In-Depth Survey Report

Removing mortar with a powered chisel with on-tool local exhaust ventilation and a higher-flow vacuum cleaner

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Abstract

Background

Workplace exposure to respirable crystalline silica can cause silicosis, a progressive lung disease marked by scarring and thickening of the lung tissue. Several construction materials (such as brick, block, mortar and concrete) contain crystalline silica. Construction tasks that cut, break, grind, abrade, or drill those materials have been associated with overexposure to dust containing respirable crystalline silica. Tuckpointing (repointing) removes damaged mortar from joints in masonry walls and replaces it with new mortar to restore the wall. The use of grinders to remove mortar results in worker overexposure to respirable crystalline silica. NIOSH scientists are conducting a study to assess respirable crystalline silica exposures associated with mortar removal when tools other than grinders are used.

Assessment

NIOSH staff visited the Bricklayers and Allied Craftworkers' Southern Ohio-Kentucky Regional Training Center located in Batavia, Ohio on April 4, 2017, and performed industrial hygiene sampling, which measured exposures to respirable dust and respirable crystalline silica while an experienced bricklayer used a powered chisel with on-tool local exhaust ventilation to remove type N mortar from an indoor brick wall. The NIOSH scientists also observed the work process in order to understand the conditions that contributed to the measured exposure and collected airflow data.

Results

Personal breathing zone respirable crystalline silica concentrations measured during 18 to 25-minute-long periods of mortar removal ranged from less than the limit of detection to 0.053 mg/m^3. The highest concentration detected was a sample result between the LOD and LOQ, which is considered a trace value with limited confidence in its accuracy. Personal breathing zone respirable dust concentrations collected on filter samples ranged from less than the limit of detection to 0.89 mg/m^3.

Conclusions and Recommendations

The powered chisel with on-tool local exhaust ventilation tested here produced respirable crystalline exposures less than those reported when grinders were used with local exhaust ventilation under similar test parameters. If this tool can remove mortar with the speed and quality required by contractors and is acceptable to workers, it represents an alternative to the use of grinders. However, if it was used for a full shift and dust levels remained constant, the highest quartz concentration measured during use of the chisel – 0.053 mg/m^3 – would be about 1.06 times the OSHA PEL and NIOSH REL, requiring the use of a respirator with an assigned protection factor of 10, such as an N-95 filtering facepiece respirator. Full-shift sampling on job sites should be conducted to validate these findings.

Introduction

Background for Control Technology Studies

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational Safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. 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 has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concept techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

Background for this Study

Crystalline silica refers to a group of minerals composed of silicon and oxygen; a crystalline structure is one in which the atoms are arranged in a repeating three-dimensional pattern [Bureau of Mines 1992]. The three major forms of crystalline silica are quartz, cristobalite, and tridymite; quartz is the most common form [Bureau of Mines 1992]. Respirable crystalline silica refers to that portion of airborne crystalline silica dust that is capable of entering the gas-exchange regions of the lungs if inhaled; this includes particles with aerodynamic diameters less than approximately 10 micrometers (µm) [NIOSH 2002]. Silicosis, a fibrotic disease of the lungs, is an occupational respiratory disease caused by the inhalation and deposition of respirable crystalline silica dust [NIOSH 1986]. Silicosis is irreversible, often progressive (even after exposure has ceased), and potentially fatal. Because no effective treatment exists for silicosis, prevention through exposure control is essential. Silicosis is associated with a higher risk of tuberculosis and other lung diseases [Parks et al. 1999]. Silica has been classified as a known human carcinogen by the International Agency for Research on Cancer [IARC 1997]. Occupational exposure to respirable crystalline silica has been associated with autoimmune diseases, such as rheumatoid arthritis, and kidney disease [Parks et al. 1999, Stratta et al. 2001].

Crystalline silica is a constituent of several materials commonly used in construction, including brick, block, and concrete. Many construction tasks have been associated with overexposure to dust containing crystalline silica [Chisholm 1999, Flanagan et al. 2003, Rappaport et al. 2003, Woskie et al. 2002]. Among these tasks are tuckpointing, concrete cutting, concrete grinding, abrasive blasting, and road milling [Nash and Williams 2000, Thorpe et al. 1999, Akbar-Kanzadeh and Brillhart 2002, Glindmeyer and Hammad 1988, Linch 2002, Rappaport et al. 2003].

Tuckpointing (repointing) removes damaged mortar from joints in masonry walls and replaces it with new mortar to restore the wall and improve its resistance to the weather, prolonging its life and preventing water from penetrating the building envelope and causing damage to the structure [Gerns and Wegener 2003]. Mortar is typically removed to a depth of at least ¾-inch (in) (19 millimeters [mm]) using electric grinders, although hammers and chisels can be used [Gerns and Wegener 2003]. Other power tools are also available, including mortar routers, a die grinder with diamond tools, a hammer drill and mortar chisel, and a saw [Yasui et al. 2003, ICS 2016, Robert Bosch Tool Corporation 2016, Arbortech 2016]. Mortar mixes contain Portland cement, lime, and sand in various proportions depending on the strength required. Type N mortar, with a minimum required compressive strength of 750 pounds per square inch (PSI), is recommended for use in exterior, above grade walls and is durable and flexible enough to replace deteriorated mortar in most walls [IMI 2002, PCA 2002, Gerns and Wegener 2003].

The use of grinders to remove mortar results in worker exposure to respirable crystalline silica 2 to 1500 times the NIOSH Recommended Exposure Limit (REL) of 50 micrograms per cubic meter (µg/m^3) [OSHA 2013]. Even with engineering controls (i.e., on-tool local exhaust ventilation [LEV]), the use of a respirator with an assigned protection factor of 10 is still required [Collingwood and Heitbrink 2007]. In its Preliminary Economic Analysis for the Proposed Rule for Occupational Exposure to Respirable Crystalline Silica [OSHA 2013], the Occupational Safety and Health Administration (OSHA) reported the results of 151 8-hour samples for respirable crystalline silica for tuckpointers. Those sample results were in three exposure categories: outdoors, uncontrolled; outdoors, some form of LEV dust control; and under other working conditions (e.g., with limited air movement, or with inadequate attempts at dust control). Respirable crystalline silica exposures for uncontrolled, outdoor tuckpointing (83 samples) ranged from 12 to 12,616 µg/m^3, with a mean of 1,601 µg/m^3 and a median of 631 µg/m^3; 59 (71%) of the samples exceeded 250 μg/m^3. Tuckpointers working outdoors with some form of LEV (56 samples) experienced respirable crystalline silica exposures from 10 to 6,196 μg/m^3, with a mean of 368 μg/m^3 and a median of 70 μg/m^3. Fifteen (27%) of those samples were greater than five times the NIOSH REL. Workers tuckpointing in other conditions[1] (12 samples) had respirable crystalline silica exposures from 146 to 75,153 μg/m^3, with a mean of 7,198 μg/m^3 and a median of 793 μg/m^3. Ninety-two percent (11) of the samples in that category exceeded 250 μg/m^3.

The tuckpointing study by Collingwood and Heitbrink [2007] reported several conditions that must be met in order for tool-mounted LEV on tuckpointing grinders to be effective: "The distance between the exhaust take-off and the uncut mortar must be minimized…the grinding wheel needs to be moved against its natural rotation so the debris is directed in the exhaust take-off…the worker must periodically stop grinding and take action to maintain [vacuum cleaner] airflow." The authors also noted that exposures increased when the distance between the tool-mounted LEV and the surface of the mortar increased, such as during plunge cuts, and when deteriorated, missing mortar provided a means for dust to escape. The OSHA sampling data for tuckpointers working outdoors with some form of LEV and the conditions that must be met for the LEV to be effective indicate that there is a need to either improve the LEV for grinders or identify tools other than grinders that may be used to remove mortar effectively and efficiently while minimizing tuckpointers' silica exposures. The intent of the current study was to evaluate the use of a powered chisel with on-tool LEV as a potential alternative to traditional tuckpointing with a grinder.

Plant and Process Description

The BAC training center resources include expert trainers and skilled apprentices to test tools and provide feedback about their utility and acceptability, as well as a suitable environment in which to assess the tools' performances and associated exposures. In addition, the trainers are experienced in vocational training curriculum development and assessment.

A brick wall was built inside the training center using block, bricks, and Type N mortar. The mortar was allowed to cure for at least 21 days before it was removed. The wall, built in the shape of the letter C, included four inside corners (Figure 1). The wall was approximately 1.5 meters (m) high, composed of 16 rows of brick on top of a row of block on a concrete base. The three closed sides of the wall were approximately 4.0 m long, while portions on both sides of the opening were approximately 0.60 m long.

[1] Including in areas with limited air circulation (e.g., a courtyard, or between a wall and a plastic tarp) or where dust controls are attempted in a manner offering little or no benefit (e.g., wetting the wall before grinding, or using damaged LEV equipment).

Figure 1 - Wall inside training center (NIOSH photo)

Air samples for respirable dust and respirable crystalline silica were collected while an experienced bricklayer removed mortar from the wall. The bricklayer wore a full-facepiece, air-purifying respirator (3M, St. Paul, MN) with 3M model 2091 P100 filters. Training, fit-testing, and medical clearance were performed by his employer. He donned and wore the respirator correctly and it appeared to be maintained properly. He also wore ear muffs, work boots, and work gloves.

The bricklayer removed mortar using a 1⅛ in (28.6 mm) special direct system plus (SDS-plus) rotary hammer (model RH228VC, Robert Bosch Tool Corp., Mt. Prospect, IL) and a ¼ in (6.4 mm) mortar removal chisel (model HS1400 ¼ in Mortar Knife SDS-plus® Bulldog™ Hammer Steel, Robert Bosch Tool Corp., Mt. Prospect, IL). He was told to use the tool to remove mortar from head and bed joints and include inside corners. Samples were collected as described below while the bricklayer removed the mortar. Figure 2 shows the tool.

Figure 2 - Hammer drill with shroud and bit (NIOSH photo)

An on-tool exhaust hood designed for hammer drills (suction casing 6621, Dustcontrol, Inc, Wilmington, NC) was attached to the front of the tool with a hose clamp. A triangular notch approximately 38 mm long at its base with sides approximately 80 cm long was cut into the hood to allow the hood to be flush with the wall when it was used for mortar removal. The diameter of the hood’s flanged inlet is approximately 60 mm. The diameter of the tool connection is 48 mm and the diameter of the hose connection is 38 mm. Figure 3 shows the hood.

Figure 3 - On tool exhaust hood (NIOSH photo)

The hood was connected to a pre-separator (model DC 2800, Dustcontrol, Inc., Wilmington, NC) with a 4.6 m length of 38 mm diameter vacuum cleaner hose. A length of 50 mm diameter hose linked the pre-separator to a vacuum cleaner (model DC Tromb 400c, Dustcontrol, Inc, Wilmington, NC) equipped with a part number 44017 prefilter and part number 44016 class-H13[2] final filter (Dustcontrol, Inc, Wilmington, NC). The use of a cyclonic pre-separator reduces the accumulation of dust and debris on the filter in the vacuum cleaner, which helps to maintain a steady airflow [Heitbrink and Santalla-Elias 2009]. The vacuum cleaner and pre-separator are shown in Figure 1.

Occupational Exposure Limits and Health Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended occupational exposure limits (OELs) when evaluating chemical, physical, and biological agents in the workplace. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Combined effects are often not considered in the OEL. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus can increase the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limit (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. The U.S. Department of Labor OSHA PELs [CFR 2003] are occupational exposure limits that are legally enforceable in covered workplaces under the Occupational Safety and Health Act. NIOSH recommendations are based on a critical review of the scientific and technical information available on the prevalence of health effects, the existence of safety and health risks, and the adequacy of methods to identify and control hazards [NIOSH 1992]. They have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the Threshold Limit Values® (TLVs®) recommended by the American Conference of Governmental Industrial Hygienists

[2] Filtration efficiency is 99.95%, according to standard EN 1822.

(ACGIH®), a professional organization [ACGIH 2016]. ACGIH TLVs are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards." Workplace Environmental Exposure Levels (WEELs) are recommended OELs developed by the American Industrial Hygiene Association, another professional organization. WEELs have been established for some chemicals "when no other legal or authoritative limits exist." [AIHA 2007].

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider the other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation) (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

Crystalline Silica Exposure Limits

When dust controls are not used or maintained or proper practices are not followed, respirable crystalline silica exposures can exceed the NIOSH REL, the OSHA PEL, or the ACGIH TLV. NIOSH recommends an exposure limit for respirable crystalline silica of 0.05 mg/m^3 as a TWA determined during a full-shift sample for up to a 10-hr workday during a 40-hr workweek to reduce the risk of developing silicosis, lung cancer, and other adverse health effects [NIOSH 2002]. When substituting less hazardous materials for crystalline silica (where feasible) and source controls cannot keep exposures below the NIOSH REL, NIOSH also recommends minimizing the risk of illness that remains for workers exposed at the REL by using appropriate respiratory protection, and by making medical examinations available to exposed workers [NIOSH 2002]. In March 2016, OSHA issued a new PEL of 0.05 mg/m^3 for 8-hr TWA exposures [81 Fed. Reg.[3] 16285 (2016)]. The ACGIH TLV for α-quartz and cristobalite (respirable fraction) is 0.025 mg/m^3 [ACGIH 2016]. The TLV is intended to mitigate the risk of pulmonary fibrosis and lung cancer.

[3] *Federal Register.* See Fed. Reg. in references.

Methodology

Personal breathing zone (PBZ) and area air samples for respirable dust and respirable crystalline silica were collected while an experienced bricklayer used a powered chisel to remove mortar from the brick wall at the training center. The bricklayer repeated the mortar removal process during six sampling periods, each approximately 20 minutes long. Figure 4 shows the tool being used to remove mortar around a brick in an inside corner.

Figure 4 – Removing mortar in an inside corner (NIOSH photo)

Personal breathing zone air samples for respirable particulate were collected at a flow rate of 9 liters/minute (L/min) using a battery-powered sampling pump (Leland Legacy sampling pump, SKC, Inc., Eighty-Four, PA) calibrated before and after sampling. The sampling pump was attached to the waistband of a back-support vest (Model 1650, Ergodyne, St. Paul, MN). The pump was connected via Tygon® tubing to a pre-weighed, 47-mm diameter, 5-micron (µm) pore-size polyvinyl chloride (PVC) filter supported by a backup pad in a three-piece conductive filter cassette sealed with a cellulose shrink band (in accordance with NIOSH Methods 0600 and 7500) [NIOSH 1998, NIOSH 2003]. The front cover of the cassette was removed and the cassette was attached to a respirable dust cyclone (BGI GK 4.162 cyclone, MesaLabs, Butler, NJ). At a flow rate of 9 L/min, the GK 4.162 cyclone has a 50% cut point of (D_{50}) of 3.91 µm, and conforms to the respirable sampling convention at flow rates between 8.5 and 9.5 liters per minute [HSL 2012]. D_{50} is the aerodynamic diameter of the particle at which penetration into the cyclone declines to 50% [Vincent 2007]. The cyclone was clipped to the suspender strap of the back-support vest near the bricklayer's head and neck within the breathing zone (Figure 5). Area air samples were collected using the same sampling method, except that the sampling pump and cyclone were placed in holders mounted atop two tripods at about breathing zone height, 1.5 m above the ground. A tripod with the sampling apparatus was placed 1.5 m from either end of the brick wall. A bulk sample of mortar dust was also collected in accordance with NIOSH Method 7500 [NIOSH 2003].

Figure 5 – Cyclone sampler in the breathing zone (NIOSH photo)

The filter samples were analyzed for respirable particulates according to NIOSH Method 0600 [NIOSH 1998]. The filters were allowed to equilibrate for a minimum of two hours before weighing. A static neutralizer was placed in front of the balance and each filter was passed over this device before weighing. The filters were weighed on an analytical balance (model AT201, Mettler-Toledo, LLC, Columbus, OH). The sequence specific limit of detection (LOD) and the limit of quantitation (LOQ) were determined using seven media blanks. The LOD is three times the standard deviation of the media blank weight differences. The LOQ is ten times the standard deviation of the media blank weight differences. The limit of detection (LOD) was 50 µg/sample. The limit of quantitation (LOQ) was 160 µg/sample.

Samples for airborne respirable crystalline silica were prepared and analyzed following NIOSH Method 7500 (NMAM 4th Edition). Each filter was removed from the cassette and folded twice into a wedge-shaped pocket to contain the particulate inside. A drop of 2-propanol was added to the inside of each cassette lid and the back side of the sample filter was used to wipe the interior of the sampling cassette. Each filter was transferred to a 15-mL sample vial. The filters were each dissolved by addition of 7 mL of tetrahydrofuran (THF) to each sample vial. The samples were mixed by vortex. The sample vials were covered with aluminum foil and placed in an ultrasonic bath for ten minutes. The sample suspension from each vail was transferred to a silver-membrane filter as follows: First, a silver-membrane filter was placed in the vacuum filtration unit. Next, 2 mL of THF solvent was placed onto the filter. The sample suspension was vortexed and immediately added onto the silver membrane filter. The sample vial was rinsed with three separate portions of 2 mL THF. Each rinse was added to the sample on top of the silver membrane filter. Finally, vacuum was applied to deposit the sample suspension onto the filter. The silver-membrane filter was transferred to a sample plate and placed in the automated sample changer for analysis by X-ray diffraction. The LOD for quartz on a 47-mm PVC 5 µm filter was 5 µg/sample. The LOQ was 17 µg/sample. The LOD and LOQ for cristobalite were 5 µg/sample and 17 µg/sample, respectively. For tridymite, the LOD was 10 µg/sample and the LOQ was 33 µg/sample.

In this sample set, the maximum air sample volume collected was 227 L. At the LOD for quartz of 5 µg/sample, the minimum detectable quartz concentration was 0.022 mg/m^3, less than half of the NIOSH REL of 0.05 mg/m^3. The minimum quantifiable quartz concentration at the LOQ of 17 µg/sample was 0.075 mg/m^3, or about 1.5 times the NIOSH REL of 0.05 mg/m^3. The minimum detectable respirable dust concentration on the filter samples at the LOD of 50 µg/sample was 0.22 mg/m^3, while the minimum quantifiable concentration at the LOQ of 160 µg/sample was 0.70 mg/m^3.

Approximately 1 g of the bulk sample was ground to a fine powder using a planetary ball mill with a tungsten carbide grinding vial. The ground powder was wet sieved through a 10 µm sieve using 2-propanol. The alcohol was evaporated in a drying oven. Approximately 2 mg of sieved-dried sample was weighed into a 15-mL test tube. Approximately 10 mL of 2-propanol was added into the test tube to create a suspension. The test tube was placed in an ultrasonic bath for about 10 minutes until agglomerated particles were broken up. The sample suspension was vortexed and immediately deposited onto a 25-mm diameter silver membrane filter, as follows: First, a silver membrane filter was placed in the vacuum filtration unit. Next, 2 mL of 2-propanol was added into the filtration funnel, followed by the sample suspension and test tube rinses. Finally, vacuum was applied to deposit the suspension onto the filter. The silver membrane filter was transferred to an aluminum sample plate and placed in the automated sample changer for analysis by X-ray diffraction. The LOD for quartz was 0.3% by weight and the LOQ for quartz was 0.83% by weight. The LOD and LOQ for cristobalite were 0.3% by weight and 0.83% by weight, respectively. The LOD for tridymite was 0.5% by weight and the LOQ was 1.7% by weight.

Real-time PBZ respirable dust sampling was performed using an aerosol photometer (SidePak AM510 aerosol monitor, TSI Inc., Shoreview, MN) with a 10-mm nylon respirable dust cyclone. The instrument’s internal sampling pump was calibrated before and after each day’s use to operate at a flow rate of 1.7 L/min. The SidePak was clipped to the worker’s belt and the cyclone was clipped to his sweatshirt in his breathing zone. A length of Tygon tubing connected the cyclone and the instrument. The SidePak was set to log data every second during the sampling period.

The NIOSH researchers used a data-logging weather station (Kestrel 4500, Nielsen-Kellerman, Boothwyn, PA) mounted on top of a tripod to record temperature, relative humidity, and air speed at the site. The weather meter was approximately

60 in (1.5 m) off the ground. The weather meter was programmed to record data every minute.

Following the site visit, the airflow through the system consisting of the hood mounted on the hammer drill, hose, and vacuum cleaner was measured in the laboratory by inserting a delta tube (model 307BZ-11-A0, Midwest Instrument, Sterling Heights, MI) in line in the hose between the chisel and the vacuum cleaner, in accordance with the manufacturer's recommendations. The differential pressure across the delta tube was measured with a Magnehelic pressure gauge (model 2050, Dwyer Instruments, Inc., Michigan City, IN). Readings were recorded with the tool running and chisel in place.

Results

The bulk sample of brick and mortar dust contained 28% quartz by weight. No cristobalite or tridymite were found in the bulk dust sample. The results of area and personal breathing zone air sampling are presented in Tables 1 and 2, below. Real-time personal breathing zone respirable dust results are summarized in Table 3.

No cristobalite or tridymite were found in any of the air samples. Personal breathing zone quartz concentrations ranged from less than the limit of detection to 0.053 mg/m^3. The highest concentration detected was a sample result between the LOD and LOQ, which is considered a trace value with limited confidence in its accuracy.

Table 1 – Personal Breathing Zone and Area Respirable Quartz Results

Test	Location	Result (µg/sample)	Duration (min)	Flow rate (L/min)	Volume (L)	Concentration (mg/m^3)
1	Personal	(6.1)	18	9.0	161	(0.037)
	Area 1	ND	18	8.9	158	---
	Area 2	ND	18	8.9	159	---
2	Personal	(7.1)	25	9.0	226	(0.031)
	Area 1	ND	23	8.9	202	---
	Area 2	ND	23	8.9	203	---
3	Personal	(12)	25	9.0	225	(0.053)
	Area 1	ND	25	8.9	225	---
	Area 2	ND	25	8.9	225	---
4	Personal	ND	25	9.0	225	---
	Area 1	ND	25	8.9	227	---
	Area 2	ND	25	8.9	225	---
5	Personal	ND	22	9.0	195	---
	Area 1	ND	21	8.9	191	---
	Area 2	ND	21	8.9	189	---
6	Personal	ND	19	9.0	172	---
	Area 1	ND	19	8.9	171	---
	Area 2	ND	19	8.9	170	---

Notes: values in parentheses indicate results between the limit of detection and the limit of quantification. These are trace values with limited confidence in their accuracy. ND means not detected, a value below the limit of detection. Dashed lines means the concentration was not calculated because the result was less than the limit of detection

Personal breathing zone respirable dust concentrations collected on filter samples ranged from less than the limit of detection to 0.89 mg/m^3. A trace amount of respirable dust was found on one area sample during the last test. Average real-time personal breathing zone respirable dust samples during each sampling period ranged from 0.103 mg/m^3 to 0.395 mg/m^3. All but two of the real-time average concentrations were less than the minimum detectable concentration of the filter samples 0.22 mg/m^3. The highest average real time respirable dust measurement and filter-sample result both occurred during the third test.

Table 2 – Personal Breathing Zone and Area Respirable Dust Results

Test	Location	Result (µg/sample)	Duration (min)	Flow rate (L/min)	Volume (L)	Concentration (mg/m^3)
1	Personal	ND	18	9.0	161	---
	Area 1	ND	18	8.9	158	---
	Area 2	ND	18	8.9	159	---
2	Personal	(130)	25	9.0	226	(0.58)
	Area 1	ND	23	8.9	202	---
	Area 2	ND	23	8.9	203	---
3	Personal	200	25	9.0	225	0.89
	Area 1	ND	25	8.9	225	---
	Area 2	ND	25	8.9	225	---
4	Personal	(77)	25	9.0	225	(0.34)
	Area 1	ND	25	8.9	227	---
	Area 2	ND	25	8.9	225	---
5	Personal	ND	22	9.0	195	---
	Area 1	ND	21	8.9	191	---
	Area 2	ND	21	8.9	189	---
6	Personal	ND	19	9.0	172	---
	Area 1	ND	19	8.9	171	---
	Area 2	(77)	19	8.9	170	(0.45)

Notes: values in parentheses indicate results between the limit of detection and the limit of quantification. These are trace values with limited confidence in their accuracy. ND means not detected, a value below the limit of detection. Dashed lines means the concentration was not calculated because the result was less than the limit of detection

Table 3 – Direct-Reading Personal Breathing Zone Respirable Dust Results

Sampling Period	Duration (min:sec)	Average (mg/m^3)	Minimum (mg/m^3)	Maximum (mg/m^3)
1	17:58	0.219	0.011	4.58
2	25:02	0.141	0.011	2.75
3	25:04	0.395	ND	9.78
4	25:03	0.170	0.006	4.04
5	21:51	0.140	0.004	2.01
6	19:16	0.103	0.006	3.17

The bricklayer removed mortar from the bottom 12 rows of brick during six tests of tool and control. Test 1 was cut short because the vacuum-cleaner hose came off the shroud. Test 6 was cut short when the bricklayer indicated that he did not want to continue with the test. It was noted that air blowing from the hammer drill's motor sometimes aerosolized dust from the mortar joints. The tool was able to remove mortar from inside corners, but using the tool sometimes chipped the bricks in the wall, causing spalling.

The average temperature was 63 °F, and the average relative humidity was 65%. The weather meter did not detect any air movement. Lower readings may be taken down to 79 ft/min (0.4 m/s) with the weather meter used here.

Airflow through the dust control system was 101 cubic feet per minute (cfm) (2.86 cubic meters per minute [m^3/min]) after the tests were completed. The hose between the chisel and the pre-separator was 1.5 in (38 mm) in diameter. The calculated average velocity in a 1.5 in (38 mm) diameter hose at a flow rate of 101 cfm (2.86 m^3/min) is approximately 8220 feet per minute (fpm) 41.8 (m/sec).

Discussion

This powered chisel with on-tool LEV and a higher-flow vacuum cleaner was able to remove mortar from joints while producing less respirable dust and respirable quartz than a grinder, regardless of whether the grinder included LEV. For example, Meeker et al. [2009] evaluated two tuck-pointing grinders with and without LEV. Trials with LEV lasted about 25 minutes. The mean PBZ respirable quartz concentration for one grinder was 0.47 mg/m^3 (range 0.28 mg/m^3 – 0.85 mg/m^3); for the other grinder, the mean PBZ respirable quartz concentration was 0.33 mg/m^3 (range 0.19 mg/m^3 – 0.50 mg/m^3) [Meeker et al. 2009]. In comparison, the mean PBZ respirable quartz concentration for the chisel-vacuum cleaner combination tested here was 0.040 mg/m^3. That represents a 91% reduction compared to one of the LEV-equipped grinders and an 88% reduction compared to the other LEV-equipped grinder in the Meeker et al. [2009] study. However, even with those reductions, if the powered chisel with on-tool LEV was used for a full shift and dust levels remained constant and consistent with those observed in this study, the highest quartz concentration measured during use of the chisel – 0.053 mg/m^3 – would exceed the OSHA PEL and NIOSH REL by 6%. That exposure would require the use of a respirator with an assigned protection factor of 10, such as an N-95 filtering facepiece respirator. However, a quartz exposure level of 0.053 mg/m^3 also means that the chisel with on-tool LEV could be used for 7.5 hours in an 8-hr work shift before the NIOSH REL and OSHA PEL of 0.05 mg/m^3, as long as no other exposure to silica took place during that shift. Respiratory protection must be used in compliance with the requirements of the OSHA respiratory protection standard 29 CFR 1910.134, including all of the elements of a respiratory protection program, such as procedures for selecting respirators, medical evaluations of employees required to use respirators, and fit-testing procedures for tight-fitting respirators.

The trace amount of dust found in the area sample during Test 6 may be due to the proximity of the work to that sampler, while the worker removed mortar from a portion of the wall. During Test 6, he was working on the outside of the wall, on the right side, which was close to area sampler 2 (see Figure 2).

The transport velocity of 8220 fpm (41.8 m/sec) should prevent clogging due to dust settling in the duct. The ACGIH industrial ventilation manual recommends a transport velocity of 3500 to 4000 fpm for “average industrial dust” (e.g., granite or limestone dust, brick cuttings, silica flour) [ACGIH 2013]. Conducting the evaluation indoors eliminated the effects of the wind on the operation.

Söderberg [2010], citing a Swedish Board of Occupational Safety and Health document, recommended a minimum air flow rate of 180 m^3/hr (106 cfm) for a chisel hammer used on concrete or stone with a 38 mm (1.5 in) diameter suction casing, like the one used here. That recommendation was verified experimentally during this evaluation by using a vacuum cleaner capable of producing airflow close to that recommendation.

Conclusions and Recommendations

The powered mortar-raking chisel with on-tool LEV produced respirable quartz exposures less than those reported when grinders were used with LEV. If the tool can remove mortar with the speed and quality required by contractors and is acceptable to workers, it represents an alternative to the use of grinders. Use of the chisel occasionally chipped the brick, which resulted in damage that may be unacceptable to a building’s owner. The damage may be due to the experience level of the bricklayer with this tool. The chisel is an additional tool available to bricklayers, for example, one that can be used on inside corners. However, if the observed short-term exposure concentrations are representative of those expected over a full shift, tuckpointing with the powered chisel and on-tool LEV will require the use of a respirator. Full-shift sampling should be conducted while the tool is used by trained bricklayers on a sufficient number of job sites to determine how well this tool works under actual working conditions.

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