HealthHazard Evaluation Program

Evaluation of Silica and Noise Exposures at a Concrete Corrosion Testing Facility

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Disclaimer

The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

Availability of Report

Copies of this report have been sent to the employer and employee representative at the facility. The state health department and the Occupational Safety and Health Administration Regional Office have also received a copy.

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Introduction

Request

An employee at a concrete infrastructure corrosion testing facility requested a health hazard evaluation of employees' exposures to respirable crystalline silica and noise during the processing of concrete samples.

Workplace

The company was located in a single-story building that also housed other businesses. The company inspected and collected samples from concrete infrastructures, such as bridges, to identify and quantify material corrosion and performance. To prepare samples for material testing, technicians cut, crushed, and pulverized concrete samples into powder for further analysis.

At the time of our site visit, two technicians cut, crushed, and pulverized concrete samples. They rotated doing these tasks. Technicians worked a single, 8-hour shift Monday through Friday. Technicians operated a masonry saw and pulverizer in a small room in the facility but only one employee worked in the room at a time. The room had a window-mounted exhaust fan. The masonry saw was equipped with a dust collection system with an attached high-efficiency particulate air (HEPA) filter. Technicians used a vacuum equipped with a HEPA filter to clean the saw and the pulverizer after each sample was processed.

Technicians were required to wear full Tyvek® suits with booties and nitrile gloves when sawing and crushing concrete samples. They also wore full-face air purifying respirators equipped with combination P100® particulate and organic vapor cartridges. During our site visit, technicians used earplugs and earmuffs that were available for voluntary use.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

We conducted an initial walkthrough of the worksite in November 2022 and returned in July 2023. During our return visit we did the following activities:

- Observed work processes, practices, and equipment.
- Collected personal air samples for respirable crystalline silica and respirable dust.
- Collected bulk samples of pulverized concrete to determine its silica content.
- Took personal noise exposure measurements from workers involved in processing concrete samples.
- Measured sound levels when concrete samples were cut, crushed, and pulverized.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Employees' exposures to respirable crystalline silica were above the Occupational Safety and Health Administration's action level.

- Employees using the masonry saw and pulverizer were exposed to respirable crystalline silica above the Occupational Safety and Health Administration (OSHA) "action level." When exposures are at or above the action level, employers are required to take steps to protect employees.
- The room used for sawing and pulverizing concrete had an exhaust fan in the window, but it didn't keep dust levels below the OSHA action level.

Work practices may have added to respirable crystalline silica exposures.

- We observed work activities that caused dust to enter the air, such as dry brushing the pulverizer wheel after crushing concrete and dry sweeping the floor after sawing concrete.
- Employees stood close to the front of the pulverizer while it was operating. We observed dust coming out of gaps in the pulverizer during use. We also observed a visible dust cloud when the employee removed the pulverizer collection drawer.
- Employees were not wearing their respirators correctly; for example, we observed employees with facial hair using tight-fitting respirators.

Employees were overexposed to noise.

- Noise exposures for technicians using the masonry saw were above the NIOSH recommended exposure limit. Depending on the time spent using the masonry saw, employees' noise exposures could also be above OSHA noise exposure limits.
- Employees did not always wear their earmuffs correctly; for example, we observed employees wearing earmuffs over the hood of their Tyvek suit.

To learn more about our results, go to Section B in the Supporting Technical Information

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Potential Benefits of Improving Workplace Health and Safety:

- ↑ Improved worker health and well-being
- ↑ Better workplace morale
- ↑ Easier employee recruiting and retention
- ↑ Enhanced image and reputation
- ↑ Superior products, processes, and services
- ↑ Increased overall cost savings

The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or practical, administrative measures and personal protective equipment might be needed. Read more about the hierarchy of controls at About Hierarchy of Controls | Hierarchy of Controls | CDC.

We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in *Recommended Practices for Safety and Health Programs* at https://www.osha.gov/safety-management.

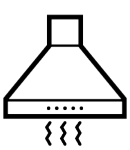
Recommendation 1: Reduce employees' exposures to respirable crystalline silica to below occupational exposure limits.

Why? Employees using the masonry saw and/or using the pulverizer were exposed to respirable crystalline silica above the OSHA action level. When exposures are at or above the action level, employers are required to take steps to protect employees.

Breathing in crystalline silica dust has been connected with lung diseases, such as silicosis, lung cancer, pulmonary tuberculosis disease, and other airway problems. These exposures have also been linked to kidney and autoimmune diseases. An autoimmune disease is when a person's body attacks its own cells as if those cells were an outside virus or bacteria.

Employers must comply with the OSHA respirable crystalline silica standard, 29 CFR 1910.1053: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1053.

How? At your workplace, we recommend these specific actions:



Install a local exhaust ventilation system for the pulverizer.

- A local exhaust system catches and removes the silica dust in the air where it is made. This prevents the dust from spreading throughout the workplace.
- Consult with a ventilation engineer to design and install a local exhaust ventilation system that captures dust at the pulverizer and exhausts the air outside away from air intakes or where people may be working or taking breaks.

- Local exhaust ventilation for the pulverizer can include these features: an exhaust hood over the pulverize or a full enclosure of the pulverizer; an exhaust duct connecting the hood or enclosure to an exhaust fan mounted in the window; an air filter upstream of the local exhaust ventilation fan would reduce the risk of exposing people in the surrounding area to silica dust as air is exhausted out of the building.
    - Make sure the pulverizer collection drawer is under the hood or within the enclosure to better capture dust from the drawer.
    - Fully enclosing the pulverizer would contain dust better and allow the employee to be close the pulverizer while operating it.
    - Ensure that any local exhaust ventilation system or enclosure does not reduce employees' ability to use the pulverizer effectively.
- If possible, design the local exhaust ventilation in a way that allows the system to be used for masonry saw as well.

Change work practices when operating the pulverizer to keep the worker farther away from the process.

- Change how the worker loads material into the pulverizer so they do not need to stand next to the machine while it operates.
- If possible, load material into the pulverizer before turning it on. Otherwise, consider installing a device for moving material into the pulverizer, such as a gravity-driven conveyor or a screw feeder.

Avoid dry brushing the wheel inside of the pulverizer during cleaning and dry sweeping the floor after sawing.

- Dry sweeping or brushing dusty surfaces will release settled dust into the air. Use a vacuum with a HEPA filter instead. A soft brush attachment for the vacuum would help improve removing the dust from the pulverizer.

Vacuum dust from Tyvek suits before taking them off after sawing or pulverizing.

- A soft brush attachment for the vacuum would help remove dust from clothing.

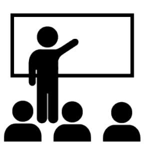
Create an exposure control plan for respirable crystalline silica.

- Document the plan in writing. In it, describe the workplace tasks that involve respirable crystalline silica exposure. Include engineering controls, work practices, and respiratory protection used to limit the exposure for each task in the plan. Finally, include housekeeping measures that can limit employees' exposures to respirable crystalline silica.

- Review and evaluate the effectiveness of this plan at least annually and update as necessary.
- Make the plan readily available, upon request, to employees.
- Conduct exposure monitoring for respirable crystalline silica at regular intervals. The OSHA silica standard requires air monitoring every 6 months when respirable crystalline silica exposures are above the action level. This additional air monitoring offers more information on the range of exposures during different dusty activities, how well control measures are working, and what level of respiratory protection might be needed.

Start a respiratory protection program.

- The respiratory program should be documented in writing and note worksite-specific tasks where employees must use respirators. A capable person should be assigned to manage the program.
- The OSHA respiratory protection standard specifies the requirements for the written program. This includes respirator selection, annual fit testing, training, medical clearance, changing filters, storage, and cleaning. Additional information can be found in OSHA's *Small Entity Compliance Guide for the Respiratory Protection Standard:* https://www.osha.gov/sites/default/files/publications/3384small-entity-for-respiratory-protection-standard-rev.pdf.
- Consider contacting the OSHA consultation program for additional assistance on developing your respiratory protection program: https://www.osha.gov/dcsp/smallbusiness/consult.html.



Educate employees on the health effects of silica exposure, the workplace tasks that can expose them to silica, and how to limit exposure.

- Conduct annual training on how to work safely with silica and to retrain employees on the best practices for reducing silica exposures in the workplace.
    - For example, training employees using respirators to be clean shaven and not have facial hair. Facial hair creates small gaps between the respirator and the face which allows air containing silica to bypass the respirator's filter.

Recommendation 2: Protect employees' from hearing loss due to noise exposure from using the masonry saw.

Why? Full-shift noise exposures for technicians using the masonry saw were above the NIOSH recommended exposure limit. Their noise exposures were also above the OSHA action level and permissible exposure limit depending on the time spent sawing.

Noise-induced hearing loss is a permanent condition that gets worse when exposed to loud noise. Unlike some other types of hearing disorders, noise-induced hearing loss cannot be treated medically. Noise-exposed workers can develop substantial noise-induced hearing loss before the problem is realized.

How? At your workplace, we recommend these specific actions:

Include all employees who use the masonry saw in a hearing conservation program.

- The hearing conservation program should include baseline (soon after being hired) and annual hearing tests. It should also include training employees on the effects of noise, how to correctly use hearing protection, and why they need their hearing tested.
- The program requires employees use hearing protection during high noise tasks. While using the masonry saw, employees should use both insert ear plugs and earmuffs.

Recommendation 3: Address other health and safety issues we identified during our evaluation.

Why? A workplace can have multiple health hazards that cause worker illness or injury. Similar to the ones identified above, these hazards can potentially cause serious health symptoms, lower morale and quality of life for your employees, and possibly increased costs to your business. We saw the following potential issues at your workplace:

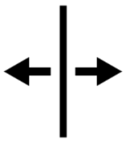
- Employees used isopropyl alcohol to clean elastomeric respirators. Isopropyl alcohol can damage respirator material.
- Respirators were stored in the lab area, next to where concrete samples were pre-crushed and weighed.
- Labels of secondary containers lacked hazard warning information (e.g., health effects, combustibility, etc.).

Although they were not the focus of our evaluation, these hazards could cause harm to your workers' health and safety and should be addressed.

How? At your workplace, we recommend these specific actions:

Clean elastomeric respirators with alcohol-free wipes.

- The isopropyl alcohol in antiseptic wipes can damage respirators so they do not work correctly. Only use cleaners approved by the manufacturer to clean respirators.



Store personal protective equipment on shelves or in a cabinet in an area outside of the immediate work or lab area.

- Storing equipment outside of the work area will help keep safety equipment clean.
- Store respirators in a clean area in individual bags to protect them from damage, contamination, dust, sunlight, and extreme temperatures.

Label secondary chemical containers with the chemical's name and any hazard warning information.

- OSHA has requirements for labeling secondary chemical containers in their hazard communication standard (29 CFR 1910.1200). Properly labeling secondary containers allows workers to identify their contents and ensures safe transport, handling, and use of hazardous chemicals.
- Refer to the OSHA Brief® Hazard Communication Standard: Labels and Pictograms for more information about labels. OSHA also has a compliance document titled Small Entity Compliance Guide for Employers That Use Hazardous Chemicals.

Supporting Technical Information

Evaluation of Silica and Noise Exposures at a Concrete Corrosion Testing Facility

HHE Report No. 2023-0001-3405

November 2024

Section A: Workplace Information

Workplace

The facility employed technicians who processed samples taken from concrete infrastructures, such as bridges, to identify and quantify corrosion and material performance issues. Technicians worked a single, 8-hour shift Monday through Friday.

Process Description

Technicians prepared samples using a masonry saw, mortar and pestle, and a pulverizer. They took turns using the saw, mortar and pestle, and pulverizer, so that one technician was not doing both sawing and pulverizing in a shift.

Technicians operated the masonry saw or the pulverizer in a small room, which was about 5 feet wide by 10.5 feet long, with a ceiling height of 8 feet. A vane-axial fan with three 12-inch blades was mounted in the window of the room, The pulverizer was placed on a table below the window mounted fan. On the opposite wall, a smaller, 8-inch fan was mounted about 2 feet above the floor. Technicians used the mortar and pestle on the outside of this wall. The masonry saw had a built-in downdraft dust extraction system equipped with a high-efficiency particulate air (HEPA) filter.

Section B: Methods, Results, and Discussion

Methods: Exposure Assessment

Air Sampling

We collected air samples for respirable dust and respirable crystalline silica (RCS) from the breathing zone of three employees over a two-day period, during work tasks with the potential for RCS exposure. We collected the air samples at a flow rate of 2.5 liters per minute on three-piece, 37-milimeter diameter cassettes with 5-micrometer (µm) pore size polyvinyl chloride filters placed in aluminum SKC air sampling cyclones.

- We analyzed each sample for respirable dust and RCS using NIOSH Methods 0600 and 7500, respectively, with a tetrahydrofuran preparation [NIOSH 2024].
- We changed the air sampling cassettes about midway through employees' shifts to avoid overloading.
- We calculated 8-hour time-weighted average (8-hr TWA) exposure concentrations for respirable dust and RCS. We assumed no exposure to RCS and respirable dust during unsampled portions of the workday when employees were not doing work activities that generated dust, such as washing beakers, weighing samples, or during lunch.

Bulk Samples

We collected bulk samples of pulverized concrete for each sample that was processed during each day of the site visit. These bulk samples were analyzed to determine the silica concentration in the concrete samples that were being processed and identify any constituents that could have interfered with the analyses of the air samples. Bulk samples were prepared and analyzed following NIOSH Method 7500 [NIOSH 2024].

Noise

We measured TWA personal noise exposures of three employees over a two-day period. We used Larson Davis Spark® integrating noise dosimeters [Model 706RC] equipped with 0.375-inch random incidence electrolet microphones [Model MPR001]. The dosimeters recorded and data-logged 1-second averaged sound levels for the duration of the measurement period.

We attached the dosimeter and microphone to the outside of employees' clothing, midway between the neck and edge of their shoulder. The microphone was covered with a windscreen to reduce artifact noise caused by air movement or accidental bumping. The dosimeters simultaneously collected noise data using three different measurement criteria settings to allow comparison of noise measurement results with three different noise exposure limits: the NIOSH recommended exposure limit (REL), the OSHA permissible exposure limit (PEL), and the OSHA action level (AL).

The dosimeters were calibrated before and after each day of measurements according to the manufacturers' instructions. Following measurements, the noise measurement data stored on the instruments were downloaded, exported, and analyzed using Larson Davis Blaze® software and Microsoft Excel for Office 365®.

Results: Exposure Assessment

Air Sampling

The 8-hr TWA concentrations for RCS ranged from 10–41 micrograms per cubic meter of air (μg/m³) (see Table C1). Three of the four 8-hr TWAs for RCS were at or above the OSHA AL of 25 μg/m³. All four 8-hr TWAs were lower than the OSHA PEL and NIOSH REL of 50 μg/m³. Results by work activity showed that sawing and pulverizing generated substantial RCS exposures. In contrast, we did not detect RCS in our samples during other work activities we monitored.

None of the 8-hr TWAs for respirable dust were higher than the OSHA PEL of 5,000 μg/m³ or the American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit value (TLV®) of 3,000 μg/m³ (see Table C2). Similar to the results shown for RCS, the respirable dust exposures were highest during sawing and pulverizing.

Bulk Samples

We collected a bulk dust sample of the concrete samples that were pulverized on each sampling day. The bulk samples contained between 31%–36% quartz and 0.98%–1.1% cristobalite. The cristobalite result may be due to interferences.

Noise

Employees' full-shift noise exposures varied substantially depending on their work tasks and time-at-task (see Table C3). Noise exposures when employees were sawing ranged from 103.9–111.2 A-weighted decibels (dBA) based on NIOSH noise measurement criteria and ranged 100.8–107.6 dBA based on OSHA AL noise measurement criteria. Noise exposures during pulverizing ranged from 80.1–83.3 dBA based on NIOSH noise measurement criteria but were below 80 dBA based on OSHA AL noise measurement criteria. Noise exposures for all other tasks were below 80 dBA. Two employees' 8-hour TWA noise exposures were above the NIOSH REL of 85 dBA. One of these employee's noise exposure was also above the OSHA AL of 85 dBA and OSHA PEL of 90 dBA.

Discussion

RCS has been recognized as a carcinogen, and steps should be taken to protect employees from potential exposures [IARC 1997; NIOSH 2002]. Three personal air samples we collected for RCS were at or above the OSHA AL. Employee exposures that are at or above the AL initiate certain required activities, such as exposure monitoring and medical surveillance. Respirable dust exposures were below occupational limits.

During our site visit, we observed work practices that may have contributed to employees' exposures to RCS. Specifically, technicians dry-swept the floor after using the masonry saw and dry-brushed the inside of the pulverizer between crushing concrete samples. Dry-brushing and sweeping can release settled dust into the air. In addition, the technician stood next to the machine while the pulverizer ground the concrete samples. We observed visible dust coming from the seams in the pulverizer's wheel cover and collection tray while it was operating.

Our results also indicate that the window-mounted vane-axial fan did not effectively reduce RCS exposures to below the AL. During our initial visit, we measured the fan's capture velocity. We observed that the capture velocity decreased from about 600 feet per minute (fpm) at the fan's face to about 100 fpm about one foot away. Capture velocity would decrease even more as the distance from the fan increased, providing little to no effective capture of dust.

The masonry saw and pulverizer were positioned about 6 feet from the window fan during use. This was well beyond the fan's ability to sufficiently capture dust generated by this equipment. Installing local exhaust ventilation (LEV) can reduce RCS exposures by capturing the dust at the source of the exposure. A potential LEV system for the pulverizer could include an exhaust hood over the pulverizer or a full enclosure of the pulverizer, connected by an exhaust duct to an exhaust fan mounted at the window. An air filter upstream of the exhaust fan would prevent RCS exposure for workers in the surrounding area as air is exhausted outside the building. This system could also be designed in a way that allows it to be used for the saw as well. A ventilation engineer can help design and install this system.

The RCS exposure of the technicians using the pulverizer was higher than the exposures of technicians who were using the masonry saw. We recommend consulting with a ventilation engineer to incorporate a LEV system for the pulverizer and improving practices related to using the pulverizer, such as distancing the technician from the machine while it is operating.

Based on the air sample results during the site visit, employees' 8-hour TWA RCS exposures would reach the OSHA AL after 83 minutes and the OSHA PEL after 166 minutes of sawing. For pulverizing, 8-hr TWA RCS exposures would reach the OSHA AL after about 45–70 minutes and the OSHA PEL after about 90–140 minutes.

The results of our evaluation indicate that, according to the OSHA RCS standard, the employer needs to take actions to reduce employees' RCS exposures to below the OSHA AL. The OSHA RCS standard requires employers do the following:

- Repeat exposure monitoring within 6 months of the most recent monitoring where the most recent exposure monitoring indicates that employee exposures are at or above the OSHA AL but at or below the PEL.
- Repeat such exposure monitoring within 6 months of the most recent monitoring until two consecutive measurements, taken 7 or more days apart, are below the AL, where the most recent (noninitial) exposure monitoring indicates that employee exposures are below the AL. The employer may then discontinue monitoring for those employees whose exposures are represented by such monitoring.
- Do not allow dry sweeping or dry brushing where such activity could contribute to employee RCS exposure unless wet sweeping, HEPA-filtered vacuuming, or other methods that minimize the likelihood of exposure are not feasible.
- Reassess exposures whenever a change in production, process, control equipment, personnel, or work practices may reasonably be expected to result in new or additional exposures at or above the AL, or when the employer has any reason to believe that new or additional exposures at or above the AL have occurred.

To comply with the OSHA RCS standard, employers are also required to establish and implement an exposure control plan. The plan must be documented in writing and identify tasks that involve exposure and the methods used to protect workers. This includes the following [OSHA 2019a]:

- A description of tasks in the workplace that involve exposure to RCS
- A description of the engineering controls, work practices, and respiratory protection used to limit employee exposure to RCS for each task
- A description of the housekeeping measures used to limit employee exposure to RCS
- Offering of initial (baseline) medical examination within 30 days after initial assignment, consisting of a medical and work history, a physical examination, a chest X-ray, and a pulmonary function test, and periodic examinations at least every three years for employees exposed at or above the action level for 30 or more days per year
- Training for employees on the health effects of silica exposure, workplace tasks that can expose them to silica, and ways to limit exposure
- Recordkeeping of employees' RCS exposure and medical exams

Our results show that employees' exposures to RCS were above the OSHA AL, but exposures could also exceed the OSHA PEL based on the amount of time spent using the pulverizer and the masonry saw. OSHA requires respirator use when exposures are above the OSHA PEL. The company policy requires employees to wear respirators when using the masonry saw and the pulverizer. We recommend continuing this policy due to high RCS concentrations during sawing and pulverizing, full-shift TWA exposures above the AL, and the potential to exceed the PEL.

We observed respirators being worn incorrectly. Some employees with facial hair wore tight-fitting respirators while sawing and pulverizing. Facial hair can interfere with seal of a tight-fitting respirator to the face of the wearer. Improper use could lead to respirators providing inadequate protection. Where respiratory protection is required, OSHA requires employers to train workers on the following: using respirators correctly, including proper donning, doffing, adjustment, and care for respirators; knowing when respirators are necessary; knowing what kind of respirator is necessary; and understanding the limitations of respirators. OSHA requires respirators be NIOSH-Approved and medical evaluation, fit testing, and training be provided before use. In addition, employees must be included in a comprehensive respiratory protection program as specified in OSHA's respiratory protection standard (29 CFR 1910.134) [OSHA 2006, 2019b].

We found that one employee's 8-hour TWA noise exposure exceeded occupational noise exposure limits. Employee noise exposures were primarily influenced by the high noise levels generated when sawing. These exposures would exceed noise exposure limits depending on the length of time spent on this task. Based on our noise measurements during sawing, employees' full-shift TWA noise exposures would exceed the NIOSH REL in 1.1–6.1 minutes, the OSHA AL in 23.9–53.7 minutes, and the OSHA PEL in 41.8–110.4 minutes.

The large difference between exposure time necessary to exceed noise exposure limits for NIOSH and OSHA is related to differences in their measurement criteria, with NIOSH having the most sensitive criteria. Our measurement results showed that when employees used the pulverizer, noise exposure levels were below 84 dBA and below 80 dBA for other work activities.

On the first day of noise monitoring, the TWA noise exposure during the time an employee was sawing was 111.2 dBA (based on NIOSH measurement criteria). However, on the second day of monitoring, the TWA noise exposure during the same task was 103.9 dBA. On the second day, the employee had placed a new blade on the saw prior to using it which might explain the noise exposure reduction at the saw. New blades cut more efficiently and likely need less force when pushing the material to the blade during sawing, resulting in decreased noise. Employees reported changing blades when they noticed blades sawing less effectively. This noise reduction illustrates an advantage to prudently changing saw blades.

Another potential noise reduction might include installing a clear acrylic barrier panel between the employee and the saw. The barrier would need to provide the saw operator with clear visibility of the saw and have a large enough gap at the bottom for the employee to successfully push the sample into the saw without causing any safety concerns. Because the room housing the saw is relatively small, acoustic paneling or treatments on the walls and ceiling could help reduce reverberant noise within the workspace. Because dust is generated in the space, the acoustic paneling or treatments would need to be cleaned periodically to maintain effectiveness.

All employees who sawed should be included in a hearing conservation program that includes audiometric testing done upon hire and repeated annually, training on the health effects of noise exposure, and how to properly use hearing protection. The workplace provided earmuffs and earplugs for voluntary use while employees sawed and pulverized. Because noise exposures are above 100 dBA when sawing, employees should be required to wear both ear plugs and earmuffs. We observed one employee place earmuffs over the hood of their Tyvek suit, which could make them less effective. And because it was voluntary, employees did not always wear hearing protection while pulverizing.

Limitations

This evaluation is subject to several limitations. Industrial hygiene sampling can only document exposures and conditions in the locations evaluated and on the day that the evaluation occurred. These results may not be representative of conditions during other days.

Conclusions

Our air sampling found that employees were primarily exposed to RCS during sawing and pulverizing. Full-shift TWA exposures exceeded the OSHA AL and could potentially exceed the OSHA PEL based on the amount of time spent using the masonry saw and/or using the pulverizer. Employees' exposures to RCS may be reduced by (1) incorporating a LEV system for the pulverizer and masonry saw, (2) modifying work practices so technicians operating the pulverizer are standing farther away from it, and (3) limiting the amount of time spent on these tasks.

While employees sawed, noise levels were above 100 dBA. Full-shift noise exposures could exceed the NIOSH REL in as little as 1–6 minutes based on our measurements. Employees sawing must be included in a hearing conservation program that includes wearing both ear plugs and earmuffs. Reassess occupational exposures whenever a change in the production process, equipment, personnel, or work practices may reasonably be expected to result in new or additional exposures and to determine if exposure controls are effectively reducing exposures.

Attribution Statement

P100 is a certification mark of the U.S. Department of Health and Human Services (HHS) registered in the United States and several international jurisdictions.

Section C: Tables

Table C1. Task and full-shift personal air sampling results for respirable crystalline silica (RCS) exposures in μg/m^3

Employee (day)	Work activities	Sample duration (minutes)	Task concentration	MDC*	MQC†	Full-shift 8-hour TWA‡
1 (day 1)	Sawing	146	83	10	30	25
	Pre-crushing / washing beakers / weighing samples	205	ND			
2 (day 1)	Pre-crushing	152	ND			41
	Pulverizing / weighing samples	206	96	10	30	
2 (day 2)	Cleaning and vacuuming saw / pulverizing	113	146	20	60	35
3 (day 2)	Preparation for sawing / sawing	42	[115]	48	163	[10]
					OSHA AL	25
					OSHA PEL	50
					NIOSH REL	50
					ACGIH TLV	25

[ ] Values shown in brackets are between the minimum detectable and minimum quantifiable concentrations. More uncertainty is associated with these concentrations.

ND = Not detected; μg/m^3 = micrograms per cubic meter; TWA = time-weighted average

* Minimum detectable concentration = limit of detection (LOD)/highest volume sampled.

† Minimum quantifiable concentration = limit of quantitation (LOQ)/highest volume sampled.

‡ The full-shift eight-hour TWA measurement assumes employees had no RCS exposure for the unsampled period.

Table C2. Task and full-shift personal air sampling results for respirable dust exposures in μg/m³

Employee (day)	Work activities	Sample duration (minutes)	Task concentration	Full-shift 8-hour TWA
1 (day 1)	Sawing	146	400	100
	Pre-crushing / washing beakers / weighing samples	205	ND	
2 (day 1)	Pre-crushing	152	ND	400
	Pulverizing / weighing samples	206	800	
2 (day 2)	Cleaning and vacuuming saw / pulverizing	113	1500	300
3 (day 2)	Preparation for sawing cores / sawing	42	500	50
			OSHA PEL	5,000
			NIOSH REL	No exposure limit
			ACGIH TLV	3,000

ND = Not detected

μg/m³ = micrograms per cubic meter

TWA = time-weighted average

Table C3. Noise exposures measurement results by task and full-shift time-weighted average (TWA) in dBA

Employee (day)	Work activities	Measurement duration (minutes)	NIOSH REL criteria† (dBA)	OSHA AL criteria† (dBA)	OSHA PEL criteria‡ (dBA)
1 (day 1)	Sawing	154	111.2	107.6	107.6
	Pre-crushing	44	76.9	70.1	57.8
	Washing beakers and weighing samples	162	63.1	49.0	26.9
	Full-shift eight-hour TWA for noise*	360	106.3	99.4	99.4
2 (day 1)	Pre-crushing	151	75.5	69.4	48.6
	Pulverizing	113	80.1	74.9	66.7
	Weighing samples	89	59.2	43.2	§
	Full-shift eight-hour TWA for noise*	353	75.5	68.0	57.0
2 (day 2)	Cleaning and vacuuming saw	55	75.9	70.1	45.5
	Pulverizing	62	83.3	78.7	72.5
	Full-shift eight-hour TWA for noise*	117	75.5	66.2	58.9
3 (day 2)	Preparation for sawing	30	60.2	44.9	§
	Sawing	28	103.9	100.8	100.6
	Full-shift eight-hour TWA for noise*	58	92.8	82.3	82.2
Full-shift TWA noise exposure limits (8-hour work shift)			85	85	90

dBA = A-weighted decibel

* Employees did not have measurable noise exposures when they were doing work other than the activities listed. The full-shift TWA measurement results integrated no noise exposures for those other periods.

† The criteria for calculating the NIOSH REL and OSHA AL includes noise exposures greater than or equal to 80 dBA.

‡ The criteria for calculating the OSHA PEL includes all noise exposures greater than or equal to 90 dBA.

§ All noise exposure during measurements was below the dosimeter threshold level, set at 90 dBA for the OSHA PEL criteria, therefore no value is provided.

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- OSHA, an agency of the U.S. Department of Labor, publishes PELs [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry]. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment (PPE), and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States includes TLVs, which are recommended by the ACGIH. The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2024].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

Respirable Crystalline Silica

Silica, or silicon dioxide, occurs in a crystalline or noncrystalline (amorphous) form. In crystalline silica, the silicon dioxide molecules are oriented in a fixed pattern versus the random arrangement of the amorphous form. The more common crystalline forms in workplace environments are quartz and cristobalite, and to a lesser extent, tridymite. Occupational exposures to RCS (quartz and cristobalite) have been associated with silicosis, lung cancer, pulmonary tuberculosis disease and other airway diseases, kidney disease, and autoimmune disorders.

Silicosis is an irreversible but preventable fibrotic disease of the lung caused by the deposition of fine crystalline silica particles in the lungs. Silicosis is caused by the inhalation and deposition of crystalline silica particles that are 10 μm or less in diameter. Particles 10 μm and smaller are considered respirable particles and have the potential to reach the lower portions of the human lung (alveolar region). Although particle sizes 10 μm and smaller are considered respirable, some of these particles can be deposited before they reach the alveolar region [Hinds 1999].

Symptoms of silicosis usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and nonspecific chest illnesses. Silicosis usually occurs after years of exposure (chronic) but may appear in a shorter period of time (acute) if exposure concentrations are very high. Acute silicosis is typically associated with a history of high exposures from tasks that produce small particles of airborne dust with a high silica content [NIOSH 1986].

Even though the carcinogenicity of crystalline silica in humans has been strongly debated in the scientific community, the International Agency for Research on Cancer (IARC) in 1996 concluded that there was “sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources” [IARC 1997]. Several other serious diseases from occupational exposure to crystalline silica include lung cancer and noncancerous disorders such as immunologic disorders and autoimmune diseases, rheumatoid arthritis, renal diseases, and increased risk of developing tuberculosis disease after exposure to the infectious agent [NIOSH 2002].

When proper practices are not followed or controls are not maintained, RCS exposures can exceed the OSHA PEL, NIOSH REL, or the ACGIH TLV. The OSHA PEL and NIOSH REL for RCS are both 50 $\mu g/m^3$ [NIOSH 2007; OSHA 2019a]. The ACGIH TLV for quartz is 25 $\mu g/m^3$ as an 8-hour TWA [ACGIH 2024]. The OSHA AL for RCS is 25 $\mu g/m^3$ [OSHA 2019a].

Noise

Noise-induced hearing loss (NIHL) is an irreversible condition that progresses with noise exposure. NIHL is caused by damage to the nerve cells of the inner ear and, unlike some other types of hearing disorders, cannot be treated medically [AIHA 2022]. Approximately 25% of U.S. workers have been exposed to hazardous noise [Kerns et al. 2018] and more than 22 million U.S. workers are estimated to be exposed to workplace noise levels above 85 dBA [Tak et al. 2009]. NIOSH estimates that workers exposed to an average daily noise level of 85 dBA over a 40-year working lifetime have an 8% excess risk of material hearing impairment. This excess risk increases to 25% for an average daily noise exposure of 90 dBA [NIOSH 1998]. NIOSH defines material hearing impairment as an average of the HTLs for both ears that exceeds 25 decibels (dB) at frequencies of 1 kilohertz (kHz), 2 kHz, 3 kHz, and 4 kHz.

Although hearing ability commonly declines with age, exposure to excessive noise can increase the rate of hearing loss. In most cases, NIHL develops slowly from repeated exposure to noise over time, but the progression of hearing loss is typically the greatest during the first several years of noise exposure [Rosler 1994]. NIHL can result from short duration exposures to high noise levels or even from a single exposure to an impulsive noise or a continuous noise, depending on the intensity of the noise and the individual's susceptibility to NIHL [AIHA 2022]. Noise exposed workers can develop substantial NIHL before it is clearly recognized. Even mild hearing losses can impair one's ability to understand speech and hear many important sounds. In addition, some people with NIHL also develop tinnitus. Tinnitus is a condition in which a person perceives hearing sound in one or both ears, but no external sound is present. Persons with tinnitus often describe hearing ringing, hissing, buzzing, whistling, clicking, or chirping like crickets. Tinnitus can be intermittent or continuous and the perceived volume can range from soft to loud. Currently, no cure for tinnitus exists.

Noise measurements are usually reported as dBA. A-weighting is used because it approximates the "equal loudness perception characteristics of human hearing for pure tones relative to a reference of 40 dB at a frequency of 1 kHz" and is considered to provide a better estimation of hearing loss risk than using unweighted or other weighting measurements [Murphy et al. 2022]. The dB unit is dimensionless, and it represents the logarithmic ratio of the measured sound pressure level to an arbitrary reference sound pressure of 20 micropascals, which is defined as the threshold of normal human hearing at a frequency of 1 kHz. Because the dB is logarithmic, an increase of 3 dB is a doubling of the sound energy, an increase of 10 dB is a 10-fold increase, and an increase of 20 dB is a 100-fold increase in sound energy. Noise exposures expressed in dB or dBA cannot be averaged using the arithmetic mean.

Workers exposed to noise should have baseline and yearly hearing tests (audiograms) to evaluate their hearing thresholds and determine whether their hearing has changed over time. Hearing testing should be done in a quiet location, such as an audiometric test booth, where background noise does not interfere with accurate measurement of hearing thresholds. In workplace hearing conservation programs, hearing thresholds must be measured at frequencies of 0.5 kHz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, and 6 kHz. NIOSH also recommends testing be done at 8 kHz [NIOSH 1998].

The OSHA hearing conservation standard requires analysis of hearing changes from baseline hearing thresholds to determine if a standard threshold shift (STS) has occurred. OSHA defines an STS as a change in hearing threshold relative to the baseline hearing test of an average of 10 dB or more at 2 kHz, 3 kHz, and 4 kHz in either ear [29 CFR 1910.95]. If an STS occurs, the company must determine if the hearing loss also meets the requirements to be recorded on the OSHA Form 300 Log of Work-Related Injuries and Illnesses [29 CFR 1904.1]. In contrast to OSHA, NIOSH defines a significant threshold shift as an increase in the hearing threshold level of 15 dB or more, relative to the baseline audiogram, at any test frequency in either ear measured twice in succession [NIOSH 1998].

Hearing test results are often presented in an audiogram, which is a plot of an individual's hearing thresholds (*y*-axis) at each test frequency (*x*-axis). Hearing threshold levels (HTLs) are plotted such that fainter sounds are shown at the top of the *y*-axis, and more intense sounds are plotted below. Typical audiograms show HTLs from −10 or 0 dB to about 100 dB. Lower frequencies are plotted on the left side of the audiogram, and higher frequencies are plotted on the right. NIHL often manifests itself as a "notch" at 3 kHz, 4 kHz, or 6 kHz, depending on the frequency spectrum of the workplace noise and the anatomy of the individual's ear [Mirza et al. 2018; Osguthorpe and Klein 1991; Schlauch and Carney 2011; Suter 2002]. A notch in an individual with normal hearing may indicate early onset of NIHL. A notch is defined as the frequency where the HTL is preceded by an improvement of at least 10 dB at the previous test frequency and followed by an improvement of at least 5 dB at the next test frequency.

NIOSH has an REL for noise of 85 dBA as an 8-hour TWA. For calculating exposure limits, NIOSH uses a 3-dB time/intensity trading relationship, or exchange rate. Using this criterion, an employee can be exposed to 88 dBA for no more than 4 hours, 91 dBA for 2 hours, 94 dBA for 1 hour, 97 dBA for 0.5 hours, etc. Exposure to impulsive noise should never exceed a peak level of 140 dBA. For extended work shifts, NIOSH adjusts the REL to 84.5 dBA for a 9-hour shift, 84.0 dBA for a 10-hour shift, 83.6 dBA for an 11-hour shift, and 83.2 dBA for a 12-hour work shift. When noise exposures exceed the REL, NIOSH recommends the using hearing protection and implementing a hearing loss prevention program [NIOSH 1998].

The OSHA noise standard specifies a PEL of 90 dBA and an AL of 85 dBA, both as 8-hour TWAs. OSHA uses a less conservative 5-decibel (dB) exchange rate for calculating the PEL and AL. Using the OSHA criterion, an employee may be exposed to noise levels of 95 dBA for no more than 4 hours, 100 dBA for 2 hours, 105 dBA for 1 hour, 110 dBA for 0.5 hours, etc. Exposure to impulsive noise must not exceed 140 dB peak noise level. OSHA does not adjust the PEL for extended work shifts. However, the AL is adjusted to 84.1 dBA for a 9-hour shift, 83.4 dBA for a 10-hour shift, 82.7 dBA for an 11-hour shift, and 82.1 dBA for a 12-hour work shift. OSHA requires implementation of a hearing conservation program when noise exposures exceed the AL [29 CFR 1910.95].

An employee's daily noise dose, based on the duration and intensity of noise exposure, can be calculated according to the formula: Dose = $100 \times (C_1/T_1 + C_2/T_2 + ... + C_n/T_n)$, where C_n indicates the total time of exposure at a specific noise level, and T_n indicates the reference exposure duration for which noise at that level becomes hazardous. A noise dose greater than 100% exceeds the noise exposure limit.

Section E: References

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