In-Depth Survey Report

Comparison of Removing Mortar by Powered Chisels, Manual Chisels and Angle Grinders

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Division of Field Studies and Engineering
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Site Surveyed:

Detroit Women's City Club
2110 Park Ave. Detroit MI

NAICS Code:

238140 Tuck pointing contractors

Survey Dates:

August 13-16, 2019

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Not applicable

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Abstract

Background

Workplace exposure to respirable crystalline silica (RCS) can cause silicosis, a progressive lung disease marked by scarring and thickening of the lung tissue. Quartz is the most common form of crystalline silica. Crystalline silica is found in several materials, such as brick, block, mortar and concrete. Construction and manufacturing tasks that cut, break, grind, abrade, or drill those materials have been associated with overexposure to dust containing RCS. Tuckpointing (repointing) removes damaged mortar from joints in masonry walls and replaces it with new mortar to restore the wall. The use of dry grinders to remove mortar results in worker overexposure to respirable crystalline silica. NIOSH researchers have been conducting a study to assess the RCS exposures associated with mortar removal when tools other than dry grinders are used. The site visit described in this report is part of that study.

Assessment

A NIOSH researcher visited a jobsite at the Detroit Women's City Club in Detroit, Michigan, between August 13 to 16, 2019, and performed industrial hygiene sampling, which measured short-term task-based exposures to respirable dust and RCS while five workers used power chisels, manual chisels, and dry grinders with on-tool local exhaust ventilation (LEV) to remove mortar from brick walls. The NIOSH researcher also observed the work process to understand the conditions that contributed to the measured exposure.

Results

Only one of the three air samples from using power chisels had a detectable amount of RCS, and its time weighted average (TWA) RCS exposure was 41.7 $\mu g/m^3$. Excluding the sample with both respirable dust and RCS masses below their detection limits, the three samples associated with using manual chisels had TWA RCS exposures ranging from 19.5 to 34.1 $\mu g/m^3$ with a mean of 27.3 $\mu g/m^3$ and a standard deviation of 7.3 $\mu g/m^3$. The eight samples associated with using both manual chisels and dry grinders had TWA RCS exposures ranging from 62.1 to 470.6 $\mu g/m^3$ with a mean of 182.5 $\mu g/m^3$ and a standard deviation of 163.6 $\mu g/m^3$.

The short-term TWA exposures from using manual chisels were significantly lower than those from using both manual chisels and dry grinders (P = 0.014 for respirable dust and P = 0.016 for RCS).

Conclusions and Recommendations

The exposure levels recorded at this site indicated that the manual chisels used in this survey effectively controlled the dust emissions and reduced the workers' RCS exposures. Although the result of the air sample from using power chisel was encouraging, the result is not conclusive because of the very limited sample size. Additional field studies evaluating power chisels with or without the use of LEV over

a full-shift will be needed to establish its effectiveness in controlling workers RCS exposure during tuckpointing. The overall results from this survey indicate that using power chisel is likely to lead to lower RCS exposure compared to using dry grinders with LEV. When applicable, the use of tools such as manual and power chisels and engineering control technology such as LEV for tuckpointing is a preferred solution and adheres to the hierarchy of controls. Before sufficient dust controls are validated and implemented, respirators should continue to be used to reduce exposures, and the employer needs to make sure that the respiratory protection program follows the OSHA standard.

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 Field Studies and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted assessments of health hazard control technologies 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.

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 project

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 (RCS) 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 RCS 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-Khanzadeh 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 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, die grinders with diamond tools, power hammer drills and mortar chisels, and power saws [Yasui et al. 2003]. 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 dry grinders to remove mortar results in worker exposure to RCS 2 to 1500 times the NIOSH Recommended Exposure Limit (REL) of 50 micrograms per cubic meter (μg/m^3). Even with engineering controls (i.e., on-tool local exhaust ventilation [LEV]), the use of a respirator with an appropriately assigned protection factor is still required [Collingwood and Heitbrink 2007]. In its Preliminary Economic Analysis for the Proposed Rule for Occupational Exposure to Respirable Crystalline Silica, the Occupational Safety and Health Administration (OSHA) reported the results of 151 8-hour samples for RCS for tuckpointers [OSHA 2013]. 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). Time weighted average (TWA) RCS 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 TWA RCS 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; 15 (27%) of the samples exceeded 250 μg/m^3. Workers tuckpointing in other conditions[1] (12 samples) had TWA RCS 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; 11 (92%) 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 discrepancy between 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 indicates that there is a need to either improve the LEV for grinders or identify tools other than dry grinders that may be used to remove mortar effectively and efficiently while minimizing tuckpointers' RCS exposures. The intent of the current project is to identify tools other than dry grinders as potential alternatives for tuckpointing with lower RCS exposures.

Background for this survey

NIOSH evaluated a few tools other than dry grinders for tuckpointing in collaboration with Bricklayers and Allied Craftworkers Southern Ohio-Kentucky Regional Training Center, Batavia, Ohio. A short-term sampling strategy was used during the evaluations with an aim to quickly identify promising tools for further field validation. Six short-term personal breathing zone (PBZ) air samples taken from an apprentice bricklayer during active tuckpointing on a brick wall outdoors using a powered chisel without LEV [NIOSH 2017a] showed TWA RCS exposures of 72 ± 34 μg/m^3 (mean ± standard deviation, which is used hereafter for the values reported in the same format). Two additional site visits [NIOSH 2017b, NIOSH 2018a] evaluating two apprentice bricklayers' short-term RCS exposures during active tuckpointing using a powered chisel with LEV on a brick wall indoors showed TWA RCS exposure of 103 ± 54 μg/m^3 from 4 PBZ samples and 111 ± 51 μg/m^3 from 7 PBZ samples, respectively. The LEV, provided by a vacuum cleaner (model DC 2900eco, Dustcontrol, Inc, Wilmington, NC) with a manufacturer-rated maximum flowrate of 126 cubic feet per minute (CFM), operated at 87 CFM and 78 CFM, respectively during the two visits. The slightly reduced LEV flowrate found in

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[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).

the 2nd site visit was likely due to the addition of a pre-separator (model DC 2800, Dustcontrol, Inc., Wilmington, NC). With an increased LEV flowrate to 101 CFM by using a higher-flow vacuum cleaner (model DC Tromb 400c, Dustcontrol, Inc, Wilmington, NC), which has a manufacturer-rated maximum flowrate of 212 CFM, NIOSH [2018b] reported short-term TWA RCS exposures of 41 ± 11 μg/m^3 for 3 PBZ samples from an experienced bricklayer during active tuckpointing using a powered chisel with LEV on a brick wall indoors. The working environment, i.e., indoor vs outdoor, the flowrate provided to the LEV, and the experience of using the tool with LEV may affect the exposures. It should be noted that the actual flowrates provided by the vacuum cleaners are often considerably lower than the manufacturer-rated maximum flowrate because of the pressure loss from the hoses, pre-separators, and filters, as well as dust loading on the filters.

Overall, the results from the short-term samples when actively removing mortar with a powered chisel are encouraging as they are much lower than the exposure levels from using angle grinders in dry operations. At actual jobsites, bricklayers do not need to conduct tuckpointing continuously throughout their full-shifts because they need to 1) often inspect the walls and identify places that need tuckpointing; 2) move to different walls or different sections of a wall upon completion; and 3) take short breaks during the operation of the heavy equipment including power tools and vacuum cleaners. Some bricklayers may mix the task of tuckpointing and repointing (applying new mortar after tuckpointing that removes the old mortar) throughout the full-shifts. The RCS exposure is expected to be much lower when a bricklayer is not actively tuckpointing due to the absence of the RCS source. Therefore, the RCS exposure during a full-shift for bricklayers is expected to be lower than the values reported from the short-term samples mentioned above when other conditions are similar.

In this survey, a NIOSH researcher conducted a site visit to evaluate the bricklayers RCS exposure at a construction site where power chisels, manual chisels and dry grinders with LEV were all used for tuckpointing. The field evaluation consisted of collecting PBZ air samples to assess the bricklayers' short-term TWA respirable dust and RCS exposures while using the specific tools.

Evaluation Site and Process Description

Introduction

The evaluation site was a building with exterior walls of brick and mortar. Tuckpointing was part of a renovation project of the building. Figure 1 shows a picture of the building under renovation. As illustrated in the picture the project was ongoing during the site visit for the wall where elevated platforms and fall-protection screens were set up.

Figure 1 – The brick wall building under renovation. Photo by NIOSH.

Process Description

The tuckpointing at this jobsite used a combination of several tools including power chisels, manual chisels and dry grinders. The bricklayers initially planned on using power chisels because of the expected lower RCS exposure. Each power chisel included a rotary hammer drill (D25263 3 Mode D-handle SDS, DEWALT, Towson, MD) and a 1.5" chisel (HS1465, BOSCH, Farmington Hills, MI). However, it was found during the first two days of the study that the power chisels chipped the bricks of the building too easily due to the softness of the bricks. The bricklayers then started using manual chisels (no brand and make information was available) with hammers and 6" tuckpoint/cutting grinders (DWE46103, DEWALT, Towson, MD) with 4.5" segmented diamond blades (SG45CP, Ridge Tool Company, Elyria, OH) for tuckpointing in dry condition.

Figure 2 shows a bricklayer using a power chisel. All the bricklayers at the jobsite wore elastomeric, half-face air-purifying respirators (3M™ 6200, the 3M Company, Saint Paul, MN) with P100 cartridges (3M™ Particulate Filter 2097, the 3M

Company, Saint Paul, MN). Other personal protective equipment (PPE) worn included hearing protection, safety shoes, safety glasses, and aprons.

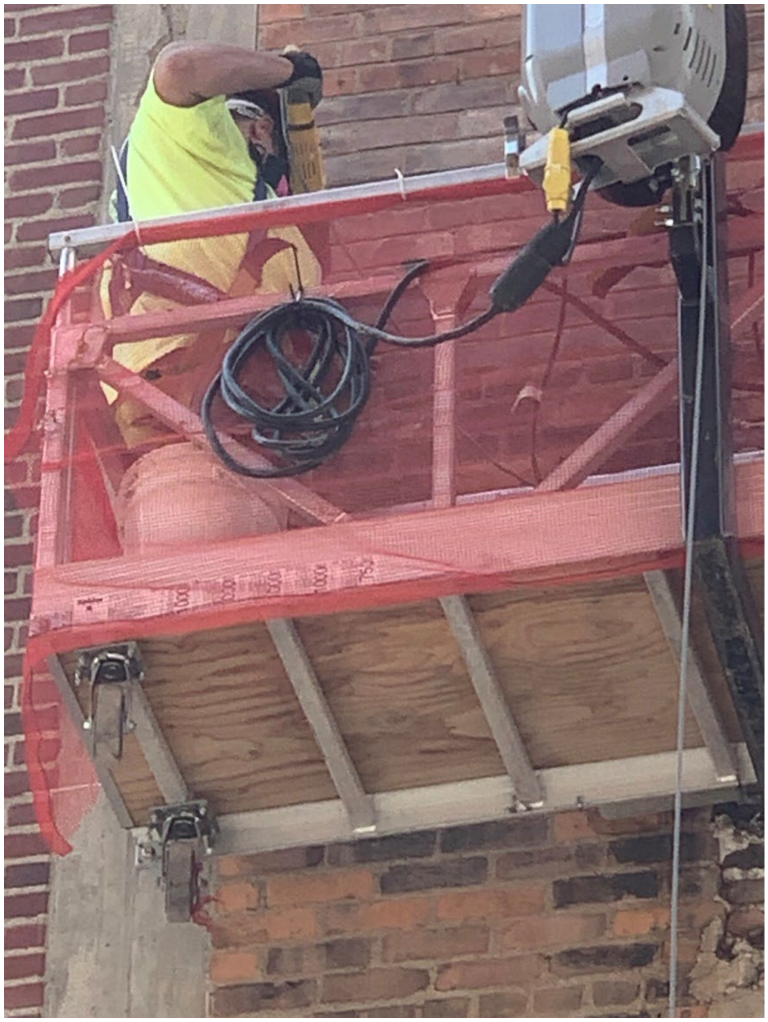

Figure 2 – A bricklayer using a power chisel without LEV for tuckpointing. Photo by NIOSH.

Control Technologies

Wet/dry vacuum cleaners (DWV012, DEWALT, Towson, MD) of 10-gallon capacity with HEPA filters and an automatic filter cleaning feature provided the LEV for each dry grinder. This vacuum cleaner has a manufacturer-rated maximum flowrate of 140 CFM. The actual flowrate of the LEV was not monitored during the survey, but it is likely to be close to 87 CFM reported by NIOSH [2017b] from a vacuum cleaner with similar manufacturer-rated maximum flowrate. The bricklayers did not use LEV when using power chisels. Figure 3 shows a bricklayer working on a section of the wall with both a power chisel without LEV and a dry grinder with LEV.

Figure 3 – A power chisel without LEV and a dry grinder with a 10-gallon wet/dry vacuum cleaner providing LEV used for tuckpointing. Photo by NIOSH.

Occupational Exposure Limits and Health Effects

The objective of implementing control technologies in this project is to reduce workers' occupational exposure to levels below the corresponding Occupational Exposure Limits (OELs). As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended 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 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 a 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 [29 CFR 1910.1000, 2016] 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 American Conference of Governmental Industrial Hygienists (ACGIH®), a professional organization [ACGIH 2018]. 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® (AIHA), 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. 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) PPE (e.g., respiratory protection, gloves, eye protection, hearing protection).

Respirable Crystalline Silica Exposure Limits

NIOSH recommends an exposure limit for RCS of 50 µg/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 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 substituting less hazardous materials for crystalline silica when feasible, by using appropriate respiratory protection, and by making medical examinations available to exposed workers [NIOSH 2002]. In cases of simultaneous exposure to more than one form of crystalline silica, the concentration of free silica in air can be expressed as micrograms of free silica per cubic meter of air sampled (µg/m^3) [NIOSH 1975].

$$\mu g S_i O_2/m^3 = \frac{\mu g Q + \mu g C + \mu g T + \mu g P}{V} \qquad (1)$$

Where Q is quartz, C is cristobalite, and T is tridymite, P is "other polymorphs", and V is sampled air volume.

The current OSHA PEL for RCS is 50 µg/m^3 as an 8-hr TWA [29 CFR 1926.1153, 2019a]. The ACGIH TLV for α-quartz (the most abundant toxic form of silica, stable below 573°C) and cristobalite (respirable fraction) is 25 µg/m^3 [ACGIH 2018]. The TLV is intended to mitigate the risk of pulmonary fibrosis and lung cancer.

Methodology

Sampling Strategy

The original plan was to sample each worker during their use of the same tools, preferably in full-shift sampling with a focus on evaluating the exposures associated with using power chisels. However, during the first two days of the study, the workers realized that the power chisels chipped the bricks of the building too easily due to the softness of the bricks. Therefore, power chisels were abandoned after collecting only three short-term air samples from using this tool. The participating workers used manual chisels and dry grinders for the next two days. Since the workers switched between using the manual chisels and dry grinders frequently, the Bluetooth® function of the sampling pumps (Gilian GilAir Plus, Sensidyne LP, Clearwater, FL) was activated to pause and resume the sampling when the workers only used manual chisels. This modified sampling strategy allowed the evaluation of the short-term TWA exposures associated with using the manual chisels. However, this strategy become unapplicable after the workers started working on higher sections of the building where Bluetooth® was out of the range from the NIOSH researcher who was on the ground level. The air samples collected when Bluetooth® was out of the range reflected the short-term TWA exposures associated with using both the manual chisel and dry grinder of each worker.

Note that this modified sampling strategy also means that the short-term task-based sampling results should not be directly compared to OSHA PEL for compliance purposes, which are for full-shift (8 hour or 10 hour) exposures.

Sampling Procedures

Air samples for respirable dust were collected at a flow rate of 4.2 liters per minute (L/min) using a battery-operated sampling pump (Gilian GilAir Plus, Sensidyne LP, Clearwater, FL) calibrated before and after each day's use using a DryCal Primary Flow Calibrator (Bios Defender 510, Mesa Laboratories, Inc., Lakewood, CO). For PBZ samples, a sampling pump was clipped to the sampled worker's belt worn at his waist. The pump was connected via Tygon® tubing and a tapered Leur-type fitting to a pre-weighed, 37-mm diameter, 5- µm pore-size polyvinyl chloride (PVC) 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) [NIOSH 1998, NIOSH 2003]. The front portion of the cassette was removed and the cassette was attached to a respirable dust cyclone (model GK2.69, Mesa Laboratories, Inc., Lakewood, CO). At a flow rate of 4.2 L/min, the GK2.69 cyclone has a 50% cut point of (D_{50}) of 4.0 µm. 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 sampled bricklayers' shirts near their breathing zone. In addition to the air samples, two field blank samples were taken on each sampling day. Two bulk dust samples (from the vacuum cleaners) were also collected in accordance with NIOSH Method 7500 [NIOSH 2003].

The filter samples were analyzed for respirable dust 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 (model AT201, Mettler-Toledo, Columbus, OH) and each filter was passed over the neutralizer before weighing. The limit of detection (LOD) and the limit of quantitation (LOQ) of the respirable dust analysis are listed in Table 1.

Table 1 – The limit of detection (LOD) and the limit of quantitation (LOQ) for all the sample analysis.

	Air Samples (µg/sample)				Bulk Samples (%)		
	respirable dust	quartz	cristobalite	tridymite	quartz	cristobalite	tridymite
LOD	20	5	5	10	0.3	0.3	0.5
LOQ	82	17	17	33	0.83	0.83	1.7

Crystalline silica analysis of air and bulk dust samples was performed using X-ray diffraction according to NIOSH Method 7500 [NIOSH 2003]. The LODs and LOQs for quartz, cristobalite, and tridymite in both air samples and bulk samples are also listed in Table 1.

Results

Silica Content in Air and Bulk Samples

No respirable dust or crystalline silica was detected on any of the field blank samples. The two bulk dust samples contained 23% and 25% of quartz, respectively. In comparison, the four bulk dust samples in NIOSH's studies at Allied Craftworkers Southern Ohio-Kentucky Regional Training Center contained 49% [2017a], 47% [2017b], 28% [2018a], and 28% [2018b] of quartz, respectively. No cristobalite or tridymite was detected in the bulk dust samples.

Table 2 – Sampling Time, Respirable Dust Masses, and Respirable Silica Masses

Date	Worker	Tools	Sampling Time (min)	Respirable dust (µg/sample)	RCS (µg/sample)
08/13/2019	Worker 1	Power chisel	23.7	20.0	3.6*
08/14/2019	Worker 2	Power chisel	31.6	14.1*	5.4
	Worker 3	Power chisel	30.8	14.1*	3.6*
08/15/2019	Worker 2	Manual chisel	211.3	110.0	17.5
	Worker 2	Manual chisel	72.9	14.1*	3.6*
	Worker 3	Manual chisel	220.8	230.0	31.8
	Worker 3	Manual chisel	72.9	60.0	8.7
	Worker 4	Manual chisel + Dry grinder	80.3	160.0	26.7
	Worker 5	Manual chisel + Dry grinder	71.8	200.0	24.6
08/16/2019	Worker 2	Manual chisel + Dry grinder	101.4	190.0	26.7
	Worker 2	Manual chisel + Dry grinder	30.9	360.0	61.6
	Worker 3	Manual chisel + Dry grinder	107.5	600.0	100.6
	Worker 3	Manual chisel + Dry grinder	27.6	50.0	8.3
	Worker 4	Manual chisel + Dry grinder	120.8	210.0	40.0
	Worker 4	Manual chisel + Dry grinder	68.5	650.0	112.9

Notes: data with a * means the sampled data was below the LOD and a value of LOD/SQRT(2) was used in the calculation.

Table 2 presents the sampling time, respirable dust and RCS masses reported for the air samples collected in this survey with the specific tools associated with each sample. All but three air samples contained at least 20 µg respirable dust, which is the LOD as listed in Table 1, while keeping the amount of the dust below the 2 mg upper limit specified by the NIOSH Methods 0600 [NIOSH 1998]. All but three air samples had detectable amounts of quartz. Neither tridymite nor cristobalite was detected in any air samples. Thus, only the quartz results were used in the calculation of the crystalline silica content of the air samples. The three air samples with either respirable dust or quartz below the respective LOD were estimated to have LOD/SQRT(2) of respirable dust or quartz (14.1 µg for respirable dust and 3.6 µg for quartz based on the LOD listed in Table 1) following Hewett and Ganser [2007].

Respirable Dust and Respirable Crystalline Silica Results

Table 3 – Respirable Dust Exposure, RCS Exposure, and Silica Content

Date	Worker	Tools	TWA respirable dust exposure (µg/m^3)	TWA RCS exposure (µg/m^3)	Silica content
08/13/2019	Worker 1	Powered chisel	201.3	36.5*	18.1%*
08/14/2019	Worker 2	Powered chisel	108.5*	41.7	38.5%*
	Worker 3	Powered chisel	111.2*	28.5*	25.7%*
08/15/2019	Worker 2	Manual chisel	122.8	19.5	15.9%
	Worker 2	Manual chisel	45.7*	11.7*	25.7%*
	Worker 3	Manual chisel	246.1	34.1	13.8%
	Worker 3	Manual chisel	194.3	28.3	14.5%
	Worker 4	Manual chisel + Dry grinding	478.4	79.8	16.7%
	Worker 5	Manual chisel + Dry grinding	666.5	82.1	12.3%
08/16/2019	Worker 2	Manual chisel + Dry grinding	442.1	62.1	14.0%
	Worker 2	Manual chisel + Dry grinding	2750.3	470.6	17.1%
	Worker 3	Manual chisel + Dry grinding	1321.8	221.6	16.8%
	Worker 3	Manual chisel + Dry grinding	429.1	71.4	16.6%
	Worker 4	Manual chisel + Dry grinding	414.6	79.0	19.1%
	Worker 4	Manual chisel + Dry grinding	2265.1	393.5	17.4%

Notes: data with a * means the sampled data was below the LOD and a value of LOD/SQRT(2) was used in the calculation.

Based on the data presented in Table 2, the RCS content for each air sample was calculated and is listed in the last column of Table 3. Excluding the sample with both respirable dust and RCS masses below their LODs, the three samples associated with using manual chisels contained from 13.8 to 15.9% crystalline silica, with a mean of 14.7% and a standard deviation of 1.0%. The eight samples associated with using both manual chisels and dry grinders contained from 12.3 to 19.1% crystalline silica, with a mean of 16.3% and a standard deviation of 2.1%. The 23 air samples collected in NIOSH's studies [2017a, 2017b, 2018a, and 2018b] at Allied Craftworkers Southern Ohio-Kentucky Regional Training Center contained 11.3 ± 4.7% quartz. Similar levels of crystalline silica content among all the air samples from different studies suggests that the mortar removed during all these studies did not have very different silica content.

Table 3 also reports the short-term TWA exposures to respirable dust and RCS from each sample. The focus of this research was to evaluate task-based exposure by comparing the short-term TWA exposure data when using different tools. When using power chisels, only one of the three air sample had a quartz mass above the LOD, and it had a TWA RCS exposure of 41.7 μg/m^3. Excluding the sample with both respirable dust and RCS masses below their LODs, the three samples associated with using manual chisels had TWA exposures ranged from 122.8 to 246.1 μg/m^3 for respirable dust, and from 19.5 to 34.1 μg/m^3 for RCS. The eight samples associated with using both manual chisels and dry grinders had TWA exposures ranged from 414.6 to 2750.3 μg/m^3 for respirable dust, and from 62.1 to 470.6 μg/m^3 for RCS.

Data analyses and discussions

Table 4 lists a summary of the statistics from the data analyses. Although three air samples were collected from using power chisels, only one of them resulted in a detectable amount of quartz during the short sampling times. Therefore, only the data from this sample was listed in Table 4. The short-term TWA RCS exposure of 41.7 μg/m^3 is encouraging as it was below the OSHA PEL or NIOSH REL of 50 μg/m^3, but the result is certainly not conclusive because of the very limited sample size. The silica content of this particular sample (38.5%) is apparently higher than that of the other two groups listed in Table 4, likely due to the underestimation of the respirable dust mass of this sample by using LOD/SQRT(2). The silica content in the air samples collected when using manual chisels was not statistically different from that of the samples collected when using both manual chisels and dry grinders (P = 0.077).

Table 4 – Summary Statistics of Data Analyses

Tools	TWA respirable dust exposure (μg/m^3)	TWA RCS exposure (μg/m^3)	Silica content (%)
Power chisel	108.5*	41.7	38.5*
Manual chisel	187.7 ± 61.9	27.3 ± 7.3	14.7 ± 1.0
Manual chisel + Dry grinder	1096.0 ± 930.2	182.5 ± 163.6	16.3 ± 2.1

Notes: data with a * means the sampled data was below the LOD and a value of LOD/SQRT(2) was used in the calculation.

All the TWA respirable dust exposures reported in Table 3 were well below the 5 mg/m^3 OSHA PEL for Particulates Not Otherwise Regulated. However, since this dust contained RCS, the RCS exposures must be compared with the RCS PEL in order to determine whether exposures were successfully controlled. The short-term TWA exposures from using manual chisels were significantly lower than those from using both manual chisels and dry grinders (P = 0.014 for respirable dust and P = 0.016 for RCS). The short-term TWA RCS exposures of 27.3 ± 7.3 μg/m^3 for using manual chisel were considerably lower than the OSHA PEL or NIOSH REL of 50 μg/m^3. When dry grinders were used together with manual chisels, the TWA RCS exposures of 182.5 ± 163.6 μg/m^3 were considerably higher than the OSHA PEL or NIOSH REL level during the short-term sampling of this study. This mean short-term TWA RCS exposure is only about half of 368 μg/m^3, the mean of the 56 samples reported by OSHA [2013] for tuckpointers using only dry grinders outdoors with some form of LEV. This result is as expected due to the lower RCS exposure associated with the use of manual chisels. However, even with this reduction, if the both dry grinders and manual chisels were used with similar patterns for a full-shift and dust levels remained constant and consistent with those observed in the short-term sampling of this site visit, the highest PBZ RCS concentration measured, 470.6 μg/m^3 would be 9.4 times the OSHA PEL and NIOSH REL. That exposure would require the use of a respirator with an assigned protection factor of 10, such as an N-95 filtering facepiece respirator. On the other hand, a RCS exposure of 470.6 μg/m^3 would permit a worker to use the tools under these conditions for up to 50 minutes in an 8-hour shift with no other exposures to RCS without exceeding the REL or PEL.

Conclusions and Recommendations

Controlling exposures to occupational hazards is the fundamental method of protecting workers. Traditionally, a hierarchy of controls has been used as a means of determining how to implement feasible and effective controls. One representation of the hierarchy controls can be summarized as follows:

- Elimination
- Substitution
- Engineering Controls (e.g., ventilation)
- Administrative Controls (e.g., reduced work schedules)
- PPE (e.g., respirators)

The idea behind this hierarchy is that the control methods at the top of the list are potentially more effective, protective, and economical (in the long run) than those at the bottom. Following the hierarchy normally leads to the implementation of inherently safer systems, ones where the risk of illness or injury has been substantially reduced.

In this survey, the workers' short-term TWA RCS exposures were well below the OSHA PEL when using manual chisels. These results suggest that the manual chisel used in this survey effectively controlled the dust emissions and reduced the workers' exposures. Although the result of the air sample from using power chisel was encouraging, with the short-term TWA RCS exposure of 41.7 μg/m^3 from the only sample with a detectable amount of RCS, the result is not conclusive because of the very limited sample size. Additional field studies evaluating this tool with or without the use of LEV in full-shift will be needed to establish its effectiveness in controlling workers RCS exposure during tuckpointing. Nevertheless, the encouraging result is indicative that using a power chisel is likely to lead to lower

RCS exposure compared to using dry grinders. When applicable, the use of tools such as manual and power chisels and engineering control technology such as LEV for tuckpointing is a preferred solution and adheres to the hierarchy of controls.

A review of the respiratory protection program was beyond the scope of this survey. NIOSH recommends (and it is mandated by OSHA where the use of respirators is required) that respirators in the workplace be used as part of a comprehensive respiratory protection program following the OSHA standard [29 CFR 1910.134, 2019b]. If half-facepiece particulate respirators with N95 or better filters are worn properly and used in accordance with good practices, they may be used to reduce RCS exposures to acceptable levels when TWA RCS concentration in the air of PBZ do not exceed 10 times the NIOSH REL [NIOSH 2008]. The short-term TWA RCS exposures observed in this survey do not exceed 10 times the NIOSH REL for RCS. All the workers involved in the production process of this site wore elastomeric, half-face air-purifying respirators with P100 cartridges. Therefore, NIOSH recommends that these respirators should continue to be used before sufficient dust control is validated and implemented, and the employer needs to make sure that the respiratory protection program follows the OSHA standard.

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