In-Depth Survey Report

Concrete Surface Preparation Tools Machines 2 & 3

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DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Site Surveyed:

GMI Engineered Products, LLC
Columbus, OH

NAICS Code:

238340 Tile and Terrazzo Contractors
238110 Structure Contractors

Survey Dates:

July 09 – 10, 2014

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Abstract

Workplace exposure to respirable crystalline silica 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 construction materials, such as brick, block, mortar and concrete. Construction tasks that cut, break, grind, abrade, or drill those materials have been associated with overexposure to dust containing respirable crystalline silica. Colored, stained, and polished concrete floors are increasingly popular for use in homes, offices, retail establishments, schools, and other commercial and industrial settings. Some businesses specify integrally-colored concrete floors in new stores in place of vinyl composite tile. Polished concrete floors are durable, sanitary, and easy to maintain. NIOSH scientists are conducting a study to develop and evaluate engineering control recommendations for respirable crystalline silica from concrete polishing operations. This survey was part of that study.

NIOSH staff visited the GMI Engineered Products, LLC (GMI) training facility in Columbus, OH from July 09 – 10, 2014. During the site visit, personal breathing zone (PBZ) air samples were collected to measure the respirable dust and respirable crystalline silica exposures of the operator while he used two different concrete polishers (HTC and Husqvarna units). Additionally, area samples were collected on top of the machines and at four locations around the polishing area during the completion of the task.

Both polishers were outfitted with a local exhaust ventilation system consisting of two exhaust ports located on the back of the shroud that encased nine polishing tools. The exhaust from both ports was connected to a vacuum system that provided a maximum theoretical airflow of 13,479 liters per minute (L/min) or 476 cubic feet per minute (cfm) of suction. The vacuum was equipped with a pre-separator. Once through the pre-separator, the air stream was HEPA filtered and then recirculated to the room.

The aim of this survey was to collect emissions data from the concrete polishers using different grits while operating the dust collection system provided with the machines. Sample times varied based on the length of time needed to polish a rectangular area of 15.8 square-meters (m^2) (170 square-feet (ft^2)) with a given grit and ranged between 24 and 38 minutes with an average sample time of 31 minutes.

Overall, the air samples measured from 10 to 28% quartz. The mean quartz percentage for all of the air samples was 17%. Bulk samples were collected from the dust captured in the bag filters of the vacuum systems connected to the concrete polishers; it contained 19% quartz. No cristobalite or tridymite were detected in the bulk or air samples.

If exposures were to continue as measured throughout the entire workday and assuming constant dust generation rates, PBZ quartz concentrations with the local

exhaust ventilation operating would range in concentrations from below the limit of detection (LOD) to 29 micrograms per cubic meter (µg/m^3). All the recorded concentrations are below the NIOSH Recommended Exposure Limit (REL) for respirable quartz of 50 µg/m^3 as a time weighted average for each of the grits evaluated during this visit.

The polishing process begins with the use of coarse diamond segments bonded in a metallic matrix and then switching to a finer resin bonded grit. The metal bond grit produced, on average, about 50% less respirable dust and respirable quartz than the resin bond grits. When switching from the metal to the resin bond (Resin 50), a larger amount of respirable dust (158 µg/m^3) and respirable crystalline silica (29 µg/m^3) was measured in the sample results. This is due to the initial finer polishing over a coarse aggregate on the concrete pad generating finer dust than with the previous metal bond. Once the floor space was polished with Resin 50, three of the remaining resin bonds (Resins 200, 400, and 800) did not generate as much respirable dust or respirable crystalline silica as Resin 50, but still produced over twice the dust generated with the initial metal bond grit. The final resin bond (Resin 1500) produced comparable dust levels as Resin 50.

Both, the HTC and Husqvarna concrete polishers evaluated in this survey were equipped with an engineering control, a local exhaust ventilation (LEV) system intended to control and remove dust particles generated during the concrete polishing process. The dust control system adequately controlled worker exposure to respirable crystalline silica during this site visit. Additional evaluation is recommended to collect repeated samples using the same equipment. Also, it would be useful to quantify the actual airflow of the vacuum system and establish a correlation between the actual and the listed airflow [13,479 L/min (476 cfm)].

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 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 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.

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]. Colored, stained, and polished concrete floors are increasingly popular for use in homes, offices, retail establishments, schools, and other commercial and industrial settings. For example, a major chain store has specified integrally-colored concrete floors in its new stores in place of vinyl composite tile. Polished concrete floors are durable, sanitary, and easy to maintain (Figure 1).

Figure 1: A polished concrete floor (Courtesy of the Concrete Polishing Association)

Concrete floor finishing work is performed by employees of tile and terrazzo contractors (NAICS 238340) and poured concrete foundation and structure contractors (NAICS 238110). In 2007, there were 11,180 tile and terrazzo contracting firms and 24,303 poured concrete contractors in the United States, employing nearly 312,000 construction workers [Census 2012]. The Bureau of Labor Statistics [2012] reported that there were 206,600 cement masons, concrete finishers, and terrazzo workers (SOC 47-2050) employed in 2008. Only about 5 percent of cement masons, concrete finishers, segmental pavers, and terrazzo workers were self-employed, a smaller proportion than in other building trades. Most self-employed masons specialize in small jobs, such as driveways, sidewalks, and patios [BLS 2012]. The number of cement masons, concrete finishers, and terrazzo workers is projected to be 234,500 in 2018 [BLS 2009]. The increasing number of workers and the growing popularity of concrete as a flooring material will only add to the number of workers exposed to silica from the tasks involved in their construction. Sentinel Event Notification System for Occupational Risk (SENSOR) surveillance data from Michigan, New Jersey, and Ohio identified 7 cases of silicosis in concrete and terrazzo finishers from 1993-2002 [NIOSH 2007]. The success of this study will reduce the number of cases of silicosis among the growing ranks of these workers.

Many walk-behind concrete surfacing tools are sold by the manufacturer with dust controls as original equipment (Figure 2). Other dust controls are offered as after-market options. However, there is little research available that demonstrates that either the original equipment or after-market controls are effective in limiting worker exposures to respirable dust or respirable crystalline silica. Flanagan et al. [2003] reported that seven of nine samples collected during concrete floor sanding exceeded the ACGIH® TLV® for respirable quartz (at that time 0.05 mg/m^3, identical to the NIOSH REL; however, since then the current TLV® has been reduced to 0.025 mg/m^3). The geometric mean and geometric standard deviation for those nine quartz samples were 0.07 mg/m^3 and 2.62 mg/m^3, respectively. These exposures demonstrate the need to identify effective dust controls for walk-behind concrete surfacing tools to reduce silica exposures among workers using these tools.

Figure 2: Floor polishing tool with water control (Courtesy of the Concrete Polishing Association)

The lack of data demonstrating the effectiveness of dust controls and the increasing popularity of polished concrete floors prompted our partners (the equipment manufacturers and the union that represents the users of these tools and dust controls) to request that NIOSH examine the efficacy of the dust controls used with walk-behind concrete surface preparation equipment.

Research methods are readily available to conduct a study of dust control effectiveness for these tools. Examples include a study by Hallin [1983] and BG Bau [2006]. Working in Sweden, Hallin examined the performance of dust controls for percussion drills, drill hammers, ceiling, floor, and wall grinders, scaling machines, floor-milling machines, and concrete channel-cutting machines. The tests were conducted in a 5x6x2.4 meter room erected inside a large factory. Personal breathing zone (PBZ) and area samples for respirable dust and quartz were collected while a laborer operated the equipment with and without the dust controls, and with and without ventilation to the room. Hallin tested 10 floor grinding machines. PBZ quartz results ranged from 0.08 mg/m^3 to 0.24 mg/m^3 for tools used with dust controls.

In a series of experiments in Bavaria, BG Bau [2006] examined dust emissions from hand-held tools such as wall chasers, diamond cutters and drill hammers operated in a 6.9x6.7x4.3 meter test room at a worker training center (Bavarian BauAkademie). Tests were conducted with the dust controls operating while the tools were used by a skilled operator. The test room was unventilated during the tests, and the operator wore appropriate respiratory protection. PBZ and area samples of inhalable and respirable dust were collected during the tests. Video exposure monitoring was performed for distribution among the tool manufacturers to generate ideas regarding improvement of the dust collection systems.

The long-term objective of this current study is to provide practical recommendations for effective dust controls that will prevent overexposures to respirable crystalline silica during concrete finishing operations. The specific aims of the project: 1) To evaluate the effectiveness of the LEV and dust suppression (water) systems sold for use with walk-behind scarifiers, grinders, and polishers and offer research-based recommendations to improve them if necessary; 2) To establish a partnership with manufacturers and users of walk-behind concrete surface preparation equipment; 3) To establish a standard method for evaluating dust controls for tools used in construction in the United States; and 4) To bridge the gap between the pool of available knowledge and the lack of standards and regulations for dust controls in construction and disseminate the information in the form of technical reports, journal articles, NIOSH Workplace Solutions documents, and trade journal articles.

In 2012, the Association of Equipment Manufacturers (AEM) approached EPHB to request an evaluation of the exposures and controls associated with walk-behind tools used in concrete grinding and polishing operations. The Operative Plasterers' and Cement Masons' International Association (OPCMIA) contacted EPHB with the same concerns. These organizations recognized EPHB’s expertise and experience in construction engineering control research. The fact that both the manufacturers and users of the tools are invested in this project from its conception increases the likelihood of success and that any resulting recommendations will be implemented.

Site and Process Description

Introduction

GMI is a manufacturer/distributor of the Original CRMX™ 3-Step Concrete Polishing System. The GMI training center is a 45,000 square-feet (ft^2) structure where about 12,000 ft^2 were dedicated for the test. This facility is equipped with a laboratory where spectrum analysis is conducted and document the texture of concrete surfaces.

Process Description

A polished concrete floor has a glossy, mirror-like finish. The design options for polished concrete are extensive including many colors, patterns created with saw cuts, and aggregates or other interesting objects embedded into the concrete prior to polishing. The reflectivity of the floor can also be controlled by using different levels of polishing.

Heavy-duty polishing machines equipped with progressively finer grits of diamond-impregnated segments or disks (similar to sandpaper) are used to gradually grind down surfaces to the desired degree of shine and smoothness. The polishing process begins with the use of coarse diamond segments bonded in a metallic matrix. These segments are coarse enough to remove minor pits, blemishes, stains, or light coatings from the floor in preparation for final smoothing. Depending on the condition of the concrete, this initial rough grinding is generally a three- to four-step process.

The next steps involve fine grinding of the concrete surface using diamond abrasives embedded in a plastic or resin matrix. Some polishing specialists use even finer grits of polishing disks (a process called lapping) until the floor has the desired sheen. For an extremely high-gloss finish, a final grit of 1500 or finer may be used. Experienced polishing personnel know when to switch to the next-finer grit by observing the floor surface and the amount of material being removed.

During the polishing process an internal impregnating sealer is applied. The sealer sinks into the concrete and is invisible to the naked eye. It not only protects the concrete from the inside out, it also hardens and densifies the concrete. Some polishing specialists apply a commercial polishing compound onto the surface during the final polishing step, to increase the sheen. These compounds also help clean any residue remaining on the surface from the polishing process and leave a dirt-resistant finish.

In simple steps, the concrete polishing process can be summarized as follows:

- Remove existing coatings (for thick coatings, use a 16- or 20-grit diamond abrasive or more aggressive tool specifically for coating removal).
- Seal cracks and joints with an epoxy or other semi-rigid filler.
- Grind with a 30- or 40-grit metal-bonded diamond.
- Grind with an 80-grit metal-bonded diamond.
- Grind with a 150-grit metal-bonded diamond (or finer, if desired).
- Apply a chemical hardener to densify the concrete.
- Polish with a 100- or 200-grit resin-bond diamond, or a combination of the two.

- Polish with a 400-grit resin-bond diamond.
- Polish with an 800-grit resin-bond diamond.
- Finish with a 1500- or 3000-grit resin-bond diamond (depending on the desired sheen level).
- Optional: Apply a stain guard to help protect the polished surface and make it easier to maintain.

Concrete polishing can be completed using wet or dry methods. Although each has its advantages, dry polishing is the method most commonly used in today's industry because it is faster, more convenient, and environmentally friendly. Wet polishing methods use water to cool the diamond abrasives and eliminate grinding dust. Because the water reduces friction and acts as a lubricant, it increases the life of the polishing abrasives. The main disadvantage of the wet method is the cleanup. Wet polishing creates a slurry that must be collected and disposed of in an environmentally friendly manner. With dry polishing, no water is required. Instead, the floor polisher is connected to a dust-removal system that, in theory, vacuums most of the generated dust from the polishing process.

Many polishing specialists use a combination of both the wet and dry polishing methods. Typically, dry polishing is used for the initial grinding steps, when a larger amount of concrete is to be removed. As the surface becomes smoother, and the coarser metal-bonded abrasives are switched to the finer resin-bonded diamond abrasives, the polishing crew could change to wet polishing methods if desired.

Two different concrete polishers were evaluated on this survey. The first one was an HTC 800 Classic which was fitted with a 15 HP motor and three grinding discs. The three grinding discs have provisions to accommodate 9 polishing tools and rotated between 300 and 1300 revolutions per minute (rpm). The HTC 800 Classic weighs approximately 365 Kilograms (805 pounds). The second machine was a Husqvarna PG 820 concrete polisher. The PG 820 polisher has a 17 HP motor with provisions for three grinding discs that will accommodate 9 polishing disks. The grinding disc speed varies between 250 and 1100 rpm and the machine weighs approximately 455 Kilograms (1003 pounds). Both polishers were outfitted with a local exhaust ventilation (LEV) to remove the dust generated during the process. The LEV system consisted of two exhaust ports located on the back of the shroud that encased 9 polishing disks.

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 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 Permissible Exposure Limits (PELs) [29 CFR 1910.1000 2003a] are occupational exposure limits that are legally enforceable in workplaces covered 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]. Recommended Exposure Limits (RELs) 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 (ACGIH®), a professional organization [ACGIH 2015]. 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 cause 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 eliminate or minimize 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 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].

$$\mu g\,SiO_2/m^3 = \frac{\mu g\,Q + \mu g\,C + \mu g\,T + \mu g\,P}{V} \qquad (1)$$

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 respirable dust containing crystalline silica for the construction industry is measured by impinger sampling. In the construction industry, the PELs for cristobalite and quartz are the same. The PELs are expressed in millions of particles per cubic foot (mppcf) and calculated using the following formula [29 CFR 1926.55 2003b]:

$$\text{Respirable PEL} = \frac{250\text{ mppcf}}{\%\text{ Silica} + 5} \qquad (2)$$

Since the PELs were adopted, the impinger sampling method has been rendered obsolete by gravimetric sampling [OSHA 1996]. OSHA currently instructs its compliance officers to apply a conversion factor of 0.1 mg/m3 per mppcf when converting between gravimetric sampling and the particle count standard when characterizing construction operation exposures [OSHA 2008]. On September 12, 2013, OSHA published a Notice of Proposed Rulemaking (NPRM) for occupational exposure to respirable crystalline silica. The NPRM was published in the Federal Register and proposes a PEL of 0.050 mg/m^3 for respirable crystalline silica as an 8-hr TWA exposure [78 Fed. Reg. 56274 (2013)].

The ACGIH TLV for α-quartz (the most abundant toxic form of silica, stable below 573°C) and cristobalite (respirable fraction) is 0.025 mg/m^3 [ACGIH2015]. The TLV is intended to mitigate the risk of pulmonary fibrosis and lung cancer.

Methodology

Sampling Strategy

PBZ air samples were collected on the concrete polishing machine operator while multiple polishing grits were used during the site visit. Sampling equipment was also placed on top of the concrete polisher and four area samples were collected on the corners of the polishing space. The polishing area was established as a 5.18 m (17 ft) by 3.05 m (10 feet) (15.8 m^2 or 170 ft^2) rectangle as shown in Figure 3 below.

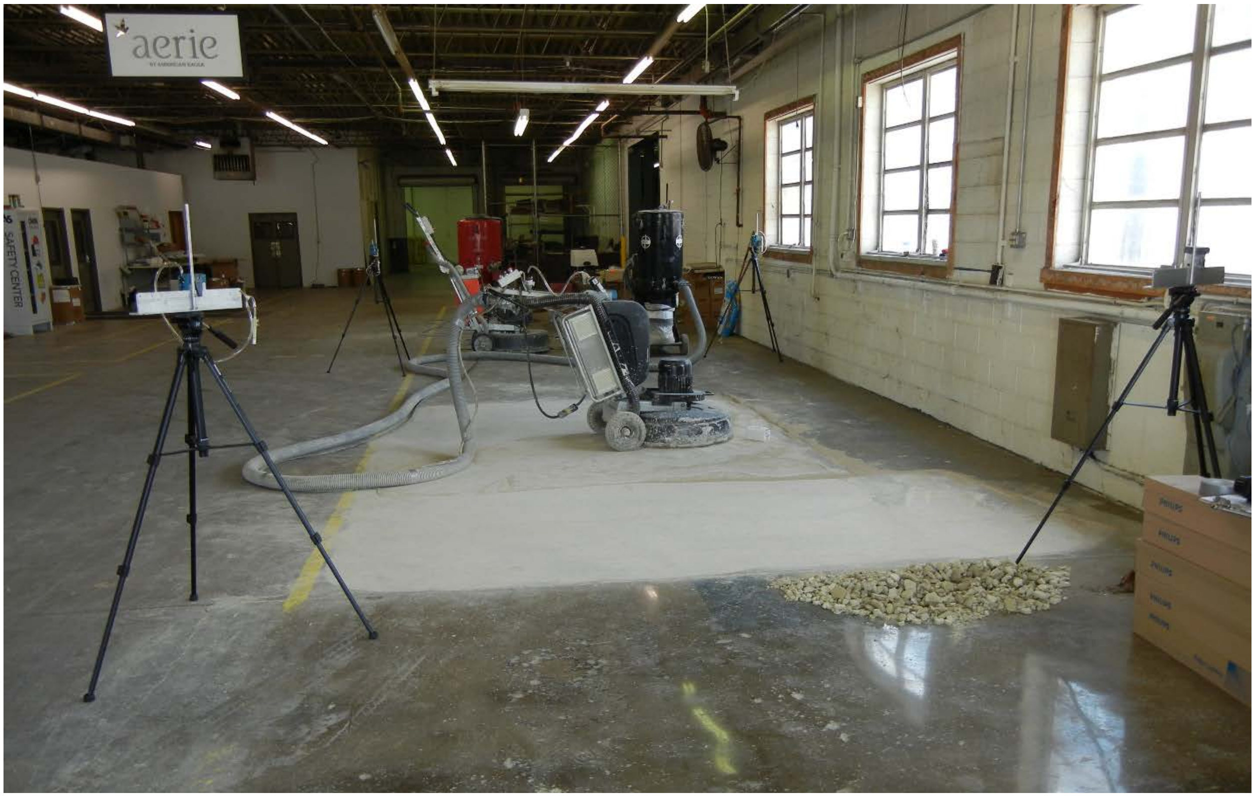

Figure 3: Polishing area and area sample array

Samples were collected while the operator polished the 15.8 m^2 area using six different grits, including metal and resin bond. After each run, the polished area was cleaned using a Pulse-Bac 1050H (CDCLarue Industries, Inc., Tulsa, OK) portable vacuum cleaner equipped with high-efficiency particulate air (HEPA) filters.

Figure 4 shows a photo of some of the grits used during this survey, and they are commonly identified as:

- 80 Metal Bond
- 50 Resin Bond
- 200 Resin Bond
- 400 Resin Bond
- 800 Resin Bond
- 1500 Resin Bond

Figure 4: Some of the different grits used during the survey

Two TSI SidePak™ Personal Aerosol Monitors AM510 (TSI Incorporated, Shoreview, MN) mounted on a tripod at breathing zone height (1.5 m) were used to verify that the room was ventilated and cleaned to background respirable dust levels no greater than 0.05 mg/m^3. Since there are no direct-reading instruments for respirable crystalline silica, using the crystalline silica REL as the respirable dust background level ensures that the background silica concentration will be lower than the NIOSH REL.

Sampling Procedures

Air Sampling

PBZ air samples for respirable particulate and crystalline silica were collected at a flow rate of 10 liters per minute (L/min) using a battery-operated sampling pump (Leland Legacy, SKC, Eighty Four, PA) calibrated before and after each day's use using a DryCal Primary Flow Calibrator (Bios Defender 510, Mesa Laboratories, Inc., Lakewood, CO). A sampling pump was clipped to the sampled worker's belt worn at his waist. The pump was connected via Tygon® tubing to a pre-weighed, 47-mm diameter, 5.0-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 (RASCAL, model GK4.162, BGI Inc., Waltham, MA). At a flow rate of 10 L/min, the model GK4.162 cyclone has a 50% cut point of (D_{50}) of 4.0 µm [BGI 2011]. 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 workers' shirts near their breathing zone. In addition to the PBZ samples, sampling equipment was also placed on top of the concrete polisher, and four area samples were collected in the corners of the polishing space. Field blank samples were taken on each sampling day. Bulk dust samples were also collected in accordance with NIOSH Method 7500 [NIOSH 2003].

The goal for this study is to evaluate as many tools and grits as possible in the shortest amount of time. Therefore, the high-flow cyclone was specifically developed under this project to provide sample results above the limit of detection (LOD) and above the limit of quantitation (LOQ) for short term samples. It is important to remember that for this industry, workers operate these concrete polishers for a full 8-hour day (and potentially longer) usually only stopping for lunch or to change the tooling and grits on the machines as needed.

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 (model AT201, Mettler-Toledo, Columbus, OH) and each filter was passed over the neutralizer before weighing. The LOD was 20 µg/sample. The LOQ was 53 µg/sample.

Crystalline silica analysis of filter and bulk samples was performed using X-ray diffraction according to NIOSH Method 7500 [NIOSH 2003]. The LODs for quartz, cristobalite, and tridymite were 5 µg/sample, 5 µg/sample, and 10 µg/sample, respectively. The LOQs for quartz, cristobalite, and tridymite were 17 µg/sample, 33 µg/sample, and 33 µg/sample, respectively.

Control Technology

Many walk-behind concrete surfacing tools are sold with dust controls as original equipment by the manufacturers. Other dust controls are offered as after-market options. However, there is little research available that demonstrates that either the original equipment or after-market controls are effective in limiting worker exposures to respirable dust or respirable crystalline silica. The HTC and Husqvarna floor polishers were outfitted with LEV consisting of two exhaust ports located on the back of the shroud that encased the nine polishing disks. The exhaust from these ports was connected to a vacuum system with a pre-separator that provided a maximum theoretical 13,479 L/min (476 cfm) of suction. Once through the pre-separator, the air stream is HEPA filtered and then recirculated to the room.

When the concrete polisher was operated, the flow induced by the spinning of the polishing tooling caused a large portion of the dust generated to be collected in the periphery of the shroud, where the vacuum ports are located. Figure 5 shows the dust-collecting shroud and the polishing disks installed on the concrete polisher.

Figure 5: Shroud and polishing disks installed on the Concrete Polisher

Results

The aim of this survey was to collect emissions data from the concrete polishers using different grits while using the dust collection system provided with the machine. This study was also conducted to determine whether the engineering controls employed on these concrete polishers were able to control respirable silica exposures below the NIOSH REL of 50 µg/m^3 (0.05 mg/m^3) if the tasks were to continue throughout an 8-hour day as they would on a regular work-day.

Table 1 includes the sample times, sampling volumes, grits used per sample, and sample numbers for the samples collected on the operator and on the concrete polisher. Sample times varied based on the length of time needed to polish the 15.8 m^2 (170 ft^2) rectangle with a given grit, ranging between 24 and 38 minutes with an average sample time of 31 minutes.

Table 1 – General Sample Information

Sample Location	Grit	Sampling Flow Rate (Lpm)	Sample Time (min)	Sample Volume (m^3)
Personal HTC	80 Metal	10.145	38	0.386
Machine HTC	80 Metal	9.955	38	0.378
Personal HTC	50 Resin	10.145	33	0.335
Machine HTC	50 Resin	9.959	33	0.329
Personal HTC	200 Resin	10.145	31	0.314
Machine HTC	200 Resin	9.959	31	0.309
Personal HTC	400 Resin	10.145	35	0.355
Machine HTC	400 Resin	9.959	35	0.349
Personal HTC	800 Resin	10.145	33	0.335
Machine HTC	800 Resin	9.959	33	0.329
Personal HTC	1500 Resin	10.145	24	0.243
Machine HTC	1500 Resin	9.959	24	0.239
Personal Husqvarna	80 Metal	9.891	30	0.297
Machine Husqvarna	80 Metal	10.338	30	0.310
Personal Husqvarna	50 Resin	9.891	31	0.307
Machine Husqvarna	50 Resin	10.338	31	0.320
Personal Husqvarna	200 Resin	9.891	31	0.307
Machine Husqvarna	200 Resin	10.338	31	0.320
Personal Husqvarna	400 Resin	9.891	32	0.316
Machine Husqvarna	400 Resin	10.338	32	0.331
Personal Husqvarna	800 Resin	9.891	28	0.277
Machine Husqvarna	800 Resin	10.338	28	0.289
Personal Husqvarna	1500 Resin	9.891	30	0.297
Machine Husqvarna	1500 Resin	10.338	30	0.310

Silica Content in Air and Bulk Samples

Table 2 presents the respirable crystalline silica and respirable dust masses reported for the personal samples and also for those samples located on top of the concrete polisher. For the operator, the sum of the respirable crystalline silica masses for each of the samples is divided by the sum of the respirable dust masses for those samples and multiplied by 100 to calculate the percent silica over the sample collection time. The total sample collection time was 194 minutes for the HTC polisher and 182 minutes for the Husqvarna polisher. The total silica exposure for the operator during this time was about 27%.

Table 2 – Respirable Silica (Quartz) Masses, Respirable Dust Masses, and Percent Silica (Quartz).

Sample Location	Grit	Respirable Particulate (µg/sample)	Respirable Quartz (µg/sample)	% Quartz
Machine HTC	80 Metal	<LOD	<LOD	
Machine HTC	50 Resin	33	9.2	27.88%
Machine HTC	200 Resin	<LOD	<LOD	
Machine HTC	400 Resin	33	<LOD	
Machine HTC	800 Resin	<LOD	<LOD	
Machine HTC	1500 Resin	43	<LOD	
Machine Husqvarna	80 Metal	33	<LOD	
Machine Husqvarna	50 Resin	<LOD	<5	
Machine Husqvarna	200 Resin	<LOD	<LOD	
Machine Husqvarna	400 Resin	<LOD	<LOD	
Machine Husqvarna	800 Resin	<LOD	<LOD	
Machine Husqvarna	1500 Resin	<LOD	<LOD	

The percent quartz in each sample was calculated and listed in the last column of Table 2. Overall, the air samples ranged from 10 to 28% quartz. The mean quartz percentage in all of the air samples was 17%. Three blank samples were collected and no crystalline silica was detected on any of the blank samples. Bulk samples were collected from the dust captured in the bag filter of the vacuum system connected to each concrete polisher and it contained 19% quartz. No cristobalite or tridymite were detected in the air samples or bulk sample.

Respirable Crystalline Silica Results

Table 3 includes respirable silica concentrations in micrograms per cubic meter (µg/m^3). A minimum detectable concentration (MDC) for quartz was calculated based on the LOD for the method and the sample volume for each sample.

Table 3 – Respirable Dust and Respirable Crystalline Silica (Quartz) Results

Sample Location	Grit	Respirable Particulate ($\mu g/m^3$)	Respirable Quartz ($\mu g/m^3$)	MDC ($\mu g/m^3$)
Machine HTC	80 Metal	<LOD		13.213
Machine HTC	50 Resin	100.416	27.995	15.215
Machine HTC	200 Resin	<LOD		16.196
Machine HTC	400 Resin	94.678		14.345
Machine HTC	800 Resin	<LOD		15.215
Machine HTC	1500 Resin	179.912		20.920
Machine Husqvarna	80 Metal	106.404		16.122
Machine Husqvarna	50 Resin	<LOD		15.602
Machine Husqvarna	200 Resin	<LOD		15.602
Machine Husqvarna	400 Resin	<LOD		15.114
Machine Husqvarna	800 Resin	<LOD		17.273
Machine Husqvarna	1500 Resin	<LOD		16.122

*All samples were below the NIOSH Silica REL of 50 $\mu g/m^3$ (0.05 mg/m^3)

Discussion

If exposures were to continue throughout the entire work-day and assuming steady, constant, and similar dust generation rates as the ones observed during this survey, the LEV used with both the HTC and Husqvarna concrete polishers was able to control respirable silica exposures below the NIOSH REL. With these assumptions in mind, the collected samples with different polishing grits were all below the NIOSH REL (ranging between non-detect to 29 $\mu g/m^3$).

The metal bond grit produced, on average, about 50% less respirable dust and respirable quartz than the resin bond grits. This seems plausible as the metal bond grits are used for the initial stages of polishing where more material is removed, potentially generating larger particles. The resin bond grits are used for fine polishing and generate more particles in the respirable size range, those capable of entering the operator airways.

When switching from the metal to the resin bond (samples collected when using Resin 50), a larger amount of respirable dust (158 µg/m^3) and respirable crystalline silica (29 µg/m^3) was measured in the sample results. This is due to the initial finer polishing over a coarse aggregate on the concrete pad generating finer dust than with the previous metal bond. The two samples collected when polishing with the Resin 50 grit resulted in concentrations above the ACGIH TLV of 25 µg/m^3 Once the floor space was polished with Resin 50, three of the remaining resin bonds (Resins 200, 400, and 800) did not generate as much respirable dust or respirable crystalline silica as Resin 50, but still over twice the dust generated when using the initial metal bond grit. The final resin bond (Resin 1500) produced comparable dust levels as Resin 50.

The metal bond grit generated respirable crystalline silica concentrations below the LOD of 5 µg/m^3 which is well below the NIOSH REL. The respirable dust concentrations from those samples collected on top of the concrete polisher are slightly lower than those collected on the operator, but follow the same trend as those samples previously discussed.

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 of controls can be summarized as follows:

- Elimination
- Substitution
- Engineering Controls (e.g. ventilation)
- Administrative Controls (e.g. reduced work schedules)
- Personal Protective Equipment (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.

Both, the HTC and Husqvarna concrete polishers evaluated in this survey were equipped with an engineering control, a LEV system intended to control and remove dust particles generated during the concrete polishing process. The dust control system adequately controlled worker exposure to respirable crystalline silica below the NIOSH REL during this site visit. Additional evaluation is recommended to collect repeated samples using the same equipment and to quantify the actual flow of the vacuum system to establish a correlation between the actual and the listed 13,479 L/min (476 cfm) airflow.

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