

Final progress Report

Principal Investigator:

Farhang Akbar-Khanzadeh, Ph.D.
Professor and Director of MSOH Program
Department of Public Health & Preventive Medicine, College of Medicine, MS 1027
University of Toledo Health Science Campus, Toledo, Ohio 43614
Tel: 419/383-4543; Fax: 419/383-5880; Email: Farhang.Akbar@UToledo.edu

Award was made to:

University of Toledo Health Science Campus, Toledo, Ohio 43614

Project title:

Crystalline Silica and RSP Control Methods Effectiveness during Concrete Grinding

Co-investigators:

Sheryl A. Milz, Ph.D.; Michael S. Bisesi, Ph.D.; Sadik Khuder, Ph.D.

Research technicians:

Cynthia D. Wagner, MSOH; April L. Ames, MSOH

Unpaid technical consultant:

Pam Susi, MSPH: The Center for Construction Research and Training

***Grant number:* 1R01OH009271-01**

***Grant period:* 09/01/2007 - 08/31/2009**

TABLE OF CONTENTS

LIST OF TERMS AND ABBREVIATIONS	3
ACKNOWLEDGEMENT	3
ABSTRACT	4
SECTION 1	5
HIGHLIGHTS / SIGNIFICANT FINDINGS	5
TRANSLATION OF FINDINGS	5
OUTCOME / RELEVANCE / IMPACT	5
SECTION 2	7
BACKGROUND FOR THE PROJECT	7
PROCEDURES, METHODOLOGY	8
RESULTS AND DISCUSSION	12
CONCLUSIONS	16
PUBLICATIONS	17
SUBJECTS INCLUSION	18
MATERIALS AVAILABLE FOR OTHER INVESTIGATORS	18
REFERENCES	18

LIST OF TERMS AND ABBREVIATIONS

ACGIH – American Conference of Governmental Industrial Hygienists
HEPA – High efficiency particulate filter
GV – General ventilation
LEV – Local exhaust ventilation
NIOSH – National Institute for Occupational Safety and Health
OSHA – Occupational Safety and Health Administration
PAPR - Powered air purifying respirator
PPE – Personal protective equipment
PVC - polyvinyl chloride
RSP – Respirable suspended particulate matter
TLV – Threshold limit value
TWA – Time-weighted average

ACKNOWLEDGMENT

Funded by the National Institute for Occupational Safety and Health, the Center for Disease Control and Prevention (Grant # 1 R01OH009271-01). However, the findings in this report do not necessarily reflect the views of this Agencies and no official endorsement should be inferred.

Robert Funa, Joshua Otiso, Amie Anschutz and Mahboubeh Akbar-Khanzadeh assisted with field data collection and data entry and verification. Bureau Veritus North America analyzed the air sample filters. Duffey Concrete Cutting Inc. provided the field lab space, concrete grinding operator, and technical assistance.

ABSTRACT

Background and Objectives - Concrete surface grinding exposes workers to unacceptable levels of airborne crystalline silica dust, known to cause diseases such as silicosis and lung cancer. The effectiveness of existing dust control methods and major confounding factors influencing the exposure levels of silica dust were examined by simulating field concrete surface grinding in an enclosed workplace laboratory.

Approach - Personal, area, and background air monitoring was performed during 201 concrete grinding sessions ranging in duration from 5-90 minutes with approximately 80% grinding and 20% rest time per session. A variety of grinders, diamond grinding cups and accessories were used on concrete slabs, containing $24 \pm 9\%$ crystalline silica, oriented in either horizontal or inclined positions. Dust control methods included general ventilation (GV), three types of local exhaust ventilation (LEV) and wet-grinding compared to conventional uncontrolled concrete grinding.

Key Findings – Task-specific mean concentrations of silica dust (mg/m^3) obtained by personal monitoring during LEV-, wet- and uncontrolled grinding, while GV was on (off) were 0.135 (0.571), 0.874 (3.48), and 8.89 (33.1), respectively. Levels of silica dust for 4-5 inch and 7 inch cup grinding were 1.14 (5.16) and 3.58 (13.1), respectively, with no significant difference among levels when grinding with 4, 4.5, and 5 inch cups. Silica dust levels were significantly lower for (1) GV "on" (75.4%) vs. "off" and (2) LEV-grinding (98.4%) or wet-grinding (89.4%) vs. uncontrolled grinding. Task-specific mean concentrations of RSP (mg/m^3) obtained by personal monitoring during LEV-, wet- and uncontrolled-grinding while GV was on (off) were 1.32 (6.15), 6.46 (24.1), and 59.4 (207), respectively. RSP levels for 4-5 inch and 7 inch cup grinding were 8.02 (32.4) and 24.3 (88.1), respectively, with no significant difference among levels when grinding with 4, 4.5, and 5 inch cups. RSP levels were significantly lower for (1) GV "on" (74.0%) vs. "off" and (2) LEV grinding (97.3%) or wet-grinding (88.3%) vs. uncontrolled grinding.

Levels of silica dust and RSP were significantly lower for (1) smaller grinding cup sizes vs. larger, and (2) samples collected on the left shoulder vs. the right shoulder for the right-handed operator. Factors that did not result in significantly different levels included: (1) orientation of grinding surfaces, (2) water flowrates for wet-grinding, or (3) task-specific sampling periods. None of the control methods lowered the 8-hour TWA exposure levels of silica dust to below the ACGIH recommended criteria of $0.025 \text{ mg}/\text{m}^3$, requiring further refinement in engineering control and the use of administrative control or respirator.

Recommendations – Relative to the confounding factors and the dust control methods that represented the parameters of this study, the most effective conditions for controlling exposure to silica dust and RSP during concrete surface grinding would be: (1) the use of a smaller size grinding cup (4 to 5 inch diameter), (2) in a smaller size (4.5 to 6 inch diameter) grinder that is either manufactured as a shrouded concrete grinder or is an angle grinder retrofitted with the durable urethane dust shroud, (3) attached to the HEPA tank vacuum or HEPA Cyclone vacuum, (4) in a well-ventilated workspace. With a work-rest regime of 25-75%, the operator may still need a half-mask respirator to reduce silica dust and RSP exposures to a level below recommended criteria. The establishment of uniform guidelines for the manual concrete grinding in industry is urgently needed.

SECTION 1

HIGHLIGHTS/SIGNIFICANT FINDINGS

- Manual concrete surface grinding, in an enclosed workplace with limited dust control measures, exposed workers to unacceptable levels of airborne crystalline silica dust that can lead to diseases such as silicosis and lung cancer.
- General ventilation reduced the levels of crystalline silica dust exposure by an average of 75% for any grinding method performed in the enclosed workplace.
- LEV and wet-grinding reduced the levels of crystalline silica dust exposure by 98.4% and 89.5%, respectively, in comparison to uncontrolled conventional grinding.
- Within the parameters of this study, no combination of dust control methods or other factors reduced the 8-hour TWA concentrations of silica dust to a level below the ACGIH criterion limit of $0.025 \mu\text{g}/\text{m}^3$. Therefore, depending on the exposure period during an 8-hour shift, the worker may need a suitable respirator.
- The use of smaller grinding cups, sizes 4-5 inch, generated significantly lower (62.7%) levels of silica dust than did the larger, 7 inch, grinding cup size. The use of the smaller sized grinders alleviated ergonomics problems present when using bulky, heavy hand-tools, such as the 7 inch angle grinder.
- There are no uniform guidelines for the manufacture or selection of equipment appropriate for manual concrete grinding, the assembly of retrofitted dust control apparatus, or the maintenance of hand-held angle grinders and the accessories that are commonly used for concrete grinding .

TRANSLATION OF FINDINGS

Exposure to unacceptable levels of airborne crystalline silica dust during concrete surface grinding leads to diseases such as silicosis and lung cancer. To prevent overexposure, the grinding should be performed by using small size (e.g., 4-5 inch) hand-held grinders attached to a built-in local exhaust ventilation (LEV). General ventilation or wet-grinding dust methods can supplement the LEV method. Uniform guidelines are needed for manufacturing, ordering, assembling and maintaining hand-held grinders and their accessories.

OUTCOME/RELEVANCE/IMPACT

How did this project lead to improvements in occupational safety and health? The results of this project have: (1) quantified the levels of respirable silica and total dust during concrete surface grinding while using hand-held grinders, (2) shown the influence of major confounders such as the grinding cup size and (3) demonstrated the effectiveness of each applicable dust control method such as the general ventilation, local exhaust ventilation and wet-grindings compared to conventional-grinding while assuming variety of work-rest regimens.

How can the findings of this study guide future investigations and research? None of the current control methods lowered the adjusted 8-hour TWA exposure levels of silica dust to below the ACGIH recommended criterion of $0.025 \text{ mg}/\text{m}^3$, requiring further refinement in the engineering control options. Therefore, the future investigations and research should be focused on designing

(1) lighter-weight hand-held grinding tools, (2) tools with less vibration, (3) more effective built-in LEV systems for the grinders, and (4) grinding tools with minimum need for maintenance. In addition, the research findings of grinding tools should be communicated to the designers, vendors, retail sale shops and customers (employers and workers) as well as to the legislators.

SECTION 2

BACKGROUND FOR THE PROJECT

Exposed Population

Concrete grinding (polishing, finishing), a common industrial activity in construction, is performed by cement masons and concrete finishers and other trades such as brick masons, block masons, and stonemasons as well as carpet, floor and tile installers and finishers, drywall installers, ceiling tile installers and tapers, plasterers and stucco masons. Decorative concrete work, the fastest growing segment of the concrete industry, requires an increasing number of additional workers to perform handwork, often in enclosed workplaces.

Exposure Health Effects

Workers involved in concrete grinding are potentially exposed to high levels (sometimes more than 1000 times the relevant criterion) of crystalline silica dust [Akbar-Khanzadeh et al., 2007; Flanagan et al., 2006; Rappaport et al., 2003; Flanagan et al., 2003; Akbar-Khanzadeh and Brillhart, 2002, Croteau et al., 2002; Lumens and Spee, 2001; Linch et al., 1998], subjecting concrete grinding workers to a variety of respiratory diseases such as silicosis and lung cancer [Yassin et al., 2005; CDC, 2005; Steenland, 2005; Linch 2002; Kane, 1997; NIOSH, 1996; Freeman and Grossman, 1995] as well as rheumatoid arthritis, scleroderma, Sjogern's syndrome, lupus and renal disease [NIOSH, 1998].

Confounding Factors

In 2006 Flanagan et al. reported that using surface concrete grinder was one of the activities generating the highest levels of dust exposure and concluded that “more research is needed to identify *the factors* that produce the highest exposure so that strategies can be identified to target and control them.” Indeed, many confounding factors can influence the outcome of silica dust exposure during concrete surface grinding in actual construction sites, including construction set up, surface grinding materials, hand-held grinder characteristics and attachments such as blade size/speed and shape/structure, and climatic conditions such as wind velocity and direction, the intermittency and duration of work, workers' characteristics and their work habits. Simulated laboratory experimentation can minimize or eliminate the effects of many of these confounding factors and can augment field sampling.

Specific Goals

To identify major confounding factors during concrete grinding and quantify their effects on the exposure to silica dust and RSP, the current study was initiated and conducted in a simulated field laboratory to:

1. *Determine and compare the levels of personal exposure during uncontrolled conventional-grinding (no dust control methods) compared to wet-grinding (wet dust reduction method) and ventilated-grinding (local exhaust ventilation method) while general ventilation is on or off.*

This goal was successfully achieved.

2. *Determine the feasibility, limitations and effectiveness of available tools (e.g., different types and sizes of grinders and accessories) and grinding surface position (e.g., inclined*

or horizontal) that can be used to add to or enhance existing exposure control methods during concrete grinding.

This goal was successfully achieved.

3. *Provide recommendations to predict and prevent unacceptable exposures to crystalline silica dust during concrete grinding.*

This goal was successfully achieved.

National Occupational Research Agenda (NORA) Priority Research Area

This research project covered the following NORA priority areas: (1) Intervention effectiveness research (2) Chronic pulmonary diseases; (3) Control technology; and, (4) Exposure assessment.

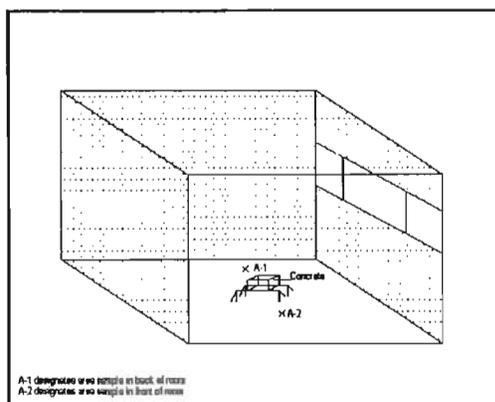
Hypothesis

Overexposure to crystalline silica dust ($> 0.025 \text{ mg/m}^3$ TWA re ACGIH) during concrete grinding activities will not be prevented with present practices unless a combination of appropriate exposure control methods is used.

PROCEDURES, METHODOLOGY

Field Lab

Concrete grinding activities were performed in a field laboratory (the Lab) setting (Picture 1). The Lab was set up within an industrial facility involved in concrete work. The Lab measured approximately 24 x 15.4 x 17.3 ft. The front of the Lab contained a large opening, 11.8 x 11.9 ft, that provided an entrance to the Lab from the interior of the host facility. This opening could be sealed off during grinding sessions with the use of a large drop-down tarp from inside the Lab and Visqueen curtains affixed to the outside of the opening. The right (re entrance) wall of the Lab contained a general ventilation opening of 32 x 32 inch with the center located at the height of 13.6 ft at the distance of 6.42 ft from the back wall. The general ventilation (GV) exhausted to the exterior of the facility at a rate of 62 room exchange/hr. The GV could easily be turned “on” or “off” by the researchers. On the average, the ambient temperature within the Lab was approximately 57 °F with relative humidity of approximately 47%.



Picture 1. Schematic of field Lab set up used in this study

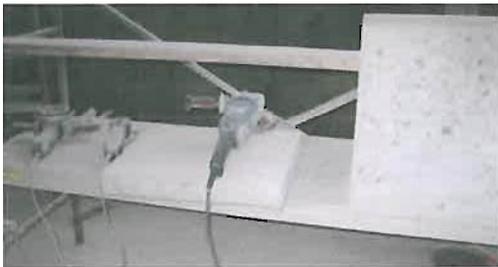
Concrete Surface Grinding Sessions

The study was designed to include concrete surface grinding sessions as follow: (1) GV on or off; (2) dust control method options: three local exhaust ventilation (LEV): HEPA/Tank vacuum, HEPA/Cyclone vacuum, shop vacuum, wet-grinding with water flowrate adjusted by the researchers, wet-grinding with water flowrate adjusted by the operator, and conventional uncontrolled-grinding option; (3) three diamond grinder cup (blade) diameter size options of 4-, 5- and 7-inch (Picture 2); (4) concrete slab surface positions of horizontal or inclined; and, (5) three different sampling times for each of the above combination factors. Thus, originally $(2 \times 6 \times 3 \times 2 \times 3) = 216$ air sampling sessions were planned; 36 sessions of each control method. Of these, a total of 201 grinding/sampling sessions was completed for final data analysis.

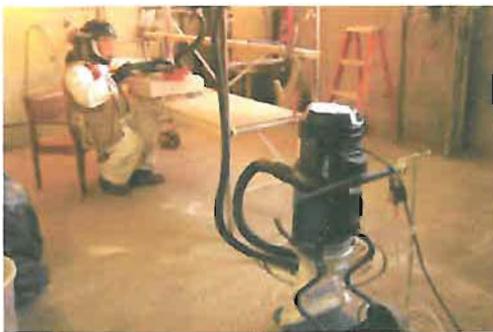
Concrete slabs were grinded in horizontal position to simulate floor grinding and in inclined position to simulate wall concrete grinding. The concrete slabs had all the similar concrete composition containing 29% average crystalline silica.

Air Monitoring Durations

Three different session monitoring times (durations) were used for each control method based on anticipated level of dust contamination: LEV sessions of 45, 60, and 90 min, wet-grinding sessions of 30, 45, and 60 min, and conventional-grinding sessions of 5, 15, 25 min. During each session the operator divided his time between grinding inside the Lab (task-specific time) and taking break outside the Lab. Air monitoring was conducted for the entire length of each session time. Since the concentration of silica dust outside the Lab was non-detected, the dust on each filter was assumed to be collected during task-specific grinding time.



Picture 2. The angle grinders used in this study



Picture 3. LEV-grinding: HEPA/cyclone vacuum; concrete slab in horizontal position



Picture 4. LEV-grinding: HEPA/tank vacuum; concrete slab in inclined position



Picture 5. LEV-grinding: Shop-vacuum; concrete slab in inclined position



Picture 6. Wet-grinding, water supply attached to wheel guard with the rubber guard around grinder housing



Picture 7. Uncontrolled conventional-grinding generates highest levels of visible dust

List of Tools Used

Angle Grinders for all Grinding Sessions – Three sizes of hand-held angle grinders, of similar type and from the same manufacturer, commonly used in construction, were selected. A 4.5-inch angle grinder (Metabo, W7-115 Quick, 4.5-inch max wheel diameter, 11,000 rpm, 8 amps) was selected as representative of the smallest commonly available grinder. A 6-inch angle grinder (Metabo, WE14-150 Quick, 6-inch max wheel diameter, 9000 rpm, 8.5 amps) was selected as representative of what is most commonly used for concrete grinding in the geographical region of this study. A 7-inch angle grinder (Metabo, W23-180, 6-inch max wheel diameter, 8500 rpm, 15 amps) was selected as representative of the largest hand-held angle grinder that is feasible to use for concrete grinding. Eibenstock/CS Unitec Concrete Grinder (Model EBS 1801, 5-inch, 10,000 rpm, 16 amps) used with Eibenstock 1500 vacuum for some LEV-grinding with Diamond Products 4- and 5-inch grinding cups.

Diamond Grinding Cups for Wet- and Conventional-grinding Sessions - Three different sizes of diamond grinding cups (Diamond Products Inc., Standard Gold Segmented Cup Grinders, Helena, Montana) were used as follow: 4-inch (D5S-07429), 5-inch (D5S-07431) and 7-inch (D5S-07434). All grinding cups, similar double-row and segmented designs, were used with the grinders of 4-, 5- and 7-inch, respectively. For the LEV-grinding sessions, three different sizes of diamond grinding cups (Joe Due Blades & Equip Inc., Double Row, Premium Cup-wheels, Mauston, WI) were used as follow: 4-inch (04-DR58), 4.5-inch (04-DR58) and 7-inch (04-DR58). All grinding cups, similar double-row and segmented designs, were used with the grinders of 4-, 5- and 7-inch, respectively.

Vacuums - Three types of vacuums were chosen as representatives of the wide range of vacuums currently in use in the industrial setting: (1) Shop-vac (model 85L575, 16 gallon, wet/dry vacuum) was chosen because it is the most commonly purchased by contractors from the local construction supply store; (2) Eibenstock vacuum (1500, rated 99.93% efficient for 3microns, 13 gal tank, pulse clean - shakes dual filter, 15amp max, 130 cfm airflow; wt 31lb) was used with the optional HEPA filters instead of the standard filters; and, (3) Dustcontrol vacuum (DC 2800c portable cyclone vacuum, rated 99.9% efficient for 3 micron dust size, 20 liter dust collecting sack, 190 m3/h max airflow; wt 14 kg).

Concrete Grinding Operator

An operator, working primarily in the concrete construction industry, performed all the concrete grinding. Operator's participation in the study was voluntary. The operator signed an informed consent approved by the Institutional Review Board of the researchers' institution. The operator

was provided with necessary PPE including a powered air purifying respirator (PAPR), Tyvek coveralls, a rain suit with overalls and jacket, rubber overboots, leather and anti-vibration gloves, hearing protectors, and safety shoes. Prior to field activities, the operator was familiarized with the PPE and fitted for the respirator. For all sessions, he wore a vest adapted for the correct positioning of personal monitoring devices and the protection of air sampling trains. The operator position during grinding, whether sitting or standing, was left to his decision.

Air Sample Collection

Air samples were collected using a portable personal pump (Airlite, Model 110-100; SKC Inc., Covington, Georgia) connected to 37mm aluminum cyclone. Sampling media (37mm PVC filter in 3-stage cassette) was provided by an accredited analytical laboratory. Air sampling pumps were calibrated prior to every session using a primary flow-meter (DryCal DC-Lite; Bios International Corporation, Butler, NJ). To characterize the climatic conditions, a sling psychrometer (Model 12-7012; Bacharach Inc., New Kensington, PA) was used to determine ambient temperature and relative humidity within and outside of the field laboratory.

To collect personal air samples, the operator wore two sampling pumps (replicate sample collection), one on each shoulder. Area air samples were collected within the Lab, but approximately 7 ft away from the operator. Outdoor air samples, used for background and quality assurance purposes, were collected each day in the yard where the general ventilation make-up air was supplied to the Lab. The field blank samples were treated as active samples except no air was passed through the filter. Bulk material samples were collected from settled concrete dust and small chips generated during concrete grinding. NIOSH Method 7500 was used to collect and analyze silica dust by x-ray diffraction and NIOSH Method 0600 to measure respirable particulate matter (NIOSH, 1998). The data were compiled and analyzed using SPSS Statistical Package.

Percent (%) dust reduction was calculated as $[(C_{nc} - C_c)/C_{nc}] \times 100$, where C_{nc} = concentration of dust with conventional-grinding (no local dust control) and C_c = concentration of dust with local dust control.

RESULTS AND DISCUSSION

Main Findings

The air sampling times, pre-set for each session by the researchers dependant on the dust control method used, ranged from 5 – 90 min, with break times outside the Lab ranged from 0-39 min. The task-specific (actual) grinding time for sessions ranged from 5-69 min. On the average, each air sampling session included 76.3% actual concrete grinding time inside the Lab and 23.7% rest time outside the Lab. The statistical analysis showed no significant difference in the silica levels in the samples obtained during short, median or long monitoring sessions. Nevertheless, all 201 sampling sessions were included in the dataset, each as an independent case.

Of the total 336 combined personal samples collected on the right ($n = 201$) and left ($n = 135$) shoulders of the operator, 100 (29.8%) were non-detected for crystalline silica dust. General ventilation increased the number of non-detected samples. Of the RSP samples 2 (0.6%) were non-detected. All background samples were non-detected for silica dust. Non-detected values for silica dust samples with a contaminant level below limit of detection (LOD) of 10 $\mu\text{g}/\text{sample}$,

were treated according to the recommendations of Hornung and Reed (1990); $10/\sqrt{2} = 7$ $\mu\text{g}/\text{sample}$. Non-detected values for RSP were treated the same way.

The statistical analysis of 135 replicate samples showed that (for a right-handed operator) the levels of silica dust and RSP collected on the right shoulder were not significantly different during LEV-grinding or wet-grinding. However, the silica dust and RSP levels were significantly ($p = 0.05$) higher for samples collected on the right shoulder than those collected on the left shoulder only during uncontrolled-grinding. For the data analysis, the silica dust and RSP concentrations of personal replicate samples (collected on right and left shoulders) were averaged and reported as the personal exposure values. In cases that no replicate samples were collected, the values of those collected on the right shoulder were included in the data analysis. The concentrations of silica dust and RSP of a total of 177 area samples were lower than, but significantly ($p = 0.000$) correlated with, those of the concurrently collected personal samples.

On the average, the concentrations of silica dust and RSP were not different using grinders with 4-, 4.5-, or 5-inch diameter cups. Based on this finding and for further analysis, the data collected using grinding cup diameters 4-, 4.5- and 5-inch were reported in a combined category. On the average, the concentrations of silica dust and RSP were significantly ($p < 0.05$) higher when grinding was performed by 7 inch diameter grinding cups than when performed by 4-5 inch diameter grinding cups.

The mean concentrations of silica dust and RSP were generally higher in 101 samples collected when grinding was performed in inclined position (to simulate wall grinding) compared to those of 100 samples collected in horizontal position (to simulate floor grinding). However, the difference was not statistically significant ($p = 0.2$), therefore, no distinction is made between concrete slab positions in the reporting of concentrations. The grinding in the vertical position was ergonomically more demanding. To overcome the problem, the 7 inch grinder was counter-balanced by using a flexible (rubber) support during inclined grinding.

The concentrations of silica dust and RSP were not significantly different when the wet-grinding was performed at a higher water flow-rate set by the operator and when it was performed at reduced, critical flow rate (just enough water flow to keep the grinding surface wet) set by the researchers. Therefore, for further data analysis, the two approaches were combined and reported as wet-grinding.

With the GV off, the mean concentrations of silica dust and RSP collected during Shop-vacuum grinding were significantly ($p < 0.01$) higher than those collected during either HEPA/Tank grinding or HEPA/Cyclone grinding. No difference was observed between the mean concentrations of silica dust and RSP collected during HEPA/Tank grinding and HEPA/Cyclone grinding. With the GV on, there were no significant differences in the silica dust and RSP between the three LEV-control methods. Thus, the results of the samples collected during HEPA/Tank grinding and HEPA/Cyclone grinding were combined into one category of LEV-HEPA grinding. Both the HEPA/Tank vacuum and the HEPA/Cyclone vacuum endured all of the scheduled sessions with minimal maintenance (clearing filters between sessions and emptying the bags when full), while the Shop-vacuum grinding had to be completely cleaned between each session, many sessions showed no dust accumulation remaining in the tank, and 3 sets of Shop-vacuum burned out during the 36 related grinding sessions.

Table I and Figures 1 and 2 summarize task-specific silica dust and RSP concentrations by control methods and grinding cup diameter sizes.

Table I. Task-specific Respirable crystalline silica dust and total respirable suspended particulate (RSP) concentrations (mg/m³) during surface concrete grinding by general ventilation, dust control method and grinding cup diameter size

GV	Control Method	Cup Size inch	N	Silica Dust		RSP	
				Mean (SD)	Min - Max	Mean (SD)	Min - Max
Off	HEPA/tank & HEPA/cyclone	4-5	33	0.34 (0.97)	0.04 – 5.71	3.33 (8.65)	0.12 – 50.5
		7	13	0.73 (0.83)	0.07 – 3.06	7.38 (9.04)	0.80 – 34.8
	Shop vacuum	4-5	6	0.60 (0.75)	0.10 – 2.01	7.73 (9.79)	0.89 – 26.7
		7	5	1.66 (0.92)	0.79 – 3.17	19.7 (10.9)	10.1 – 37.7
	Wet-grinding	4-5	17	0.96 (1.50)	0.15 – 5.51	7.79 (11.1)	1.17 – 43.5
		7	8	8.83 (6.68)	1.67 – 22.2	58.7 (37.2)	12.3 – 123
	Uncontrolled	4-5	14	23.6 (21.8)	3.14 – 64.6	142 (108)	24.3 – 368
		7	6	55.3 (27.7)	28.7 – 102	359 (126)	250 – 526
On	HEPA/tank & HEPA/cyclone	4-5	34	0.11 (0.13)	0.04 – 0.77	0.77 (0.65)	0.17 – 2.64
		7	13	0.20 (0.27)	0.05 – 1.04	2.40 (4.01)	0.12 – 15.1
	Shop vacuum	4-5	8	0.12 (0.09)	0.05 – 0.31	1.22 (0.94)	0.22 – 2.96
		7	5	0.14 (0.07)	0.08 – 0.22	2.37 (0.73)	1.26 – 3.01
	Wet-grinding	4-5	15	0.32 (0.26)	0.08 – 1.05	3.15 (2.20)	1.17 – 9.49
		7	6	2.25 (1.36)	0.53 – 3.54	14.7 (7.20)	5.76 – 21.6
	Uncontrolled	4-5	12	5.78 (3.87)	0.98 – 14.8	39.2 (22.6)	12.6 – 89.1
		7	6	15.1 (5.24)	8.66 – 23.3	99.8 (31.7)	64.9 – 133

GV = general ventilation; N = number of samples; SD = standard deviation; HEPA=High efficiency particulate air (filter)

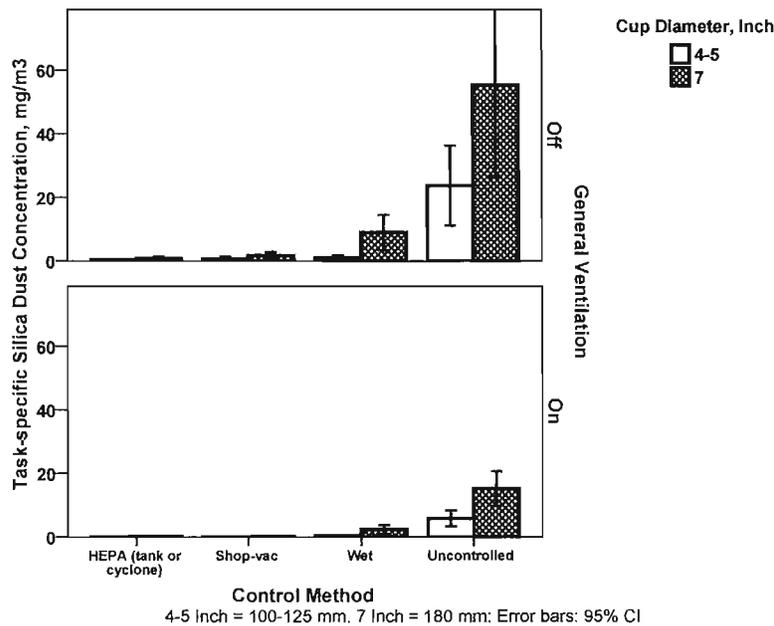


Figure 1. Task-specific Respirable Silica Dust Exposure Levels by General Ventilation, Dust Control Method and Grinder Cup Diameter Size

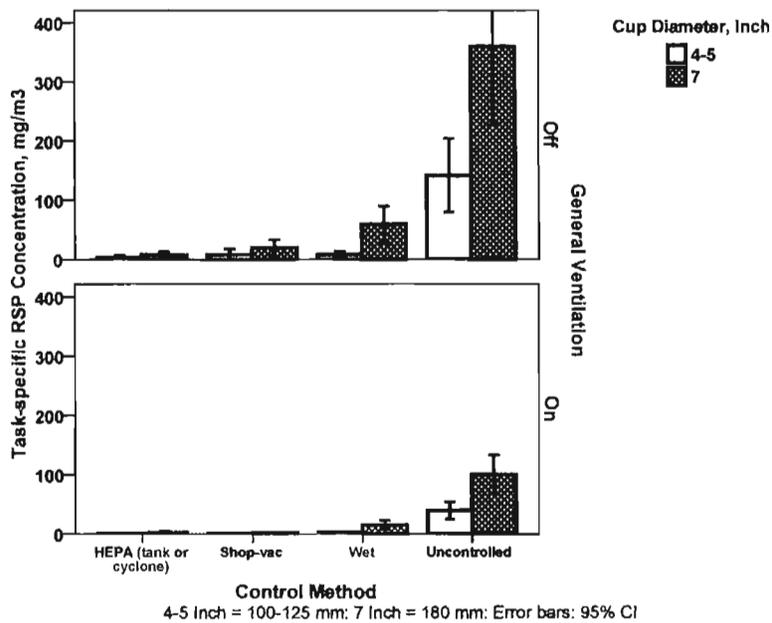


Figure 2. Task-Specific Total Respirable Suspended Particulate Matter (RSP) Exposure Levels Showing the Influence of General Ventilation, Dust Control Method and Grinder Cup Diameter Size

EXPOSURE ASSESSMENT

The findings of this study reveal that the application of LEV-grinding or wet-grinding methods can reduce the concentrations of respirable silica dust and RSP considerably. However, a simple examination of minimum numbers in min-max column of Table 1 shows that the levels of respirable silica dust during grinding including LEV-grinding and wet-grinding are above the ACGIH TLV of 0.025 mg/m³. Following the recommended exposure criteria given as ACGIH TLV, grinding within spaces (such as our field lab), regardless of control method applied, may require the use of a respirator. LEV-grinding with a 4-5 inch grinding cup size may only require the use of half-mask or even a disposable HEPA respirator. In agreement with our study, Nij et al. (2003) have concluded that “to control silica dust in construction, the combined use of more than one dust control method may be necessary.”

Table of Exposure Reduction Matrix

Following the mandated OSHA PEL (U.S. 29 CFR 1910.2000), the exposure to silica dust in sessions have been distributed by general ventilation, dust control methods, grinding cup diameter sizes and variety of work-rest regimens (Table II).

Table II. Crystalline Silica Dust Exposure Assessment Results as Influenced by General Ventilation (GV), Local Dust Control Methods, and Grinder Cup Diameter Sizes Calculated for Four Work-Rest Regimens; No Shadow Conditions where the Mean Exposure to Silica Dust are at Levels Less than OSHA-PEL which May or May not Need Respirator; Gold Shade (25%) Shows Conditions Where the Mean Exposure to Silica Dust Exceed the OSHA-PEL, Which May Require a Half-mask Respirator Use. Light-Orange Shade (50%) Shows Conditions Where the Mean Exposure to Silica Dust at Levels More than 10 Times the OSHA-PEL, Which require the use of a Full-face Respirator. Dark Shade (75%) Shows Conditions Where the Mean Exposure to Silica Dust at Levels More than 100 Times the OSHA-PEL, Which May Need a Powered Air-Purifying Respirator (PAPR) or SCBA Use

GV	Control Method	Cup Size inch	N	Four Work-Rest (%W-%R) Regimens				
				100-0 (not realistic)	50-50 (realistic, not practical)	25-75 (realistic, practical)	10-90 (realistic, practical)	
Off	HEPA/tank & HEPA/cyclone	4-5	33					
		7	13					
	Shop vacuum	4-5	6					
		7	5					
	Wet-grinding	4-5	17					
		7	8					
	Uncontrolled	4-5	14					
		7	6					
	On	HEPA/tank & HEPA/cyclone	4-5	34				
			7	13				
Shop vacuum		4-5	8					
		7	5					
Wet-grinding		4-5	15					
		7	6					
Uncontrolled		4-5	12					
		7	6					

GV = general ventilation; N = number of samples; SD = standard deviation, HEPA=High efficiency particulate air (filter)

CONCLUSIONS

- The equipment, engineering controls, and grinding methods chosen for this study represent those that are readily available and in current use for manual concrete surface grinding.
- Overall, the general ventilation reduced the grinding dust 75%.
- With the general ventilation on or off, overall the LEV-grinding reduced the silica dust 98.4% and RSP 97.3% and the wet-grinding reduced the concentrations of silica dust 89.4% and RSP 88.3% as compared to conventional grinding under the same factors.
- The concentrations of the silica dust and RSP collected by personal sampling were significantly higher: (1) than those collected by area sampling; (2) on the right side of the (right-handed) operator (where the dust was physically thrown to by the grinding wheel) than on the left side; (3) using the larger grinding cup diameter of 7 inch than of the 4-5 inch.
- The concentrations of the silica dust and RSP collected by personal sampling were not significantly different: (1) among 4-, 4.5-, and 5-inch diameter grinding cups; (2) during

grinding a surface in the vertical position compared to an inclined position; (3) by water flowrates for wet-grinding adjusted by the researchers or by the grinding operator; and, (4) for three task-specific sampling periods.

- At the above levels of exposure lasting for an entire 8-hour workshift, the current control methods do not reduce silica dust to below the ACGIH recommended silica dust exposure criteria of 0.025 mg/m^3 , requiring further refinement in the engineering control options, and additional administrative control or the use of respirators.
- When concrete grinding is performed in an enclosed workplace: (1) Install and use general ventilation; (2) Use grinders equipped with local exhaust ventilation (LEV-grinding) or with water attachment (wet-grinding); (3) Use grinders and accessories designed specifically for concrete grinding; (4) Use smaller size hand-held grinders preferably 4 inch but not exceeding 5 inch; (5) Until the appropriate higher efficiency control methods are devised and used, use respirators (half-mask with LEV-grinding; full-face with wet-grinding and powered air-purifying respirator for uncontrolled concrete grinding) during concrete grinding; (6) Use appropriate personal protective equipment such as coverall, face and eye protection, anti-vibration gloves and hearing protectors; and, (7) Use appropriate work-rest regimen.
- The smaller size grinder (e.g., 4-5 inch) also helps eliminate ergonomics problems of bulky, heavy hand-tools such as 7 inch grinder size.
- There is an urgent need for uniform guidelines for the manufacture and selection of equipment appropriate for manual concrete grinding, the assembly of retrofitted dust control apparatus, and the maintenance of hand-held angle grinders and the accessories that are commonly used for concrete grinding .

PUBLICATIONS: JOURNAL ARTICLES; PROCEEDINGS; DISSERTATIONS/THESIS

Akbar-Khanzadeh F, Milz SA, Wagner CD, Bisesi MS, Ames AL, Khuder S, Akbar-Khanzadeh M, Susi P: [2009] Silica Dust and RSP Exposure during Manual Concrete Surface Grinding – Influential Factors and Effectiveness of Dust Control Methods. JOEH (submitted)

Akbar-Khanzadeh F, Milz SA, Wagner CD, Bisesi MS, Ames AL, Khuder S, Susi P. Factors Influencing Silica Dust Exposure and Effectiveness of Control Methods during Manual Concrete Grinding. X2009 Sixth International Conference on Innovations in Exposure Assessment. Harvard School of Public Health Boston, MA, August 17–20, 2009.

Akbar-Khanzadeh, F, Milz S, Wagner C, Ames A, Bisesi M. Noise Exposure during Hand-held Concrete Grinding - Effects of Dust Control Methods and Grinder Size. The American Industrial Hygiene Conference & Exposition, Toronto, Canada, May 30-June 4, 2009.

Akbar-Khanzadeh F, Milz SA, Wagner CD, Ames AL, Bisesi MS, Khuder S, Susi P. Task-specific Noise Levels during Hand-held Concrete Grinding. The 15th Engineering and Work Practice Controls Work Group By NIOSH/CPWR, Orlando, FL, March 26-27, 2009.

Akbar-Khanzadeh F, Milz SA, Wagner CD, Ames AL, Bisesi MS, Khuder S, Susi P. Crystalline Silica and RSP Control Methods Effectiveness during Concrete Grinding (Progress

report). The 15th Engineering and Work Practice Controls Work Group By NIOSH/CPWR, Orlando, FL, March 26-27, 2009.

Akbar-Khanzadeh F. Crystalline Silica and RSP Control Methods Effectiveness during Concrete Grinding. 14th CPWR/NIOSH Engineering and Work Practice Controls Work Group, Lake Buena Vista, FL, Jan 31-Feb 1, 2008.

Mersereau DR: [2008] Global Availability of Concrete Grinding Tools and Dust Control Methods, MPH Scholarly Project, University of Toledo Health Science Campus.

Publication based on the pilot study:

Akbar-Khanzadeh F, Milz SA, Ames A, Susi P, Bisesi M, Khuder S, Akbar-Khanzadeh M. Crystalline Silica Dust and Respirable Particulate Matter during Indoor Concrete Grinding — Wet-grinding and Ventilated-grinding Compared with Uncontrolled Conventional-grinding JOEH 4:770-779 (2007).

SUBJECTS INCLUSION

Inclusion of gender and minority study subjects

Non-applicable

Inclusion of children

Non-applicable

MATERIALS AVAILABLE FOR OTHER INVESTIGATORS

Sampling and other data collection forms may be requested by email.

REFERENCES

- Akbar-Khanzadeh F, Milz SA, Ames A, Susi P, Bisesi M, Khuder S, Mahboubeh Akbar-Khanzadeh M. Crystalline Silica Dust and Respirable Particulate Matter during Indoor Concrete Grinding — Wet-grinding and Ventilated-grinding Compared with Uncontrolled Conventional-grinding JOEH 4:770-779 (2007).
- Akbar-Khanzadeh, F., and R.L. Brillhart: Respirable crystalline silica dust exposure during concrete finishing (grinding) using hand-held grinders in the construction industry. *Ann. Occup. Hyg.* 46:341-346 (2002).
- American Conference of Governmental Industrial Hygienists (ACGIH): *Threshold limit values and biological exposure indices*. Cincinnati, Ohio (2009).
- Centers for Disease Control and Prevention: Silicosis mortality, prevention, and control--United States, 1968-2002. *MMWR. Morbidity and Mortality Weekly Report.* 54:401-405 (2005).
- Croteau, G.A., S.E. Guffey, M.E. Flanagan, and N.S. Seisax: The effects of local ventilation controls on dust exposure during concrete cutting and grinding activities. *Am. Ind. Hyg. J.* 63:458-467 (2002).
- Croteau, G., M. Flanagan, J. Camp, and N.S. Seixas: The efficacy of local exhaust ventilation for controlling dust exposures during concrete surface grinding. *Ann. Occup. Hyg.* 38:509-518 (2004).
- Flanagan, M.E., C. Loewenherz, and G. Kuhn: Indoor wet concrete cutting and coring exposure evaluation. *Appl. Occup. Environ. Hyg.* 16:1097-1100 (2001).
- Flanagan, M.E., N. Seixas, M. Major, J. Camp, and M. Morgan: Silica dust exposure during selected construction activities. *Am. Ind. Hyg. J.* 64:319-328 (2003).

- Flanagan, M.E., N. Seixas, P. Becker, B. Takacs, and J. Camp: Silica exposure on construction sites: Results of an exposure monitoring data compilation project. *J. Occup. Environ. Hyg.* 3:144-152 (2006).
- Freeman, C.S., and E.A. Grossman: Silica exposures in workplace in the United States between 1980 and 1992. *Scand. J. Work, Environ. Health* 21:Suppl(2) 47-49 (1995).
- Hornung, R.W., and L.D. Reed: Estimations of average concentration in the presence of non-detectable values. *Appl. Occup. Environ. Hyg.* 5:46-51 (1990).
- Kane, F.: The campaign to end silicosis. *Job Safety & Health Quarterly*; 8:16-19 (1997).
- Linch, K., W.E. Miller, R.B. Althouse, D.W. Groce, and G.M. Hale: Surveillance of respirable crystalline silica dust using OSHA compliance data (1979-1995). *Am. J. Ind. Med.* 34:547-558 (1998).
- Linch, K.: Respirable concrete dust – Silicosis hazard in the construction industry. *Appl. Occup. Environ. Hyg.* 17:209-211 (2002).
- Lumens, M., and T. Spee: Determinants of exposure to respirable quartz dust in the construction industry. *Ann. Occup. Hyg.* 45:585-595 (2001).
- National Institute for Occupational Safety and Health: Hazard Review: Health Effects of Occupational Exposure to Respirable Crystalline Silica. Washington, D.C.: NIOSH (2002).
- National Institute for Occupational Safety and Health: *Manual of analytical methods* (Methods 0600 and 7500). 4th ed. Washington, D.C.: NIOSH (1998).
- National Institute for Occupational Safety and Health: *Request for assistance in preventing silicosis and deaths in construction workers*. Publ. No. 96-112, Washington, D.C.: NIOSH (1996).
- Nij, E., S. Hilhorst, T. Spee, J. Spierings, F. Steffens, M. Lumens, and D. Heederik: Dust control measures in the construction industry. *Ann. of Occup. Hyg.* 47:211-218 (2003).
- Rappaport, S.M., M. Goldberg, P. Susi, and R.F. Herrick: Excessive exposure to silica in the US construction industry. *Ann. Occup. Hyg.* 47:111-122 (2003).
- Steenland, K.: One agent, many diseases: exposure-response data and comparative risks of different outcomes following silica exposure. *Am. J. Ind. Med.* 48:16-23 (2005).
- U.S. DOL BLS 2007 Occupational Outlook Handbook, 2008-09 Edition Cement Masons, Concrete Finishers, Segmental Pavers, and Terrazzo Workers
<http://stats.bls.gov/oco/ocos204.htm>
- Yassin, A., F. Yebesi, R. Tingle: Occupational exposure to crystalline silica dust in the United States, 1988-2003. *Environ. Health Perspectives.* 113:255-260 (2005).

END
