scabbler, with a valve mounted about midway down the handle. The hose mounted on the scabbler was fitted with a standard garden hose fitting to allow it to be connected to a water supply hose. Figure 2 shows the control in place on the scabbler.

Methods

Personal breathing zone samples were collected at a flow rate of 4.2 liters/minute using a battery-operated sampling pump connected via Tygon® tubing to a BGI GK 2.69 nickel-plated aluminum cyclone and a preweighed, 37-mm-diameter, 5-micron (μm) pore-size polyvinyl chloride filter supported by a backup pad in a three-piece filter cassette sealed with a cellulose shrink band, in accordance with NIOSH Methods 0600 and 7500.⁽¹⁾ In addition to the personal samples, bulk samples of settled dust were collected in accordance with NIOSH Method 7500.

Gravimetric analysis for respirable particulate was carried out with the following modifications to NIOSH Method 0600: (1) the filters and backup pads were stored in an environmentally controlled room ($21 \pm 3^\circ\text{C}$ and $50 \pm 5\%$ relative humidity), and were subjected to the room conditions for at least two hours for stabilization prior to tare and gross weighing; and (2) two weighings of the tare weight and gross weight were performed. The difference between the average gross weight and the average tare weight is the result of the analysis. The limit of detection (LOD) for this method is 0.02 milligrams (mg).

Crystalline silica analysis was done using X-ray diffraction. NIOSH Method 7500 was used with the following modifications: (1) filters were dissolved in tetrahydrofuran rather than being ashed in a furnace; and (2) standards and samples were run concurrently, and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure. These samples were analyzed for two forms of crystalline silica—quartz



FIGURE 1
The scabbler in use without the control.

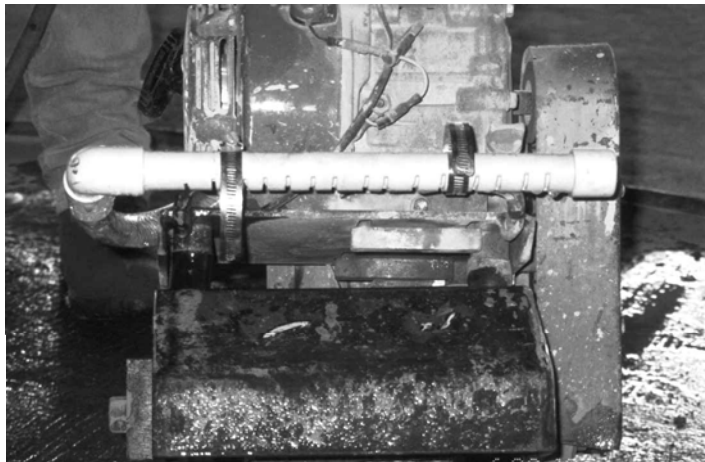


FIGURE 2

Close-up of the control. Note the slots and the hose clamps that hold the spray bar in place.

and cristobalite. The LODs for air samples for quartz and cristobalite were 0.01 mg and 0.02 mg, respectively. The limit of quantitation (LOQ) for air samples was 0.03 mg for both quartz and cristobalite. Bulk samples were collected and analyzed qualitatively for quartz and cristobalite by X-ray diffraction to determine if any interferences were present in the material. The LODs in bulk samples were 0.8 percent for quartz and 1 percent for cristobalite. The LOQ was 2 percent for both forms of crystalline silica in bulk samples.

A direct-reading instrument and video exposure monitoring techniques were also used to characterize exposure.⁽²⁾ The worker being sampled wore a HazDust II real-time personal dust monitor with a respirable particulate pre-separator, while his actions were recorded using a digital video camcorder mounted on a tripod. The HazDust II was equipped with a preweighed, 37-mm diameter, 5- μ m pore-size polyvinyl chloride filter supported by a backup pad in a two-piece filter cassette sealed with a cellulose shrink band in-line after the sensor. This filter was analyzed as noted above to determine the percentage of crystalline silica in the sample. In the laboratory, the data collected with the personal dust monitor were overlaid onto the video recording.

During an initial site visit, preliminary “range-finding” sampling was conducted to observe the effectiveness of the control and determine the need for more sampling. This sampling consisted of four brief trials of personal breathing zone sampling and video exposure monitoring. Two trials were conducted while an employee operated the scabbler with the control in use, and two trials were conducted without the use of the control. Additional personal breathing zone sampling and video exposure monitoring were conducted on a follow-up visit. Sixteen samples were collected in eight paired tests. One of the tests in each pair was performed with the use of water (control “on”), and one test in each pair was performed without the use of water (control “off”). The order of the tests in each pair was determined randomly. Based on results from the initial survey, eight samples each of control “on” and control “off” were considered the optimal number to detect a reduction in exposure levels when the control is used compared to when it is not used, assuming a significance (α) of 0.05 and power of between 90 and 95 percent to detect a reduction.

The flow rate of water supplied to the tool was measured using a 1-gallon bucket and a stopwatch. The time required to fill the bucket was measured and recorded.

Criteria

Silicosis is an occupational respiratory disease caused by inhaling respirable crystalline silica dust. Silicosis is irreversible, often progressive (even after exposure has ceased), and potentially fatal. Exposure to silica dust occurs in many occupations, including construction. Because no effective treatment exists for silicosis, prevention through exposure control is essential. When proper practices are not followed or controls are not maintained, silica exposures can exceed the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) or the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL).^(3,4)

The NIOSH REL for respirable crystalline silica is a 10-hour time-weighted average (TWA) level of 0.05 mg/cubic meter (m^3). NIOSH has classified crystalline silica as a potential occupational carcinogen. Therefore, NIOSH recommends that employers make efforts to reduce silica exposures to levels below the REL.

The OSHA PEL for respirable dust containing ≥ 1 percent quartz is expressed as the following equation:

$$\text{Respirable PEL} = \frac{10}{(\% \text{ Silica}) + 2}$$

Thus, if the dust contains no crystalline silica, the PEL is 5 mg/m^3 , and if the dust is 100 percent crystalline silica, the PEL is 0.1 mg/m^3 . For tridymite and cristobalite (other forms of crystalline silica), OSHA uses half the value calculated when using the formula for quartz.

Results

The results of the preliminary sampling performed during the initial site visit are presented in Table I. These results illustrated the ability of the control to reduce employee exposures to respirable dust and crystalline silica, and demonstrated the need for additional sampling to quantify the extent of the reduction in exposure.

TABLE I
Results of air sampling to evaluate control effectiveness

Pair	Condition	Time (min)	Volume (m ³)	Respirable dust (mg)	Quartz (mg)	Respirable dust (mg/m ³)	Quartz (mg/m ³)
Initial survey							
	Dry	8	0.034	0.57	0.069	17	2.1
	Dry	7	0.029	0.39	0.050	13	1.7
	Wet	11	0.046	ND ^A	NA ^B		
	Wet	16	0.067	0.027	NA	0.40	
Follow-up survey							
1	Wet	5	0.021	ND	NA		
	Dry	5	0.021	ND	NA		
2	Wet	5	0.021	ND	NA		
	Dry	5	0.021	ND	NA		
3	Dry	5	0.021	0.12	NA	5.7	
	Wet	5	0.021	ND	NA		
4	Dry	5	0.021	ND	NA		
	Wet	5	0.021	ND	NA		
5	Dry	5	0.021	0.17	(0.01) ^C	8.1	0.48
	Wet	5	0.021	ND	NA		
6	Dry	5	0.021	ND	NA		
	Wet	5	0.021	ND	NA		
7	Dry	5	0.021	0.28	(0.02)	13	0.95
	Wet	5	0.021	ND	NA		
8	Dry	5	0.021	0.57	0.045	27	2.1
	Wet	5	0.021	ND	NA		

^AND = not detected

^BNA = not analyzed because respirable dust values were less than the silica LOQ

^CNumbers in parentheses were between the LOD and the LOQ, and should be regarded as trace values with limited confidence in their accuracy.

Table I also presents the results of the follow-up sampling. In four of eight trials conducted, respirable dust results were less than the LOD (0.02 mg) for both the control “on” and control “off” conditions. While one would expect results less than the LOD for the control “on” condition, the reasons for these results for the control “off” condition were not readily apparent when the sampling was conducted. (It is possible that the wind direction changed, or the sampler inlet was blocked by a fold of the employee’s shirt.) For the other four trials, the control “on” samples were all not detected (ND), while the control “off” samples ranged from 0.12 to 0.57 mg/sample, or 5.7 mg/m³ to 27 mg/m³ for a 21-liter (L) sample. For the four control “off” samples where respirable dust was found, the amounts of quartz

on the filters were ND, 0.01 mg/sample, 0.02 mg/sample, and 0.045 mg/sample. An 80-percent reduction in the mean exposure levels of respirable dust was found with the use of the water control, from a geometric mean of 3.88 mg/m³ to 0.64 mg/m³. This difference was statistically significant at the p = 0.05 level. The difference was detected with 50 percent power in the 10 pairs of samples using a standard two-group t-test for equality of means.

Comparable results were not obtained for quartz levels, since all but two measurements were below the LOQ and the correction factor commonly used ($LOQ/\sqrt{2}$) was not appropriate in this case. The garden hose supplied water at a rate of about 15 gallons per minute.

The results from the direct-reading instrument measurements collected dur-

ing the initial site visit are presented in Figure 3. The sample times in the graph were truncated at 300 seconds for clarity, although actual sample times ranged from 348 seconds for the first control “off” trial to 982 seconds for the last control “on” trial. Figure 3 is a plot of the logarithms of the data. (This type of graph allows data with orders of magnitude differences to be displayed in a convenient way.) In order to take the logarithm of these data, 0.001 was added to the zero measurement with the control “on” at 285 seconds, before taking the log. These results show a substantial reduction in the concentration of respirable dust when the control is used. For the two control “off” trials, the average respirable dust values were 16 mg/m³ and 11 mg/m³, while the average (arithmetic) respirable dust values for the two control “on” trials

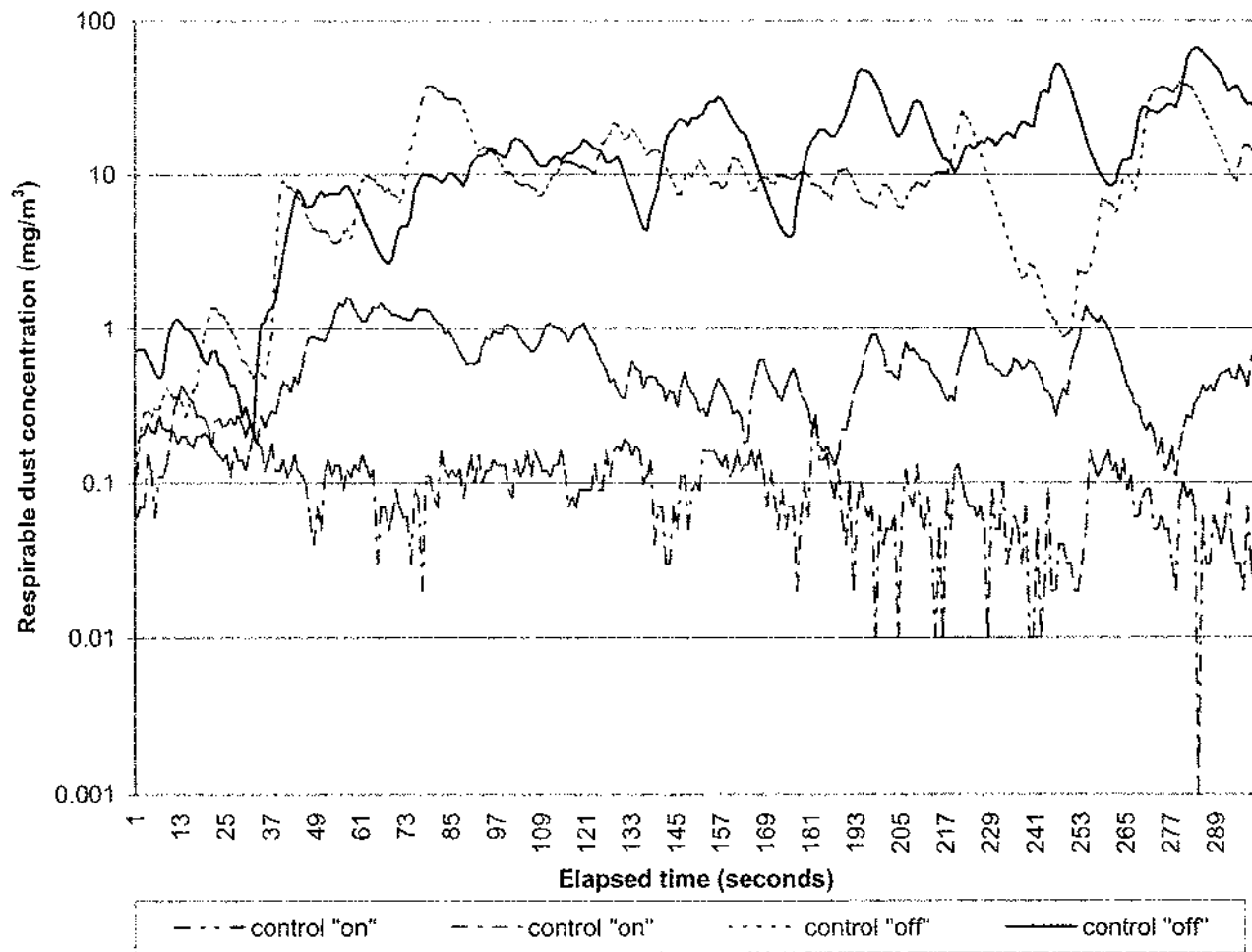


FIGURE 3
Scabblers control test.

were $0.21 \text{ mg}/\text{m}^3$ and $0.54 \text{ mg}/\text{m}^3$, with maximum values of $66 \text{ mg}/\text{m}^3$ and $40 \text{ mg}/\text{m}^3$ for the control "off" trials, and maximum values of $1.6 \text{ mg}/\text{m}^3$ and $0.85 \text{ mg}/\text{m}^3$ for the control "on" trials. The direct-reading results from the follow-up sampling contained many missing values and are not included in this report. As was the case with the pump and filter sampling, the reasons for these questionable results were not readily apparent at the time the samples were collected. Figure 4 shows the scabblers in use with the control "on."

Review of the video exposure monitoring from the initial sampling showed that peak exposures were associated with (1) repeatedly going over the same area, aerosolizing dust that had been produced



FIGURE 4
The scabblers in use with the control in place. Note the spray bar and the valve on the handle.

during previous passes over the concrete surface, and (2) changes in the wind direction that caused the cloud of dust to blow into the operator's breathing zone.

Conclusions and Recommendations

This study demonstrated the ability of a simple, job-built control to achieve an 80-percent reduction in exposures to respirable dust, and (by inference) to reduce exposures to respirable crystalline silica. Additional studies could be performed to determine the minimum water application required to achieve acceptable dust control. Detailed studies of the effects on dust control of slot size or the use of holes or nozzles versus slots in the spray bar could also be conducted to optimize water use. Obviously, this control is best suited for use in warm weather, where freezing temperatures will not affect the use of the control or present a slipping or cold haz-

ard to employees. The manufacturer of this scabbler offers an optional dust collector. The performance of this dust collector should be evaluated for its use with the scabbler in cold weather. Finally, although the parking structure in this study was open on all sides, for other projects, employers should be aware of the potential hazard for carbon monoxide exposure posed by the use of small gasoline engines in enclosed spaces.

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