Evaluation of Silica Exposures During Drywall Sanding

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Table of Contents

Main Report

Supporting Technical Information

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Introduction

Request

Management from a drywall finishing company requested a health hazard evaluation concerning employee exposure to respirable crystalline silica during drywall-sanding activities.

Workplace

The work took place on a commercial construction site. The employees who we evaluated in this project applied joint compound between sheets of hanging drywall and then sanded it smooth once the compound dried. Sanding occurred about once every four days. The length of the overall project depended upon the scope of work. The crew size on this job varied from 6 to 12 employees. All employees belonged to a union. During our visits, the crew worked a single shift about 8 hours long. The length of time spent sanding could change depending on the project. For this project, the sanding took from 3 to 6 hours. During a given workday, most employees performed tasks that included hand and pole sanding. One employee operated a power drywall sander attached to a vacuum equipped with high efficiency particulate air (HEPA) filters. The employee who used the power sander was responsible for emptying the vacuum contents.

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

Our Approach

We visited the work location on 2 days in July 2019. During our visits, we did the following activities:

- Observed work processes and work practices.
- Measured the air velocity in the vacuum hose.
- Collected air samples for respirable crystalline silica and respirable dust
- Collected bulk samples of sanding dust to determine its silica content.

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

Our Key Findings

Employees were not overexposed to silica

- Concentrations of respirable crystalline silica were below relevant occupational exposure limits in all the samples we collected.

- One sample for respirable crystalline silica in air would have been above the American Conference of Governmental Industrial Hygienists (ACGIH®) recommended limit and the Occupational Safety and Health Administration (OSHA) action level had employees been sanding all day. The action level is when employers must take certain steps to further protect their employees.

Some employees were overexposed to respirable dust

- On each sampling day, we collected one respirable dust sample that exceeded the ACGIH recommended limit. We did not collect any samples above the OSHA regulatory limit.
- Concentrations of respirable dust would exceed the OSHA regulatory limit in three samples and ACGIH recommended limit in nine samples had employees been sanding for the entire day.

Vacuums were sometimes used improperly

- We observed the vacuum being used without a disposable bag on one day. We also noticed that the vacuum canister was not always empty before it was used at the start of the work shift.
- The disposable bags inside the vacuum are meant to prevent dust from being resuspended in the air when emptying the vacuum by removing and disposing of the intact bag. Emptying the vacuum less often can allow dust to build up in the vacuum canister and escape the bag. Employees can be exposed to dust if the loose contents in the vacuum canister are dumped into the trash bin.
- We observed dust from the vacuum being emptied into a 5-gallon bucket, and then that bucket was emptied into the trash bin. The extra step of moving the dust into the bucket and then to the trash bin could unnecessarily expose employees to the dust.
- We saw vacuum filters being removed and tapped on the trash bin to dislodge dust. Tapping the filter on the trash bin can potentially increase the risk for dust exposure.

The company voluntary respiratory protection program could be strengthened

- Employees were not wearing their respirators correctly.

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: Conduct periodic exposure sampling

Why? Although the levels of respirable dust we measured were below the OSHA permissible exposure limit, some samples exceeded the ACGIH recommended limit for respirable dust and were approaching regulatory limits.

Two days of sampling from a single work site may not fully represent typical exposure levels, so further sampling may be required to determine if exposure control strategies are needed. Engineering controls or respiratory protection may be necessary to reduce exposure levels. Additionally, more respirable crystalline silica may be present in the dust in work sites that are different than the one we sampled in this evaluation. 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:

Perform additional personal air sampling for respirable dust and silica.

- Multiple days of sampling in a variety of work sites will provide more information about potential respirable dust exposures.
- Further sampling efforts may reveal certain work-site conditions that contribute to higher or lower exposures and present alternative intervention options to respiratory protection.
- This is particularly important in work activities, like these, that can be highly variable day-to-day.

Recommendation 2: Improve the existing respiratory protection program

Why? We observed employees using filtering facepiece respirators incorrectly, and a mandatory respiratory protection program may be necessary to protect employees from higher exposures.

Although it is a voluntary respiratory protection program, proper use of respirators is recommended. OSHA does not prohibit facial hair in "atmospheres which are not hazardous," but facial hair is discouraged (https://www.osha.gov/laws-regs/standardinterpretations/2006-02-06-0). Similarly, there is no mandate that employees wear respirators properly if the mask itself does not create a hazard.

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

Train employees on proper respirator use.

- The 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.

Do not allow facial hair for employees using respirators.

- Facial hair can interfere with the sealing surface of respirators.

Consider implementing a mandatory respiratory protection program.

- Other projects could expose employees to higher respirable dust exposures and greater silica content.

- A mandatory respiratory protection program would ensure that all employees are appropriately protected from exposures to respirable dust and respirable crystalline silica, regardless of the project conditions.
- The mandatory program 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.

Recommendation 3: Improve practices around vacuum care and maintenance

Why? Standard operating procedures are important parts of reducing potential exposures. The vacuum will perform better when it is operated and maintained according to the manufacturer's specifications.

Opportunities existed to reduce potential employee exposure to respirable dust when emptying the vacuum. We observed that the vacuum did not always have a disposable bag in it, so employees dumped the vacuum contents into the trash bin. Different work sites could have more respirable crystalline silica in the dust than those we sampled in this evaluation.

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

Establish clear guidelines for when to empty the vacuum.

- Remove and replace the vacuum cleaner bags at the end of the shift and as needed throughout the day. Develop a schedule for changing the bags based on experience (i.e., number of rooms or number of hours used). Replace the bags more frequently to reduce the chances of having the bag tear and the vacuum canister fill with dust.
- By changing the bags more often, the amount of dust not captured by the disposable bag should be reduced. More frequent changes could also improve the lifespan of the HEPA filters in the vacuum.
- Ensure that an adequate supply of bags is always available. The bag should be replaced once the airflow becomes restricted.
- Properly maintaining the vacuum will be more effective at reducing potential exposures. If you find that you are filling and changing vacuum bags several times during a shift, consider purchasing a larger capacity vacuum cleaner.

Inspect the vacuum at the start and end of each shift.

- Inspect all aspects of the vacuum including filters, disposable bag, power cord, and vacuum hose. Replace any defective components immediately. Report any issues to your foreman.

- Always use the disposable bags. If there is no bag from the last person who used it, install one.
- Clean dust from air vents once per week. Use a damp cloth with water. Never use solvents or cleaning chemicals because they can weaken the vacuum components.
- Never use a brush to clean the filters because this can damage the filter membrane. The vacuum has an automatic cleaning system for the filters, so cleaning them is typically unnecessary.
- Replace filters whenever visual damage is detected. The manufacturer reports that filters typically last from 6–12 months, depending on use and care.

Stop tapping vacuum filters to clean them.

- Tapping the filter on a trash bin to dislodge dust is unnecessary because the vacuum cleaner has an automatic filter cleaning system.
- Rinsing the filters with room temperature water, and allowing to air dry, can be done if needed. Filters may need to be replaced when suction noticeably decreases.

Recommendation 4: 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 increased costs to your business. We saw the following potential issues at your workplace:

- Some work tasks involved moving the rolling scaffolding while employees were on top of it. This action could result in falls or injuries from improper use of the scaffolding.
- Some employees reported that their safety glasses often fogged up, and they were not able to see the areas they were sanding. So, employees did not always wear safety glasses while sanding, although safety glasses were required at the job site.
- Some employees had head lamps, used site lights on tripods, or held portable work lights on their shoulders while standing on stilts or scaffolding and sanding. Holding the light while also sanding could cause employees to lose their balance while working and result in falls or injuries.
- The employee using the power sander spent long periods of time with arms raised overhead, supporting the weight of the sander while sanding the ceilings.

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:

Train employees on appropriate procedures for moving scaffolding.

- Correct procedures would generally include not moving the rolling scaffolding while employees are standing on it, locking wheels prior to climbing onto the scaffolding, and stepping off scaffolding before unlocking and moving to a different location. Incorporate the correct procedures into your safety training.

Explore alternative personal protective equipment ensembles and procedures.

- If combining safety glasses, respirator, and hard hat is uncomfortable for some employees, explore more suitable alternatives. For example, different types of loose-fitting powered air purifying respirators, or PAPRs, can incorporate a hard hat and an American National Standards Institute (ANSI) Z87.1-2015 compliant face shield.
- Providing antifog wipes or spray for the safety glasses may be a short-term measure to take now, while exploring alternative ensembles. Drywall sanding requires close inspection of the work surface to ensure a high-quality finish, presenting challenges to using eye and face protection.

Provide head lamps to all employees if they wish to use them. Discourage employees from holding portable work lights on their shoulders while working.

- Head lamps provide light directly where the employee is working. Employees could lose their balance while working if they were holding the lights while sanding. Losing balance while working could result in falls or injuries.

Consider alternative work practices when sanding ceilings with the power sander.

- When employees hold the power sander over their heads for long periods of time, they risk musculoskeletal injury and pain.
- Employees may need to use scaffolding to comfortably reach high ceilings to avoid situations like the one depicted in Figure A2. The ceilings on this work site required the employee using the power sander to fully extend their arms overhead when using it.
- Employees using scaffolding while power sanding should follow the appropriate procedures for moving scaffolding that were previously discussed.

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Supporting Technical Information

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Section A: Workplace Information

Workplace

The work took place on a multistory commercial building construction site. Sanding occurred approximately once every four days. The length of a project depended upon the scope of the work.

Employee Information

- Eight employees participated in the evaluation on the first visit. Nine employees participated on the second visit. All employees belonged to a union.
- During our visit, the crew worked a single shift that was about eight hours long. The length of the shift could change depending on the scope and stage of the project. For this project, the sanding took between 3 and 6 hours.

Process Description

In interior finishing, drywall installers fit gypsum boards to wall studs or ceiling joists and secure them in place with screws. The joints between the drywall boards are taped, and a joint compound is applied to fill the joints and fix any defects in the drywall board. After installation is completed, drywall finishers utilize dry-sanding techniques to prepare the surfaces for paint application [NIOSH 1997]. Before each of our visits, the drywall finishers had applied three coats of joint compound in approximately 10 rooms on one floor of the building. While we were on-site, the job task was to sand the joint compound that had been applied to the joints between drywall sheets and around fixtures. These techniques included hand sanding, pole sanding, and power sanding. Most employees performed a combination of hand and pole sanding (Figure A1).

Figure A1. Employees hand (left) and pole (right) sanding. The hand sander is on stilts to reach the ceiling. The pole sanders are using the poles to sand the upper walls and ceilings. Photo by the National Institute for Occupational Safety and Health (NIOSH).

One employee used a power sander (Figure A2).

In hand sanding, the drywall finisher sanded the drywall with a sanding sponge to create a uniform surface. For ceiling-level sanding, the finisher either stood on stilts or on a scaffold to reach the areas to be sanded.

In pole sanding, the drywall finisher used an extendable pole with sanding sheets attached at the end to sand surfaces out of arm's reach. By using the pole, the finisher was able to remain standing at ground level while sanding ceiling surfaces, eliminating the need for stilts or scaffolding. Occasionally, pole sanding was done by employees on stilts or scaffolding in hard to reach areas.

In power sanding, a drywall finisher operated an electric motor-driven sander with a disk head that spins. The power sander was attached to a dust-extraction vacuum cleaner equipped with HEPA filters and disposable fleece filter bags (Figure A3).

Figure A2. Employee using a power sander. Photo by NIOSH.

Figure A3. A power sander attached to a dust-extraction vacuum cleaner equipped with HEPA filters. The top of the vacuum has been removed to empty it. Note that there is no bag in the canister. 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

- We observed that employees sanded for approximately one-half of their workday. The remainder of the day was used for cleanup or to apply joint compound on other floors of the building.
- Finishers worked individually, in pairs, or in teams of three or four. Most employees used a combination of hand and pole sanding, and one employee used a power sander. Employees were either on stilts, standing on the floor, or standing on low, rolling scaffolds while sanding. Each employee had their own rolling scaffold where they stored their equipment and personal items. Employees moved their rolling scaffold from room to room as the work progressed.
- A Porter Cable Model 7800 power sander was connected to a 10-gallon (38 liter) capacity dust-extraction DeWALT vacuum cleaner, Model DWV012 (Figure A3), with a 13' (3.96 meter) long, 1-1/4" (3.2 centimeter) diameter vacuum hose. The vacuum was equipped with Model 9330 HEPA filters, disposable 3.3-gallon (12.5 liter) Model DWV 9402 fleece filter bags, and an automatic filter cleaning mechanism.
- The sander was plugged into the vacuum cleaner, and the vacuum cleaner started automatically when the sander was switched on. On Day 1, we noted that the vacuum bag inside the canister was not connected to the inlet within the vacuum. On Day 2, there was no bag present.
- We learned that the vacuum was emptied approximately once per shift. On Day 1, the vacuum was emptied in the room where it was being used when an employee determined that it was full. The employee opened the vacuum, removed the fleece filter bag, and placed the bag into the trash bin. There was still drywall dust in the vacuum cleaner canister that needed to be dumped into the trash bin after the bag was removed. The employee replaced the disposable bag, visually inspected the HEPA filters, tapped the filters to release caked on dust, and reassembled the vacuum. On Day 2 of sampling, the vacuum was emptied into a five-gallon bucket and then the bucket was emptied into the trash bin. Because there was no disposable bag, the employee opened the vacuum, dumped the debris into the trash bin, and reassembled the vacuum.
- Sanding activities generated a large amount of fine dust, to the extent that by the end of the workday, the workers were caked in the powder as it mixed with their sweat. It appeared that

more visible dust was generated in units where power sanding was taking place alongside pole or hand sanding.

- Lamps were deployed as light sources for the finishers so that they could clearly see the texture of the walls they were sanding. We observed the finishers using head lamps, site lights on tripods, or portable work lights. On both days of our site visits, we observed some employees standing on stilts, balancing a portable work light on their shoulder with one hand, and hand sanding with the other hand.
- All employees wore hard hats, long pants, high visibility shirts, and boots. Employees wore gloves while they sanded and took them off intermittently, stating that they relied heavily on touch to determine the texture of the surface they were sanding.
- Most employees had safety glasses with them during the shift, but not all employees wore their safety glasses while working. Employees told us that the amount of dust and lack of ventilation in the spaces they worked in would cause their safety glasses to become foggy or covered with sanding dust. Foggy or dusty glasses prevented employees from being able to do their job, which relies heavily on seeing the surface that they are sanding. Many employees started their shifts wearing safety glasses but removed them as the day progressed because of dust and/or fogging.
- Some employees wore N95 filtering facepiece respirators on a voluntary basis. The company had determined that respirators were not necessary, but employees could wear respirators if they desired. Some employees wore the respirators correctly, but many employees had facial hair or did not have the respirator straps positioned correctly.
- The workplace was warm and humid on both days of sampling. The building's ventilation system was not operational in the rooms where sanding took place.

Methods: Exposure Assessment

Air Sampling

We collected air samples for respirable crystalline silica (RCS) from the breathing zone of eight employees on Day 1 and on nine employees on Day 2. We used three-piece, 37-millimeter diameter cassettes with 5-micrometer (µm) pore size polyvinyl chloride filters. We 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 the NIOSH Methods 0600 and 7500 with a tetrahydrofuran preparation [NIOSH 2019].
- We removed the air samplers from some employees during their morning break and replaced them afterwards.
- We calculated respirable dust and RCS concentrations for drywall-sanding activities (i.e., the task-based air samples) and the eight-hour time-weighted average (8-hr TWA). The calculated 8-hr TWA accounts for the remainder of the workday when employees were not sanding and assumes there is zero exposure to respirable dust or RCS. We were informed that employees would not be sanding for the remainder of the days that we performed air sampling. We

observed employees putting sanding equipment away and preparing equipment to be used for applying drywall compound on another floor of the building. Therefore, we did not conduct air sampling during non-sanding work.

Vacuum Airflow

At the end of each day's sanding, the airflow through the system, consisting of the drywall sander, hose, and vacuum cleaner, was measured by inserting a Mid-West Instrument Model 307BZ-11-A0 delta tube in line in the hose between the sander and the vacuum cleaner, in accordance with the manufacturer's recommendations (Figure A3). The differential pressure across the delta tube was measured using these micromanometers—Dwyer Instruments Model 478A and KANOMAX USA Model PVM100. We used the reading to calculate the airflow rate in accordance with the delta tube manufacturer's manual.

Bulk Samples

We collected bulk samples of sanding dust from multiple locations on both sampling days. We wanted to determine the silica concentration in the substrate that was being sanded 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. Task-based air samples for RCS collected over the duration of time the employees sanded ranged from not detected to 20 micrograms per cubic meter of air (μg/m^3) on Day 1 and from not detected to 33 μg/m^3 on Day 2. None of the RCS concentrations measured were above the minimum quantifiable concentration set by the laboratory, which means that there is more uncertainty associated with these results. If employees were exposed to these concentrations for an entire day (i.e., they sanded for the entire shift), they would still be below the OSHA and NIOSH limit of 50 μg/m^3. The task-based air sample result of 33 μg/m^3 for RCS would exceed the ACGIH limit and the OSHA action level of 25 μg/m^3 if an employee was exposed to that concentration for an entire day (i.e., if they sanded for the entire shift).

The 8-hr TWA concentrations for RCS ranged from not detected to 14 μg/m^3 on Days 1 and 2 (three employees had concentrations above 'not detected'). All 8-hr TWA air samples for RCS were lower than the OSHA, NIOSH, and ACGIH limits for RCS (Figure B1).

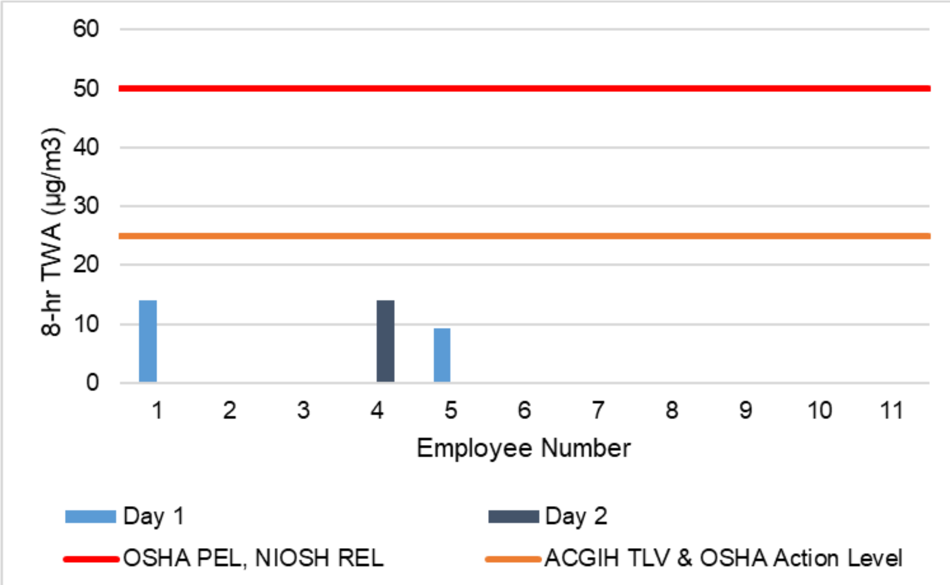

Figure B1. A graph of the calculated 8-hr TWA RCS concentrations compared to occupational exposure limits (OELs), including the OSHA permissible exposure limits (PELs) and the NIOSH recommended exposure limit (REL), for Days 1 and 2. Three employees had measurable concentrations above 'not detected.'

Task-based air samples for respirable dust collected over the duration of time the employees sanded ranged from 1,700 to 6,300 µg/m³ on Day 1 and from 2,000 to 7,300 µg/m³ on Day 2. If employees were exposed to these concentrations for an entire day (i.e., if they sanded for the entire shift), three samples would be higher than the OSHA limit of 5,000 µg/m³. Nine of the task-based air samples were higher than the ACGIH limit of 3,000 µg/m³.

The 8-hr TWA concentrations for respirable dust ranged from 1,100 to 4,300 µg/m³ on Day 1 and from 890 to 3,400 µg/m³ on Day 2. None of the 8-hr TWA samples for respirable dust were higher than the OSHA limit. Two 8-hr TWA samples were higher than the ACGIH limit of 3,000 µg/m³ (Figure B2).

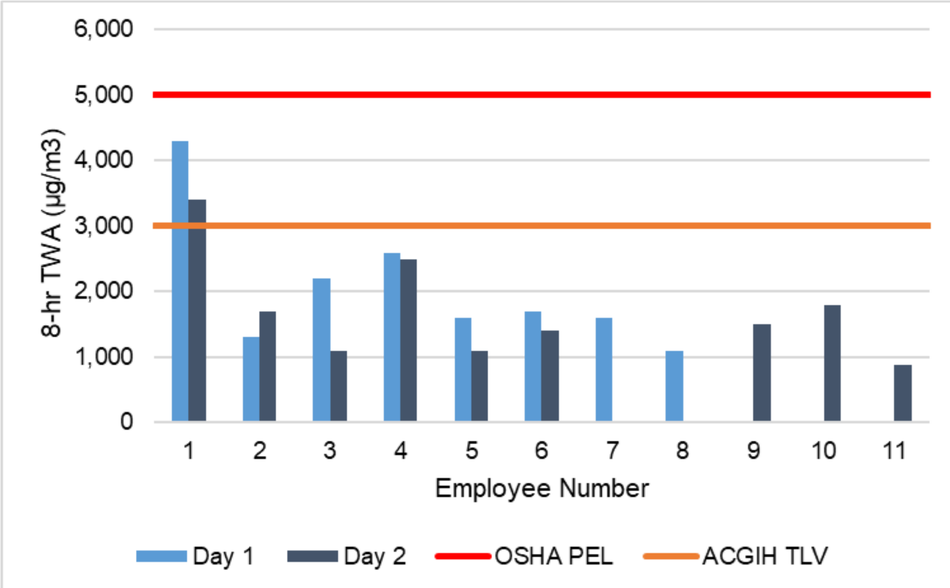

Figure B2. A graph of the calculated 8-hr TWA respirable dust concentrations compared to OELs for Days 1 and 2.

We sampled the employee using the power sander on Day 1 of sampling. The task-based concentration for RCS collected over the duration of time the employee was sanding was 10 µg/m^3. If the employee was exposed to this concentration for an entire day (i.e., if they sanded for the entire shift), they would still be below the OSHA, NIOSH, and ACGIH limits for RCS. The 8-hr TWA concentration for RCS was not detectable. The minimum detectable concentration was 15 µg/m^3, which is less than the OSHA, NIOSH, and ACGIH limits for RCS. The task-based concentration for respirable dust for the employee using the power sander was 2,400 µg/m^3. If the employee was exposed to this concentration for an entire day (i.e., if they sanded for the entire shift), they would still be below the OSHA and ACGIH limits for respirable dust. The 8-hr TWA concentrations for respirable dust was 1,600 µg/m^3, which is less than the OSHA and ACGIH limits for respirable dust.

Vacuum Airflow

The vacuum had an adjustable flowrate and was set to maximum flow during both of our visits. We measured an airflow of 58 cubic feet per minute at the end of sanding on the first and second sampling day. The vacuum cleaner is rated for a maximum airflow of 155 cubic feet per minute, but it is unclear how and where this was measured (i.e., with or without a tool attached, at the vacuum, or near the tool).

Bulk Samples

We collected three bulk dust samples of settled dust from different rooms and from the pile of dust that came out of the vacuum. The bulk samples contained between 0.41% and 1.3% quartz (Table C2). We took bulk dust samples from the floor, the window sill, and the vacuum canister.

Discussion

All personal air samples we collected for RCS were lower than the OSHA, NIOSH, and ACGIH occupational exposure limits (OELs). No respirable dust samples were higher than the OSHA permissible exposure limit (PEL), although two respirable dust samples were higher than the ACGIH threshold limit value (TLV). Although we did not find overexposures to RCS, continued sampling during different types of jobs or when new equipment is deployed may be warranted. The company reported that they never sand more than half of the day. However, if the sanding tasks were performed for the entire shift, there is a potential for overexposures to RCS and respirable dust.

Based on our site visits, no regulatory requirement exists for respiratory protection during the drywall-sanding tasks described previously. However, we did see one sample on each day that exceeded the ACGIH TLV for respirable dust. One or two days of sampling on a small amount of people may not be representative of the true exposures; further sampling may be needed to determine if respiratory protection is required. We observed very little air movement in the units being sanded during the two sampling days. Other work sites may have different conditions that could affect exposure levels. The company may need to develop a tiered approach to respiratory protection or investigate further engineering controls depending on work site conditions. A tiered approach to respiratory protection may involve requiring respirators on projects where there is likely to be more respirable dust (i.e., where there is more sanding than typical projects or where there is less air movement in the building). Further engineering controls would involve controlling exposures using additional dust control methods (i.e., in addition to the vacuum used with the power sander) rather than controlling exposures by implementing a mandatory respiratory protection program.

The company voluntary respiratory protection program could be improved. We observed respirators being worn incorrectly, and some employees had facial hair. Training employees about proper donning, doffing, and care for respirators will increase awareness about potential dust and RCS exposures. Improved training will ensure that the respirator the employee chooses to wear will protect them, even if there is no requirement to wear it. Continuing to allow employees to wear respirators improperly now could lead toward respirators being worn improperly if respirator use becomes a requirement in the future.

Employees switched between hand and pole sanding throughout the day, so we cannot determine from these data if using a pole sander affected exposure levels. The RCS exposure of the employee using the power sander was well below all relevant OELs. The vacuum attached to the power sander appeared to work well, but we discovered issues related to its use and maintenance. On Day 1, the vacuum appeared to be filled beyond capacity before being emptied (the fleece bag inside the vacuum canister was overflowing and not connected to the hose). On Day 2, a disposable fleece bag was not used.

A cyclonic pre-separator in line between the tool and the vacuum cleaner would prolong vacuum cleaner HEPA filter life and increase the time between the need to replace bags, reducing the cost of purchasing new filters and bags. Relatively low-cost cyclones that can be mounted on top of a five-gallon plastic bucket are available. Alternatively, some drywall sander/vacuum cleaner combinations are sold with integrated pre-separators. We observed filter removal and tapping filters on the trash bin to dislodge dust, increasing the potential dust exposure. The vacuum cleaner manufacturer's instructions note that "Cleaning of the filters is typically unnecessary. Even if the filter is covered with dust, the automatic filter cleaning system will maintain maximum performance and continue to function." If needed, the filters can be rinsed with room temperature water and allowed to air dry. Filters may need to be replaced when a decrease in suction is noted.

We did not evaluate the cleanup stages of this process because cleanup was being performed by laborers who were not employed by the drywall installation contractor after the drywall finishers had moved on to other tasks. We learned that sometimes employees helped with cleanup activities. Cleanup included dry sweeping and scraping the cement floors after all sanding is complete. This process created visible clouds of dust when we observed the laborers cleaning up rooms. If employees helped with cleanup, this could increase overall exposures to respirable dust and RCS because the dry sweeping will resuspend dust into the air.

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 which the evaluation occurred. These results may not be representative of conditions during other days. Additionally, the small size and homogenous nature of the population sampled limit the generalizability of our evaluation results.

Conclusions

Our air sampling found overexposures to respirable dust, but no overexposures to RCS. However, there could be overexposures to RCS if sanding was performed for the entire day. We found that vacuum care and maintenance could be enhanced, and we recommended improvements. We also recommended that the company explore alternative PPE ensembles to improve compliance and strengthen their voluntary respiratory protection program.

Section C: Tables

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

Job title	Sample duration (minutes)	RCS		Respirable dust	
		Task Concentration*	8-hour TWA†	Task Concentration	8-hour TWA
Day 1					
Finisher 1	325	[20]	[14]	6,300	4,300
Finisher 2	239	[8]	ND	2,700	1,300
Finisher 3	323	[10]	ND	3,300	2,200
Finisher 4	303	ND	ND	4,100	2,600
Finisher 5	320	[14]	[9.3]	2,400	1,600
Finisher 6	323	[8.1]	ND	2,500	1,700
Finisher 7	323	[10]	ND	2,400	1,600
Finisher 8	314	[6]	ND	1,700	1,100
Day 2					
Finisher 1	221	ND	ND	7,300	3,400
Finisher 2	203	[19]	ND	4,100	1,700
Finisher 3	219	[7.7]	ND	2,500	1,100
Finisher 4	205	[33]	[14]	5,900	2,500
Finisher 5	220	[8.7]	ND	2,500	1,100
Finisher 6	220	[8.5]	ND	3,000	1,400
Finisher 9	215	ND	ND	3,400	1,500
Finisher 10	220	ND	ND	4,000	1,800
Finisher 11	213	[7.6]	ND	2,000	890
OSHA PEL		50		5,000	
NIOSH REL		50		—	
ACGIH TLV		25		3,000	

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

ND = Not detected

* The minimum detectable concentrations for RCS ranged from 4 to 20 μg/m^3. The minimum quantifiable concentrations for RCS ranged from 13 to 55 μg/m^3.

† Nondetectable values were substituted with the analytical limit of detection divided by the square root of two in order to calculate the 8-hr TWA.

Table C2. Percent quartz detected in bulk samples

Sample location	% Quartz*
Day 1	
Dust collected from the floor	[0.72]
Dust collected from window sill	[0.69]
Dust collected from vacuum canister	[0.56]
Day 2	
Dust collected from window sill	[0.41]
Dust collected from the floor	1.3
Dust collected from vacuum canister	0.85

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

* 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 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, 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 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

Methods

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