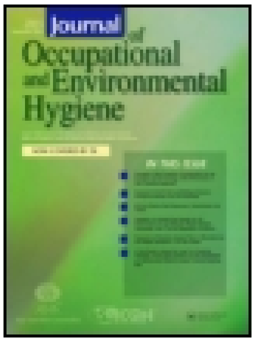

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Laboratory Evaluation to Reduce Respirable Crystalline Silica Dust When Cutting Concrete Roofing Tiles Using a Masonry Saw

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Respirable crystalline silica dust exposure in residential roofers is a recognized hazard resulting from cutting concrete roofing tiles. Roofers cutting tiles using masonry saws can be exposed to high concentrations of respirable dust. Silica exposures remain a serious threat for nearly two million U.S. construction workers. Although it is well established that respiratory diseases associated with exposure to silica dust are preventable, they continue to occur and cause disability or death. The effectiveness of both a commercially available local exhaust ventilation (LEV) system and a water suppression system in reducing silica dust was evaluated separately. The LEV system exhausted 0.24, 0.13, or 0.12 m^3/sec of dust laden air, while the water suppression system supplied 0.13, 0.06, 0.03, or 0.02 L/sec of water to the saw blade. Using a randomized block design, implemented under laboratory conditions, the aforementioned conditions were evaluated independently on two types of concrete roofing tiles (s-shape and flat) using the same saw and blade. Each engineering control (LEV or water suppression) was replicated eight times, or four times for each type of tile. Analysis of variance was performed by comparing the mean airborne respirable dust concentrations generated during each run and engineering control treatment. The use of water controls and ventilation controls compared with the "no control" treatment resulted in a statistically significant ($p < 0.05$) reduction of mean respirable dust concentrations generated per tile cut. The percent reduction for respirable dust concentrations was 99% for the water control and 91% for the LEV. Results suggest that water is an effective method for reducing crystalline silica exposures. However, water damage potential, surface discolorations, cleanup, slip hazards, and other requirements may make the use of water problematic in many situations. Concerns with implementing an LEV system to control silica dust exposures include sufficient capture velocity, additional weight of the saw with the LEV system, electricity connections, and cost of air handling unit.

Keywords construction, engineering controls, masonry saw table, occupational health

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The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

INTRODUCTION

Respirable crystalline silica dust exposure in residential roofers while cutting concrete roofing tiles is a recognized hazard. Residential roofers use hand-held gasoline- or electric-powered saws to cut the roofing tiles to fit them into various sections of the roof. On average, cutting tasks account for approximately 60 min of a full, 8-hr work shift.[(1)] Each cut lasts approximately 10 to 20 sec. Concrete roofing tiles are used for residential roofs throughout the western states.

In a pilot study conducted using a mock roofing setup, short-term personal breathing zone (PBZ) samples were collected on roofers cutting concrete roofing tiles with a gasoline-powered saw. Five PBZ samples showed respirable dust concentrations ranging from less than 1.6 to 5.4 mg/m^3 with a mean of 3.5 mg/m^3. If continued for a full shift, four of the five samples would have exceeded the general industry Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for respirable silica of 0.53 mg/m^3. Three of the above five short-term PBZ samples taken while using the powered saw resulted in silica concentrations ranging from 0.41 to 0.45 mg/m^3 (semiquantitative results), and, if extrapolated for a full shift, would potentially exceed by a factor of eight the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) for silica of 0.05 mg/m^3[(2)]

A laboratory study is reported here to evaluate several engineering control methods and identify the most cost-effective control(s) for reducing dust and silica exposures. Based on the results from this laboratory study, it would be worthwhile to test both control methods at residential construction roofing sites to determine if the controls reduce silica exposure below applicable occupational exposure limits (OELs).

Respirable crystalline silica dust can be generated when existing concrete or any silica-containing material is removed, repaired, or altered, thereby producing a potential silicosis hazard for exposed workers. Construction workers are exposed to silica in such high-risk jobs as abrasive blasting (sandblasting), masonry work, stone cutting, jack hammering, rock drilling, quarry work, and tunneling.[3] Although it is well established that respiratory diseases associated with exposure to silica dust are preventable, they continue to occur and cause disability or death.[4,5]

Silica exposures remain a serious threat to nearly 2 million U.S. construction workers, with a large percentage having been exposed to silica concentrations higher than limits set by current standards and regulations.[6,7] According to the International Labor Organization (ILO), 5 to 10% of the world's work force serves in the construction industry.[8] In 1996, the building construction industry accounted for 7% of the U.S. gross domestic product, producing nearly $564 billion in revenue,[9] with over one-third (38%) of the building construction activity in remodeling and reconstruction.[10]

Silica is the name that collectively describes various forms of silicon dioxide (SiO_2), including both the crystalline and noncrystalline (amorphous) forms of silica.[11] Quartz is the most prevalent form of crystalline silica found in the workplace and is the most common mineral in the earth's crust.[12]

The primary health concerns in workers exposed to silica dust are the fibrogenic capacity of the inhaled silica particles, which can lead to the development of silicosis and an increased risk of tuberculosis.[13] Airborne silica dust enters the body primarily by inhalation through the nose and/or mouth. The mucociliary escalator aids in removing the inhaled particles, which are deposited in the upper airway. Small inhaled particles with an aerodynamic diameter less than 10 μm travel beyond the upper airway and are frequently deposited in the thoracic and respiratory regions.[14] Specifically, it is in the respiratory region where the alveoli are located, where oxygen and carbon dioxide exchange occur, and where silicosis develops. The inhalation of silica dust over a long period and at sufficient concentrations can result in the formation of fibrotic lesions that form specific rounded nodules inside the lungs.[12]

Research has been conducted on the use of modern tools, such as pneumatic hammers and drills, powered saws, grinders, chippers, and mills used to build or repair concrete structures such as highways, bridges, and buildings, potentially producing high concentrations of airborne respirable crystalline silica dust.[15,16] These tools, if not operated with adequate dust controls, could produce respirable crystalline silica dust with concentrations exceeding the OSHA PEL or the NIOSH REL for silica of 0.05 mg/m^3.[2] The use of hand-held gasoline- or electric-powered saws in residential roofing construction can also result in high concentrations of respirable crystalline silica dust if controls are not used.

This laboratory study was devised to evaluate two potential engineering methods for controlling silica dust: (1) local exhaust ventilation (LEV), and (2) wet methods. Both a LEV system and a water suppression system mounted on the saw were tested to assess their ability to control airborne respirable dust generated inside an enclosed testing chamber.

MATERIALS AND METHODS

Testing Chamber

Due to the nature of construction work, the duration and frequency of crystalline silica exposure to individual workers is highly variable. Some of the variability is due to weather conditions, construction material used, work location, type of work performed, work activity duration and frequency, work practices, personal protective equipment (PPE), and dust control measures or lack thereof. Dust control evaluations were therefore conducted in a laboratory setting to control for many of the variables that affect exposure levels. The same testing chamber and setup used by Beamer et al.[17] was used for this study.

A diagram of the testing chamber is shown in Figure 1. The dimensions of the chamber were 1.2 × 1.2 × 3.7 m (volume = 5.3 m^3). A dust collection air handling unit (Polaris Industrial Ventilation Inc., Harbor Springs, Mich.) pulled outside air through a series of HEPA filters (efficiency 99.9%) at an

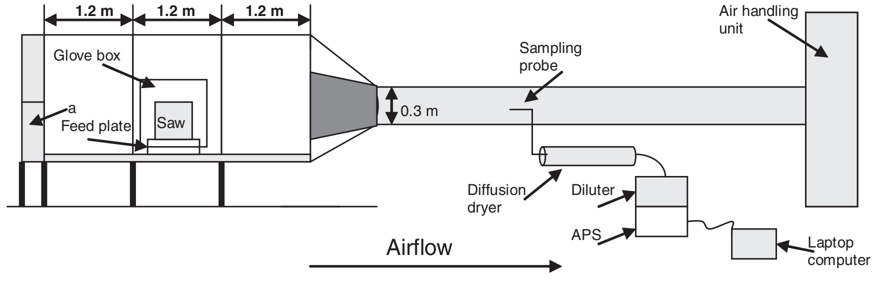

FIGURE 1. Schematic of testing chamber. HEPA filters are denoted by (a).

average flow rate of 1.4 m^3/sec. The distance from the masonry saw blade to the tapered exhaust opening that connects to the 0.3 m diameter duct was 1.8 m. Air velocity measurements through the duct were recorded at the beginning, middle, and end of each engineering control treatment using a pitot-static tube and a micromanometer (Airflow, Netcong, N.J.).

The enclosed testing chamber provided a controlled environment to help collect replicable data and protect research personnel from inhaling silica dust generated during the cutting of concrete roofing tiles. Access to items inside the chamber was through two gloves attached to the front panel of the chamber, creating a glove box-type interface directly in front of the masonry table saw. The testing chamber housed a portable GMS-14 electric masonry saw (EDCO Inc., Frederick, Md.). The saw used a standard 35.6 cm diameter, wet/dry, masonry saw blade (Pearl Abrasive Co., Commerce, Calif.). To obtain a constant tile feed rate, a 0.5 hp (370 W) motor (Dayton Electric Manufacturing Co., Niles, Ill.) controlled the feed rate of the concrete tiles to 0.013 m/sec. The motor was in turn controlled by a variable speed controller (Dayton Electric). The feed rate used in this experiment is slower than those typically used by contractors; this was done to minimize the chance of accidentally binding the concrete tile in the saw blade, since automatic equipment was used to maintain a constant feed rate.

Roofing Tiles

Two types of concrete roofing tiles were used throughout this experiment: (1) Tejas Espana (flat tile), Desert Sage (Monier Life Tile, Irvine, Calif.), with dimensions of 0.43 × 0.019 × 0.33 m, and (2) Saxony Profiles (s-shape tile), Harvest, (Monier Life Tile) with dimensions of 0.42 × 0.025 × 0.33 m. Each tile used in this experiment was from the same batch (either the s-shape or flat tile batch), but some composition variability was still observed. According to the manufacturer, the approximate composition of material in each tile is 20–30% Portland cement, 50–60% sand and aggregate (variable crystalline silica content), 0–5% limestone, 0–8% fly ash, less than 1% mold release agent (diesel/petroleum oil, vegetable oil), 0–8% acrylic polymer, and the remainder is dependent on color (metal oxide pigments; cobalt metal pigments [blue]; iron oxide pigments [black, red, and yellow]; titanium dioxide pigment [white]; or chromium oxide pigments [green]). The selection of the tile and blade was made to simulate fairly typical, real-world scenarios. For example, the tiles used are appropriate for a wide variety of applications, and the blade chosen is appropriate for both wet and dry cutting and similar to those used in practice.

Engineering Control Treatments

During ventilation treatments, a dust hood control system (model no. 40320; EDCO), composed of a dust hood and curtain assemblies, was installed directly behind the saw following the manufacturer's instructions. The dust hood was tapered with face dimensions of 0.45 × 0.22 m. The distance from the face of the dust hood to the blade was 0.13 m. The dust hood was enclosed within the chamber and connected to 3 m of 0.13 m (5 in.) diameter duct that passed through the back panel of the closed chamber leading to another air filtering unit (Polaris). A blast gate was installed in the duct to set the airflow through the hood as dictated by the study design. Velocity and airflow rates through the 0.13-m duct were determined by taking static pressure measurements using a 0.13-m duct delta tube (Midwest Instrument, Sterling Heights, Mich.).

Water was also evaluated as a dust control measure for sawing roof tiles. The EDCO saw had a water delivery system built into the blade guard and supplied water to the top of the blade. The manufacturer recommended a water flow rate of approximately 0.13 L/sec. When water study treatments were conducted, a shield of dimensions 0.45 × 0.22 m was bolted to the face of the dust hood, and the air filtration unit attached to the hood was not operated during water treatments. Non-recirculated (single-pass) tap water regulated at approximately 6.9 kPa, or water via a pump reservoir from a portable tank, was used in the laboratory where testing took place. Non-recirculating water was used for higher flows, and water provided via a pump was used to obtain lower flow rates. Water flowed through Tygon tubing through a 25.4-cm water flow meter (King Instrument Company, Inc., Garden Grove, Calif.), and then to the blade. Water was collected in a reservoir at the bottom of the saw and was removed using a suction pump.

Air Sample Collection

Air was sampled downstream of the process (Figure 1, sampling probe location) for both the water and LEV controls as the dust laden air was drawn past the saw and into 4.5 m of 0.3 m diameter ductwork. Air velocity measurements were taken within the 0.3-m exhaust duct using a 0.3-m Delta tube. The velocities inside the 0.3-m duct ranged from 18.9 to 19.5 m/sec. The chamber and the length of ductwork were designed to obtain an appropriately representative sample during each run.

Once the dust laden air flowed into the chamber exhaust duct, a sample was drawn into an isokinetic sampling probe; the nozzle for the isokinetic sampling probe has an inside diameter of 0.003 m and a wall thickness of 7.6×10^{-5} m. Over a length of 0.076 m, the nozzle diameter expanded to 0.019 m. This nozzle was mounted into a 0.019 m diameter copper elbow with a turning radius of 0.019 m. A 0.23 m length of vertical copper tubing connected the elbow to a diffusion dryer (TSI, Inc., Shoreview, Minn.) containing silica gel.

The sample airstream velocity was high enough to mimimize particle loss from the airstream in the diffusion dryer. Subsequently, the sample airstream then flowed to an Aerodynamic Particle Sizer (APS, model no. 3321; TSI) outfitted with a diluter (model no. 3302A; TSI). The dilution ratio was set to 20:1. The APS sampled at a total rate of 5 L/min. The APS measured both aerodynamic diameters and light-scattering intensity by measuring the time-of-flight of individual particles in an accelerating flow field, providing an accurate count size distribution for particles with an aerodynamic particle size ranging from 0.5 to 20 μm and a light-scattering intensity for particles ranging in size from 0.3 to 20 μm.

Aerosol Instrument Manager Software for APS Sensors (TSI, Inc.) was used to collect and store sample data from the APS for later use. For the calculation of surface area and mass concentrations, the software program assumes that all the particles are perfect spheres with the density of 2.5 g/m^3. An analyzed sample of the crystalline dust showed a density of 2.5 g/m^3.

EXPERIMENTAL DESIGN AND DATA ANALYSIS

To test the effectiveness of engineering controls (water suppression and local exhaust ventilation) for the reduction of airborne respirable dust, a randomized block design was used to guide the experimental process. Beginning from the manufacturer's recommended flow rates of 0.13 L/sec for water and 0.24 m^3/s for air, each flow rate was halved, and the airborne dust concentration in the air was tested at each flow rate. The following four water flow rates of 0.02, 0.03, 0.06, and 0.13 L/sec were tested independently, along with three independent airflow rates 0.12, 0.13, and 0.24 m^3/s. EDCO's recommended airflow rate (0.24 m^3/sec), water flow rate (0.13 L/sec), and no control (0 m^3/sec and 0 L/sec) were replicated eight times in random order. The impact of lowering the airflow rate through the dust hood and water flow rate supplied to the blade from the manufacturer's recommended levels were tested subsequently. The remainders of the air and water flow rates were replicated four times in random order.

Eight replicates were used for the initial tests based on an estimated variability found in a similar study (Beamer et al.[17]). This allowed for a desired power of 80% and a significance level of 0.05. Based on results from the initial tests, four replicates were used in the second phase of the study.

Each test consisted of a 120-sec background sample collection, during which the corresponding water or local exhaust ventilation was supplied to the rotating blade, but no tile cutting was carried out. This was followed by a 75-sec tile-cutting sample composed of two cuts. Concentration readings from the APS were taken on 5-sec intervals over both the 120-sec background period and the 75-sec cutting period. The actual tile cutting for flat and s-shape tiles occurred between 10 and 40 sec of elapsed time, and two cuts were made during this 30-sec interval. Only readings taken during this 30-sec time period were used as a representative sample.

The intent of the experiment was to determine the effect of engineering controls on airborne respirable dust levels within the chamber. To minimize the effects of background particulate and droplet levels on test results, the median of the 120-sec background samples for each flow rate tested was subtracted from each tile-cutting sample taken in the 75-sec cutting period.

The median background concentrations ranged from 0.0001 to 0.12 mg/m^3. Therefore, results reported for each test represent the particle count of respirable dust corrected for background concentration.

Analysis of variance (ANOVA) with Tukey multiple comparison adjustments were used to test for differences between mean concentrations obtained at each flow rate for each type of tile. In addition, the percent reduction for respirable dust is reported for each treatment, along with the mass of respirable dust measured per cut. For each cut, the same amount of material was generated; however, as would be expected, the concentration of respirable dust measured in the chamber depended on the effect of the applied control. Percent reduction for each control was calculated using Eq. 1. The corresponding 95% confidence intervals are reported as a measure of variability. All calculations were done using PROC GLM under SAS/STAT (v. 9.2).

$$\%\text{reduction} = \frac{\bar{C}_{nc} - \bar{C}_{e,i}}{\bar{C}_{nc}} \times 100 \qquad \textbf{(1)}$$

where

$\bar{C}_{nc}$ = Average concentration of no control treatment, (mg/m^3)
$\bar{C}_{e,i}$ = Average concentration of the engineering control treatment, (mg/m^3)

RESULTS

Results of all tests are shown in Tables I and II and Figures 2 and 3. Respirable dust concentrations were calculated from measurements made during actual cutting cycles and not the time between cuts. All results were based on a cutting time of 30 sec. The concentrations observed in the tables are for both cuts made on each tile. All measurements were found to follow a log-normal distribution, so logarithms of the measured values were used for further statistical analyses. ANOVA with Tukey multiple comparison adjustments were used to test for differences between geometric mean concentrations obtained at each flow rate for each type of tile. T-tests revealed a statistically significant difference between type of tile in geometric mean concentrations with no control device (water flow rate = 0) but no statistically significant differences at other flow rates.

No Control

When no water was applied to the saw blade and no ventilation controls were used, the geometric mean respirable dust concentration and 95% confidence interval were 39.2 mg/m^3 (38.1, 40.4 mg/m^3) and 49.7 mg/m^3(48.1, 51.2 mg/m^3) for the s-shape and flat tiles, respectively, measured using the APS. Eight randomized replicates were conducted during the no control treatments. The geometric mean mass generation of respirable dust and 95% confidence interval were 1.72 g/cut (1.67, 1.77 g/cut) and 2.18 g/cut (2.11, 2.24 g/cut) for the s-shape and flat tiles, respectively.

Water Suppression Control

The results from eight replicates using 0.13 L/sec of freely flowing water over the blade showed a geometric mean concentration of respirable dust in the vent pipe of 0.57

TABLE I. Geometric Mean Respirable Dust Concentrations and Mass Airborne Dust per Cut for Water Suppression Trials Compared with No Control during Tile Cutting

Tile	Water Flow Rate (L/sec)	No. of Samples	Geometric Mean Respirable Dust (mg/m^3)	Geo. Std. Dev.	Mass of Airborne Dust (g/cut)
Flat	0	8	49.7	1.04	2.18
Flat	0.02	4	1.28	1.06	0.05
Flat	0.03	4	0.98	1.07	0.04
Flat	0.06	4	0.67	1.30	0.03
Flat	0.13	8	0.57	1.12	0.02
S-shape	0	8	39.2	1.04	1.72
S-shape	0.02	4	0.88	1.08	0.04
S-shape	0.03	4	0.71	1.08	0.03
S-shape	0.06	4	0.49	1.08	0.02
S-Shape	0.13	8	0.36	1.20	0.02

and 0.36 mg/m^3 for the flat and s-shape tiles, respectively. The percent reduction of respirable dust when using 0.13 L/sec of water was 98.9 and 99.1% for flat and s-shaped tile, respectively. The percent reduction of respirable dust, along with error bars for the 95% confidence limit for each water flow rate, is shown in Figure 2. Also, the results from eight replicates using 0.13 L/sec of freely flowing water over the blade resulted in a generation rate of 0.02 grams per cut of respirable dust. The results from four replicates when decreasing the water flow rate by half to 0.06 L/sec yielded a geometric mean respirable dust concentration of 0.67 and 0.49 mg/m^3(i.e., reductions of 98.7 % and 98.8%) for flat s-shape

TABLE II. Geometric Mean Respirable Dust Concentrations and Mass Airborne Dust Concentrations for Local Exhaust Ventilation Trials Compared with No Control During Tile Cutting

Tile	Airflow Rate (m^3/sec)	No. of Samples	Geometric Mean Respirable Dust (mg/m^3)	Geo Std. Dev.	Mass of Airborne Dust (g/cut)
Flat	0	8	49.6	1.04	2.18
Flat	0.12	3	6.48	1.23	0.28
Flat	0.13	4	6.32	1.18	0.27
Flat	0.24	8	4.32	1.17	0.19
S-shape	0	8	39.2	1.04	1.72
S-shape	0.12	3	9.90	1.14	0.43
S-shape	0.13	4	8.37	1.03	0.36
S-shape	0.24	8	5.42	1.21	0.23

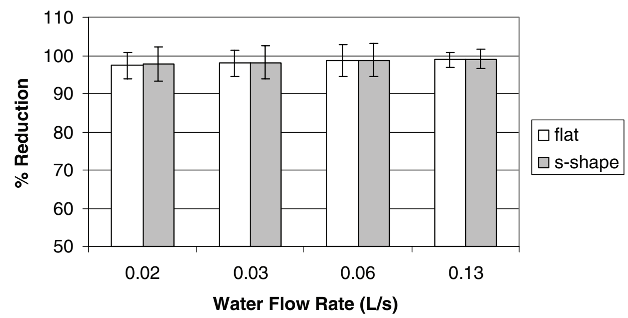

FIGURE 2. Percent reduction for respirable dust using water suppression controls.

tiles, respectively. When reducing the water flow rate further to one-quarter (0.03 L/sec) of the manufacturer's recommended water flow rate, the geometric mean concentration resulted in 0.98 and 0.71 mg/m^3 of respirable dust for the flat and s-shape tiles, respectively. The percent reduction of respirable dust inside the vent pipe is 98% for flat tiles and 98.2% for s-shape tiles. The reduction of water flow to the blade to a rate of 0.02 L/sec increased the geometric mean respirable dust concentration to 1.28 and 0.88 mg/m^3 for the flat and s-shape tiles, respectively. The percent reduction for a water flow rate of 0.02 L/sec was 97.4 for the flat tile and 97.8 for the s-shape tile.

Local Exhaust Ventilation Control

The LEV consisted of a dust hood that was attached to a vacuum following the manufacturer's recommendations. The baseline or no control geometric mean respirable dust concentration was 49.7 and 39.2 mg/m^3 for the flat and s-shape tiles, respectively. At the highest exhaust airflow rate of 0.24 m^3/sec, the geometric mean concentration of respirable dust was 4.32 and 5.42 mg/m^3 (i.e., a reduction of 91.3 and 86.2%) for the flat and s-shape tiles, respectively. The percent reductions at each airflow rate, along with error bars for the 95% confidence limit for the percent reduction of respirable dust, are presented in Figure 3. When reducing the recommended airflow rate of 0.24 m^3/s to 0.12 m^3/sec, the

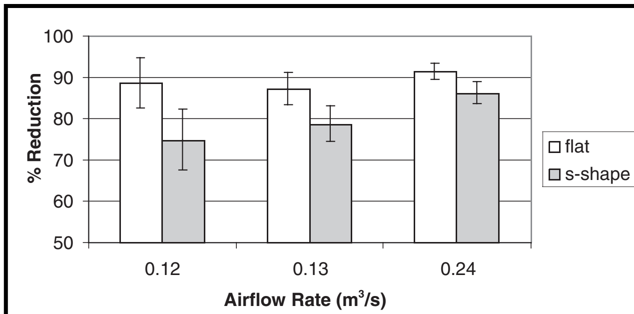

FIGURE 3. Percent reduction for respirable dust using LEV system controls.

geometric mean respirable dust concentration increased to 6.48 and 9.90 mg/m^3 for the flat and s-shape tiles, respectively. At a ventilation rate of 0.12 m^3/sec, the airflow began to fluctuate slightly, so the airflow rate was increased to 0.13 m^3/sec to steady the flow rate. The geometric mean respirable dust concentration at 0.13 m^3/sec was 6.32 and 8.37 mg/m^3 for the flat and s-shape tiles, respectively. The percent reduction of the respirable dust concentration was 87.3% for the flat tile and 78.7% for the s-shape tile. Thus, the respirable dust concentrations were only slightly lower at a flow rate of 0.13 m^3/sec than at 0.12 m^3/sec.

A two-way ANOVA model was first tested for differences in mean concentration between tile type (flat or s-shape) and control (LEV or water suppression) and control*tile interaction. Statistically significant differences were found between tile type ($p < 0.001$) and controls ($p = 0.001$). For control type, "no control" had a higher geometric mean concentration than LEV, and LEV had a higher geometric mean concentration than water control. For tile type, flat tiles had a higher geometric mean concentration than s-shape tiles.

Since statistically significant interaction was found between controls and tile type, ANOVA models by control type were then tested to examine differences between tile type, flow rates, and interactions between tile type and flow rates. For LEV treatments, significant differences between tile type were found ($p < 0.001$). The s-shape had a significantly higher geometric mean concentration level than that of the flat. The airflow rate of 0.24 m^3/sec had a significantly lower geometric mean concentration than those of 0.12 and 0.13 m^3/sec. No significant differences were found between 0.12 and 0.13 m^3/sec.

For water suppression control, significant differences between tile type were found ($p<0.001$). Flat tiles have significantly higher geometric mean concentration levels than that of s-shape tiles. Tukey multiple comparison tests indicated that respirable dust concentrations for all water flow rates (0.02, 0.03, 0.06, and 0.13 L/sec) were statistically different from each other. No statistically significant interaction was found between tile shapes and flow rates in either water control or LEV control.

DISCUSSION

In this study, the effectiveness of both a commercially available LEV system and a water suppression system in reducing silica dust was evaluated separately. The experiments consisted of four or eight replicates of three runs, with each testing both flat and s-shape tiles. Overall, both the water treatment and the ventilation treatment resulted in substantial reductions of respirable dust concentrations for all the water flow rates and airflow rates tested.

The estimates of respirable dust reduction showed that the manufacturer's recommended water flow rate of 0.13 L/sec resulted in a percent reduction of approximately 98.9% and 99.1% for the flat and s-shape tiles, respectively, indicating that water is effective in reducing the respirable dust concentration inside the testing chamber. An additional question still remains: Will the decrease in water flow rate produce results that are comparable to the results achieved using the manufacturer's recommendation? If so, what level of reduction can be achieved with the use of less water? The data suggest that lower water flow rates to one-half, one-quarter, or one-sixth of the recommended water flow rate yields results that are similar (although statistically different) to the results achieved using the recommended water flow rate. A reduction of the manufacturer's recommended water flow rate by half produced a geometric mean respirable dust concentration that is 98.7% lower than the no control level. This suggests that the amount of water recommended by the manufacturer may be an overestimate of what is required to reduce the silica dust levels to a reasonable level. The decrease to one-quarter (0.03 L/sec) of the recommended water flow rate resulted in a 98% reduction of respirable dust for the flat tiles and a 98.2% reduction for the s-shape tiles. Even at this extremely low water flow rate, the reduction of silica dust inside of the chamber is substantial.

The recommended airflow rate of 0.24 m^3/sec resulted in a reduction of silica dust by 91.3% for the flat tile and 86.2% for the s-shape tile. Reducing the recommending airflow rate by half resulted in a reduction of respirable dust by 87% and 74.8% for the flat and s-shape tiles, respectively. The s-shape tile had a lower geometric mean respirable dust concentration than the flat tile except following the LEV treatments where the s-shape tile concentrations were higher. The reason for these differences is unknown to the researchers. Both tiles were of the same weight and of similar composition.

Given the constraints and difficulties with PPE and administration and process controls, engineering controls (specifically, water spray and local exhaust ventilation) have the potential to effectively control crystalline silica exposures based on the results from this laboratory study. For example, water appears to greatly reduce crystalline silica exposures. However, water source and disposal requirements, water damage potential, surface discoloration, material expansion, cleanup requirements, and cold water issues (freezing, hypothermia, and slip hazards) make use of water challenging in many situations.[18]

LIMITATIONS

The experiment presented here is intended to provide information concerning the relative effectiveness of the two controls and does not predict actual worker exposures. The laboratory setting controlled variability such as weather conditions, work practices, work activity, and duration. There may be differences between the s-shape and flat tiles made among different manufactures. The amount of quartz in masonry varies greatly depending on the local materials available at the manufacturing plant, and type of concrete tile. Therefore, actual field exposures to respirable crystalline silica are likely to vary.

CONCLUSIONS AND RECOMMENDATIONS

The results from this study showed a reduction in respirable dust concentrations of up to 99% using a water control and up to 91% using local exhaust ventilation. This demonstrates that both water and LEV are effective methods for controlling crystalline silica exposures when cutting roofing tiles. However, both water and LEV control methods need to be field tested during actual residential roofing construction to ascertain the effectiveness of the controls and to integrate the use of these control systems into actual roofing construction activities. For example, the LEV control system should not substantially increase the weight of the powered saw; wet methods should not create a slipping hazard nor discolor the roof tiles. Thus, field testing may lead to further refinement of the controls.

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