Partnering to Control Dust from Fiber-Cement Siding

CHAOLONG QI, PHD

ALAN ECHT, DrPH, MPH, CIH

CAPTAIN, U.S. PUBLIC HEALTH SERVICE

Site Surveyed:

1500 Pebble Creek Drive
Glenview, IL

NAICS Code:

238170 Siding Contractors

Survey Dates:

July 9-11, 2013

Surveys Conducted By:

Chaolong Qi, NIOSH/DART/EPHB

Alan Echt, NIOSH/DART/EPHB

Employer Representatives Contacted:

Peter Pawelko
Pro-Home Services Inc.
655 N. Central Unit F
Wood Dale, IL 60191

Employee Representatives Contacted:

No employee representatives

Analytical Work Performed by:

Bureau Veritas North America

Disclaimer

Mention of any company or product does not constitute endorsement by NIOSH. In addition, citations to websites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these websites. All Web addresses referenced in this document were accessible as of the publication date.

Table of Contents

Abstract

Background

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. Fiber-cement products can contain as much as 50% crystalline silica, and cutting this material has been shown to cause excessive exposures to respirable crystalline silica. NIOSH scientists are conducting a study to develop engineering control recommendations for respirable crystalline silica from cutting fiber-cement siding. This site visit was part of that study.

Assessment

NIOSH staff visited Pebble Creek construction site in Glenview, IL on July 9-11, 2013. During the site visit, they performed industrial hygiene sampling which measured the exposures to respirable dust and respirable crystalline silica of five workers who cut and installed fiber-cement siding. Two different engineering control measures were implemented and tested separately. One had a dust-collecting circular saw connected to a regular shop vacuum. The shop vacuum provided local exhaust ventilation to remove the dust generated from cutting fiber-cement siding. The other control measure was a prototype circular saw with a built-in cyclone dust collector and an air filter. The NIOSH scientists also monitored the wind speed and direction at the site, and collected data about the work process in order to understand the conditions that led to the measured exposures.

Results

Air sampling for respirable crystalline silica showed that on all three days, the 10-hour and 8-hour time weighted average (TWA) exposures to respirable crystalline silica for the installers and the two cutters who used the shop vacuum control measure were in the range of 0.001 to 0.013 mg/m^3 and 0.002 to 0.016 mg/m^3, respectively, which were considerably lower than both the NIOSH Recommended Exposure Limit (REL) of 0.05 mg/m^3 TWA, for up to a 10-hour workday in a 40-hour workweek, and the Threshold Limit Value (TLV®) of 0.025 mg/m^3 TWA for an 8-hour workday and a 40-hour workweek of the American Conference of Governmental Industrial Hygienists (ACGIH®). Their exposures were also considerably lower than the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for respirable dust that contains greater than 1% crystalline silica, with the 8-hour TWA exposures during the survey in the range of 0.02 to 0.12 mg/m^3.

For the cutter who used the prototype circular saw with a built-in cyclone dust collector and an air filter, the 10-hour TWA exposure to respirable crystalline silica was higher than the NIOSH REL on one of the three days; and the 8-hour TWA exposure was higher than the ACGIH® TLV® on all three days. For this cutter, the 8-hour TWA exposures to respirable dust that contains greater than 1% crystalline silica were in the range of 0.32 to 0.99 mg/m^3, which was lower than the corresponding OSHA PELs.

Conclusions and Recommendations

The exposure levels indicated that the evaluated engineering control measure consisting of a regular shop vacuum connected to a dust-collecting circular saw was effective in reducing the workers' exposures to concentrations below both the NIOSH REL and ACGIH® TLV® for respirable crystalline silica, and the OSHA PEL for respirable dust. This engineering control measure has the potential to provide an effective, simple and low cost solution for workers cutting fiber-cement siding. The engineering control measure consisting of a circular saw with a built-in cyclone dust collector and air filter was not as effective and will need further improvement to maintain exposures consistently below the NIOSH REL and ACGIH® TLV® for respirable crystalline silica.

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]. Fiber-cement products can contain as much as 50% crystalline silica. Cutting this material has been shown to cause excessive exposures to respirable crystalline silica [Lofgren et al. 2004, Qi et al. 2013].

The use of fiber-cement siding in construction and renovation is undergoing rapid growth. From 1991 to 2010, the market share of fiber-cement siding has climbed from 1% to 13% [US Census Bureau 2013]. In contrast, the market share of wood siding in residential construction has decreased from 38% to 8% [US Census Bureau 2013]. The durability and appearance of fiber-cement siding, which simulates wood without the maintenance issues associated with wood siding, is appealing and provides a competitive advantage over other building materials [Bousquin 2009]. The use of fiber-cement siding is expected to continue to increase. The number of workers exposed to dust containing crystalline silica as a result can also be expected to increase as the use of fiber-cement siding displaces other siding products.

Cellulose fiber, sand or fly ash, cement, and water are the principal ingredients used in the manufacture of fiber-cement products. James Hardie Industries, CertainTeed, Maxitile, GAF, and Nichiha are the major manufactures of fiber-cement products.

Fiber-cement board is cut using three methods: scoring and snapping the board, cutting the board using shears, and cutting the board using a power saw. When scoring and snapping the board, a knife is used to score the board by scribing a deep line into the board. The board is bent, and it breaks along the scored line. This method should be relatively dust-free. The score and snap method can be used when installing fiber-cement board used for tile underlayment, but is not applicable to siding. Commercially available tools used to shear fiber-cement siding include a foot-powered shear and hand-held powered shears. These shears are reportedly a relatively dust-free method of cutting fiber-cement siding. However, slow production rates and low precision limit the use of shears by siding contractors [Bousquin 2009].

Power saws, such as circular saws and compound miter saws, are used to cut fiber-cement siding. These saws are used with polycrystalline diamond-tipped blades with 4-8 teeth specifically designed to cut fiber-cement siding and minimize dust generation. Several commercially available saws are manufactured with hoods and exhaust take-offs that can be connected to vacuum cleaners or to dust-collection bags. These hoods partially enclose the saw blade. Available blade diameters are 5, 7.25, 10, and 12 inches (in).

The study by Lofgren et al. [2004] reported that cutters' uncontrolled exposures to respirable crystalline silica ranged from 0.02 milligrams per cubic meter (mg/m^3) to 0.27 mg/m^3 during sampling, and 8-hour (hr) time weighted average (TWA) exposure ranged from 0.01 mg/m^3 to 0.17 mg/m^3 depending on the length of exposure on the day sampled. The highest result was 3.4 times the NIOSH Recommended Exposure Limit (REL) for respirable crystalline silica of 0.05 mg/m^3.

In an earlier in-depth field survey, Qi et al. [2013] reported that a cutter's uncontrolled exposures to respirable crystalline silica ranged from 0.059 to 0.127 mg/m^3 during sampling, and 8-hr TWA exposure ranged from 0.021 mg/m^3 to 0.127 mg/m^3 depending on the time of exposure on the day sampled. The highest result was 2.54 times the NIOSH REL for respirable crystalline silica of 0.05 mg/m^3.

The long-term objective of this study is to provide practical recommendations for effective dust controls that will prevent overexposures to respirable crystalline silica while cutting fiber-cement siding. The specific aims of the project are: 1) determine the dust generation rate from cutting fiber-cement siding in the lab; 2) experimentally develop local exhaust ventilation recommendations for circular saws used to cut fiber-cement siding; 3) validate, at actual construction sites, the recommendations developed from the laboratory studies; and 4) disseminate the information in the form of technical reports, journal articles, NIOSH Workplace Solutions document, trade journals articles, home remodeling publications, and other media directed at the construction and remodeling industries, including the do-it-yourself market, to promote the use of the recommendations.

Background for this Survey

A laboratory study on the generation rate and engineering control of dust from cutting fiber-cement siding was conducted at the NIOSH Alice Hamilton Laboratory in Cincinnati, OH. Several circular saws with dust-reduction designs and miter saws were tested. The study found that connecting a dust-collecting circular saw (described in detail later in this report) to a dust collector can remove 80-90% of the dust from cutting fiber-cement siding, even at a low flow rate of about 0.014 cubic meter per second (m^3/s) (30 cubic feet per minute (CFM)). This result suggests that connecting a dust-collecting circular saw to a regular shop vacuum with built-in air filters, which normally runs at a higher flow rate than 0.014 m^3/s (30 CFM), is a simple and low-cost engineering control for the dust generated from cutting fiber-cement siding. Separately, a prototype circular saw with a built-in cyclone dust collector and an air filter was developed by James Hardie Industries

(Mission Viejo, CA) to collect the dust while cutting without using an external dust collector or shop vacuum. In order to assess the effectiveness of these two dust control measures, a field survey was conducted to evaluate exposures at a site where they were used for cutting fiber-cement siding. This survey was performed on July 9th, 10th, and 11th, 2013 at the Pebble Creek construction site in Glenview, IL. Air sampling was conducted to assess the respirable dust and crystalline silica exposures of workers cutting and installing fiber-cement siding. One group of installers was supplied with boards by two cutters using the dust collecting circular saw equipped with a shop vacuum. Another installer was provided with boards by a cutter using the prototype dust saw.

Construction Site and Process Description

Introduction

The Pebble Creek project was a remodeling project for a community of two-story townhouses, where old aluminum siding was replaced with fiber-cement siding. The siding job was done by Pro-Home Services, Inc. During this survey, the siding crews worked on one row of townhouses that included six units. Figure 1 shows a corner of the building, where fiber-cement siding was being cut and installed.

Figure 1 — The Construction Site. Photo courtesy of NIOSH.

Process Description

Fiber-cement siding was installed on the external walls of the townhouses by six construction workers on all three days of the survey. The six workers were divided into three groups. Each group consisted of one cutter who operated a circular saw to cut fiber-cement siding on a work bench, and one installer, who took the measurements, verbally communicated the size requirement to the cutter, and installed the siding. The cutter and installer in the same group often needed to help each other with their installation and cutting tasks. Figure 2 shows a cutter cutting fiber-cement siding on his work bench using a dust-collecting circular saw connected to a shop vacuum. During this survey, two cutters shared this setup. The third cutter worked at a different work bench and used a prototype circular saw with a built-in cyclone dust collector and an air filter (Figure 3). This prototype circular saw was developed by James Hardie Industries and referred to as the "red-spur saw" in this report. During the survey, the two work benches located at the two ends of the building with about 37 meters (120 feet) distance between them. Personal breathing zone air samples were taken from all three cutters and two of the three installers, resulting in a total of five sampled workers during this survey. None of the workers wore a respirator during the survey.

Figure 2 – A worker (cutter) cutting fiber-cement siding using a dust-collecting circular saw that was connected to a shop vacuum. Photo courtesy of NIOSH.

Figure 3 – A worker (cutter) cutting fiber-cement siding using a prototype circular saw with a built-in cyclone dust collector and an air filter ("red-spur saw"). Photo courtesy of NIOSH.

The dust-collecting circular saw (Model 5057KB, Makita U.S.A., Inc., La Mirada, CA) was equipped with a built-in dust collection container, which serves as a hood and covers about 69% of the saw blade's surface. When fiber-cement siding was cut, the flow induced by the spinning blade caused a large portion of the dust generated to be collected in the container and also directed the dust to an exhaust port at the end of the container, which could be connected to an external dust collector or shop vacuum.

The red-spur saw from James Hardie Industries also had a dust-collecting feature with a built-in shroud covering the saw blade. The shroud was connected to a cyclonic dust collector and a subsequent chamber which housed an air filter. When cutting fiber-cement siding, the flow induced by the spinning blade caused the shroud to collect a large portion of the dust generated when the fiber cement was cut. The induced air flow also directed the dust through the cyclone and air filter, eliminating the need for an external dust collector or shop vacuum.

Both saws used a polycrystalline diamond blade (Model D0704DH, Freud America, Inc., High Point, NC) with four teeth and a diameter of 18.2 centimeters (7.25 in), a kerf width of 1.8 millimeters (mm) (0.071 in) and a maximum speed of 10,000 rotations per minute (RPM). The Makita circular saw has a no-load speed of 5,800 RPM, according to the manufacturer's technical specification. The actual no-load speed of this saw was measured in the lab using a Pocket Tachometer (Model TAC2K, Dwyer Instruments Inc., Michigan City, IN) and it was found to be 5,500

RPM. The speed of the prototype red-spur saw was not provided by James Hardie Industries.

Both the fiber-cement siding boards and the trim boards cut and installed during this survey were manufactured by James Hardie Industries. Table 1 lists the specifications of the boards used. Both types of boards contained crystalline silica (quartz) as reported by the manufacturer's Material Safety Data Sheet (MSDS). Since the MSDS provides only a range of the quartz content for each type of board, averaged quartz contents were taken from it and included in Table 1. The averaged quartz content was used later in the report to estimate the amount of quartz in the material removed by the cutters.

Table 1 – Specifications of the fiber-cement siding and trim boards

Board type	Board thickness (mm; in)	Board density (kg/m^2; lbs/ft^2, MSDS)	Quartz % (MSDS)	Quartz % (used in this report)
lap siding	7.94; 5/16	11.2; 2.3	30-45	37.5
trim board	25.4; 1.0	27.6; 5.65	15-30	22.5

Notes: kg/m^2 means kilograms per square meter, and lbs/ft^2 means pounds per square feet.

Occupational Exposure Limits and Health Effects

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

Most OELs are expressed as a 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 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 2013]. 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 [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however, and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider the other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation) (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

Crystalline Silica Exposure Limits

When dust controls are not used or maintained or proper practices are not followed, respirable crystalline silica exposures can exceed the NIOSH REL, the OSHA PEL, or the ACGIH TLV. NIOSH recommends an exposure limit for respirable crystalline silica of 0.05 mg/m^3 as a TWA determined during a full-shift sample for up to a 10-hr workday during a 40-hr workweek to reduce the risk of developing silicosis, lung cancer, and other adverse health effects [NIOSH 2002]. When 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 ($\mu g/m^3$) [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]:

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

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/m^3 per mppcf when converting between gravimetric sampling and the particle count standard when characterizing construction operation exposures [OSHA 2008]. In August 2013, OSHA proposed a new PEL of 0.05 mg/m^3 for 8-hr TWA exposures [OSHA 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 [ACGIH 2013]. The TLV is intended to mitigate the risk of pulmonary fibrosis and lung cancer.

For the purposes of this survey, when the workday exceeded eight hours, the model developed by Brief and Scala [1975] was used to adjust the PEL and TLV®. The conservative Brief and Scala model results in the calculation of a reduction factor, expressed as:

$$RF = \frac{8}{h} \times \frac{24 - h}{16} \qquad (3)$$

Where RF is the reduction factor and h is the actual work shift time in hours. The occupational exposure limit (e.g., the PEL or TLV®; the numbers 10 and 14 are substituted for 8 and 16, respectively, for the REL when the work shift exceeds 10 hours) is multiplied by the reduction factor to arrive at an adjusted occupational exposure limit.

Methodology

Sampling Strategy

On all three sampling days, one sample was taken before lunch and one after lunch for each sampled worker, except that only one sample was taken for one cutter before lunch on July 11th as he left the job site after lunch. The total sampling times reflect the period sampled while the workers were working on the construction site.

Sampling Procedures

Air Sampling

Personal breathing zone air samples for respirable particulate 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). 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, BGI Inc., Waltham, MA). 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 [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 personal breathing zone air samples, at least two field blank samples were taken on each sampling day. Bulk dust samples were also collected in accordance with NIOSH Method 7500 [NIOSH 2003].

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 limit of detection (LOD) was 20 μg/sample. The limit of quantitation (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 5μg/sample, 5μg/sample, and 10μg/sample, respectively. The LOQs for quartz, cristobalite, and tridymite were 17μg/sample, 17μg/sample, and 33μg/sample, respectively.

Weather Monitoring Methods

On each survey working day, the NIOSH researchers used a Kestrel model 4500 Weather Meter (Nielsen-Kellerman Co., Boothwyn, PA), which was placed atop a tripod at the construction site. The weather meter was programmed to record data (including wind direction and speed, temperature, relative humidity and altitude) every 10 minutes.

Average wind direction was calculated using the equation [EPA 2000]

$$\bar{\theta}_{RV} = ArcTan\left(V_x/V_y\right) + FLOW \qquad (4)$$

$$FLOW \begin{matrix} = +180; for\ ArcTan\left(V_x/V_y\right) < 180 \\ = -180; for\ ArcTan\left(V_x/V_y\right) > 180 \end{matrix} \qquad (5)$$

Where

$$V_x = -\frac{1}{N}\sum \sin\theta_i \qquad (6)$$

And

$$V_y = -\frac{1}{N}\sum \cos\theta_i \qquad (7)$$

$\bar{\theta}_{RV}$ is the resultant mean wind direction

V_x is the magnitude of the east-west component of the unit vector mean wind

V_y is the magnitude of the north-south component of the unit vector mean wind

θ_i is the azimuth angle of the wind vector, measured clockwise from north (i.e., the wind direction)

In spreadsheet programs, use of the function ATAN2 avoids the extra checks needed to insure that V_x and V_y are nonzero, and are defined over a full 360 degree range [EPA 2000].

Measuring Productivity

Productivity of the cutters was measured by counting the number of cuts, their length, the number of boards stacked and cut, and the thickness of each board cut during each sampling period. The kerf width of the diamond blade is 1.8 mm (0.071 inch). Thus, the volume of material removed for each cut can be estimated by multiplying the length of the cut, the number of boards in the stack, the board thickness and the kerf width of the blade. The mass of material removed was calculated by multiplying the volume of material removed and the board density according to the manufacturer's MSDS, as listed in Table 1. The amount of quartz in the removed material of each cut was then calculated by multiplying the mass of the material removed and the average quartz percentage of the board, which is

also listed in Table 1. The daily productivity of the cutters and the productivity corresponding to each individual air sample can thus be estimated by summing up the above-mentioned metrics from all the corresponding cuts.

Control Technology

A laboratory study on the generation rate and engineering control of dust from cutting fiber-cement siding was conducted at the NIOSH Alice Hamilton Laboratory in Cincinnati, OH. That study found that connecting a dust-collecting circular saw to a dust collector removed about 80-90% of the dust produced when fiber-cement siding was cut, even at a low dust collector flow rate of about 0.014 m^3/s (30 CFM). It was also found that further increasing the flow rate of the dust collector did not lead to a higher dust collection rate. These results suggest that connecting a dust-collecting circular saw to a regular shop vacuum, typically having a higher flow rate than 0.014 m^3/s (30 CFM) can be a simple and low-cost engineering solution to control the dust generated from cutting fiber-cement siding.

In this survey, a 12-gallon shop vacuum (model 586-62-11, Shop-Vac$^®$ Corporation, Williamsport, PA) was used to provide local exhaust ventilation for the Makita dust-collecting circular saw used by two cutters. As described earlier, this dust-collecting circular saw has a built-in container which serves as a hood and covers most of the saw blade. When fiber-cement siding is cut, the flow induced by the spinning blade causes a large portion of the dust generated to be collected in the container and also directs this dust to an exhaust port at the end of the container. A vacuum hose was used to connect the saw's exhaust port to the shop vacuum. Figure 4 shows the dust-collecting circular saw and its connection to the shop vacuum. A high efficiency disposable filter bag (fine filtration bag, part number 90672, Shop-Vac$^®$ Corporation, Williamsport, PA) was used in the shop vacuum to trap most of the dust and a Prolong cartridge filter (part number 90304, Shop-Vac$^®$ Corporation, Williamsport, PA) was used to capture the dust passing through the filter bag. Since most of the dust was captured in the filter bag rather than the cartridge filter, the life of the cartridge filter was greatly extended.

The shop vacuum was rated to provide a 0.094 m^3/s (200 CFM) flow rate by the manufacturer, which is sufficient to provide good local exhaust ventilation for the cutting task, based on the NIOSH laboratory study. However, the actual flow rate can be affected when the shop vacuum is connected to the filters and vacuum hose. More importantly, the flow rate might change from dust loading on the filter bag and cartridge filter. Thus, a data logging pressure transducer (Smart Reader SRP-004-30G-128K 0-30 PSI-G, ACR Systems, Surrey, BC, Canada) was placed in the tank of the shop vacuum, between the filter bag and the cartridge filter in the flow path, to log the local absolute air pressure. A laboratory study at NIOSH found that the difference between the absolute air pressure in the shop vacuum tank when the shop vacuum is on and off is linearly correlated with the actual air flow rate, as measured using a Delta tube (model # 307BZ-11-AO, Mid-West Instrument, Sterling Heights, MI). In the laboratory study, a gate valve was used to adjust the air flow rate so that the correlation between the actual flow rate read from the

Delta tube and the absolute air pressure difference from the data logging pressure transducer in the shop vacuum tank could be obtained. This correlation was used with the pressure data collected from the shop vacuums at the job site to estimate their actual flow rates during the survey. A battery pack (model # BP-101, ACR Systems, Surrey, BC, Canada) was used together with the data logging pressure transducer in each shop vacuum in order to obtain the vacuum tank pressure readings every 2 seconds.

Figure 4 –The dust-collecting circular saw and its connection to the shop vacuum used in this survey. Photo courtesy of NIOSH.

Both the circular saw and the shop vacuum were plugged into an iVAC switch (iVAC Switch Box 10031-0100, BCTINT Ltd, Kanata, ON, Canada), which automatically turns on/off the shop vacuum whenever the circular saw is turned on/off. The iVAC switch is also featured a 6-second delay in turning off the shop vacuum when the saw is turned off, removing the remaining dust in the vacuum hose following the cutting of a board.

As mentioned earlier, the other engineering control measure tested in this survey was the prototype red-spur saw (Figure 5). The red-spur saw collects dust in its

built-in cyclone dust collector and air filter without using an external shop vacuum. It utilizes a shroud to cover the blade and the flow induced by the spinning blade to direct the dust to a built-in chamber which works as a cyclone dust collector to remove larger dust particles by their inertial effect. The cyclone chamber is inter-connected to another chamber on its side where an air filter is incorporated to remove the residual dust escaping from the cyclone.
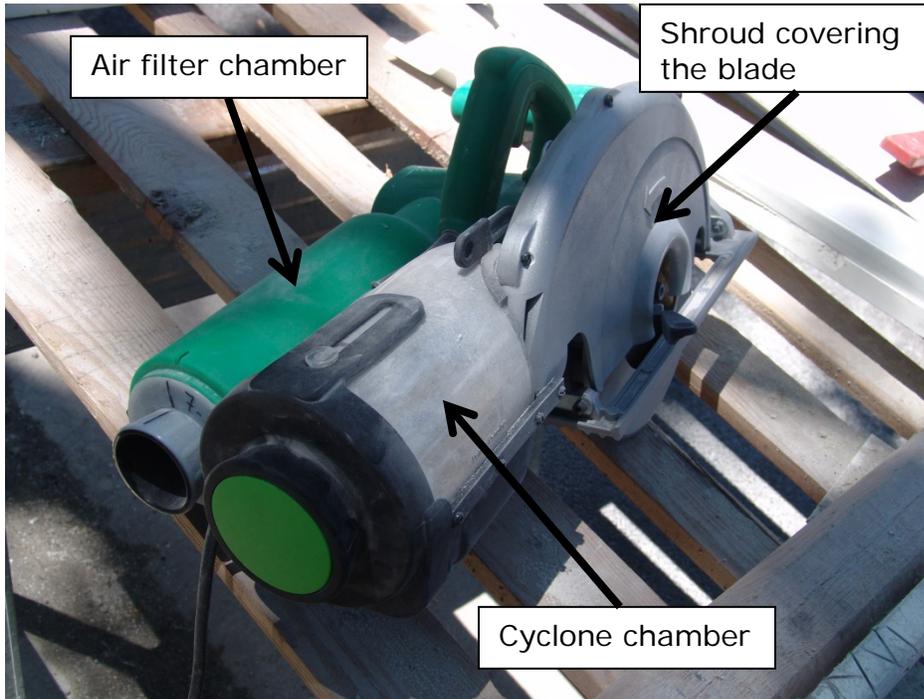
Figure 5 – The prototype red-spur saw with its built-in cyclone dust collector and air filter. Photo courtesy of NIOSH.

Results

The respirable dust and respirable quartz data in Table 2 were used to calculate percent quartz in the samples, and then used to compute the respirable dust PELs. The tables in the Appendix provide the sampling data used to calculate the results provided in Tables 2–4.

Silica Content in Air and Bulk Samples

Table 2 presents the respirable crystalline silica and respirable dust masses reported for every air sample collected during this survey. For each worker, the sum of the respirable crystalline silica masses for each of their samples included in their daily TWA is divided by the sum of the respirable dust masses for those samples and multiplied by 100 to calculate the percent silica over the workday. That value is used to calculate the OSHA PEL for each worker, for each day [OSHA 2008].

$$\% \text{ Silica} = \frac{\text{Sample}_1 \text{ Silica Mass (µg)} + \cdots + \text{Sample}_n \text{ Silica Mass (µg)}}{\text{Sample}_1 \text{ Dust Mass (µg)} + \cdots + \text{Sample}_n \text{ Dust Mass (µg)}} \times 100 \qquad (8)$$

Table 2 – Respirable Silica Masses, Respirable Dust Masses, and Percent Silica.

Date	Worker	Sample period	Respirable dust (µg/sample)	Respirable quartz (µg/sample)	Quartz %	Daily Quartz %
7/09/2013	Cutter 1	1	880	85.0	9.7	7.7
7/09/2013	Cutter 1	2	1100	68.0	6.2	
7/09/2013	Cutter 2	1	86	6.6	7.7	10.0
7/09/2013	Cutter 2	2	56	7.6	13.6	
7/09/2013	Cutter 3	1	66	8.4	12.7	15.2
7/09/2013	Cutter 3	2	140	23.0	16.4	
7/09/2013	Installer 1	1	160	15.0	9.4	11.0
7/09/2013	Installer 1	2	76	11.0	14.5	
7/09/2013	Installer 2	1	46	3.5*	7.7	8.7
7/09/2013	Installer 2	2	56	5.3	9.5	
7/10/2013	Cutter 1	1	560	42.0	7.5	6.2
7/10/2013	Cutter 1	2	480	22.0	4.6	
7/10/2013	Cutter 2	1	26	3.5*	13.6	14.8
7/10/2013	Cutter 2	2	200	30.0	15.0	
7/10/2013	Cutter 3	1	36	3.5*	9.8	11.0
7/10/2013	Cutter 3	2	86	9.9	11.5	
7/10/2013	Installer 1	1	26	15.0	57.7	35.6
7/10/2013	Installer 1	2	26	3.5*	13.6	
7/10/2013	Installer 2	1	26	3.5*	13.6	11.7
7/10/2013	Installer 2	2	66	7.2	10.9	
7/11/2013	Cutter 1	1	500	43.0	8.6	9.2
7/11/2013	Cutter 1	2	140	16.0	11.4	
7/11/2013	Cutter 2	1	36	3.5*	9.8	9.8
7/11/2013	Cutter 3	1	66	5.6	8.5	9.2
7/11/2013	Cutter 3	2	56	5.6	10.0	
7/11/2013	Installer 1	1	26	3.5*	13.6	29.7
7/11/2013	Installer 1	2	14.1*	8.4	59.4	
7/11/2013	Installer 2	1	56	6.5	11.6	10.9
7/11/2013	Installer 2	2	36	3.5*	9.8	

Notes: data with a * means the sampled data was below the LOD and a value of LOD/SQRT(2) was used to calculate the TWA exposure. There were 29 air samples; it was found that 8 of them were below the LOD of respirable quartz and 1 of them was below the LOD of respirable dust. The rest of the data were log-normally distributed with a geometric standard deviation of 2.57 for respirable quartz and 3.26 for respirable dust. Under these conditions, Hewett and Ganser [2007] suggested that using LOD/SQRT(2) for non-detectable samples has fairly modest bias in the 95th percentile of the mean.

Based on the data presented in Table 2, the Daily Quartz % (percent silica over the workday) for each worker was calculated using Equation (8) and listed in the last column. Overall, the air samples contained from 4.6 to 16.4% quartz except two

samples which have an abnormally high percentage of quartz (>50%) possibly due to sampling and/or analysis limits. The mean of the quartz percentage for all of the samples was 9.1%. Two blank samples were collected each day and no crystalline silica was detected on any of the blank samples. One bulk sample was collected from the dust captured in the bag filter of the shop vacuum and it contained 19% quartz; two bulk samples were collected from the cyclone dust collector of the red-spur saw and they contained 19% and 21% quartz. No cristobalite or tridymite were detected in the bulk samples.

In this survey, Cutter 1 used the prototype red-spur saw and Cutter 2 and 3 used the Makita circular saw with a shop vacuum. Installer 1 and Cutter 1 worked as a group, and Installer 2 and Cutter 2 worked as a group. The installer that worked with Cutter 3 did not participate in the sampling survey.

Respirable Dust Results

As shown in Table 2, the quartz content in the workers' daily respirable dust samples ranged from 6.2% to 35.6%, resulting in respirable dust containing crystalline silica PELs from 0.62 mg/m^3 to 2.24 mg/m^3 according to the calculation using Equations (2) and (3) and the corresponding conversion factor. Table 3 reports the TWA respirable dust concentrations, 8-hour TWA respirable dust concentrations, and applicable respirable dust PELs. The 8-hour TWAs were calculated assuming that no further exposure occurred during the unsampled portion of the workday [OSHA 2008]. This was the case for all of the workers on all three days.

Table 3 – Respirable Dust Results.

Date	Worker	Daily sampling time (minutes)	Respirable dust TWA concentration (mg/m^3)	Respirable dust 8-hr TWA concentration (mg/m^3)	OSHA PEL (mg/m^3)	Adjusted PEL
7/09/2013	Cutter 1	398	1.19	0.99	1.96	no
7/09/2013	Cutter 2	449	0.08	0.07	1.67	no
7/09/2013	Cutter 3	446	0.11	0.10	1.24	no
7/09/2013	Installer 1	393	0.15	0.12	1.56	no
7/09/2013	Installer 2	440	0.06	0.05	1.83	no
7/10/2013	Cutter 1	480	0.51	0.51	2.24	no
7/10/2013	Cutter 2	487	0.11	0.11	1.23	yes
7/10/2013	Cutter 3	468	0.06	0.06	1.56	no
7/10/2013	Installer 1	476	0.03	0.03	0.62	no
7/10/2013	Installer 2	483	0.04	0.04	1.49	yes
7/11/2013	Cutter 1	268	0.57	0.32	1.76	no
7/11/2013	Cutter 2	220	0.04	0.02	1.69	no
7/11/2013	Cutter 3	399	0.07	0.06	1.76	no
7/11/2013	Installer 1	267	0.04	0.02	0.72	no
7/11/2013	Installer 2	400	0.06	0.05	1.57	no

Overall, the 8-hour TWA respirable dust exposures ranged from 0.32 mg/m^3 to 0.99 mg/m^3 for Cutter 1; from 0.02 mg/m^3 to 0.11 mg/m^3 for Cutter 2 and 3; and from 0.02 mg/m^3 to 0.12 mg/m^3 for the two installers. They were all lower than the corresponding OSHA PELs, especially for the installers and the two cutters (Cutter 2 and 3) who used a shop vacuum as the engineering control measure. For Cutter 1 who used the red-spur saw, the 8-hour TWA exposure was as high as about 50.5% of the PEL (on July 9th).

Respirable Crystalline Silica Results

Table 4 presents the respirable crystalline silica sampling results including the TWA respirable crystalline silica concentrations, 10-hour and 8-hour TWA respirable crystalline silica concentrations, the NIOSH REL and the ACGIH® TLV®.

Table 4 – Respirable Crystalline Silica Results.

Date	Worker	Daily sampling time (minutes)	Respirable crystalline silica TWA concentration (mg/m^3)	Respirable crystalline silica 10 hr/8-hr TWA concentration (mg/m^3)	NIOSH REL/ACGIH® TLV® (mg/m^3)	Adjusted
7/09/2013	Cutter 1	398	0.092	0.061/0.076	0.05/0.025	no
7/09/2013	Cutter 2	449	0.008	0.006/0.007	0.05/0.025	no
7/09/2013	Cutter 3	446	0.017	0.013/0.016	0.05/0.025	no
7/09/2013	Installer 1	393	0.016	0.010/0.013	0.05/0.025	no
7/09/2013	Installer 2	440	0.005	0.004/0.004	0.05/0.025	no
7/10/2013	Cutter 1	480	0.031	0.025/0.031	0.05/0.025	no
7/10/2013	Cutter 2	487	0.016	0.013/0.016	0.05/0.024	yes(TLV®)
7/10/2013	Cutter 3	468	0.007	0.005/0.007	0.05/0.025	no
7/10/2013	Installer 1	476	0.009	0.007/0.009	0.05/0.025	no
7/10/2013	Installer 2	483	0.005	0.004/0.005	0.05/0.025	yes(TLV®)
7/11/2013	Cutter 1	268	0.053	0.024/0.029	0.05/0.025	no
7/11/2013	Cutter 2	220	0.004	0.001/0.002	0.05/0.025	no
7/11/2013	Cutter 3	399	0.007	0.004/0.006	0.05/0.025	no
7/11/2013	Installer 1	267	0.011	0.005/0.006	0.05/0.025	no
7/11/2013	Installer 2	400	0.006	0.004/0.005	0.05/0.025	no

The 10-hour TWA respirable crystalline silica exposures ranged from 0.024 mg/m^3 to 0.061 mg/m^3 for Cutter 1; from 0.001 mg/m^3 to 0.013 mg/m^3 for Cutter 2 and 3; and from 0.004 mg/m^3 to 0.010 mg/m^3 for the two installers. They were all lower than the NIOSH REL except for Cutter 1 on July 9th when his exposure was 22% higher than the NIOSH REL. The higher exposure for Cutter 1 on July 9th was possibly due to the incorrect fit and finish of the prototype red-spur saw, which was discovered and corrected later on that day. The 8-hour TWA respirable crystalline silica exposures ranged from 0.029 mg/m^3 to 0.076 mg/m^3 for Cutter 1; from 0.002 mg/m^3 to 0.016 mg/m^3 for Cutter 2 and 3; and from 0.004 mg/m^3 to 0.013

mg/m^3 for the two installers. For the two installers and the two cutters using shop vacuum (Cutter 2 and 3), the 8-hour TWA respirable crystalline silica exposure was lower than the ACGIH® TLV® on all three days; however, for the cutter using the red-spur saw (Cutter 1), the 8-hour TWA respirable crystalline silica exposure was higher than the ACGIH® TLV® on all three days.

Weather Monitoring Results

During the three day survey, the air temperature at the site ranged from 70°F to 86°F; and the relative humidity from 37% to 84%. Matching the wind speed and direction to the workers' sampling periods resulted in the data shown in Table 5. Table 6 presents the wind speed and direction for the workers' sampling days (i.e., averaged over the total sampling periods). The standard deviation of the wind speed was about 112%, 66%, and 57% of the average wind speed for the three days. The variation of wind direction on each day was small, with the wind direction frequency within 90° of the average wind direction at about 43%, 59%, and 74% of the three days.

Table 5 Wind speed and direction by worker and sample period.

Date	Sample period	Average wind speed (kph; mph)	Wind speed range (kph; mph)	Average wind direction (degrees)
7/09/2013	1	1.5; 0.9	0 to 5.1; 0 to 3.2	41
7/09/2013	2	2.0; 1.3	0 to 8.2; 0 to 5.1	354
7/10/2013	1	2.7; 1.7	0 to 10.1; 0 to 6.3	6
7/10/2013	2	3.8; 2.4	0 to 7.2; 0 to 4.5	67
7/11/2013	1	2.7; 1.7	0 to 6.4; 0 to 4.0	51
7/11/2013	2	3.4; 2.1	0 to 7.1; 0 to 4.4	85

Table 6 – Wind speed and direction by sampling day.

Date	Average wind speed (kph; mph)	Wind speed range (kph; mph)	Average wind direction (degrees)
7/09/2013	1.8; 1.1	0 to 8.2; 0 to 5.1	32
7/10/2013	3.3; 2.0	0 to 10.1; 0 to 6.3	58
7/11/2013	3.0; 1.8	0 to 7.1; 0 to 4.4	73

Productivity Results

The number of cuts, the length, the number of boards in the stack, and the board thickness of each cut were recorded during each sampling period. As mentioned above, the volume and mass of the material removed, and the estimated mass of

quartz in the removed material were used as measures of productivity in this survey. The results are listed in Table 7.

Table 7 – Cutters' productivity by date and sample period.

Date	Cutter	Sample period	Volume of material removed (cm^3)	Mass of material removed (g)	Mass of Quartz in the removed material (g)
7/09/2013	1	1	468.82	663.27	248.73
7/09/2013	1	2	628.96	850.62	299.56
7/09/2013	2	1	458.08	617.37	216.30
7/09/2013	2	2	553.74	783.41	293.78
7/09/2013	3	1	227.88	322.39	120.90
7/09/2013	3	2	384.46	535.50	196.64
7/10/2013	1	1	743.30	934.09	292.05
7/10/2013	1	2	603.57	760.75	239.12
7/10/2013	2	1	189.53	205.84	46.31
7/10/2013	2	2	529.37	747.58	279.68
7/10/2013	3	1	197.59	253.35	82.02
7/10/2013	3	2	402.44	565.33	210.01
7/11/2013	1	1	411.85	569.76	207.26
7/11/2013	1	2	79.72	112.78	42.29
7/11/2013	2	1	133.91	150.63	37.25
7/11/2013	3	1	429.18	552.88	180.41
7/11/2013	3	2	338.50	478.89	179.59

Engineering Control Results

The shop vacuum used in the survey was used by both Cutter 2 and Cutter 3. A new filter bag was installed in the shop vacuum every morning before the job started. Inspection of the shop vacuum conducted at the same time found that the cartridge filter was in good condition with little dust loading. Thus, the same cartridge filter was used in the shop vacuum throughout the survey.

As mentioned previously, the flow rate of the shop vacuum can be estimated based on the logged air pressure in the vacuum and the correlation between the flow rate and pressure found in the laboratory study. The estimated operating flow rates of the shop vacuum during the survey are listed in Table 8. For the most part, the flow rates remained stable and were much higher than 0.014 m^3/s (30 CFM), the flow rate which was found to provide effective dust control in the laboratory study.

Table 8 – Estimated operating flow rate of the shop vacuums.

Date	Flow rate of (m^3/s; CFM)
7/09/2013	0.036; 76.0
7/10/2013	0.033-0.040; 70.5-84.6
7/11/2013	0.035-0.038; 73.7-80.6

Data analyses

A total of 29 air samples were taken during this survey, with 6 samples for Cutter 1, who used the red-spur saw, 11 samples for Cutter 2 and 3, who used the Makita circular saw with a shop vacuum, and 12 samples for the two installers. Data analysis was performed separately for the 6 samples from Cutter 1, the 11 samples from Cutter 2 and 3, the 12 samples from the two installers; and the 29 combined samples. The exposure data were found to be log-normally distributed in the individual and the combined groups. The summary statistics are listed in Table 9.

Table 9 - Summary Statistics and 95% Confidence Limits of the Geometric Means

Exposure Variables	Job Type	Number of Samples	Geometric Mean	95% Confidence Limits of Geometric Mean		Geometric Standard Deviation
Respirable dust TWA concentration (mg/m^3)	Cutter 1	6	0.706	0.454	1.100	1.52
	Cutter 2 and 3	11	0.070	0.048	0.102	1.75
	Installers	12	0.051	0.035	0.075	1.84
Respirable crystalline silica TWA concentration (mg/m^3)	Cutter 1	6	0.054	0.029	0.100	1.79
	Cutter 2 and 3	11	0.0081	0.005	0.013	1.91
	Installer	12	0.0075	0.0045	0.012	2.19

As listed in Table 9, the exposures for the cutters using shop vacuum as a control (Cutter 2 and 3) were in a similar level to those for the installers. And their exposures seemed to be all well under control, with the 95% upper confidence limit of the respirable crystalline silica TWA concentration being only 0.012 mg/m^3 for the installers and 0.013 mg/m^3 for Cutter 2 and 3, which were considerably lower than both the NIOSH REL of 0.05 mg/m^3 and the ACGIH® TLV® of 0.025 mg/m^3. However, the exposure for Cutter 1 was apparently higher, with the geometric mean of the respirable crystalline silica TWA concentration being 0.054 mg/m^3, which was higher than both the NIOSH REL and the ACGIH® TLV®. The 95% upper confidence limit for Cutter 1 was 0.100 mg/m^3, which was almost twice the NIOSH REL. The respirable dust TWA data followed a similar trend, with the exposure of Cutter 1 apparently higher than that of the installers and Cutter 2 and 3 as a group.

A Pearson correlation analysis was also performed to investigate the possible correlation between the cutters' exposure levels and the mass of material removed in unit time during each sampling period. The exposure to respirable dust was tested for correlation with the mass of material removed (data in Table 7) in unit time; and the exposure to respirable crystalline silica was tested for correlation with the mass of quartz in the removed material (data in Table 7) in unit time. All the Person Correlation Coefficients of the variables of interest were between 0.43 and 0.56, which are not statistically significant. This indicates that there is no

statistically significant evidence for a positive linear relationship between the cutters' exposure levels and the mass of material removed in unit time. This is possibly due to the small number of samples analyzed and the influence of other factors, such as wind, the cutters' standing positions, etc.

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)
- 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.

From the data for Cutter 2 and 3, who used the evaluated engineering control measure consisting of a regular shop vacuum connected to a dust-collecting circular saw, the 8-hour TWA exposures to respirable dust were less than 10% of the OSHA PEL, and the 10- hour TWA exposures to respirable crystalline silica were less than 26% of the NIOSH REL. These results indicate that this engineering control measure effectively controlled the dust emissions and reduced the workers' exposures to concentrations below both the NIOSH REL and ACGIH[®] TLV[®] for respirable crystalline silica, and the OSHA PEL for respirable dust. The use of this type of engineering control technology for the dust-collecting circular saws is the preferred solution comparing to respirator use and adheres to the hierarchy of controls. From the data for Cutter 1, who used the engineering control measure consisting of a circular saw with a built-in cyclone dust collector and an air filter (the red-spur saw), the 8-hour TWA exposures to respirable dust were less than 50.5% of the OSHA PEL during all three days, and the 10- hour TWA exposures to respirable crystalline silica were below the NIOSH REL during the two days when it was operated properly with correct fit and finish. These results indicate that, this engineering control measure, when operated properly, provides an effective method of managing the respirable dust and respirable crystalline silica associated with cutting fiber-cement siding (lap siding in this survey). Further improvement and test for this control measure are suggested to confirm it reduces the worker's exposures consistently below the NIOSH REL and ACGIH[®] TLV[®] for respirable crystalline silica.

References

ACGIH[®] [2013]. 2013 TLVs[®] and BEIs[®]: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2007]. 2007 Emergency Response Planning Guidelines (ERPG) & Workplace Environmental Exposure Levels (WEEL) Handbook. Fairfax, VA: American Industrial Hygiene Association.

Akbar-Khanzadeh F, Brillhart RL [2002]. Respirable crystalline silica dust exposure during concrete finishing (grinding) using hand-held grinders in the construction industry. Ann Occup Hyg 46:341-346.

BGI [2011]. An Excel spreadsheet for Q vs D50 calculations. Available on-line at http://www.bgiusa.com/cyc/gk2.69_calculator.xls. Accessed Dec. 31, 2012.

Brief RS, Scala RA [1975]. Occupational exposure limits for novel work schedules. American Industrial Hygiene Association Journal, 36: 6, 467 — 469.

Bousquin J [2009]. Fiber cement's aesthetics and durability continue to gain fans. Building Products Magazine. Publication date: February 13, 2009. [http://www.prosalesmagazine.com/industry-news.asp?sectionID=0&articleID=875202] accessed 11/30/2009.

Bureau of Mines [1992]. Crystalline silica primer. Washington, DC: U.S. Department of the Interior, Bureau of Mines, Branch of Industrial Minerals, Special Publication.

CFR [2003a]. 29 CFR 1910.1000. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

CFR [2003b]. 29 CFR 1926.55. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Chisholm J [1999]. Respirable dust and respirable silica concentrations from construction activities. Indoor Built Environ 8:94-106.

EPA [2000]. Meteorological monitoring guidance for regulatory modeling applications. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. EPA-454/R-99-005.

Flanagan ME, Seixas N, Majar M, Camp J, Morgan M [2003]. Silica dust exposures during selected construction activities. AIHA Journal 64:319-328.

Glindmeyer HW, Hammad YY [1988]. Contributing factors to sandblasters' silicosis: inadequate respiratory protection equipment and standards. J Occup Med. 30:917-921.

Hewett P, Ganser GH [2007]. A comparison of several methods for analyzing censored data. Ann Occup Hyg; 51: 611–32.

Linch, KD [2002]. Respirable concrete dust-silicosis hazard in the construction industry. Appl Occup Environ Hyg, 17:209-221.

Lofgren DJ, Johnson DC, Walley TL [2004]. OSHA Compliance issues: silica and noise exposure during installation of fiber-cement siding. Occup & Env Hyg J 1:D1-D6.

Nash NT, Williams DR [2000]. Occupational exposure to crystalline silica during tuckpointing and the use of engineering controls. Appl Occup Environ Hyg, 15:8–10.

NIOSH [1975]. Criteria for a recommended standard – Occupational exposure to crystalline silica. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, HEW Publication No. (NIOSH) 75-120.

NIOSH [1986]. Occupational respiratory diseases. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-102.

NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

NIOSH [1998]. Particulates not otherwise regulated, respirable. NIOSH Manual of Analytical Methods (NMAM®), 4th ed., 2nd Supplement, Schlecht, P.C. & O'Connor, P.F. Eds. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-119.

NIOSH [2002]. NIOSH Hazard Review: Health Effects of Occupational Exposure to Respirable Crystalline Silica. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-129.

NIOSH [2003]. Silica, crystalline, by XRD (filter redeposition). NIOSH Manual of Analytical Methods (NMAM®), 4th ed., 3rd Supplement, Schlecht, P.C. & O'Connor, P.F. Eds. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-154.

OSHA [1996]. Memorandum for regional administrators from: Joseph A. Dear. Subject: special emphasis program (SEP) for silicosis. May 2nd, 1996. Appendix F: Permissible Exposure Limits for Construction and Maritime.

OSHA [2008]. National emphasis program - Crystalline silica. CPL 03-00-007. 01/24/2008. Appendix E: Conversion factor for silica PELs in construction and maritime. Retrieved September 29, 2010 from http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=3790#e

OSHA [2013]. OSHA Fact Sheet: OSHA's proposed crystalline silica rule: overview. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration. https://www.osha.gov/silica/factsheets/OSHA_FS-3683_Silica_Overview.html

Qi C, Echt A, See M [2013]. In-Depth Survey Report: Partnering to Control Dust from Fiber-Cement Siding. DHHS/CDC/NIOSH Cincinnati, OH. Report No. EPHB 358-11a. http://www.cdc.gov/niosh/surveyreports/pdfs/358-11a.pdf

Rappaport SM, Goldberg M, Susi P, Herrick RF [2003]. Excessive exposure to silica in the U.S. construction industry. Ann Occup Hyg 47:111-122.

Thorpe A, Ritchie AS, Gibson MJ, Brown RC [1999]. Measurements of the effectiveness of dust control on cut-off saws used in the construction industry. Ann Occup Hyg 43:443-456.

US Census Bureau [2013]. SURVEY OF CONSTRUCTION, Principle Type of Exterior Wall Material of New One-Family Houses Completed. http://www.census.gov/const/C25Ann/sftotalexwallmat.pdf. Accessed November 13, 2013.

Vincent JH [2007]. Aerosol sampling. Chichester, West Sussex, England: John Wiley&Sons, Ltd. Pp. 203.

Woskie SR, Kalil A, Bello D, Virji MA [2002]. Exposures to quartz, diesel, dust, and welding fumes during heavy and highway construction. AIHA Journal 63:447-457.

Appendix

Table A1 - Respirable Dust Sampling Results

Date	Worker	Sampling Period	Duration (min)	Volume (L)	Respirable Particulate (µg/sample)	Respirable Concentration (mg/m³)
7/09/2013	Cutter 1	1	194	814	880	1.081
7/09/2013	Cutter 1	2	203	852	1100	1.291
7/09/2013	Cutter 2	1	204	844	86	0.101
7/09/2013	Cutter 2	2	244	1010	56	0.055
7/09/2013	Cutter 3	1	202	835	66	0.079
7/09/2013	Cutter 3	2	244	1007	140	0.139
7/09/2013	Installer 1	1	191	790	160	0.202
7/09/2013	Installer 1	2	202	833	76	0.091
7/09/2013	Installer 2	1	198	815	46	0.056
7/09/2013	Installer 2	2	242	1000	56	0.056
7/10/2013	Cutter 1	1	220	940	560	0.596
7/10/2013	Cutter 1	2	260	1111	480	0.432
7/10/2013	Cutter 2	1	225	966	26	0.027
7/10/2013	Cutter 2	2	262	1123	200	0.178
7/10/2013	Cutter 3	1	213	910	36	0.040
7/10/2013	Cutter 3	2	255	1095	86	0.079
7/10/2013	Installer 1	1	217	931	26	0.028
7/10/2013	Installer 1	2	259	1110	26	0.023
7/10/2013	Installer 2	1	223	955	26	0.027
7/10/2013	Installer 2	2	260	1114	66	0.059
7/11/2013	Cutter 1	1	213	890	500	0.562
7/11/2013	Cutter 1	2	55	228	140	0.613
7/11/2013	Cutter 2	1	220	920	36	0.039
7/11/2013	Cutter 3	1	214	894	66	0.074
7/11/2013	Cutter 3	2	185	772	56	0.073
7/11/2013	Installer 1	1	214	896	26	0.029
7/11/2013	Installer 1	2	54	223	14*	0.063
7/11/2013	Installer 2	1	214	893	56	0.063
7/11/2013	Installer 2	2	186	777	36	0.046

Notes: data with a * means the sampled data was below the LOD and a value of LOD/SQRT(2) was used to calculate the TWA exposure. min means minutes, L means liters, µg means micrograms, and mg/ m³ means milligrams per cubic meter.

Table A2 – Silica Sampling Results

Date	Worker	Sampling Period	Duration (min)	Volume (L)	Quartz (µg/sample))	Quartz Concentration (mg/m^3)
7/09/2013	Cutter 1	1	194	814	85.0	0.104
7/09/2013	Cutter 1	2	203	852	68.0	0.080
7/09/2013	Cutter 2	1	204	844	6.6	0.008
7/09/2013	Cutter 2	2	244	1010	7.6	0.008
7/09/2013	Cutter 3	1	202	835	8.4	0.010
7/09/2013	Cutter 3	2	244	1007	23	0.023
7/09/2013	Installer 1	1	191	790	15	0.019
7/09/2013	Installer 1	2	202	833	11	0.013
7/09/2013	Installer 2	1	198	815	3.5*	0.004
7/09/2013	Installer 2	2	242	1000	5.3	0.005
7/10/2013	Cutter 1	1	220	940	42.0	0.045
7/10/2013	Cutter 1	2	260	1111	22.0	0.020
7/10/2013	Cutter 2	1	225	966	3.5*	0.004
7/10/2013	Cutter 2	2	262	1123	30	0.027
7/10/2013	Cutter 3	1	213	910	3.5*	0.004
7/10/2013	Cutter 3	2	255	1095	9.9	0.009
7/10/2013	Installer 1	1	217	931	15	0.016
7/10/2013	Installer 1	2	259	1110	3.5*	0.003
7/10/2013	Installer 2	1	223	955	3.5*	0.004
7/10/2013	Installer 2	2	260	1114	7.2	0.006
7/11/2013	Cutter 1	1	213	890	43.0	0.048
7/11/2013	Cutter 1	2	55	228	16.0	0.070
7/11/2013	Cutter 2	1	220	920	3.5*	0.004
7/11/2013	Cutter 3	1	214	894	5.6	0.006
7/11/2013	Cutter 3	2	185	772	5.6	0.007
7/11/2013	Installer 1	1	214	896	3.5*	0.004
7/11/2013	Installer 1	2	54	223	8.4	0.038
7/11/2013	Installer 2	1	214	893	6.5	0.007
7/11/2013	Installer 2	2	186	777	3.5*	0.005

Notes: data with a * means the sampled data was below the LOD and a value of LOD/SQRT(2) was used to calculate the TWA exposure. min means minutes, L means liters, µg means micrograms, and mg/ m^3 means milligrams per cubic meter.

National Institute for Occupational Safety and Health

NIOSH

Delivering on the Nation's promise: Safety and health at work for all people through research and prevention.

To receive NIOSH documents or other information about occupational safety and health topics, contact NIOSH at

1-800-CDC-INFO (1-800-232-4636)

TTY: 1-888-232-6348

E-mail: cdcinfo@cdc.gov

or visit the NIOSH Web site at www.cdc.gov/niosh

For a monthly update on news at NIOSH, subscribe to NIOSH eNews by visiting www.cdc.gov/niosh/eNews

SAFER • HEALTHIER • PEOPLE