Health Hazard Evaluation Program

Evaluation of Silica Exposures During Dowel Drilling

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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].

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Introduction

Request

Management from a dowel drilling company requested a health hazard evaluation concerning employee exposure to respirable crystalline silica during dowel drilling activities.

Workplace

Dowel drilling is one step in the process of repairing a road, with the work taking place on a roadway construction site. Two employees who performed this task were evaluated in this project—a backhoe operator who operated the backhoe and drill rig operator who used the drill rig to drill the dowel holes. A water spray was used to reduce the amount of dust in the air during these activities. During our visits, the crew worked a single shift about 5 hours long. The length of time spent drilling could change depending on the project. For this project, the drilling took from 4 to 6 hours.

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

Our Approach

We visited the work location over 3 days in September 2019. During our visits, we did the following activities:

- Observed work processes and work practices.
- Estimated the amount of water used to control dust during each day.
- Collected air samples for respirable crystalline silica and respirable dust.
- Collected bulk samples of the slurry produced from drilling to determine its silica content.
- Used a portable weather station to record information about temperature, relative humidity, and wind speed.

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

Our Key Findings

Silica concentrations for some employees exceeded occupational exposure limits

- Concentrations of respirable crystalline silica were above the Occupational Safety and Health Administration (OSHA) regulatory limit on Day 2 of 3 of sampling for the drill rig operator.
- Concentrations of respirable crystalline silica for the drill rig operator were above the American Conference of Governmental Industrial Hygienists (ACGIH®) recommended limit and the

OSHA action level on Day 1 of 3 of sampling. The action level is when employers must take certain steps to further protect their employees.

- Concentrations of respirable crystalline silica were below all relevant occupational exposure limits for the backhoe operator on all days.

Samples of respirable dust did not exceed any exposure limits

- Concentrations of respirable dust were below relevant occupational exposure limits for all samples.

Improvements to the respiratory protection program could be made

- The drill rig operator was required to wear a respirator while working, but there was no written respiratory protection program, medical clearance, or annual respiratory training.
- The respirator worn by the drill rig operator was appropriate for controlling exposures to respirable crystalline silica.
- The respirator was put on and taken off correctly, cleaned after each shift, and stored appropriately.

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.

Benefits of Improving Workplace Health and Safety:

- ↑ Improved employee health and well-being
- ↑ Better workplace morale
- ↑ Easier employee recruiting and retention
- ↑ Enhanced image and reputation
- ↑ Superior products, processes, and services
- ↑ May increase 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 https://www.cdc.gov/niosh/topics/hierarchy/.

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/shpguidelines/index.html.

Recommendation 1: Improve the respiratory protection program

Why? The drill rig operator is required to wear a respirator while operating the drill rig. The drill rig operator was wearing an appropriate, protective respirator; also, the operator was comfortable wearing the respirator and knowledgeable about its care and storage.

However, there is no written respiratory protection program as is required by OSHA when respirator use is mandatory. Opportunities existed to create a strong respiratory protection program that ensures employees are protected from respirable crystalline silica while they are working.

Concentrations of respirable crystalline silica were found to be above occupational exposure limits. Occupational exposures to respirable crystalline silica have been associated with silicosis, lung cancer, pulmonary tuberculosis disease, and other airway diseases. Exposure can happen through breathing dust in the air that contains silica.

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

Create a written respiratory protection program.

- Because the company performed dowel drilling more than 30 calendar days per year and required the drill rig operator to wear a respirator, a written program should be developed.
- Respiratory protection programs should comply with the OSHA respiratory protection standard for construction 29 CFR 1926.103, which is identical to the general industry standard 29 CFR 1910.134.
- Because roadways contain varying levels of crystalline silica, other projects could expose employees to similar, lower, or higher respirable crystalline silica levels. A mandatory respiratory protection program would ensure that all employees are appropriately protected from exposures to respirable crystalline silica, regardless of the project conditions.
- More information about respirable crystalline silica requirements can be found here: https://www.osha.gov/Publications/OSHA3681.pdf. The local OSHA consultation office may be able to help with complying with the respiratory protection and respirable crystalline silica standards. The local consultation program can be found here: https://www.osha.gov/html/RAmap.html.

Require drill rig operators wearing respirators to receive medical clearance at least every 3 years.

- Employees who are required to wear respirators must receive medical clearance to wear them. The OSHA respirable crystalline silica standard requires medical examinations for respiratory protection at least every 3 years (29 CFR 1926.1153). Fit testing, in addition to the medical clearance, is only required when the respirator is tight fitting. Loose fitting powered air purifying respirators, or PAPRs, worn by the drill rig operators, do not require fit testing.
- Medical examinations should be performed by a licensed healthcare professional familiar with occupational medicine. At a minimum, medical evaluations should cover information found in Appendix C of the OSHA respiratory protection standard: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.134Appc.

Train drill rig operators on proper respirator use.

- Training must be comprehensive and offered at least annually to all employees who wear respirators.
- Training should include putting on and removing the respirator, limitations on its use, and care and maintenance.

Improve respirator cleaning and storage practices.

- Use alcohol-free respirator cleaning wipes to clean respirators before and after each shift. Cleaning and storage of PAPRs seemed appropriate, but alcohol-based wipes can degrade silicone and plastic components of respirators, reducing their service life.
- Store clean and dry respirators in plastic bags inside the totes in the work truck.

Explore alternative respirators.

- Suitable alternatives exist if the respirator an employee currently wears is uncomfortable or difficult to work with. For example, there are different types of loose fitting PAPRs that can incorporate a hard hat and an American National Standards Institute (ANSI) Z87.1-2015 compliant face shield.

Recommendation 2: Address other health and safety issues we identified during our evaluation

Why? A workplace can have multiple health hazards that cause employee 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 increase costs to your business. We saw the following potential issues at your workplace:

- The drill rig got caked with slurry and dust during the shift and then was left to dry overnight.
- Employees were observed to be in the construction zone without high visibility apparel because they failed to put on high visibility vests before leaving their equipment cabs.
- Some employees were observed stepping into the live traffic lane while filling and covering patches.
- Vehicle spacing and logistical difficulties resulted in safety issues. Instead of waiting at a distance for work to finish in front of them, some employees were observed crowding the crew working in front of them—one incident resulted in a vehicle sustaining damage.

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

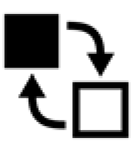
How? At your workplace, we recommend these specific actions:

Spray the drill rig with water at the end of each shift.

- In the morning, dried dust can be resuspended in the air. Spraying the drill rig at the end of the shift will prevent this, decreasing dust exposure.

Require high visibility safety apparel for all equipment operators.

- Although wearing high visibility safety apparel is not required for the operation of equipment, always wearing it will ensure that employees do not forget to put it on when exiting the equipment.



Explore alternatives to stepping into the live traffic lane.

- Consider having a separate flagger or spotter move with the crew for intermittent traffic control when filling the patches with cement and applying the tarps.

Improve vehicle spacing and safety within the work zone.

- Vehicle spacing and safety within the work zone can be improved. The following options (or a combination of them) would result in a safer work zone for all employees:
    - Enforce appropriate spacing between the different tasks. Provide training and reminders that employees should wait for the crew ahead of them to finish working on the patch before moving forward. The following crew cannot begin their tasks until the crew in front of them is finished. Moving forward while a

crew is still working puts unnecessary vehicles near the patch and can result in harm to employees and/or damage to equipment.

- Stagger the start times for each crew. Instruct the crews to wait an additional amount of time before starting their work tasks to allow the crews ahead of them time to complete their work without interference.
- Identify the slow part of the process and add a second crew to help speed up the overall work. During our visit, the crew digging out the patches seemed to be the slow part of the process. Adding a second digging crew could speed up that process and keep the timing of the crews more even.

Supporting Technical Information

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Section A: Workplace Information

Workplace

The work took place on a state road construction site. Weather permitting, work occurred during week days. The total length of the project varies from project to project and depends on the scope of the work.

Employee Information

Two employees participated in the evaluation and belonged to a union. During our visit, the crew worked a single shift that was about 5 hours long. The length of the shift could change depending on the scope and stage of the project. Employees did not take a lunch break and were observed eating between drilling activities.

Process Description

Roadway repair occurs in multiple steps. First, sections of the road were identified for repair. Each section was referred to as a "patch" in the road. After patch locations were identified, the edges of the patch were cut by a drivable concrete cutter, the asphalt was broken up with a jackhammer, and the patch was dug out by a backhoe. Once the patch was clear of debris, holes were drilled for the dowels. Dowels and rebar were inserted into the patch, and the patch was filled in with concrete.

This evaluation focused on the dowel-drilling step. For each patch, the drill rig (Figure A1) would drill a maximum of 10 holes on each side (total of 20) of the patch. Some patches received less holes depending on the condition of the walls within each patch. There were two employees who performed the dowel-drilling step. One operated the backhoe, and one operated the drill rig. The drill rig operator stood in or on the edge of the patch when the drilling was happening (Figure A2). The backhoe operator remained in the cab of the backhoe during drilling.

When the drilling was complete for a patch, the team moved to the next patch to repeat the drilling process. If the next patch was not ready for the drilling team, they waited between the two patches until the patch was cleared.

Figure A1. The entire backhoe and drill rig setup. The drills are mounted on the arm of the backhoe and the water control system is mounted on the front. The water control system is connected to the drills with tubing. Photo by the National Institute for Occupational Safety and Health (NIOSH).

Figure A2. Employee operating the drill rig. Photo by NIOSH.

Section B: Methods, Results, and Discussion

Methods: Observations of Work Processes, Practices, and Conditions

We evaluated the following during our site visit:

- Work processes
- Personal protective equipment (PPE) use
- Workplace conditions

Results: Observations of Work Processes, Practices, and Conditions

- The crew drilled 301 holes on Day 1, 252 holes on Day 2, and 204 holes on Day 3. This work site required holes to be drilled 9 inches deep. The drill bits were Brunner and Lay, Inc., Model T1607LO heavy duty 1-5/8" diameter H-thread carbide rock bits. The bits were 3–5 days old, and we were informed by management that the bits lasted 7–10 days, depending on the pavement. The drill steels were Brunner and Lay, Inc., Model E11018H 18" H-thread steels. The shank size was 7/8" × 3/4". The steels were approximately 2 weeks old, and we were informed by management that the steels lasted about 30 days, depending on the pavement.
- The drill rig and water control were mounted on a John Deere® backhoe, Model 410E. The air compressor and water pump were mounted on the front of the backhoe, and the drill rig was mounted on the back of the backhoe. The drill rig was an EZ Drill Model 201-5 multi-gang concrete drill. The air compressor was a LeRoi, Model Q375 DCU. There were TeeJet® Model XR8002VS flat spray nozzles fed by a Fimco Model HFP-45060-113 High-Flo 4.5 gallons per minute water pump. The water was drawn from a 120-gallon drum of water, which was mounted on the backhoe.
- We learned that the water drum was topped off approximately once per shift. The drill rig used 55–60 gallons of water each day.
- The drill rig operator wore a loose-fitting PAPR with P100 filters, a high visibility shirt, long pants, and boots. The backhoe operator wore long pants and boots. There was a high visibility shirt or jacket in the backhoe cab.
- Employees did not report that their PAPR was uncomfortable. We had discussions with management and employees while on site about how the belt and hose might get in the way of employees while they are working.
- Drill rig operators were required to wear PAPRs while working, but we were told by management that there was no written respiratory protection program and that employees had not received medical clearance to wear respirators.

- The drill rig operator drove a work truck between patches and removed the PAPR prior to entering the truck. We observed that the employee was comfortable and did not show obvious signs of difficulty when putting on and taking off (donning and doffing) the PAPR.
- The PAPR was stored inside a plastic tote in the work truck cab. We observed that the tote contained extra PAPR supplies (e.g., filters, air hoses, extra batteries). Employees reported that the respirator was cleaned at the end of each shift with an alcohol-based cleaning wipe before being stored inside the tote.
- Dust that caked onto the drill rig at the end of the day appeared to cause more visible dust at the beginning of the next shift. We observed that the first use of the drill had a larger visible dust cloud than the other times of use. Suggestions that the visible cloud was caused by water vapor and cooler morning temperatures were reported, but the second use of the drill happened minutes after the first, and the cloud was not as large as the first use of the drill. Water vapor may have contributed to the visible cloud, but it was not consistent through the colder morning hours.
- Some machine operators were observed exiting the cab of the machine without wearing their high visibility safety apparel. Even if they were in the cab for most of the shift, they still needed to be wearing the high visibility safety apparel when they exited the cab in the work zone.
- The edges of the patches were close to the live traffic lane, and employees stepped into the live traffic lane when they were filling the patch with cement and when putting tarps over the patches.
- Vehicle spacing and logistics difficulties resulted in safety issues. Instead of waiting at a distance for work to finish in front of them, some employees and equipment were observed crowding the crew working in front of it—one incident resulted in a vehicle sustaining damage.

Methods: Exposure Assessment

Air Sampling

We collected air samples for respirable crystalline silica (RCS) from the breathing zone of two employees on 3 days. We used three-piece, 37-millimeter diameter cassettes with 5-micrometer (µm) pore size polyvinyl chloride filters. We also used a Mesa Labs Model GK 2.69 high-flow personal sampling cyclone at a flow rate of 4.2 liters of air per minute.

We analyzed each sample for respirable dust and RCS using NIOSH Methods 0600 and 7500 with a tetrahydrofuran preparation [NIOSH 2019].

Weather

To capture weather parameters, we set up a Kestrel Instruments Model 4500 portable weather station, with data logging capabilities. The weather station logged information once per minute on a variety of parameters including wind speed, temperature, and relative humidity. We moved the weather station as the crew moved along the road during the workday.

Bulk Samples

We collected bulk samples of slurry produced by drilling on each day. Our objective was to determine the silica concentration in the substrate that was being drilled and identify anything in those samples that would interfere with the analyses of the air samples.

Results: Exposure Assessment

Air Sampling

- The air sampling results are presented in Table C1. Air samples for RCS ranged 12 to 93 micrograms per cubic meter of air (μg/m³) for the drill rig operator (Figure B1). On Day 1, the drill rig operator exceeded the ACGIH limit and the OSHA action level of 25 μg/m³. On Day 2, the drill rig operator exceeded the OSHA, NIOSH, and ACGIH limits of 50 μg/m³, 50 μg/m³, and 25 μg/m³, respectively. On Day 3, air samples for RCS were lower than the OSHA, NIOSH, and ACGIH limits.

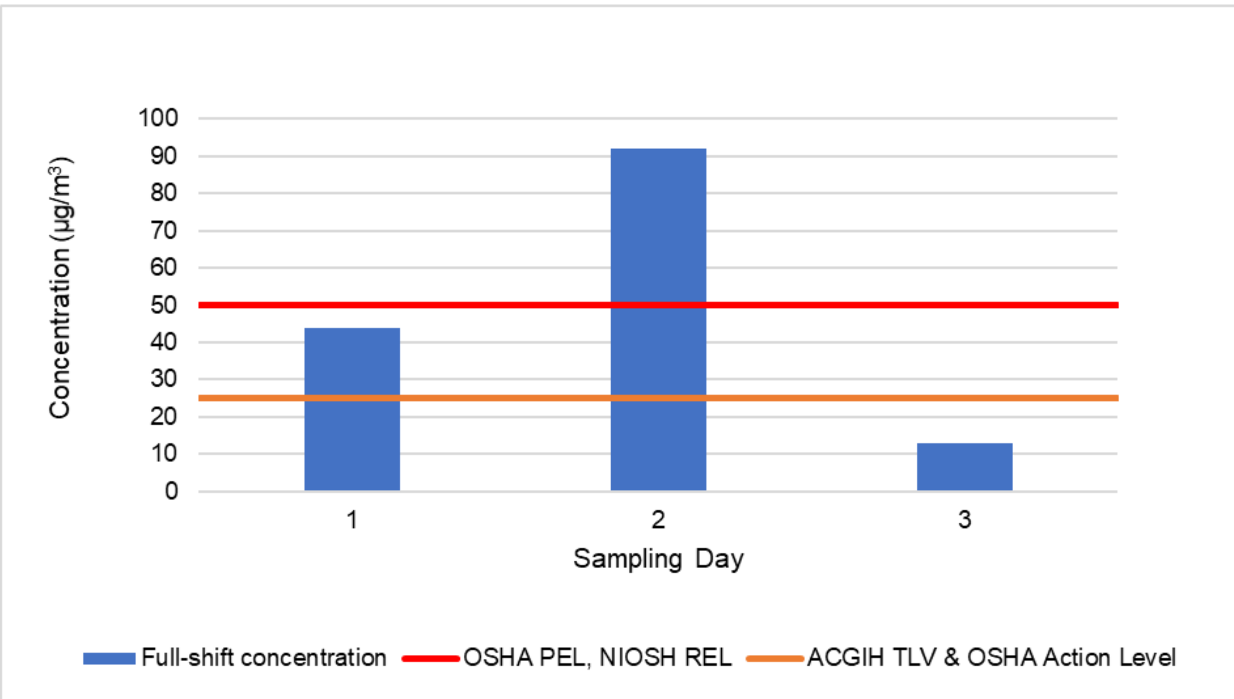

Figure B1. A bar graph of RCS concentrations compared to occupational exposure limits (OELs) for the drill rig operator.

- We did not detect RCS in any of the air samples for the backhoe operator. The minimum detectable concentrations for RCS ranged 4 to 6 μg/m³.
- Air samples for respirable dust ranged from not detected to 1,000 μg/m³. All air samples for respirable dust were lower than the OSHA and ACGIH limits of 5,000 μg/m³ and 3,000 μg/m³, respectively.

Weather

For the 3 days we sampled, average wind speed was 1.7 meters per second, average temperature was 67°F, and average relative humidity was 59%.

Bulk Samples

We collected three bulk dust samples of the slurry produced by the drill. The bulk samples contained 10%–13% quartz (Table C2).

Discussion

RCS has been recognized as a carcinogen and steps should be taken to protect employees from potential exposures [IARC 1997, NIOSH 2002]. Some personal air samples we collected for RCS were above the OSHA regulatory limit, OSHA action level, or ACGIH recommended limit. No respirable dust samples were higher than the OSHA or ACGIH limits. Based on our personal air sampling results for RCS (Table C1) and using NIOSH respiratory selection criteria, the drill rig operator was wearing an appropriate respirator [NIOSH 2004]. The NIOSH assigned protection factor (APF) for a hood PAPR is 25. Multiplying the NIOSH APF of 25 by the OEL for RCS of 50 $\mu g/m^3$ gives a maximum use concentration of 1,250 $\mu g/m^3$.

The respirator that the drill rig operator was required to wear is protective for the exposures that we measured during this evaluation. Additionally, the employee wearing the respirator appeared comfortable wearing it and knowledgeable about its care and storage. Because the airborne exposures to RCS did not exceed the maximum use concentration of 1,250 $\mu g/m^3$, a hood PAPR would also be sufficiently protective. Periodic training for employees required to wear respirators is important for continued proper use and maintenance of respirators.

Employees and management reported concerns that the belt and air hose of the PAPR could interfere with drill rig operation. We discussed the potential for alternative PAPR configurations and told them that one PAPR is not necessarily better than another. Employee comfort is an important factor with any PPE decision. Providing a more comfortable model of respirator (or other PPE) may increase compliance with respiratory protection requirements. In other words, employees are more likely to wear correctly and care for PPE if they are comfortable. Appropriate wear and care of PPE is vital for protection against contaminants like RCS.

Different work sites from where this evaluation took place may have different conditions that could affect exposure levels. Furthermore, the amount of silica in the substrate (e.g., asphalt or concrete) is variable and likely will change from work site to work site, and potentially from patch to patch on the same work site. The existing practices around respiratory protection used by the drill rig operators are adequate to protect employees from RCS exposures. Some modifications to existing practices will allow the company to become compliant with regulatory requirements of the OSHA respiratory protection and RCS standards as well as best practices for cleaning and storage.

Limitations

This evaluation is subject to several limitations. Industrial hygiene sampling and an engineering control evaluation can only document exposures and conditions in the locations evaluated and on the days the evaluation occurred. These results may not be representative of conditions during other days or on other work sites. Additionally, the small size and homogenous nature of the population sampled limit the generalizability of our evaluation results.

Conclusions

Our air sampling showed that the drill rig operation led to concentrations of RCS above relevant occupational exposure limits; however, the operator was wearing appropriate respiratory protection. We recommended specific improvements that could reduce potential exposures and improve respirator use. These recommended improvements included developing a written respiratory protection program, sending drill rig operators for medical respirator clearance, and providing employees training about respirator use and maintenance. We also recommended improved safety around other nonrelated hazards on the work site.

Section C: Tables

Table C1. Personal air sample results for respirable dust and RCS exposures (µg/m^3)

Job title	Sample duration (minutes)	Respirable dust	Respirable crystalline silica*
Day 1			
Backhoe operator	302	59	ND
Drill rig operator	209†	780	44
Day 2			
Backhoe operator	277	86	ND
Drill rig operator	259	1,000	92
Day 3‡			
Drill rig operator	306	200	13
OSHA permissible exposure limit		5,000	50
NIOSH recommended exposure limit		—	50
ACGIH threshold limit value		3,000	25

ND = Not detected

* The minimum detectable concentrations for RCS for the backhoe operator ranged 4 to 6 µg/m^3.

† This sample lost approximately 90 minutes of sampling time throughout the shift. We suspect this occurred when the operator was sitting in the cab between drilling patches.

‡ The backhoe operator sample from Day 3 is not presented because there was a problem with the sampling pump.

Table C2. Percent silica detected in bulk samples of slurry collected from drill spoils

Day	% Silica*
1	13
2	10
3	12

* The limit of quantification was 0.83%.

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended 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 time-weighted average (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 permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH recommended exposure limits (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, 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 include the threshold limit values or 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 2019].

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 noncarcinogenic disorders such as immunologic disorders and autoimmune diseases, rheumatoid arthritis, renal diseases, and an 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 2016]. The ACGIH TLV for quartz is 25 $\mu g/m^3$ as an 8-hour TWA [ACGIH 2019]. The OSHA action level for RCS is 25 $\mu g/m^3$ [OSHA 2016]. An action level is the level at which the employer must provide periodic medical surveillance and air monitoring.

Section E: References

Discussion

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Occupational Exposure Limits

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