Silica Contamination Control

A Gathering Storm?

By Jeremy Slagley

Unconventional (horizontal) drilling, while used in the oil and gas industry for decades, has unleashed an explosion of natural gas development across the U.S. in the past several years (Stevens, 2012). The affected states have benefited enormously from this renewed economic activity due to the presence of the various shale layers underlying their land. State and federal regulators have been working with industry to responsibly develop the resource while protecting safety, health and the environment.

However, not all associated hazards were well understood from the beginning of the boom. NIOSH released a report in 2013 on its 2-year effort to analyze the degree of airborne silica health hazards for workers conducting hydraulic fracturing operations at oil and gas wells. NIOSH reported 111 personal breathing zone samples for various jobs, with some exposures several times the proposed OSHA permissible exposure limit (PEL) of 0.05 mg/m^3.

Table 1 (p. 36) shows some of the 8-hour time weighted average (TWA) full-shift samples reported in the study. In some cases, the exposures exceeded the protection factor afforded by the select respirators worn by the workers. According to OSHA's Respiratory Protection Standard, a half-face elastomeric air-purifying respirator has an assigned protection factor of 10. Any exposure above 0.50 mg/m^3 would exceed the maximum use concentration at the proposed PEL.

The researchers also found some high exposures for workers less involved with handling silica, such as the chemical truck operator who had a maximum measured TWA of 0.319 mg/m^3 (Table 1). This suggests that environmental silica release could contribute significantly to bystander exposures (Esswein, Breitenstein, Snawder, et al., 2013). Oliver and Miracle-McMahill (2006) discovered high silica exposures among bystanders in their study of silica exposures and health effects among tunnel construction workers.

Silica is a known occupational health hazard (OSHA, 2013), particularly related to the risk of silicosis, a lung disease. Silica exposures are linked to other adverse health outcomes as well. While Oliver and Miracle-McMahill (2006) found no silicosis by chest X-ray in their epidemiological study, they found chronic bronchitis, symptoms consistent with asthma, shortness of breath and physician-diagnosed asthma at a prevalence of 10.7%, 25%, 29% and 6.6%, respectively. Forty-four of the 70 air samples collected were above the current OSHA PEL.

Finkelstein (2000) reports that exposures at the current OSHA PEL give a lifetime risk of 5% to 10% for silicosis and a 30% risk for lung cancer. He advocates for reducing the PEL to the current NIOSH recommended exposure limit of 0.05 mg/m^3, with an accompanying risk below 5% (Finkelstein, 2000). While the hazard of silica exposure is not disputed, workers may view silica as a familiar hazard and, thus, give less attention to following prescribed preventive measures (Haas & Cecala, 2015).

The advent of widespread hydraulic fracturing means that exposures to silica have likely increased (Cyrs, Le, Hollins, et al., 2014). OSHA's proposed rulemaking activity has heightened silica awareness as well. The proposed regulation would apply to the natural gas industry and reduce the allowable exposure as well as require expanded ancillary occupational health measures.

IN BRIEF
- **Silica is a known health hazard, and unconventional oil and gas development has placed it in the public eye.**
- **OSHA's proposed standard includes provisions for regulated areas, cross-contamination and decontamination. HEPA vacuuming and wet methods are prescribed in the proposed standard, but air showers are another viable method.**
- **Direct-reading instruments may be part of employers' arsenal for decontamination procedures.**

Worker Decontamination

While protective gear such as coveralls and respirators protect workers against exposure, not all

Jeremy M. Slagley, Ph.D., CSP, CIH, is an assistant professor in the Department of Safety Sciences at Indiana University of Pennsylvania. He retired from 20 years active duty as an Air Force bioenvironmental engineer officer engaged in industrial hygiene, environmental health and emergency response. He holds a B.S. in Environmental Engineering from the U.S. Military Academy, an M.S. in Industrial Hygiene from the University of Iowa and a Ph.D. in Occupational Safety and Health from West Virginia University. Slagley is a professional member of ASSE's Western Pennsylvania Chapter.

Table 1

Samples of Respirable Quartz Silica

Job title	No. of samples	Minimum TWA (mg/m³)	Maximum TWA (mg/m³)	Median TWA (mg/m³)
Sand mover operator	50	0.007	2.755	0.381
T-belt operator	6	0.015	2.570	0.453
Sand truck driver	1	0.041	0.041	0.041
Chemical truck operator	3	0.040	0.319	0.139

Note. *Personal breathing zone 8-hour time-weighted average samples of respirable quartz silica (mg/m³). Adapted from "Occupational Exposures to Respirable Crystalline Silica During Hydraulic Fracturing," by E.J. Esswein, B. Breitenstein, J. Snawder, et al., 2013,* Journal of Occupational and Environmental Hygiene, 10*(7), 347-356.*

workers wear protection. Furthermore, workers at dusty locations will wear respirators, then remove them when they are away from the immediate area. The contamination on their coveralls, even after decontamination, may present a hazard to them and other unprotected workers.

In addition, the doffing process can release particles. One study examined a release of simulated anthrax particles from a respirator when it was dropped to simulate doffing (Kennedy & Hinds, 2004). The respirators were coated with 1 µm polystyrene latex spheres, then dropped in a chamber. Researchers found a 0.16% to 0.29% particle release from filtering face-piece respirators when dropped. While it would be difficult to relate directly to a TWA exposure to silica, this finding demonstrates that particles can be released during doffing.

In a related study, the researchers coated respirators with different sized particles and dropped them from different heights. Particle releases tended to be higher for increased drop height and increased particle size (Birkner, Fung, Hinds, et al., 2011). Since respirators are not always dropped, the researchers progressed to stretching the respirator bands to better simulate careful doffing, and they found no significant particle release (Birkner, Kovalchik, Fung, et al., 2011).

Thus, careful respirator doffing can prevent cross-contamination. However, the PPE doffing process involves more than just removing a respirator. Employees often remove their respirators then continue working in other locations throughout the day. Resuspension of particles from their coveralls can introduce a health hazard to those workers and their coworkers.

This hazard of unprotected exposure is addressed not only by standard protective measures for workers, but also by proposed decontamination and regulated area restrictions. If anything can be gleaned from the enforcement actions surrounding OSHA's heavy metals standards [e.g., lead (29 CFR 1910.1025), hexavalent chromium (29 CFR 1910.1026) and cadmium (29 CFR 1910.1027)], silica-using industries may need to prepare for a gathering storm.

Common enforcement action areas for heavy metals include housekeeping, cross-contamination, and maintenance of regulated areas or access control plans. For example, of 12 violations cited on May 24, 2010, against the U.S. Department of Air Force at Robins Air Force Base, GA, eight involved housekeeping, decontamination and potential cross-contamination of heavy metals (OSHA, 2010). The Department of Defense has undertaken an immense effort to control heavy metal particulate contamination in the past several years.

For multiemployer dynamic work sites such as those found in unconventional energy resource development, the challenge may be even greater. Consider, for example, that during hydraulic fracturing of an unconventional gas well, layers of subcontractors may have to enter regulated silica areas to perform work. In addition, sand truck drivers may move their vehicles into a potential regulated area to deliver sand.

Regulated areas would be designated based on potential for exposure above the proposed PEL. Employers would have to conduct an exposure assessment to determine the need for regulated areas or access control plans for those areas where workers could experience exposures in excess of the proposed PEL. This could foreseeably include truck drivers as they leave their vehicles to deliver the contents. Although the single sand truck driver measurement from the 2013 NIOSH report did not exceed the proposed PEL (Table 1), if the site layout had drivers in a regulated area where other workers' TWAs exceeded the proposed PEL, then the requirements would apply.

Anecdotally, the author has observed sand truck drivers delivering at active hydraulic fracturing sites with good dust control systems. So, systems exist in industry that could prevent drivers' exposures from approaching the proposed PEL. However, depending on the systems and the layout, anyone in the regulated area would require respiratory protection as well as decontamination.

The proposed standard provides for either high-efficiency particulate air (HEPA) vacuuming or wet methods for decontamination of clothing or work surfaces. Wet methods work well for work surfaces, but may not be as acceptable for worker clothing, especially in winter months outdoors.

NIOSH researchers examined methods of decontamination (Cecala, O'Brien, Pollock, et al., 2007). They found no statistical difference in mass (in grams) of dust remaining on dosed coveralls after treatment between HEPA vacuuming and compressed air blow-off. OSHA does not allow compressed air blow-off because it disperses the contaminant, but these researchers included this method because it is still commonly used. They reported a significant difference between either method (HEPA or compressed air hose) and an air shower. OSHA (2015) allows air showers, or blowers, as long as the booth is under negative pressure and the exhaust is filtered.

Vacuuming can be an effective method of decontamination and it removes the contaminant from the workplace. However, it can be difficult to execute. Vacuuming is closely tied to a worker's motivation and the availability of a coworker to assist, as well as management enforcement. Vacuuming also takes 5 to 6 minutes per worker (Cecala, et al., 2007). That time would be compensated so deploying a HEPA vacuum solution may require several vacuum units to prevent choke points during key worker movements (e.g., breaks, shift changes).

Air showers are an alternative option for rapid, repeatable decontamination. Two common shower mechanisms are compressed air or air blowers, each of which has positive and negative aspects. Compressed air can deliver effective velocity and volume, but requires cycle times to periodically refill the tank. Other concerns include hazardous noise, water buildup and corrosion. For example, the background noise produced by a prototype compressed air shower system used by Cecala, et al. (2007), inside the booth was 87 dBA without the air running and 101 dBA with the system running.

Blower systems tend to require large fans to deliver effective air velocity and volume, and these consume significant electricity. However, there is no cycle downtime waiting for compressed air tank refills. One recent laboratory study found that an air shower protocol was more effective in reducing estimated total dust levels compared to a HEPA vacuum protocol. This study used direct-reading instruments to estimate total dust concentrations in the breathing zone (Cavanaugh, Slagley & Engler, 2014).

Confirmation of Decontamination Effectiveness

Regardless of the method, any decontamination system tends to work best when a direct-reading instrument is available to confirm successful contaminant removal. The standard gravimetric methods prescribed for analysis of silica exposures, such as NIOSH Method 7500, cannot be applied to the assessment of unprotected exposures during the doffing of protective equipment (OSHA, 2013). The doffing time is too short to collect sufficient particulate mass for analysis. NIOSH Method 7500 requires a minimum of 400 L at various flow rates depending on the respirable cyclone used. The aluminum cyclone allows the highest flow rate of 2.5 L/min, which would require a minimum sample time of 160 minutes to capture sufficient mass to be above the limit of detection for the method (NIOSH, 2003). Doffing times are far shorter.

A direct-reading instrument can estimate exposures during a short duration process such as doffing PPE. While real-time light-scattering instruments have some limitations in estimating particle concentrations, the literature highlights available methods (Heitbrink, Evans, Peters, et al., 2007; O'Shaughnessy & Slagley, 2002; Peters, Ott & O'Shaughnessy, 2006). Several simplifying assumptions would be required, and those estimates likely would not be admissible as satisfactory exposure assessments. However, they can give a relative indication of decontamination success.

Conclusion

Silica-using industries can see a storm gathering on the horizon. Learning from past expanded enforcement actions by OSHA regarding heavy metals, regulated areas, housekeeping and worker decontamination protocols should be assessed in anticipation of compliance. **PS**

References

Birkner, J.S., Fung, D., Hinds, W.C., et al. (2011). Particle release from respirators, Part I: Determination of the effect of particle size, drop height and load. *Journal of Occupational and Environmental Hygiene, 8*(1), 1-9.

Birkner, J.S., Kovalchik, S., Fung, D., et al. (2011). Particle release from respirators, Part II: Determination of the effect of tension applied in simulation of removal. *Journal of Occupational and Environmental Hygiene, 8*(1), 10-12.

Cavanaugh, D., Slagley, J.M. & Engler, J.M. (2014). Simulated dry aerosol personal decontamination method effectiveness evaluated by post-decontamination total dust breathing zone concentration. Poster presentation at AIHCE, San Antonio, TX, June 2-5, 2014.

Cecala, A.B., O'Brien, A.D., Pollock, D.E., et al. (2007). Reducing respirable dust exposure of workers using an improved clothes cleaning process. *International Journal of Miner Research Engineering, 12*(2), 73-94. Retrieved from www.cdc.gov/niosh/mining/userfiles/works/pdfs/rrdeo.pdf

Cyrs, W.D., Le, M.H., Hollins, D.M., et al. (2014, April). Settling the dust: Silica past, present and future. *Professional Safety, 59*(4), 38-43.

Esswein, E.J., Breitenstein, B., Snawder, J., et al. (2013). Occupational exposures to respirable crystalline silica during hydraulic fracturing. *Journal of Occupational and Environmental Hygiene, 10*(7), 347-356.

Finkelstein, M.M. (2000). Silica, silicosis and lung cancer: A risk assessment. *American Journal of Industrial Medicine, 38,* 8-18.

Haas, E.J. & Cecala, A.B. (2015). Silica safety: Understanding dust sources to support healthier work practices. *Pit & Quarry, 107*(8), 54-55.

Heitbrink, W.A., Evans, D.E., Peters, T.M., et al. (2007). Characterization and mapping of very fine particles in an engine machining and assembly facility. *Journal of Occupational and Environmental Hygiene, 4*(5), 341-351.

Kennedy, N.J. & Hinds, W.C. (2004). Release of simulated anthrax particles from disposable respirators. *Journal of Occupational and Environmental Hygiene, 1*(1), 7-10.

NIOSH. (2003). NIOSH Manual of Analytical Methods: 7500, Silica, crystalline, by XRD. Retrieved from www.cdc.gov/niosh/docs/2003-154/pdfs/7500.pdf

Oliver, L.C. & Miracle-McMahill, H. (2006). Airway disease in highway and tunnel construction workers exposed to silica. *American Journal of Industrial Medicine, 49*(12), 983-996.

O'Shaughnessy, P.T. & Slagley, J.M. (2002). Photometer response determination based on aerosol physical characteristics. *American Industrial Hygiene Association Journal, 63*(5), 578-585.

OSHA. (2010). Inspection: 312530322—U.S. Department of Air Force, Robins Air Force Base. Retrieved from www.osha.gov/pls/imis/establishment.inspection_detail?id=312530322

OSHA. (2013, Sept. 12). Notice of proposed rulemaking: Occupational exposure to respirable crystalline silica. *Federal Register, 78,* 56273-56504.

OSHA. (2015). SLTC eTool: Clothes cleaning air shower. Retrieved from www.osha.gov/SLTC/etools/battery_manufacturing/popup/hygiene_shower.html

OSHA & NIOSH. (2012). Worker exposure to silica during hydraulic fracturing. Retrieved from www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.html

Peters, T.M., Ott, D. & O'Shaughnessy, P.T. (2006). Comparison of the Grimm 1.108 and 1.109 portable aerosol spectrometer to the TSI 2231 aerodynamic particle sizer for dry particles. *Annals of Occupational Hygiene, 50*(8), 843-850.

Stevens, P. (2012). *The shale gas revolution: Developments and changes* (Briefing paper). London, U.K.: Chatham House.