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HAZARD ALERT

Worker Exposure to Silica during Hydraulic Fracturing

The National Institute for Occupational Safety and Health (NIOSH) identified exposure to airborne silica as a health hazard to workers conducting some hydraulic fracturing operations during recent field studies.

Introduction

Hydraulic fracturing or "fracking" is a process used to "stimulate" well production in the oil and gas industry. It is not a new process, but its use has increased significantly in the last 10 years because of new horizontal drilling and multi-stage fracking (or "completions") technologies that improve access to natural gas and oil deposits. It involves pumping large volumes of water and sand into a well at high pressure to fracture shale and other tight formations, allowing oil and gas to flow into the well.

NIOSH's recent field studies show that workers may be exposed to dust with high levels of **respirable crystalline silica** (called "silica" in this Hazard Alert) during hydraulic fracturing.

This Hazard Alert discusses the health hazards associated with hydraulic fracturing and focuses on worker exposures to silica in the air. It covers the health effects of breathing silica, recommends ways to protect workers, and describes how OSHA and NIOSH can help. Workers and employers need to be aware of the hazard that silica dust poses. Employers must ensure that workers are properly protected from exposure to silica. This Hazard Alert also provides a brief summary of other health and safety hazards to workers conducting hydraulic fracturing activities.

Crystalline silica is a common mineral found in the earth's crust. It occurs primarily as quartz and is a major component of the sand, clay and stone materials used to make every day products such as concrete, brick and glass.

Respirable crystalline silica is the portion of crystalline silica that is small enough to enter the gas-exchange regions of the lungs if inhaled; this includes particles with aerodynamic diameters less than approximately 10 micrometers (μm).

Photo credit: NIOSH

Silica dust cloud by worker delivering sand from sand mover to transfer belt.

OSHA and **NIOSH** have been investigating worker safety and health hazards in oil and gas extraction, including chemical exposures during hydraulic fracturing operations.

OSHA has jurisdiction over the safety and health of workers, including workers involved in upstream oil and gas operations. The General Duty Clause of the Occupational Safety and Health (OSH) Act and OSHA's General Industry Standards (29 CFR 1910) apply to the upstream industry. As part of the enforcement of these regulations, five OSHA regions located in areas of significant upstream activities use national, regional, and local emphasis programs to inspect oilfield worksites, including those that may have ongoing hydraulic fracturing operations.

NIOSH made safety and health in the oil and gas extraction industry a priority focus area in 2005 by creating the National Occupational Research Agenda (NORA) Oil and Gas Extraction Council, which includes OSHA and industry leaders in a cooperative effort to address occupational safety and health issues. To address an existing lack of information on occupational dust and chemical exposures associated with hydraulic fracturing, NIOSH established specific industry partnerships and initiated the NIOSH Field Effort to Assess Chemical Exposures to Oil and Gas Extraction Workers (http://www.cdc.gov/niosh/docs/2010-130/pdfs/2010-130.pdf). Exposure to silica during hydraulic fracturing has been the focus of the NIOSH study to date.

Why is silica a concern for workers during hydraulic fracturing?

Recent NIOSH field studies identified overexposure to airborne silica as a health hazard to workers.

Large quantities of silica sand are used during hydraulic fracturing. Sand is delivered via truck and then loaded into sand movers, where it is subsequently transferred via conveyer belt and blended with other hydraulic fracturing fluids prior to high pressure injection into the drilling hole. Transporting, moving, and refilling silica sand into and through sand movers, along transfer belts, and into blender hoppers can release dusts containing silica into the air. Workers can be exposed if they breathe the dust into their lungs.

NIOSH identified seven primary sources of silica dust exposure during hydraulic fracturing operations:

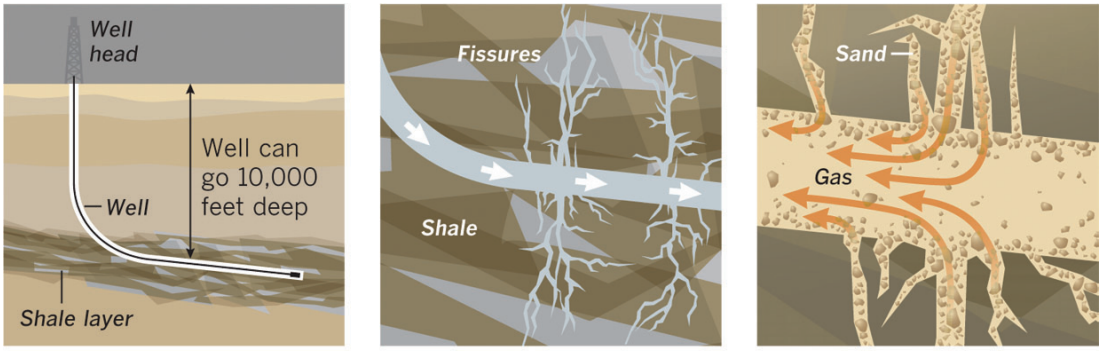
- Dust ejected from thief hatches (access ports) on top of the sand movers during refilling operations while the machines are running (hot loading).
- Dust ejected and pulsed through open side fill ports on the sand movers during refilling operations.
- Dust generated by on-site vehicle traffic.
- Dust released from the transfer belt under the sand movers.
- Dust created as sand drops into, or is agitated in, the blender hopper and on transfer belts.
- Dust released from operations of transfer belts between the sand mover and the blender; and
- Dust released from the top of the end of the sand transfer belt (dragon's tail) on sand movers.

Photo credit: NIOSH

Silica dust clouds from delivery trucks loading into sand movers.

An Overview of the "Fracking" Process

The process known as "fracking" has long been used to extract oil from depleted wells. It is now widely used across the country to tap previously unreachable oil and natural gas locked within deep rock formations.



1. Well may be bored using directional drilling, a method that allows drilling in vertical and horizontal directions to depths of over 10,000 feet.

2. Large amounts of water, sand and chemicals are injected into the well at high pressure, causing fissures in the shale.

3. Sand flows into the fissures, keeping them open so that the oil or natural gas from the shale can flow up and out of the well.

Fracturing fluid is made up of a base fluid, proppant, and chemical additives. Water accounts for about 90 percent of the fracturing mixture and sand accounts for about 9.5 percent. Chemicals account for the remaining one half of one percent of the mixture. The base fluid applies pressure to the formation and delivers the proppant to the fractures.

The **base fluid** is usually water, but can include methanol, liquid carbon dioxide, and liquefied petroleum gas.

Proppant consists of particles that hold open the fractures created by hydraulic fracturing, allowing the oil and gas to flow out of the formation and into the well bore. **Silica sand** is frequently used as a proppant. Other proppants can include sintered bauxite or ceramics, and resin-coated sand.

Chemical additives include friction reducers, scale inhibitors, solvents, acids, gelling agents, and biocides that are added to protect equipment, reduce pumping requirements, and maintain the integrity of the oil or gas formation.

NIOSH Findings on Worker Exposures to Silica

In cooperation with oil and gas industry partners, NIOSH collected 116 full shift air samples at 11 hydraulic fracturing sites in five states (Arkansas, Colorado, North Dakota, Pennsylvania and Texas) to determine the levels of worker exposure to silica at various jobs at the worksites. Many air samples showed silica levels for workers in and around the dust generation points above defined occupational exposure limits.[1]

Of the 116 samples collected:

- 47% showed silica exposures **greater than** the calculated OSHA PEL.
- 79% showed silica exposures **greater than** the NIOSH REL of 0.05 milligrams per cubic meter (mg/m^3).
- 9% of **all** samples showed silica exposures 10 or more times the PEL, with one sample more than 25 times the PEL.
- 31% of **all** samples showed silica exposures 10 or more times the REL, with one sample more than 100 times the REL.

Determining worker exposure levels is important for selecting the right type of control measures, including engineering controls and respiratory protection. For example, half-face respirators are not protective for silica levels over 10 times the exposure limit.

NIOSH found that sand mover and blender operators, and workers downwind of these operations (especially during hot loading), had the highest silica exposures. Workers upwind and not in the immediate area of sand movers (sand delivery truck spotters) also had exposures above the NIOSH REL, possibly from the dust created by traffic at the well site.

Photo credit: NIOSH

Silica dust by worker conducting sand transfer operations. Photo shows sand mover and transfer system.

[1] Employers are required to take actions to reduce worker exposures if air samples show levels above OSHA's calculated Permissible Exposure Limit (PEL). The OSHA PEL is the legally enforceable regulatory limit. The NIOSH Recommended Exposure Limit (REL) is a non-mandatory, recommended occupational exposure limit. However, because OSHA recognizes that many of its PELs are outdated and inadequate measures of worker safety, both OSHA and NIOSH recommend that employers take actions to keep worker exposures below the NIOSH REL.

The OSHA general industry PEL for quartz, the common form of crystalline silica found in sand, is an 8-hour time-weighted average exposure to respirable dust calculated using the following formula:

$$PEL = \frac{10}{(\%\ Silica) + 2}$$

The PEL is approximately equal to 0.1 mg/m^3 for pure quartz silica.

The PEL is outlined in 29 CFR 1910.1000 Table Z-3. If other forms of crystalline silica are present, the PEL calculation must be modified as per Table Z-3.

The NIOSH REL is a fixed value of 0.05 mg/m^3.

Worker and area samples collected in enclosed but non-filtered cab vehicles (e.g., chemical and blender trucks) were above the REL, even when spending most of the day in the cab. Worker and area samples collected in enclosed vehicles with air conditioning and filtration (e.g., data vans) had silica exposures below the NIOSH REL.

Health Hazards of Silica

Hydraulic fracturing sand contains up to 99% silica. Breathing silica can cause silicosis. Silicosis is a lung disease where lung tissue around trapped silica

What are the symptoms of silicosis?

Silicosis is classified into three types: chronic/classic, accelerated, and acute.

Chronic/classic silicosis, the most common type, occurs after 10-20 years of moderate to low exposures to respirable crystalline silica. Symptoms associated with chronic silicosis may or may not be obvious; therefore, workers need to have a chest X-ray to determine if there is lung damage. As the disease progresses, the worker may experience shortness of breath when exercising and have clinical signs of poor oxygen/carbon dioxide exchange. In the later stages, the worker may experience fatigue, extreme shortness of breath, cough, and, in some cases, respiratory failure.

Accelerated silicosis can occur after 5-10 years of high exposures to respirable crystalline silica. It is similar to chronic silicosis, but progresses more rapidly.

Acute silicosis occurs after only a few months or a few years following exposures to extremely high levels of respirable crystalline silica. Symptoms of acute silicosis include rapidly progressive and severe shortness of breath, weakness, and weight loss. Though much less common than other forms of silicosis, acute silicosis nearly always leads to disability and death.

particles reacts, causing inflammation and scarring and reducing the lungs' ability to take in oxygen.[2] Workers who breathe silica day after day are at greater risk of developing silicosis. Silica can also cause lung cancer and has been linked to other diseases, such as tuberculosis, chronic obstructive pulmonary disease, and kidney and autoimmune disease.[3]

What can be done at hydraulic fracturing worksites to protect workers from exposure to silica?

Under the *Occupational Safety and Health Act of 1970*, employers are responsible for providing safe and healthy working conditions for their workers. Employers must determine which jobs expose workers to silica and take actions to control overexposures and protect workers. A combination of engineering controls, work practice, protective equipment, and product substitution where feasible, along with worker training, is needed to protect workers who are exposed to silica during hydraulic fracturing operations.

Several OSHA standards and directives cover operations that may expose workers to silica, including:

- Air Contaminants (29 CFR 1910.1000)
- Hazard Communication (29 CFR 1910.1200)
- Respiratory Protection (29 CFR 1910.134)

OSHA's Directive CPL 03-00-007, titled *National Emphasis Program – Crystalline Silica,* has detailed information on silica hazards, guidelines for air sampling, guidance on calculating PELs for dust containing silica, and other compliance information.

One way to reduce silica exposure is to use alternative proppants (e.g., sintered bauxite, ceramics, resin-coated sand) where feasible. However, before using other proppants, it is important to evaluate the health hazards associated with them. If safe proppant alternatives are not feasible, then employers should monitor worker exposures, take measures to prevent exposures to silica, and inform workers of hazards, as described below.

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

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

Monitor the air to determine worker exposures to silica

- Collect **respirable dust** samples to determine which jobs expose workers to silica above exposure limits. Employers should consult with a trained occupational safety and health professional, such as a certified industrial hygienist, or contact OSHA's free on-site consultation service.
- If air samples show levels above OSHA's calculated PEL, employers are required to take actions to reduce worker exposures. However, both OSHA and NIOSH recommend that employers take the actions below to keep worker exposures below the NIOSH REL.

Control dust exposures by improving existing engineering controls and safe work practices

Engineering controls and work practices provide the best protection for workers and must be implemented first, before respiratory protection is used. Working with industry partners, NIOSH has identified the following control options for hydraulic fracturing operations:

Short-term work practice and procedural changes that can be implemented quickly:

- **Mandate the capping of unused fill ports (e.g., cam lock caps) on sand movers.** Securing unused fill ports can help reduce the dust released, especially during filling.
- **Reduce the drop height between the sand transfer belt and T-belts and blender hoppers.** Limiting the distance that sand falls through the air can help reduce dust.
- **Limit the number of workers, and the time workers must spend in areas** where dust and silica levels may be elevated, and **consider ways to perform dusty operations remotely** to completely remove employees from these areas.
- **Apply fresh water to roads and around the well site to reduce the dust.**

Practices that involve equipment changes:

- **Enclose points where dust is released.** Install thick plastic stilling or staging curtains around the bottom sides of the sand movers to limit dusts released from belt operation. Enclosures can also be added along and at the ends of the sand transfer belt.
- Where possible, **use enclosed cabs or booths.** Consider configuring operator cabs and booths with HEPA filtration and climate controls to further protect workers.
- **Use local exhaust ventilation** to collect silica-containing dusts and prevent dust escape. Install dust collection systems onto machines or equipment that can release dust.

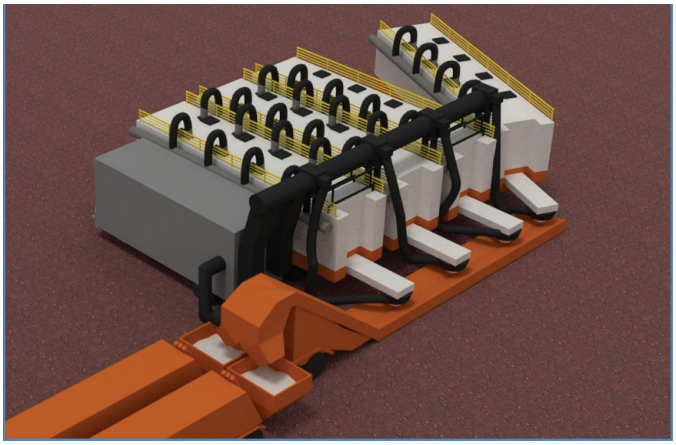


Image credit: Frac Sand Dust Control LLC

A conceptual example of dust control technologies being used by industry.

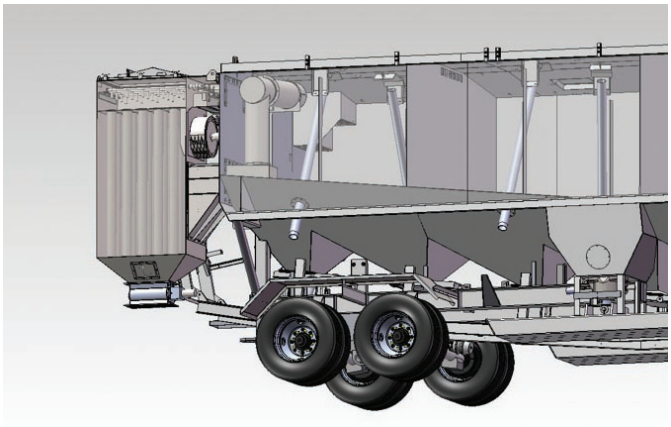


Image credit: NOV Appco

A conceptual example of a baghouse assembly on the back of a truck.

- **Replace transfer belts with screw augers on sand movers in new designs or retrofits.** Dust can be released from the sand moving belt under the sand movers from the actions of belt movement or vibration. Moving sand through an auger system rather than a belt will help contain the sand and reduce dust release.

Image credit: NIOSH

A conceptual example of a screw auger retrofit assembly.

Provide respiratory protection when it is needed to protect workers

When engineering and work practice controls are not feasible, while they are being implemented, or when they do not reduce silica levels below OSHA PELs, employers must provide workers with respirators. Whenever respirators are used, the employer must have a respiratory protection program that meets the requirements of OSHA's Respiratory Protection standard (29 CFR 1910.134). This program must include proper respirator selection, fit testing, medical evaluations, and training.

- If respirators are provided, use at least a NIOSH-approved N95 respirator. If the silica level is more than 10 times the PEL, a half-face respirator is not protective and a respirator that offers a greater level of protection (e.g., a full-facepiece respirator, which will protect workers at silica levels up to 50 times the PEL) must be used. Full-face powered air-purifying respirators (PAPR) provide more protection than half-face air-purifying respirators. In general, workers find PAPRs to be more comfortable.

NIOSH-approved N95 filtering facepiece (top) and elastomeric (bottom) half-face respirators can be used only if silica concentrations are less than 10 times the PEL.

For more information, see OSHA's Safety and Health Topics page and eTool on respiratory protection.

Provide training and information to workers about the hazards of silica and other chemicals

OSHA's Hazard Communication standard requires that employers provide their workers with training and information about hazardous chemicals used in the workplace. ***Employers must provide training and information to workers in a manner and language that the worker understands.*** Employers must:

- Prepare and implement a written hazard communication program.
- Provide training and information on the hazards of silica and other chemicals used in the workplace.
- Provide workers access to Safety Data Sheets (SDSs) on silica sand and other hazardous chemicals they are exposed to during hydraulic fracturing operations.

OSHA recently revised the Hazard Communication standard to conform with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS). "Material Safety Data Sheets" (MSDSs) are now referred to as SDSs, and the information on SDSs will be presented in the standard 16 section format. Refer to OSHA's Hazard Communications webpage to get more information.

Consider medical monitoring for workers who are exposed to silica

As part of its National Emphasis Program on Silica, OSHA recommends that employers medically monitor all workers who may be exposed to silica dust levels at or above one-half the PEL. Recommended medical tests include:

- A medical exam that focuses on the respiratory system and includes a work and medical history.
- A chest X-ray, evaluated by a qualified professional as described in Directive CPL 03-00-007.

OSHA recommends that these tests be repeated every three years if the employee has less than 15 years of silica exposure, every two years if the employee has 15 to 20 years of exposure, and every year if the employee has 20 or more years of exposure.

See *"A Guide to Working Safely With Silica. If It's Silica, It's Not Just Dust"* (U.S. Department of Labor and NIOSH) for more information about the hazards of silica and protecting workers from silica exposures.

What additional health and safety hazards exist during hydraulic fracturing?

In addition to silica hazards, workers may be exposed to other worksite health hazards that can include exposure to diesel particulate and exhaust gases from equipment, high or low temperature extremes, high noise levels, and overexertion leading to sprains and strains. In addition, fatigue may be a concern due to long working hours.

Hydraulic fracturing sites also have **safety hazards** similar to those at other oil and gas drilling sites, including:

- Being struck by moving equipment, including motor vehicle accidents (primarily when traveling to and between well sites), tools, and falling objects.
- Poor lighting.
- Being caught in pinch points (such as hammer union wings and hammers, pump iron, and racks).
- Falling from heights.
- Being struck by high-pressure lines or unexpected release of pressure (for example, mismatched or worn hammer unions, line failure).
- Fires or explosions from flowback fluids containing ignitable materials (e.g., methane) and other flammable materials stored or used at the well site.
- Working in confined spaces, such as sand storage trailers, frac tanks, and sand movers without taking the required precautions.

See OSHA's Oil and Gas Well Drilling and Servicing eTool website (http://www.osha.gov/SLTC/etools/oilandgas/index.html) for more information on safety and health hazards at oil and gas extraction sites.

How Can OSHA and NIOSH Help?

OSHA has compliance assistance specialists throughout the nation who can provide information to employers and workers about OSHA standards, short educational programs on specific hazards or OSHA rights and responsibilities, and information on additional compliance assistance resources. Contact your local OSHA office for more information.

OSHA's On-Site Consultation Program offers free and confidential advice for small businesses with fewer than 250 employees at a site (and no more than 500 employees nationwide) to help identify and correct hazards at your worksite. On-site consultation services are separate from enforcement and do not result in penalties or citations. To locate the OSHA Consultation Office nearest you, visit OSHA's website at www.osha.gov or call 1-800-321-OSHA (6742).

OSHA's Cooperative Initiatives: OSHA, NIOSH, and several U.S. onshore exploration and production industry trade associations, companies, and individual experts have formed a Respirable Silica Focus Group to further explore silica exposure during hydraulic fracturing and to develop practical short- and long-term solutions to protect worker safety and health.

NIOSH is designing conceptual engineering controls to minimize exposure to silica during hydraulic fracturing. NIOSH is looking for industry partners to help test these engineering controls. If you are interested, please contact NIOSH at westernstatesoffice@cdc.gov. NIOSH is also looking for additional partners in drilling and well servicing to help evaluate worker exposures to chemical hazards and develop controls as needed. Please refer to the document *NIOSH Field Effort to Assess Chemical Exposure Risks to Gas and Oil Workers* (http://www.cdc.gov/niosh/docs/2010-130/pdf) for details and contact us if you have questions or wish to participate. In addition, NIOSH has an active program that encourages Prevention through Design considerations so that occupational health and safety aspects (such as dust control) are built into equipment during the design phase.

Employers and workers can always request a NIOSH Health Hazard Evaluation. For more information about this program, please visit the website http://www.cdc.gov/niosh/hhe/HHEprogram.html.

NIOSH recommendations for preventing silicosis, including dust control, sampling and analysis methods, medical monitoring of workers, training, and respiratory protection, can be found at the Silica Topics webpage at http://www.cdc.gov/niosh/topics/silica.

For more information, see Best Practices for Dust Control in Metal/Nonmetal Mining (www.cdc.gov/niosh/mining/pubs/pubreference/outputid3388.htm), which discusses dust control in underground mining operations. Research results from this document have direct relevance for minerals handling operations in hydraulic fracturing operations.

Worker Rights

Workers have the right to:

- Working conditions that do not pose a risk of serious harm.
- Receive information and training (in a language and vocabulary they understand) about workplace hazards, methods to prevent them, and the OSHA standards that apply to their workplace.
- Review records of work-related injuries and illnesses.
- Get copies of test results that find and measure hazards.
- File a complaint asking OSHA to inspect their workplace if they believe there is a serious hazard or that their employer is not following OSHA's rules. OSHA will keep all identities confidential.
- Exercise their rights under the law without retaliation or discrimination.

For more information, see OSHA's page for workers (http://www.osha.gov/workers.html).

Contact OSHA

For questions or to get information or advice, to report an emergency, to report a fatality or catastrophe, to order publications, to file a confidential complaint, or to request OSHA's free on site-consultation service, contact your nearest OSHA office, visit www.osha.gov, or call OSHA at 1-800-321-OSHA (6742), TTY 1-877-889-5627.

Many states operate their own occupational safety and health programs approved by OSHA. States enforce similar standards that may have different or additional requirements. A list of state plans is available at www.osha.gov/dcsp/osp/index.html.

Contact NIOSH

To receive documents or more information about occupational safety and health topics, please contact NIOSH: 1-800-CDC-INFO (1-800-232-4636); TYY: 1-888-232-6348; email: cdcinfo@cdc.gov or visit the NIOSH web site at www.cdc.gov/niosh.

Disclaimer

This Hazard Alert is not a standard or regulation, and it creates no new legal obligations. It contains recommendations as well as descriptions of mandatory safety and health standards [and other regulatory requirements]. The recommendations are advisory in nature, informational in content, and are intended to assist employers in providing a safe and healthful workplace. The Occupational Safety and Health Act requires employers to comply with safety and health standards and regulations promulgated by OSHA or by a state with an OSHA-approved state plan. In addition, the Act's General Duty Clause, Section 5(a)(1), requires employers to provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm. The mention of any non-governmental organization or link to its website in this Hazard Alert does not constitute an endorsement by OSHA or NIOSH of that organization or its products, services, or website.

U.S. Department of Labor
Hilda L. Solis, Secretary of Labor

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