IN-DEPTH SURVEY REPORT. CONTROL OF SILICA EXPOSURE FROM HAND TOOLS IN CONSTRUCTION GRINDING CONCRETE

at

Frank Messer and Sons Construction Company
Newport, KY

REPORT WRITTEN BY
Alan Echt MPH, CIH
William K (Karl) Sieber PhD

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4676 Columbia Parkway, Mail Stop R-5
Cincinnati, Ohio 45226-1998

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SURVEYS CONDUCTED BY	Alan Echt, NIOSH Daniel S Watkins, NIOSH William A Heitbrink, NIOSH John McKernan, NIOSH Cherie F Estill, NIOSH
EMPLOYER REPRESENTATIVES CONTACTED	Alison Muth Director of Safety Jay Zint Safety Coordinator

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ABSTRACT

When construction workers use hand-held grinders to smooth poured concrete surfaces after forms are stripped, they risk overexposure to respirable dust and crystalline silica. This report examines the performance of a local exhaust ventilation system for hand-held grinders. The system consisted of the grinder, which was equipped with a ventilated shroud, a length of flexible corrugated hose, and a portable electric vacuum cleaner that acted as the fan and dust collector for the ventilation system. Air samples for respirable dust and crystalline silica were collected during five days of grinding. Eight-hour TWA respirable dust results ranged 0.55 mg/m^3 to 1.2 mg/m^3, or from 0.45 to 1.5 times the PEL. These results exceeded the OSHA PEL for respirable dust containing ≥1% quartz on 4 of 5 sampling days. Eight-hour time weighted average quartz exposures ranged from 0.036 mg/m^3 to 0.13 mg/m^3, or from 0.72 to 2.6 times the REL of 0.05 mg/m^3. These results exceeded the NIOSH REL for crystalline silica on 4 of 5 sampling days. The results of air sampling indicate that this vacuum cleaner and shroud system control exposures within the range of protection provided by a half-mask respirator.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is located in the Centers for Disease Control and Prevention (CDC), under the Department of Health and Human Services (DHHS) NIOSH was established in 1970 by the Occupational Safety and Health Act, at the same time that the Occupational Safety and Health Administration (OSHA) was established in the Department of Labor (DOL) The OSHAct legislation mandated NIOSH to conduct research and education programs separate from the standard-setting and enforcement functions conducted by OSHA An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards

The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology (DART) has been given the lead within NIOSH to study and develop engineering controls and assess their impact on reducing occupational illness Since 1976, EPHB (and its forerunner, the Engineering Control Technology Branch) has conducted a large number of studies to evaluate engineering control technology based upon industry, process, or control technique The objective of each of these studies has been to evaluate and document control techniques and to determine the effectiveness of the control techniques in reducing potential health hazards in an industry or for a specific process

This is the second report of a project to investigate exposures to construction workers that result from chipping and grinding concrete and other construction materials that contain crystalline silica, and engineering controls to reduce those exposures This report describes the exposures that resulted from the use of local exhaust ventilation during concrete grinding Exposures and controls associated with tuck-pointing, which typically involves removing mortar from brick and block walls with grinders, are described in other EPHB reports from this project

OCCUPATIONAL EXPOSURE TO CRYSTALLINE SILICA

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 NIOSH Recommended Exposure Limit (REL) or the OSHA Permissible Exposure Limit (PEL) [1,2]

The NIOSH REL for respirable crystalline silica is a 10-hour, time-weighted average level of 0 05 mg/m^3 NIOSH has classified crystalline silica as a potential occupational carcinogen Therefore, NIOSH recommends that employers make efforts to reduce silica exposures below the REL

The OSHA PEL for respirable dust containing 1% quartz or more is expressed as an equation

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

Thus, if the dust contains no crystalline silica, the PEL is 5 mg/cubic meter (m^3), and if the dust is 100% 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 using the formula for quartz

METHODS

Personal breathing zone samples were collected at a flow rate of 1 7 liters/minute using a battery operated sampling pump connected via Tygon tubing to a 10-millimeter (mm) nylon cyclone (a Dorr-Oliver cyclone) and a pre-weighed, 37-mm diameter, 5-micron (µm) pore-size polyvinyl chloride filter supported by a backup pad in a two-piece filter cassette sealed with a cellulose shrink band, in accordance with NIOSH Methods 0600 and 7500 [3] In addition to the personal samples, bulk samples of settled dust were collected in accordance with NIOSH Method 7500 Two personal breathing zone samples were collected each day The pump was turned off during breaks and at lunch time, and when the worker left the area or performed a task other than grinding

Samples were analyzed in accordance with NIOSH Methods 0600 and 7500 with modifications Gravimetric analysis for respirable particulate was carried out with the following modifications to NIOSH Method 0600 1) The filters and backup pads are stored in an environmentally controlled room (21±3 °C and 50±5% relative humidity) and are 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 are performed The difference between the average gross weight and the average tare weight is the result of the analysis The limit of detection 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, and cristobalite The limits of detection for quartz and cristobalite on filters are 0 01 and 0 02 mg, respectively The limit of quantitation is 0 03 mg for both quartz and cristobalite on filters Bulk samples were collected and analyzed qualitatively for quartz and cristobalite by X-ray diffraction to determine if any interference were present in the material The limits of detection in bulk samples are 0 8% for quartz and 1% for cristobalite The limit of quantitation is 2% for both forms of crystalline silica in bulk samples

Productivity was quantified by using a tape measure to mark off the area of concrete surface finished during each day of sampling Vacuum cleaner performance was measured in terms of the capacity of the vacuum cleaner bag, the total pressure of the vacuum cleaner, and the static pressure and air flow through the shroud-hose-vacuum cleaner system Bag capacity was measured using a portable electronic scale to weigh the empty bag and weigh the bag when the cement mason judged it to be full The time was also noted each time the vacuum cleaner bag was changed to determine how long it took the vacuum cleaner to reach its capacity Static pressure was measured by inserting a smooth-walled metal tube the same diameter as the vacuum cleaner hose in line with the hose between the shroud and the vacuum cleaner and measuring the suction using a U-tube manometer placed on a hole drilled in the side of the metal tube while the shroud was held against a flat surface Air flow was calculated by measuring the air velocity in the vacuum cleaner hose and multiplying this by the cross sectional area of the hose Pressure and air velocity measurements were made a sufficient number of hose diameters from the tool and the vacuum cleaner to mitigate the effects of turbulence on the measurements Centerline velocity was measured using a TSI Velocicalc Plus model 8386 multi-parameter ventilation meter

RESULTS

The work described in this report involved using an electric hand-held grinder to remove surface imperfections from poured concrete walls and columns The work took place inside a parking garage under construction. All of the work during the sampling days took place on level 1 (ground level) which was an enclosed area except for the entrance and exit at either end The cement finisher wore work boots, work gloves, a hard hat, safety glasses, and a face shield while grinding In addition, he wore a 3M model 6300 dual cartridge half-mask air-purifying respirator with 3M model 2096 P100 filters He used a Metabo model W7-115 Quick 10,000 rpm grinder to grind the concrete, except on March 6, when he used a Bosch model 1347A grinder The grinders were equipped with a Pearl Abrasive Vacu-Guard shroud connected to a Dust Control model DC 2700 C vacuum cleaner equipped with a Model 4504 pleated cellulose filter with a surface area of 1 5 square meters This filter is rated by the manufacturer to be 99 99% efficient when tested using DIN 24184, a European standard, by the German certification organization Berufsgenossenschaftliches Institut für Arbeitssicherheit (BIA) The test aerosol is composed mostly of silica dust with a particle size range of 1-3 micrometers [4] Two different DC2700 C vacuum cleaners were used The vacuum cleaner used during the first two days of sampling had visible dust inside the motor housing and inside the manometer, indicating that dust may have been bypassing the filter. The vacuum cleaner used on the following three days of sampling did not have any visible dust inside the motor housing or the manometer

Industrial hygiene sampling

The results of air sampling and analyses for respirable dust and quartz are presented in Table 1 No cristobalite was detected in any of the air samples Bulk sample results ranged from 7 4 to 15% quartz in samples of concrete dust No cristobalite was detected in any of the bulk samples

PELs for respirable dust containing ≥1% crystalline silica for each day were calculated based on percentage of quartz in samples. PELs were tested and found to follow a lognormal distribution (in order to perform statistical tests based on the shape of the distribution) with mean PEL over the 5 days of .83 mg/m^3 Table 1 shows that 8-hour TWA respirable dust results ranged 0 55 mg/m^3 to 1 2 mg/m^3, or from 0 45 to 1 5 times the PEL These results exceeded the OSHA PEL for respirable dust containing ≥1% crystalline silica on 4 of 5 sampling days Respirable dust data were tested and found to follow a lognormal distribution Logarithms of the measured values were therefore used for further analyses The arithmetic mean concentration was estimated to be 1 14 mg/m^3 with geometric mean of 1 35 mg/m^3 and geometric standard deviation of 1 43 An upper exact 95% confidence limit for exposure levels was found to be 1 83 mg/m^3, indicating that we can be 95% confident that the true arithmetic mean exposure for respirable dust in this case is less than 1 83 mg/m^3 We can be 95% confident that the true mean exposure is less that 5 times the (average) PEL of 83 mg/m^3 Five times the PEL was chosen as an arbitrary limit because it is one half the assigned protection factor of a half-facepiece respirator, and thus offers a large margin of safety for the use of that type of respirator

Review of Table 1 also indicates that 8-hour time weighted average quartz exposures ranged from 0 036 mg/m^3 to 0 13 mg/m^3, or from 0 72 to 2 6 times the REL of 0 05 mg/m^3 These results exceeded the NIOSH REL for crystalline silica on 4 of 5 sampling days The quartz data was also tested and found to follow a lognormal distribution Logarithms of the measured values were therefore used for further analyses The arithmetic mean concentration was estimated to be 0 159 mg/m^3 with geometric mean of 0 142 mg/m^3 and geometric standard deviation 1 655 An exact 95% confidence limit for exposure levels was found to be 233 mg/m^3, indicating that we can be 95% confident that the true arithmetic mean exposure for quartz in this case is less than 233 mg/m^3 We can be 95% confident that the true mean exposure is less that 5 times the REL of 05mg/m^3

Productivity and performance

Table 2 lists the square feet of concrete surface finished each day These typically included a mixture of walls and columns The vacuum cleaner bag was emptied twice on February 21 and 22, once on February 26, a day which was devoted primarily to finishing six sets of paired columns, twice on March 2, and once on March 6, a day which also involved grinding more columns than walls The scale was used to weigh bags on February 22 The two full bags weighed approximately 18 pounds each It was not clear whether the decision to empty the bag was determined by the physical capacity of the bag, or a decision by the cement mason to change the bag at a manageable size and weight

Air velocity measurements were made once each day on February 21 and 22 and on March 2 The average airflow calculated from these measurements was 96 cubic feet per minute (range 86 to 106 cfm) Static pressure was measured on March 2 and found to be 21 inches of water (in wg) A graph in the manufacture's catalog rates the flow at approximately 100 cfm at a static pressure of approximately 21 in wg, indicating that performance in the field is in line with the manufacturer's specifications.[4] The manufacturer rates the maximum flow of this vacuum cleaner as 112 cfm, with a maximum negative pressure of 84 in wg.

DISCUSSION AND CONCLUSIONS

The results of air sampling indicate that this vacuum cleaner and shroud system control exposures within the range of protection provided by a half-mask respirator, and the task of changing bags and cleaning the vacuum cleaner filter do not seem to interfere with the productivity of the cement mason He reported that electricians had told him that they didn't need to clean concrete dust from the light fixtures they were installing, and form crews were able to work nearby stripping forms while he was grinding (the issue of bystander exposures is beyond the scope of this study, but should be addressed) Uncontrolled grinding would not have permitted this to occur In fact, tasks that took place nearby such as form stripping, drilling holes for pipe hangers, floor sweeping, and forklift traffic, may have contributed to the cement mason's exposure This illustrates one of the difficulties in conducting field studies to assess the effectiveness of engineering controls for construction tasks

The selection of the vacuum cleaner filter may also have contributed to the cement mason's exposure if fine particles that passed through the filter A future study could determine the particle size distribution associated with concrete grinding to aid in filter selection The same study could address the issue of effective filter life, to determine a filter change schedule The same company that manufactures the vacuum cleaner produces a device that uses compressed air to clean the filters, thus potentially prolonging their usable life

There was a learning curve associated with the use of the vacuum cleaner and shroud on the part of the cement mason and the employer Initially, the cement mason cleaned the filter by removing it from the vacuum cleaner and dropping or pounding it on the floor of the garage This was the technique he used with a canister vacuum that he had used previously with this shroud, and he reportedly had not received training in the use of the new vacuum cleaner He learned to use the valve on the side of the vacuum cleaner to use back pressure to clean the filter, which reduced down time and probably prolonged filter life In addition, because of a reported shortage of bags, the cement mason dumped the filled bags on the floor, where they became an aerosol source when forklift traffic drove through them or when they were swept up by another worker Finally, the weight of the shroud and hose in addition to the grinder, used for periods of up to 340 minutes, reportedly caused some upper extremity pain for the cement mason However, this may have been due in part to his practice of reaching as high on the wall as he could while grinding, and only using his portable scaffold for the portion at the top of the wall that was beyond his reach Keeping the tool in a neutral position in front of his body might reduce his discomfort

While this shroud was only able to reduce exposures to levels that were in excess of applicable exposure limits, one should remember that in this study, the cement mason spent most of the day grinding walls, which is not typical of his work Thus, in actual use, the time weighted average exposures would be somewhat lower

REFERENCES

1 NIOSH [1997] NIOSH pocket guide to chemical hazards Cincinnati, OH U S Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No 97-140

2 *29 CFR 1910 1000* Occupational Safety and Health Administration air contaminants

3 NIOSH [1994] NIOSH manual of analytical methods 4th rev ed , Eller PM, ed Cincinnati, OH U S Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No 94-113

4 Dustcontrol AB [1999] Mobile equipment for source extraction and industrial cleaning, 1999/2000 Norsborg, Sweden Dustcontrol AB, Art Nr 9004

Table 1: Industrial Hygiene Sampling Results

Date	Sample	Sample Duration (Minutes)	Volume (Liters)	Respirable Dust Mass (mg)	Respirable Dust Concentration (mg/m^3)	Quartz Mass (mg)	Quartz Concentration (mg/m^3)	Quartz %	PEL	Respirable Dust TWA (mg/m^3)	Respirable Dust 8-hr TWA (mg/m^3)	Quartz TWA (mg/m^3)	Quartz 8-hr TWA (mg/m^3)
2/21	1	130	225	0 18	0 80	0 010	0 044	6	1 2	1 0	0 55	0 065	0 036
	2	135	233	0 28	1 2	0 020	0 086	7					
2/22	1	177	305	0 46	1 5	0 049	0 16	11	0 78	1 5	0 88	0 16	0 096
	2	109	188	0 27	1 4	0 030	0 16	11					
2/26	1	160	272	0 44	1 6	0 039	0 14	9	0 89	1 8	1 2	0 16	0 11
	2	162	276	0 53	1 9	0 050	0 18	9					
3/2	1	189	324	0 63	2 0	0 054	0 17	9	0 82	2 0	1 2	0 20	0 13
	2	109	187	0 38	2 0	0 049	0 26	13					
3/6	1	180	308	0 24	0 78	0 071	0 23	30	0 44	0 88	0 62	0 18	0 13
	2	160	274	0 27	0 99	0 034	0 12	13					

Table 2: Productivity

Date	Concrete surface finished (ft^2)
2/21	984
2/22	1071
2/26	1056
3/2	894
3/6	808