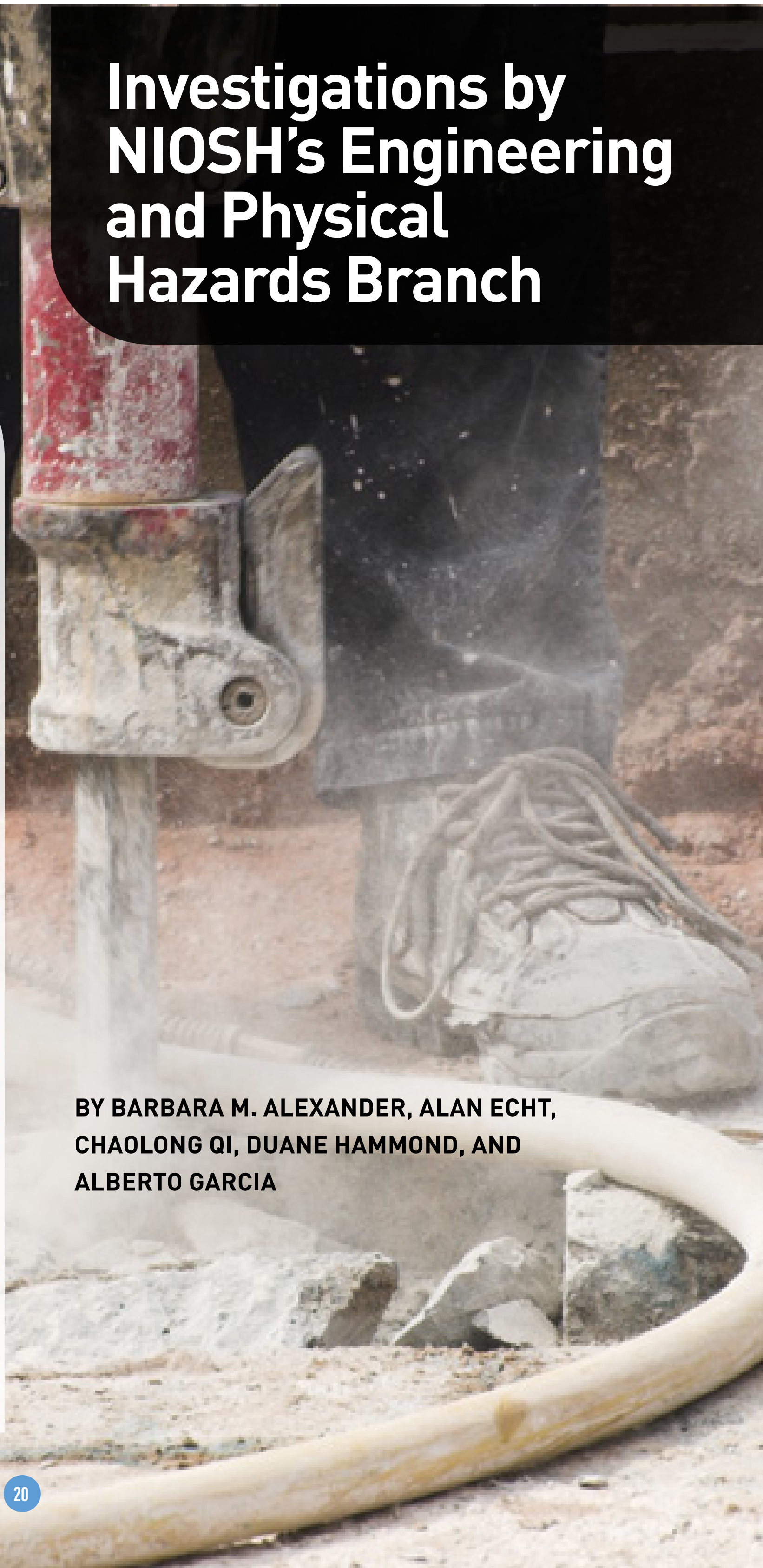
Engineering Controls for Respirable Crystalline



Investigations by NIOSH's Engineering and Physical Hazards Branch

BY BARBARA M. ALEXANDER, ALAN ECHT, CHAOLONG QI, DUANE HAMMOND, AND ALBERTO GARCIA

Respirable crystalline silica is one of the oldest occupational hazards, yet exposures to RCS still cause illness today. Inhalation of RCS is associated with a range of serious illnesses, but it is known primarily for causing silicosis, an incurable and often fatal fibrotic lung disease. Although engineering controls to reduce inhalation of RCS have been known and available for decades, people continue to succumb to its associated health effects. Researchers in the Engineering and Physical Hazards Branch (EPHB), in the Division of Field Studies and Engineering (DFSE) at NIOSH, have extensively studied engineering controls for tasks that produce RCS. In other NIOSH divisions, research on RCS controls also continues to be a priority.

Silica, or silicon dioxide (SiO_2), can be found in crystalline or amorphous forms. Its most abundant crystalline form is alpha quartz, an extremely common mineral found in sand, gravel, soil, clay, shale, slate, sandstone, granite, calcined diatomaceous earth, portland cement concrete, asphalt pavement, ceramics, brick, tile, masonry, mortar, and other materials. It is frequently found alongside deposits of ores and other resources that are mined, such as coal. We are surrounded by it—we walk on it, drive on it, eat and drink from it, and build with it. Although it can comprise many useful materials, it becomes hazardous after it is pulverized, aerosolized, and inhaled.

RCS: A HAZARD OF THE PAST AND FUTURE

The hazards associated with RCS became widely known during one of the most disastrous episodes in the history of occupational health in the United States: the drilling of the Hawk's Nest Tunnel in Gauley Bridge, West Virginia, in the early 1930s. Part of this tunnel was drilled through a nearly pure deposit of quartz, and it is estimated that 764 workers

Silica Hazards

died from silicosis during the drilling. More than three quarters of the workers who died were African American.

Due to the high silica exposures, some tunnel workers had already passed away from acute silicosis by the end of the 18 months of construction. This led to the first recognition of acute silicosis by the American medical profession.

The Hawk's Nest Tunnel Disaster has been characterized as America's worst industrial disaster. In 1936, Secretary of Labor Frances Perkins—who was also the United States' first female presidential cabinet secretary—convened a national silicosis conference consisting of five committees, one of which focused on preventing silicosis through the application of engineering controls. However, the awareness stimulated by this conference did not put an end to silicosis: from 1968 to 2002, silicosis caused over 16,000 deaths in the U.S.

Currently, U.S. regulation of RCS exposure is the most protective it has ever been. OSHA published its final rule on silica in 2016, reducing the permissible exposure limit (PEL) for RCS, which had been unchanged since 1971, from as high as 0.24 mg/m^3 to 0.05 mg/m^3. OSHA estimated that 2.3 million workers are exposed to silica in the workplace, primarily in the construction industry, and the agency expected the lower exposure limit to save over 600 lives and prevent more than 900 new cases of silicosis every year.

According to the hierarchy of controls, the most preferable option would be to eliminate the silica-containing material or to substitute one less likely to cause silica exposure. Engineering controls, such as local exhaust ventilation (LEV) with a dust-collecting hood and a vacuum dust collector or the use of water sprays, are the next most preferable options and can be effective at reducing RCS exposures. These are not new concepts—they were among the recommendations of the 1936 silicosis conference. But at highway and even residential construction projects today, you may still see workers without respiratory protection surrounded by clouds of uncontrolled concrete dust.

Under the current regulations, engineering and work practice controls are required to be implemented unless they are unfeasible. Table 1 in 29 CFR 1926.1153, OSHA's silica standard for the construction industry, specifies engineering controls, work practices, and respiratory protection for a variety of tasks. NIOSH EPHB research formed the scientific basis of this table. Where engineering controls cannot reduce the 8-hour time-weighted average (TWA) workplace exposures to below 0.5 mg/m^3, a respirator with an assigned protection factor (APF) greater than 10 is required. For exposures exceeding an RCS concentration of 2.5 mg/m^3, only a supplied-air respirator, such as a self-contained breathing apparatus (SCBA), with an APF of at least 1,000 will suffice. Because there are several tasks that can cause exposures higher than this level, the need for using effective engineering controls to mitigate worker RCS exposures is clear.

EPHB'S STUDIES OF RCS EXPOSURES

EPHB researchers have studied engineering controls for RCS during many occupational tasks, including:

- ceramics manufacturing
- cleaning foundry castings with chipping and grinding tools
- jackhammering
- concrete breaking, drilling, cutting, grinding, sanding, and polishing
- cutting brick, concrete blocks, concrete roofing tiles, and fiber cement siding
- tuckpointing
- stone countertop grinding and polishing
- hardscaping
- milling asphalt
- hydraulic fracturing

Some examples of exposures during these tasks, with and without engineering controls, can be found in Table 1 on page 22. There are large differences in exposures between some tasks, both controlled and uncontrolled. Several factors account for these differences.

The materials being worked on can have varying contents of crystalline silica, from trace amounts in some materials to over 90 percent in engineered quartz stone. The proximity of exposure can also differ from task to task: some tasks, including tuckpointing, are performed at arm's length, while in other activities, such as the use of walk-behind equipment, dust is generated farther away from the breathing zone. Certain tasks require the removal of large quantities of material, as when grinding, while activities such as breaking concrete remove smaller quantities. Finally, exposure durations can vary considerably. There are tasks that make up only a relatively small fraction of the working day, while others may be performed almost continuously throughout a work shift.

Differences such as these impact the function of engineering controls. LEV may be more effective for tasks in

Table 1. Uncontrolled and controlled personal breathing zone exposures to RCS during occupational tasks. Unless otherwise noted, exposures are 8-hour or 10-hour time-weighted averages.

Task	Uncontrolled exposure (mg/m³)	Controlled exposure (mg/m³)	Engineering Control	Resource
Ceramics manufacturing	0.13–0.22*	0.027–0.179*	Enclosures, automation, substitution of some non-silica materials, improved housekeeping, and improved local exhaust ventilation	**bit.ly/cooper1993**
Cleaning foundry castings	0.124–0.16	59%–79% reduction from uncontrolled	Local exhaust ventilation	**bit.ly/gressel1997**
Jackhammering	0.05–0.43†	0.04–0.29†	Water spray	**bit.ly/surveywaterspray** (PDF)
Grinding concrete	1.73	0.142–0.208	Local exhaust ventilation	**bit.ly/handtoolssurvey** (PDF)
Cutting concrete roofing tiles	ND–0.45‡	ND‡	Tile breaker	**bit.ly/tile-saws-report** (PDF)
Cutting concrete block	6.6–38.0‡	0.79–1.1‡	Local exhaust ventilation	**bit.ly/niosh-concrete-cutting** (PDF)
Concrete dowel drilling	0.0221–0.675	0.024–0.42	Local exhaust ventilation	**bit.ly/niosh-drilling-ctrls** (PDF)
Tuckpointing	0.012–12.6	0.06–0.15‡	Saw with local exhaust ventilation instead of grinder	**bit.ly/removingmortar** (PDF)
Cutting fiber-cement siding	0.021–0.127	0.002–0.041	Local exhaust ventilation	**bit.ly/fibersidingsurvey** (PDF) and **bit.ly/cutting-siding-eval** (PDF)
Walk-behind concrete surfacing	0.07^	ND–0.124‡	Local exhaust ventilation	**bit.ly/SiO2construction** (PDF) and **bit.ly/niosh-concrete-prep** (PDF)
Stone countertop grinding	--	0.094–0.569‡	Grinder with center water feed	**bit.ly/niosh-comp-report** (PDF)
Stone countertop grinding	--	0.052–0.389‡	Grinder with water spray	**bit.ly/niosh-comp-report** (PDF)
Stone countertop grinding	--	0.015–0.054@	Grinder with water spray plus sheet water wetting	**bit.ly/niosh-comp-report** (PDF)
Milling asphalt	ND–0.07	ND–0.024	Combination water spray and local exhaust ventilation	**bit.ly/hwayrepair** and **bit.ly/hwaysilicaexps**
Hydraulic fracturing	0.006–2.755	--	--	**bit.ly/silicafrackingexps**

ND=non-detectable; *Geometric mean exposures for a range of job titles; †One-hour exposures; ‡Short-term (34 minutes or less) TWA exposures when actively performing the tasks; ^Geometric mean exposures for an average time of 184 minutes; @Short-term (95-168 minutes) TWA exposures

which the dust collection hood remains in continuous close contact with the work surface, but less effective when tools are in motion, such as while hammering. In those cases, other control measures, such as wet methods, may be more effective.

EPHB RESEARCH IN RCS ENGINEERING CONTROLS

Much EPHB research into controlling RCS exposures has been carried out in cooperation with partners in labor, industry, and government. Some of the earliest EPHB research into RCS exposure occurred as part of a cooperative state-federal program, the NIOSH Sentinel Event Notification System for Occupational Risks (SENSOR), which started in 1987. Industries studied included the ceramics industry and foundry casting.

Using video exposure monitoring with direct reading instruments, a technique developed by EPHB researchers, RCS exposures in the ceramics industry were associated with dusty raw materials, the wiping and scraping of castings, and poor housekeeping. By substituting some raw materials that did not contain silica, employing engineering controls such as enclosing and automating dusty processes, and improving work practices, such as by maintaining cleaner work areas and dampening dry castings before wiping and scraping, personal breathing zone RCS exposures were reduced by an average of 79 percent.

Most foundries use molds made from sand and binders to mold metal castings. RCS exposures occur when cooled and hardened castings are cleaned to remove excess metal and embedded sand using pneumatic chipping and grinding tools. In a 1997 NIOSH article, a downdraft booth used for LEV was shown to be effective in reducing RCS exposures. Depending on the tool used, EPHB found that reductions in RCS exposures of 59–79 percent could be achieved.

From 1999 to 2004, EPHB researchers studied RCS exposure during the use of jackhammers on concrete and tested LEV and water sprays to control RCS. Use of water sprays achieved reductions in RCS exposures of up to 77 percent, but special care must be taken not to create icy conditions during winter work.

Aside from jackhammers, other construction tools used in chipping, grinding, drilling, and demolishing concrete include handheld grinders, electric and pneumatic chipping hammers, and hammer drills. Uncontrolled 8-hour TWA exposures to RCS as high as 1.73 mg/m³ were measured when grinding poured concrete structures to make them smooth after forms had been removed. LEV was demonstrated to be an effective control when an appropriate industrial vacuum was used for dust collection. The vacuum should have high efficiency, adequate capacity to hold collected dust, and the ability to be cleaned without RCS exposure to the operator. In addition to reducing worker exposures, the use of LEV as an RCS control for grinding poured concrete structures and other dusty tasks in construction provides benefits that include reducing the subsequent cleanup required and allowing other crafts to work nearby without bystander exposure.

RCS exposures during the cutting of cement blocks were investigated in an EPHB study published in 2007. Use of LEV with a handheld abrasive cutter was shown to reduce personal breathing zone RCS exposures by an average of 95 percent when cutting concrete blocks. Use of a handheld abrasive cutter with water spray was shown to reduce exposures by about 90 percent. The engineering controls tested in this study were commercial products.

Dowel drills are used for drilling long, narrow holes in concrete slabs for the insertion of steel dowels. In an EPHB study of dowel drilling published in 2013, worker exposures to RCS were high even when using LEV. This was primarily attributed to re-aerosolization of RCS while cleaning drilled holes and handling the dust collectors and filters.

The Automatic Tools Testing Chamber developed by EPHB has been and continues to be used to study engineering controls for aerosols generated by cutting and grinding activities (see Figure 1). The large air handling unit at the right pulls air through the high-efficiency particulate air (HEPA) filter at the opposite end, providing a steady flow of clean air through the enclosure. An automated system repeatedly feeds a workpiece to a tool under study. The concentration and size distribution of aerosols released with and without controls are measured by use of direct-reading instruments and gravimetric samplers. An example of results obtained for cutting fiber cement siding, which can contain up to 50 percent crystalline silica, with and without LEV as an engineering control is shown in Figure 2.

The chamber studies allow quick identification and optimization of engineering controls before conducting expensive field evaluations. Field studies validated the effectiveness of LEV in controlling RCS exposures while cutting fiber cement siding, as identified from the chamber study. An optimized engineering control for this application was created by connecting circular saws with dust-collecting shrouds to a standard shop vacuum with an airflow rate of 30 cubic feet per minute (cfm), or 0.85 cubic meters per minute, or higher and a hose with an inside diameter of at least 1.25 inches, or 3.2 centimeters.

Exposures to operators of walk-behind concrete floor surfacing equipment were studied by EPHB researchers in 2014 and 2015. Although these machines were tested with vendor-supplied LEV, exposures to the operators were highly variable. Results differed with machine design and the fineness of the sanding pads used. EPHB researchers suggested that improvements to the LEV system may be

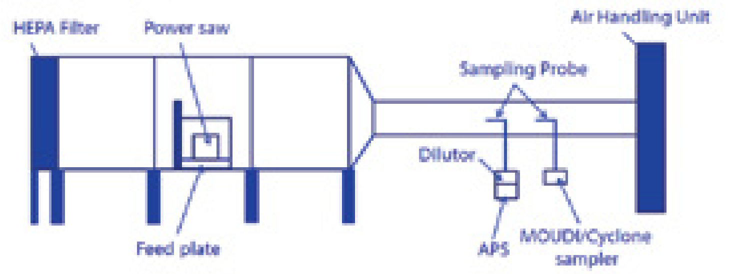


Figure 1. A diagram of the Automatic Tools-Testing Chamber in the Engineering Controls Research Area at the NIOSH Alice Hamilton Building in Cincinnati, Ohio. Air flows from left to right through the system. The Aerodynamic Particle Spectrometer (APS) and Micro-Orifice Uniform Deposition Impactor (MOUDI) with cyclone are used to do size-selective sampling of aerosols produced when cutting and grinding construction materials. From NIOSH: **bit.ly/cutting-siding-eval** (PDF).

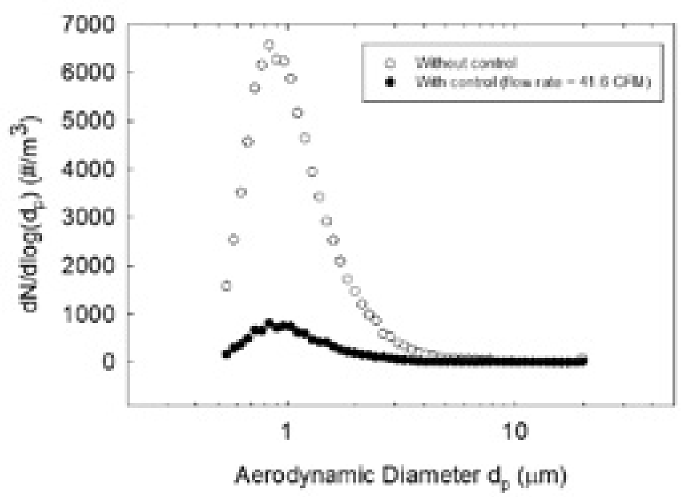


Figure 2. Number concentration of aerosols generated by cutting of fiber-cement siding using a radial saw with and without local exhaust ventilation as an engineering control. From NIOSH: **bit.ly/cutting-siding-eval** (PDF).

needed, including higher dust capture velocities, a reduced gap between the shroud and the floor, and shorter and smoother hoses connecting to the dust-collecting vacuums.

Uncontrolled RCS exposures during tuckpointing are among the highest documented in EPHB research due to the close proximity of the breathing zone to the work surface, the high RCS content in the dust produced, and the long, continuous duration of the task. During an EPHB study of tuckpointing, at the highest RCS exposure measured, 12.6 mg/m^3, a worker not protected by engineering controls or a respirator would be overexposed for the 8-hour TWA at the end of two minutes of work. However, LEV works well as an engineering control for this task because the tuckpointing tool stays in close contact with the work surface for extended periods of time, allowing efficient dust collection. When using LEV, a worker could

Figure 3. Sheet water wetting is an effective engineering control for RCS exposure during stone countertop grinding. From NIOSH: **bit.ly/niosh-comp-report** (PDF).

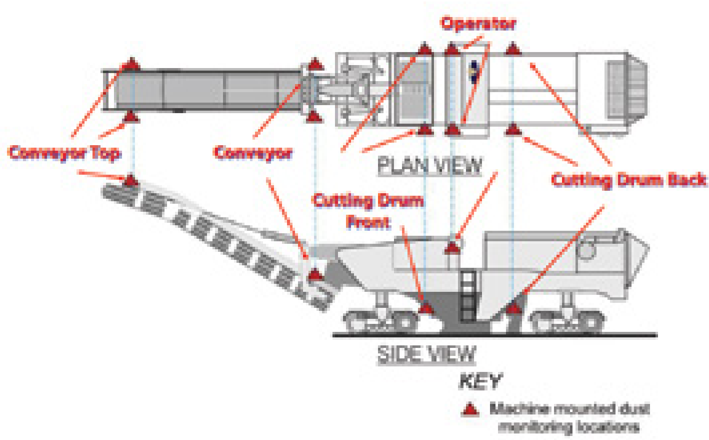


Figure 4. Diagram of an asphalt milling machine, showing dust sampling locations. From NIOSH: **bit.ly/asphaltdust** (PDF).

perform tuckpointing for at least 160 minutes before exceeding the 8-hour TWA.

EPHB 3D printing capabilities made it possible to customize engineering controls for some investigations. For example, a modified LEV capture hood was tested for tuckpointing applications. In this study, the customized hood was found to be effective, but not more effective than a commercially available hood. Respiratory protection is still required for tuckpointing.

For controlling RCS exposure during stone countertop grinding and polishing, EPHB researchers tested engineering controls that included a dust collection booth, water sprays incorporated into grinding and polishing tools, and a simple garden hose used for sheet water wetting (see Figure 3). Stone countertop fabricators are at high risk of RCS overexposure due to the high silica content in the engineered stone and the large portion of their workday spent performing tasks that generate RCS. Sheet water wetting as an engineering control provided the best exposure reductions, as water sprays incorporated into grinding and polishing tools did not always direct sufficient water where it is needed. This is an important finding, as multiple deaths among stone countertop fabricators due to silicosis have been reported worldwide, including the deaths of two U.S. workers who were less than 40 years of age.

Hardscaping is a specialty of landscaping, focused on the construction of masonry structures such as brick paver patios, walkways, and retaining walls. Although uncontrolled RCS exposures to workers performing hardscaping have not been studied to date, hardscapers use circular saws to cut brick and concrete, so their exposures might be similar to those measured for workers in the construction industry who cut bricks and concrete blocks. Commercially available engineering controls include water sprays for handheld saws and either water sprays or dust capture for table saws. Preliminary data collected by EPHB researchers for hardscapers using table saws with integral dust capture show that exposures can exceed the OSHA PEL, even when using engineering controls.

Much larger pieces of equipment generate RCS in asphalt milling and hydraulic fracturing. Asphalt pavement, which is composed of sand and gravel mixed with petroleum asphalt, is the primary source of RCS generation during asphalt milling operations. The cutting drum (indicated in Figure 4, a diagram of an asphalt cold milling machine) scrapes up chunks of pavement, producing RCS and potentially causing exposures to the operator, ground crew, and bystanders. While investigating these operations, EPHB expertise in tracer gas studies was employed along with area and personal breathing zone sampling. Working in partnership with industry trade associations, unions, and manufacturers of cold milling machines, EPHB researchers identified a combination of water sprays and LEV as effective in controlling RCS exposures. This led to the publication of two best practice documents in 2015 and the implementation of dust controls by all manufacturers of large asphalt milling machines in 2017.

In the oil and gas extraction industry, RCS exposures during hydraulic fracturing result from the movement of massive quantities of silica sand. A groundbreaking NIOSH study, published in 2013, documented high RCS exposures in hydraulic fracturing workers, especially sand mover operators (see Figure 5), during pneumatic transfer of sand. Researchers in EPHB and the NIOSH Western States Division worked for several years on a dust-capturing "mini baghouse" engineering control for RCS in hydraulic fracturing, which demonstrated that reducing exposures was possible. Ultimately, commercial innovations, such as substitutes for sand, sand treatments, and replacing the pneumatic transfer of sand with gravity-fed methods, were widely adopted in the oil and gas extraction industry to reduce RCS exposures.

TURNING RESEARCH INTO PRACTICE

Some engineering controls may not be commercially available, making it necessary for workers and employers to improvise. Water sprays may not be acceptable at certain work sites, such as inside occupied buildings or in locations where icy conditions may result. LEV can require the use of bulky hoses and dust collecting vacuums and may be impractical in some locations: for example, on roofs or where electric power is unavailable. Nevertheless, acceptable engineering controls can usually be found. Engineering controls may be inconvenient and slow the pace of work, but they are fundamental to the controlling of RCS exposures.

However, working with partners can help surmount these barriers to implementing engineering controls. With the help of partnerships between health and safety professionals, workers, and employers, some engineering controls may become welcome and routine in the workplace, as in the case of asphalt milling mentioned above. Furthermore, in Chicago, the widespread adoption of LEV on tuckpointing grinders was credited to the combined efforts of labor unions, public pressure, and regulator activity.

Do activities at your work site create dust from materials potentially containing silica? If so, then follow best practices to control exposures to RCS: with engineering controls in place to mitigate RCS exposure, personal respiratory protection can be reduced or even eliminated, but worker health can still be protected.

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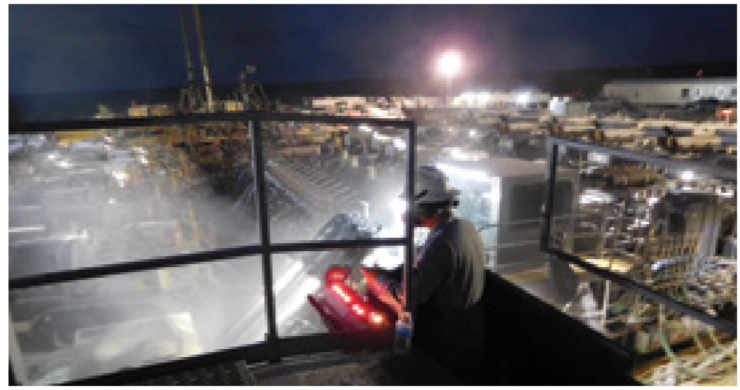

Figure 5. A cloud of dust containing RCS near a sand mover operator during pneumatic transfer of sand for hydraulic fracturing. From NIOSH: **bit.ly/researchrounds1803**.

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Send feedback to **synergist@aiha.org**.

RESOURCES

The American Industrial Hygiene Association Journal: "An Evaluation of a Local Exhaust Ventilation Control System for a Foundry Casting-Cleaning Operation" (May 1997).

The American Industrial Hygiene Association Journal: "Successful Reduction of Silica Exposures at a Sanitary Ware Pottery" (October 1993).

Applied Occupational and Environmental Hygiene: "Control of Silica Exposure from Hand Tools in Construction: Grinding Concrete" (July 2002).

International Journal of Occupational and Environmental Health: "The Power of Local Action in Occupational Health: The Adoption of Local Exhaust Ventilation in the Chicago Tuckpointing Trade," **bit.ly/pwr-local-acts** (April 2016).

The Journal of Occupational and Environmental Hygiene: "Evaluation of an Improved Prototype Mini-Baghouse to Control the Release of Respirable Crystalline Silica from Sand Movers" (March 22, 2016).

The Journal of Occupational and Environmental Hygiene: "Respirable Crystalline Silica Exposures During Asphalt Pavement Milling at Eleven Highway Construction Sites" (July 2016).

NIOSH: "Comprehensive Report: Engineering Control of Silica Dust from Stone Countertop Fabrication and Installation – Evaluation of Wetting Methods for Grinding," **bit.ly/niosh-comp-report** (PDF, June 2021).

NIOSH: "Comprehensive Report: Evaluation of the Dust Generation and Engineering Control for Cutting Fiber-Cement Siding," **bit.ly/cutting-siding-eval** (PDF, October 2014).

NIOSH: "In-Depth Survey of Dust Control Technology for Cutting Concrete Block and Tuckpointing Brick," **bit.ly/niosh-concrete-cutting** (PDF, April 2007).

NIOSH: "In-Depth Survey Report of a Demonstration and Evaluation of Roofing Tile Saws and Cutters Controlling Respirable and Crystalline Silica Dust," **bit.ly/tile-saws-report** (PDF, September 2006).

NIOSH: "In-Depth Survey Report: Concrete Surface Preparation Tools Machine 7," **bit.ly/niosh-concrete-prep** (PDF, October 2019).

NIOSH: "In-Depth Survey Report: Control Technology for Dowel Drilling in Concrete," **bit.ly/niosh-drilling-ctrls** (PDF, October 2013).

NIOSH: "In-Depth Survey Report: Removing Mortar with a Powered Saw and Modified On-Tool Hood," **bit.ly/niosh-mortar-report** (PDF, May 2019).

NIOSH: "NIOSH Hazard Review: Health Effects of Occupational Exposure to Respirable Crystalline Silica," **bit.ly/niosh-rcs-effects** (PDF, April 2002).

NIOSH: "NIOSH Numbered Publications," **bit.ly/niosh-index**.

NIOSH: "Workplace Solutions: Water Spray Control of Hazardous Dust When Breaking Concrete with a Jackhammer," **bit.ly/niosh-water-spray** (PDF, May 2008).

OSHA: "Safety and Health Topics – Silica, Crystalline," **bit.ly/osha-sio2**.

Yale University Press: *The Hawk's Nest Incident: America's Worst Industrial Disaster*, 1989.

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April 2022

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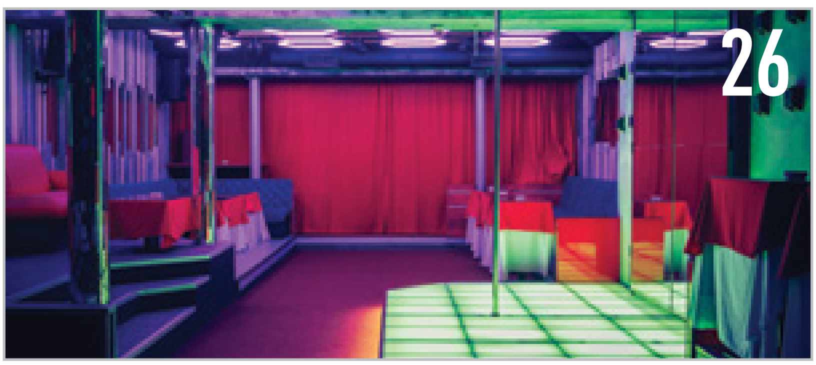


REVEALING EXPOSURES

HEALTH AND SAFETY CONCERNS IN STRIP CLUBS

The American strip club is a $7 billion industry with a rich history in the tradition of the circus, burlesque, cancan, go-go dancing, and striptease. Unfortunately, strip clubs and other businesses in the adult entertainment industry are often considered taboo workplaces; as a result, they may be hesitant to request outside help, including from safety and health professionals.

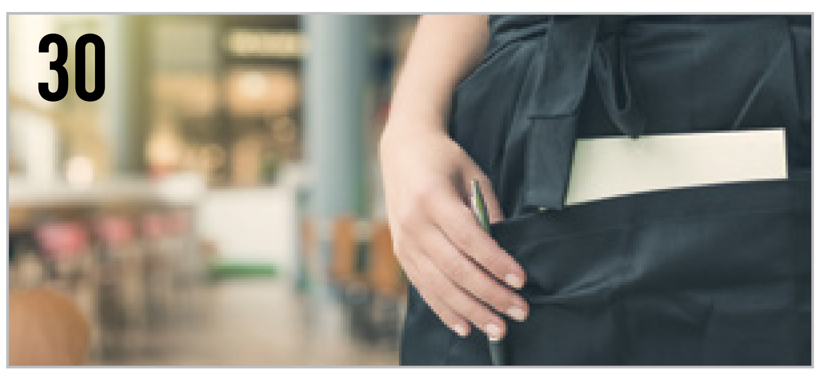
BY EVA M. GLOSSON

WORKER WELL-BEING IN THE GREAT RESIGNATION

A STORY OF RISKS, ILLS, AND CULTURES

Over 4.5 million American workers left their jobs in November 2021, the highest number since the Bureau of Labor Statistics began keeping these figures in December 2000. Many hourly, entry-level, minority, and low-wage workers—those who earn less than $60,000 per year—have seriously considered leaving or have left their jobs in search of better opportunities.

BY DEBORAH IMEL NELSON



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