Health Hazard Evaluation Program

Evaluation of Respirable Dust and Respirable Crystalline Silica Exposures During Asphalt Mix Production and Road Paving Operations

HHE Report No. 2023-0072-3403

September 2024

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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Keywords: North American Industry Classification System (NAICS) 237310 (Highway, Street, and Bridge Construction), Florida, Asphalt Production, Road Paving, Road Milling, Road Repair, Silica, Construction, Respirable Crystalline Silica, RCS, Respirable Dust

Disclaimer

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

Availability of Report

Copies of this report have been sent to the employer and employees at the plant. The state and local health departments and the Occupational Safety and Health Administration Regional Office have also received a copy.

Recommended Citation

NIOSH [2024]. Evaluation of respirable dust and respirable crystalline silica exposures during asphalt mix production and road paving operations. By Methner MM. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2023-0072-3403, https://www.cdc.gov/niosh/hhe/reports/pdfs/2023-0072-3403.pdf.

Table of Contents

Main Report

Supporting Technical Information

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Introduction

Request

Management from an asphalt mix production and paving company requested a health hazard evaluation concerning employee exposure to respirable dust and respirable crystalline silica (RCS) during asphalt mix production and road paving activities.

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

Our Approach

We visited the facility in July 2023 to conduct an observational walkthrough assessment. During the visit, we met with company management to discuss the health hazard evaluation request. We observed work processes and practices, equipment type and usage, and workplace conditions. We also spoke with some employees about the workplace, their job duties, and other tasks associated with their work. Our other activities included the following:

- Observed specific job titles and work practices within the production yard that could cause workers to be exposed to respirable dust and RCS.
- Observed a dry rotary broom attached to a tractor used to sweep the yard.
- Observed a field crew milling (grinding) and re-paving a section of highway.

At the end of the visit, we summarized our activities, discussed preliminary observations, and identified a variety of jobs to monitor for exposure to respirable dust and RCS.

In October 2023, we returned to the facility and conducted air monitoring of employees in job titles previously identified during the observational walkthrough assessment. Our work took place over four days in three locations: two different road re-surfacing worksites and the asphalt production yard. The total length of each road re-surfacing project varied from project to project and depended on the length of the road surface being installed or replaced. During our site visit, we observed that some employees (mainly yard workers) worked a single shift of about 7 hours long each day. However, some jobs involved specific work tasks where exposure to respirable dust and RCS was possible and ranged from 1.5 hours to 7 hours. We evaluated 10 different job titles during yard and road paving operations.

During the evaluation, we completed the following activities:

- Measured 28 employees' exposures to respirable dust and RCS in the air. These personal breathing zone air samples were collected for an entire work shift, if possible. For these samples, we calculated the employees' 8-hour time-weighted-average exposures. This is the average concentration of a substance in the air over an 8-hour time period. Some of the air samples were collected for a shorter duration to measure exposures for specific work tasks.

- Collected bulk samples of the dust on the ground at each worksite to determine the type and amount of crystalline silica present.
- Collected air samples (personal breathing zone and area samples from devices attached to the outside of the equipment) to evaluate the effectiveness of the enclosed cab air filtration system on the tractor used to operate the rotary broom during yard cleanup. We also tested to see how effective using a water-based dust suppression system attached to the rotary broom during road paving and yard cleanup operations would be.

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

Our Key Findings

Personal exposures to respirable dust and RCS were below occupational limits

- Personal exposures to respirable dust and RCS were below occupational limits set by the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH).
- However, a quality control laboratory technician's exposure to RCS while operating and cleaning the rock shaker was above several occupational limits.
- Depending on the length of the task, RCS exposures for employees using a pneumatic chipping hammer to remove hardened material off the vanes inside the large mixing drum could be above occupational exposure limits for RCS.

The enclosed cab with air filtration reduced the amount of respirable dust and RCS inside the cab during rotary broom dry sweeping operations in the yard

- We compared air sample results collected inside and outside the enclosed cab. The enclosed cab had 6 times less respirable dust and 13 times less RCS than the outside air.

The use of a water-based dust suppression system attached to the rotary broom reduced the amount of respirable dust and RCS in the air during sweeping operations

- When water was used, air samples showed a decrease in respirable dust and RCS. The reduction ranged from 4 times to 14 times compared with when water was not used.

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

Our Recommendations

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

Potential Benefits of Improving Workplace Health and Safety:

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

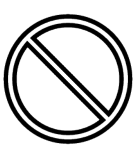
The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted 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/hierarchy-of-controls/about/index.html.

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

Recommendation 1: Reduce exposure to RCS during rock shaker use and cleanout

Why? Exposure can happen through breathing dust in the air that contains silica. Occupational exposures to RCS have been associated with many serious diseases. These include silicosis, lung cancer, pulmonary tuberculosis, other airway diseases, and kidney disease. The laboratory technician operating and cleaning the rock shaker with compressed air was exposed to concentrations of RCS above several occupational limits.

How? When working with the rock shaker, include these processes:



Avoid using compressed air to clean the rock shaker indoors.

- If the use of compressed air is necessary to clean the rock shaker, remove all trays and clean them outside.

Install a ventilated enclosure around the rock shaker so that RCS dust is captured on a filter and exhausted outside.

Use a vacuum equipped with a high efficiency particulate air (HEPA) filter to clean the rock shaker and trays of any dust or debris.

Require the use of an N95® filtering-facepiece respirator during these tasks.

Recommendation 2: Use the water-based dust suppression attachment on equipment when sweeping during paving and yard cleanup operations

Why? Dry sweeping using the rotary broom generates a large amount of dust and can put RCS in the air. In the air, RCS can be inhaled by employees.

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

Install the water-based dust suppression attachment on equipment that uses the rotary broom to sweep roadways and the yard.

- Make sure there is adequate water in the onboard water supply tank when operating.
- Stop sweeping if the water supply tank runs dry. Refill the tank with water before resuming sweeping.

Recommendation 3: Reduce exposures to RCS during mixing drum chipping and maintenance

Why? Exposure can happen through breathing dust in the air that contains silica. Occupational exposures to RCS have been associated with serious diseases, such as silicosis, lung cancer, pulmonary tuberculosis, other airway diseases, and kidney disease. RCS exposures were very high during the time an employee was using a pneumatic chipping hammer to remove hardened material. off the vanes inside the large mixing drum. Depending on the amount of time doing this task, exposures could exceed occupational exposure limits for RCS.

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

Provide exhaust ventilation for the mixing drum to reduce the buildup of dust created during chipping tasks.

Limit the total time performing drum chipping to 90 minutes or less during a shift.

Continue to wear appropriate respiratory protection during this task.

Recommendation 4: Implement the requirements of the OSHA silica standard

Why? Exposure can happen through breathing dust in the air that contains silica. Exposures to RCS while on-the-job have been associated with serious diseases. Compliance with the OSHA silica standard will help protect workers from exposure and the potential for silica-related disease.

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

Create and use an exposure control plan for RCS. The plan should be in writing and include the following:

- Define workplace tasks that involve exposure to RCS.
- Describe engineering controls, work practices (including housekeeping measures, and respiratory protection used to limit exposure to RCS for each task.
- Review and evaluate the effectiveness of this plan at least annually. Update it as needed and make the plan readily available to employees.

Conduct exposure monitoring for RCS at regular intervals.

- The OSHA silica standard requires air monitoring every 6 months when RCS exposures are above the action level. At or above the OSHA action level, an employer must take certain steps to protect workers from exposure.
- Additional air monitoring provides more information on the range of exposures during different dusty activities, how well control measures are working, and what level of respiratory protection might be needed.

Recommendation 5: Address other health and safety issues we identified during our evaluation. Assess the potential for excessive noise exposure during different job tasks and determine the appropriate level of hearing protection

Why? A workplace can have multiple health hazards that cause worker illness or injury. Similar to the ones identified above, these hazards can potentially cause serious health symptoms, lower morale and quality of life for your employees, and possibly increased costs to your business. We saw the following potential issues at your workplace: Some employees did not wear hearing protection, such as disposable foam earplugs, when operating noisy equipment (e.g., plate compactor).

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

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

Conduct noise monitoring to help identify high noise tasks. This will help determine which employees need to be included in a hearing conservation program.

Have the road crew supervisor tell employees to wear appropriate hearing protection if noise monitoring shows it is needed during specific jobs or tasks.

Supporting Technical Information

Evaluation of Respirable Dust and Respirable Crystalline Silica Exposures During Asphalt Mix Production and Road Paving Operations

HHE Report No. 2023-0072-3403

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Section A: Workplace Information

Production Yard

The facility consisted of a fenced outdoor yard that houses administrative offices, an area to store raw materials, a mechanic shop, an asphalt production plant, and an indoor quality assurance/quality control (QA/QC) laboratory. Raw materials such as sand, gravel, and aggregate stone were stored in the yard as large piles and loaded into hoppers using a front-end loader. The materials were mixed and fed to the production plant via a series of conveyors and a rotating mixing drum.

The production plant mixed the raw materials and stores the final asphalt mix in silos prior to loading the mix into dump trucks that deliver the mix to a paving jobsite. The QA/QC laboratory tested various components of the asphalt mix (aggregate stone, sand, gravel) and also performed destructive testing on core samples and other components of the asphalt mix. Cleanup of the yard involved operating a tractor that used a rotary broom to push material into piles near the raw material storage area.

Road Paving

The paving crew used various pieces of equipment to mill (grind away) the old road surface and subsequently sweep, deposit, and smooth the delivered asphalt. Some tasks involved manual shoveling and raking while other tasks involved the operation of equipment such as a tractor-driven rotary broom, paver/screeder, and a roller.

Job Descriptions

Exposure to respirable dust and respirable crystalline silica (RCS) was measured among employees during tasks involved in asphalt mix production and paving operations.

Six Different Job Titles Were Evaluated in the Asphalt Mix Production Yard:

1. Roll-off container driver (picked up, emptied, and exchanged roll-off containers used to remove old road materials consisting of asphalt and concrete rubble in the yard).

Figure A1. Yard area where roll-off container truck operator dumps reclaimed asphalt and concrete rubble collected from road-side asphalt and concrete tear-out operations. Photo by NIOSH.

2. Groundman (cleaned, maintained, and dry swept the area within the production plant area).

Figure A2. Worker dry sweeping yard beneath asphalt production plant. Photo by NIOSH.

3. Laboratory QA/QC technician (tested asphalt, sand, rocks, and other materials in a laboratory. Operates rock shaker machine to sort rocks by size.

Figure A3. Laboratory QA/QC technician using compressed air to clean out a rock shaker machine. A small box fan was used to try and remove dust generated during cleanout. Photo by NIOSH.

Figure A4. Laboratory QA/QC technician using compressed air to clean out a rock shaker machine. A small fan is positioned near the rock shaker to try and move airborne dust outside through the door opening. Photo by NIOSH.

4. Front end loader operator (supplies and moves raw material such as sand and aggregate around the yard and production plant).

Figure A5. Front end loader with enclosed cab used to load raw materials into hoppers that feed the asphalt production plant via the conveyor belt system. Photo by NIOSH.

5. Mixing drum maintenance technician (uses a pneumatic chipping hammer to remove and clean hardened material buildup from mixing vanes inside the rotating mixing drum). This task is performed periodically (every few weeks based on the degree of buildup) and only lasts 1–2 hours.

Figure A6. Worker using a pneumatic chipping hammer to remove buildup off vanes inside mixing drum. Photo by NIOSH.

Figure A7. Worker chipping buildup off vanes inside mixing drum located within the yard. Photo by NIOSH.

6. Rotary broom operator (operates a rotary broom pushed by a tractor or skid-steer machine to clean up dust and gravel within the yard).

Figure A8. Rotary broom attached to a tractor used to sweep yard. Photo by NIOSH.

Figure A9. Tractor with front mounted rotary broom sweeping yard space. Rotary broom does not have a water-based dust suppression attachment. Photo by NIOSH.

Figure A10. Water-based dust suppression nozzles attached to the rotary broom on the front of a skid-steer machine. Photo by NIOSH.

Figure A11. Yard sweeping using the rotary broom with water-based dust suppression attachment on a skid-steer machine. Photo by NIOSH.

Five Different Job Titles Were Evaluated in the Preparation and Application of Asphalt Re-Paving Operations:

1. Rotary broom operator (sweeps freshly-milled road surface prior to asphalt application).

Figure A12. Dry sweeping road with rotary broom after asphalt milling prior to re-paving. Photo by NIOSH.

Figure A13. Water-based dust suppression attachment being used to sweep freshly-milled road surface prior to re-paving. No substantial dust generation was observed. Photo by NIOSH.

2. Paver/screeder operator (operates the machine that deposits and levels the asphalt onto the road surface).

Figure A14. Paver/screeder machine laying down asphalt over freshly-milled road surface. No observable dust generated during this task. Photo by NIOSH.

3. Roller operator (operates a ride-on roller machine to compress and smooth applied asphalt).

Figure A15. Asphalt roller used to smooth surface. Photo by NIOSH.

4. Shoveler (scoops excess asphalt squeeze-out during paving/screeding and re-deposits the material back onto the road) while (5) raker/luteman rakes and distributes asphalt along the road edges during paving).

Figure A16. Shovelers and raker/luteman spreading and smoothing freshly laid asphalt. Photo by NIOSH.

Section B: Methods, Results, and Discussion

Methods: Exposure Assessment

Air Sampling

We collected 28 personal and 2 area air samples for respirable dust and RCS at the three different worksites: Worksite #1, Worksite #2, and the production yard. Ten different job titles were evaluated. We collected these samples as either duration-of-task or full-shift as an 8-hr time-weighted-average (TWA), depending on the time necessary to complete a task. For task-based samples, the calculated 8-hour TWA accounts for the remainder of the workday when employees were not performing tasks generating dust (e.g., driving to another worksite) and assumes no exposure to respirable dust or RCS for those periods.

We collected the air samples at a flow rate of 4.2 liters per minute on three-piece, 37-millimeter diameter cassettes with 5-micrometer (μm) pore size polyvinyl chloride filters. The cassettes were placed in Mesa Labs Model GK 2.69 high-flow personal sampling cyclones. We changed cassettes approximately every 2–4 hours to avoid overloading when employees were working in dusty conditions.

To evaluate the air filtration system on the tractor, we collected air samples inside and outside the enclosed tractor cab while the dry rotary broom was being used during road paving and yard cleanup operations. We followed the same sampling strategy to evaluate the effect of using a water-based dust suppression system attached to the rotary broom during road paving and yard cleanup operations.

We analyzed each sample for respirable dust (NIOSH Method 0600) and RCS (NIOSH Method 7500) with a tetrahydrofuran preparation [NIOSH 2024].

Bulk Samples

At each work location, we collected a bulk dust sample present on the ground to determine the amount of silica present in the dust. This would provide insight into the potential for exposure to silica from dust being resuspended in the air during the workday or during cleanup.

Results: Exposure Assessment

Air Sampling

The air sampling results for respirable dust are presented in Table C1. The 8-hour TWA air concentrations for respirable dust ranged from none detected (ND) (collected on a raker/luteman) to 1,240 micrograms per cubic meter of air (μg/m³) (collected outside the tractor cab during dry sweeping of the yard with the rotary broom). None of the TWA measurement results for respirable dust were higher than the OSHA permissible exposure limit (PEL) of 5,000 μg/m³ or the ACGIH® Threshold Limit Value (TLV®) of 3,000 μg/m³.

The air sampling results for RCS are presented in Table C2. The 8-hour TWA air concentrations for RCS ranged from ND (collected on multiple job titles) to 71 μg/m³ (collected outside the tractor cab during dry sweeping of the yard with the rotary broom). None of the TWA personal measurement results for RCS were higher than the OSHA PEL or NIOSH recommended exposure limit (REL) of

50 μg/m³. However, the TWA measurement result collected from a laboratory QA/QC technician while operating/cleaning a rock shaker (Figures A1 and A2) was 48 μg/m³. This exposure exceeded the OSHA action level (AL) and ACGIH TLV of 25 μg/m³ and was nearly at the OSHA PEL and NIOSH REL.

The RCS exposure for the employee chipping hardened material buildup off the vanes inside the mixing drum was nearly at the OSHA AL and ACGIH TLV (25 μg/m³). Based on the concentration of 101 μg/m³ measured during the 98-minute task, the full-shift TWA exposure would exceed the OSHA AL and ACGIH TLV after 119 minutes (less than 2 hours) of chipping material off the vanes in the mixing drum. The full-shift TWA exposure would reach the OSHA PEL and NIOSH REL (50 μg/m³) in 238 minutes (less than 4 hours) if the same concentration was extrapolated out.

Bulk Samples

All three bulk samples were collected from surface dust deposits from either freshly milled road surfaces or the paved ground within the yard. These samples were analyzed using NIOSH Method 7500. The sample collected from the milled road surface at Worksite #2 contained 35% silica (quartz) by weight. The sample from the milled road surface at Worksite #1 contained 21% silica (quartz) by weight. The sample collected within the company yard contained the highest amount of quartz silica when compared to the other two worksites (42% by weight).

Results: Evaluation of the Water-based Dust Suppression Attachment

During the on-road evaluation of the rotary broom sweeping operation (with and without water-based dust suppression) at the re-paving Worksite #1, we observed that using water-based dust suppression resulted in a 4.1-fold reduction in the airborne concentration of respirable dust in the personal breathing zone (PBZ) of the operator (see Figures A10 and A11). The measurements show a decrease from 74 μg/m³ (dry) to 18 μg/m³ (wet), as shown in Table C1. No RCS was detected on these samples or any other PBZ samples collected at Worksite #1 (Table C2).

During the yard cleanup evaluation of the rotary broom sweeping operation, we examined the effectiveness of an enclosed tractor cab equipped with an air filtration system. We observed a 5.8-fold reduction in the airborne respirable dust concentration during dry sweeping. The measurements show a decrease from 1,240 μg/m³ outside the tractor cab to 213 μg/m³ PBZ inside the cab (see Figures A7 and A8). We saw a 13-fold reduction when comparing measurements for airborne RCS concentrations. These measurements decreased from 71 μg/m³ outside the cab to 5.5 μg/m³ PBZ inside the cab (Tables C1 and C2).

Two different yard cleaning equipment configurations were used during our visit. We sampled outside and inside of the cab for each equipment configuration in use to assess the effectiveness of the water-based dust suppression attachment for the rotary broom. The first yard cleanup event consisted of an enclosed cab tractor pushing the rotary broom dry (Figure A8). The second yard cleanup event used an open cab skid-steer machine pushing the same broom but equipped with the water-based dust suppression attachment (Figure A4). With only one water-based dust suppression attachment, employees used different equipment configurations depending on what was available at each worksite when the task needed to be performed.

Air samples collected for respirable dust showed a 10-fold reduction when using the water-based dust suppression, the measurements decreasing from 1,240 μg/m³ (dry) to 119 μg/m³ (wet) outside the tractor cab. For airborne RCS concentrations, the measurements decreased from 71 μg/m³ (dry) to 6.0 μg/m³ (wet) outside the tractor cab, a 12-fold reduction (Tables C1 and C2). It should be noted that the dry sweeping operation in the yard using the rotary broom represented a worst-case scenario (uncontrolled dust generation) that produced the most airborne dust. Therefore, to determine any effect on exposure as a result of using the water-based dust suppression attachment, we used the worst-case scenario as a benchmark. We compared that benchmark with the exposure measurement results obtained while using the water-based dust suppression attachment, assuming all other factors were the same.

Discussion

None of the employees monitored had respirable dust exposures higher than OSHA, NIOSH, or ACGIH occupational exposure limits. In addition, none of the employees were exposed to RCS at concentrations above the OSHA PEL or NIOSH REL. However, one personal air sample we collected for RCS (from the laboratory QA/QC technician operating/cleaning the rock shaker) exceeded the OSHA AL and the ACGIH TLV and was nearly at the OSHA PEL and NIOSH REL. Depending on the amount of dust generated, on some days it is possible that exposures could exceed the OSHA PEL and NIOSH REL. We also found that RCS during chipping hardened material buildup off the vanes inside the mixing drum was nearly at the OSHA AL and ACGIH TLV. Exposure could exceed exposure limits for RCS based on the amount of time an employee spent on the task.

RCS has been recognized as a carcinogen and steps should be taken to protect employees from potential exposures [IARC 1997; NIOSH 2002]. Employee exposures at or above the OSHA AL initiate certain required activities, such as exposure monitoring, medical surveillance, and implementing an exposure control plan for RCS. If the most recent exposure monitoring indicates that employee exposures are at or above the AL but below the PEL, the employer needs to repeat such exposure monitoring within 6 months of the most recent monitoring [OSHA 2016]. Additionally, the OSHA RCS standard for construction states that the employer needs to reassess exposures whenever a change in the production, process, control equipment, personnel, or work practices may reasonably be expected to result in new or additional exposures at or above the AL, or when the employer has any reason to believe that new or additional exposures at or above the AL have occurred [OSHA 2016].

We observed that the use of compressed air during cleanout of the rock shaker created a cloud of dust that contained silica and contributed to RCS exposure. Although the employee placed a small box fan near the rock shaker in an attempt to pull dust away, it did not have sufficient air moving capability to adequately control RCS exposures. Strategies for reducing RCS exposures during this task include using a vacuum equipped with a HEPA filter to clean the rock shaker and trays, placing the rock shaker inside a ventilated enclosure that captures the dust produced during cleanout and filters it before exhausting it outside of the building, and avoiding or limiting the use of compressed air. Due to the high likelihood of exceeding the OSHA PEL and NIOSH REL on some days, employees cleaning the rock shaker should wear respiratory protection such as an N95® filtering facepiece or half-mask respirator equipped with P100® filters until controls adequately reduce RCS exposures.

Chipping hardened material buildup off the vanes inside the mixing drum was a task that only lasted 98 minutes during our measurements. However, the RCS exposure level during this task was high enough that the 8-hour TWA nearly reached the OSHA AL and ACGIH TLV even when the employee had no additional RCS exposure for the remainder of the work shift. Based on our measurements, RCS exposure could reach or exceed exposure limits on some days if the employee spent more time on the task or dust levels were higher. We recommend controlling exposures through ventilation and/or limiting the time at this task to less than 90 minutes. Employees doing this task should continue to wear respiratory protection.

The use of the water-based dust suppression attachment, regardless of worksite location (on-road versus yard cleanup) resulted in lower amounts of respirable dust and RCS produced and dispersed into the air. The comparison of sample results collected with and without the water-based dust suppression attachment indicated reductions in respirable dust and RCS ranging from 4-fold to 13-fold when water was used.

With respect to the potential exposure to noise, we noticed an employee not wearing hearing protection while operating a noisy plate compactor. Although we did not measure noise as part of this evaluation, it is important to inform employees of the potential hazards associated with their job. Availability of personal protective equipment (PPE) such as foam earplugs at the jobsite, along with the foreman reminding employees to wear the PPE would be helpful in addressing this issue.

Limitations

This evaluation is subject to several limitations. Industrial hygiene sampling and engineering control evaluations can only document exposures and conditions at the locations evaluated and on the days the evaluation occurred. These results may not be representative of conditions during other days or on other worksites. Additionally, the small size of the population sampled limit the generalizability of our evaluation results. For the comparison of the water suppression system and equipment not using the system, an assumption that all other factors (besides the water suppression system) were the same. However, brush spin rate, amount of material on the ground, operation time, operator differences, etc. are all factors that could impact the comparison, but results indicated that the water suppression system was successful in reducing potential exposures.

Conclusions

Our air sampling showed that operating and cleaning the rock shaker led to concentrations of RCS that were above the OSHA AL and ACGIH TLV, and almost to the OSHA PEL and NIOSH REL. The use of compressed air to clean the unit most likely played a role in the amount of RCS produced. Efforts to control exposure to RCS while operating or cleaning the rock shaker appear warranted. Options include placing the equipment inside a ventilated enclosure that exhausts contaminated air outside the work area, using a vacuum equipped with a HEPA filter, or requiring the use of appropriate respiratory protection.

RCS exposures during chipping of hardened material buildup off the vanes inside the mixing drum also had the potential to exceed exposure limits and indicate the need for exposure control and continued use of respiratory protection. The tractor with an enclosed cab with air filtration provided the operator with some protection from respirable dust and RCS. However, the water-based dust suppression attachment provided a reduction in potential exposures and should continue to be used in cleanup operations in the yard and during road paving work.

Attribution Statement

N95 is a certification mark of the U.S. Department of Health and Human Services (HHS) and is registered in the United States and several international jurisdictions.

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

Section C: Tables

Table C1. Full-shift personal air sampling results for respirable dust exposures in micrograms per cubic meter of air (µg/m^3)

Job title	Task	Location	Sample duration (minutes)	8-hour TWA
Roll-off container driver	Drop/pickup/dump container of broken concrete	Yard/offsite	471	88
Groundman	Sweeping/cleanup	Yard/plant	446	197
			416	[57]
Laboratory technician (QA/QC)	Sieving, batching, rock shaker operation	Lab	398	134
	Rock shaker, rock shaker cleanout		421	570
	Making/cutting pills (core samples)		466	362
Front end loader operator	Move, dump, load sand/gravel	Yard	439	93
Raker/luteman	Rake asphalt during road application	Worksite #2	200	[18]
Roller operator	Compact/smooth asphalt		212	[13]
Shoveler	Scoop/shovel asphalt during road application		158	[28]
Paver/screeder operator	Run paving machine/set depth of applied asphalt		193	[23]
Yardman/maintenance	Chipping buildup off vanes inside mixing drum	Yard/plant	98	179
Rotary broom operator	Dry sweeping previously milled road (PBZ sample collected inside tractor with enclosed cab)	Worksite #1	234	74
	Wet sweeping previously milled road using water-based dust suppression attachment (PBZ sample collected on skid-steer machine with no enclosed cab)		196	[18]
Raker/luteman	Rake asphalt during application	Worksite #1	172	ND
Roller operator	Compact/smooth asphalt		184	[13]
Shoveler	Scoop/shovel asphalt during application		183	[33]
Paver operator	Run paving machine		180	[28]
Screeder operator	Set depth of applied asphalt		184	[28]
Rotary broom operator	Dry sweeping yard (PBZ sample collected inside enclosed cab tractor with air filtration	Yard	131	213
	Dry sweeping yard (area sample collected outside enclosed cab of tractor)		126	1240*
Rotary broom operator	Wet sweeping previously milled road using skid-steer machine with no enclosed cab and a water-based dust suppression attachment (PBZ sample)	Yard	130	179
	Wet sweeping previously milled road using skid-steer machine with no enclosed cab and a water-based dust suppression attachment (area sample collected outside rollover cage)		129	119*

Abbreviations: TWA = Time-weighted average; Minimum detectable concentration (MDC) = limit of detection/highest volume sampled. For these samples, the value was 18 µg/m^3; Minimum quantifiable concentration (MQC) = limit of quantitation/highest volume sampled. For these samples, the value was 70 µg/m^3; ND = None detected. Result was below MDC; PBZ = Personal breathing zone

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

* Area sample results cannot be compared directly with occupational exposure limits.

Table C2. Full-shift personal air sampling results for respirable crystalline silica exposures in micrograms per cubic meter of air (μg/m³)

Job title	Task	Location	Sample duration (minutes)	8-hour TWA
Roll-off container driver	Drop/pickup/dump container of broken concrete	Yard/offsite	471	ND
Groundman	Sweeping/cleanup	Yard/plant	446	[4.8]
			416	ND
Laboratory technician (QA/QC)	Sieving, batching, rock shaker operation	Lab	398	ND
	Rock shaker operation, rock shaker cleanout		421	47.7
	Making/cutting pills (core samples)		466	[10.9]
Front end loader operator	Move, dump, load sand/gravel	Yard	439	ND
Raker/luteman	Rake asphalt during application	Worksite #2	200	ND
Roller operator	Compact/smooth asphalt		212	ND
Shoveler	Scoop/shovel asphalt during application		158	[8.9]
Paver/screeder operator	Run paving machine/set depth of applied asphalt		193	ND
Yardman/maintenance	Chipping buildup off vanes inside mixing drum	Yard/plant	98	21
Rotary broom operator	Dry sweeping previously milled road (PBZ sample collected inside tractor with enclosed cab)	Worksite #1	234	ND
	Wet sweeping previously milled road using water-based dust suppression attachment (PBZ sample collected on skid-steer machine with no enclosed cab)		196	ND
Raker/luteman	Rake asphalt during application	Worksite #1	172	ND
Roller operator	Compact/smooth asphalt		184	ND
Shoveler	Scoop/shovel asphalt during application		183	ND
Paver operator	Run paving machine		180	ND
Screeder operator	Set depth of applied asphalt		184	ND
Rotary broom operator	Dry sweeping yard (PBZ sample collected inside enclosed cab of tractor with air filtration)	Yard	131	[5.5]
	Dry sweeping yard (area sample collected outside enclosed cab of tractor)		126	71*
Rotary broom operator	Wet sweeping previously milled road using skid-steer machine with no enclosed cab and a water-based dust suppression attachment (PBZ sample)	Yard	130	[8.9]
	Wet sweeping previously milled road using skid-steer machine with no enclosed cab and a water-based dust suppression attachment (area sample collected outside rollover cage)		129	[6.0]*

Abbreviations: TWA = Time-weighted average; Minimum detectable concentration (MDC) = limit of detection/highest volume sampled. For these samples, the value was 18 μg/m³; Minimum quantifiable concentration (MQC) = limit of quantitation/highest volume sampled. For these samples, the value was 70 μg/m³; ND = None detected. Result was below MDC; PBZ = Personal breathing zone

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

* Area sample results cannot be compared directly with occupational exposure limits.

Section D: Occupational Exposure Limits

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

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

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

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

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

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

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

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

Respirable Crystalline Silica

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

Silicosis is an irreversible but preventable fibrotic disease of the lung caused by the deposition of fine crystalline silica particles in the lungs. Silicosis is caused by the inhalation and deposition of crystalline silica particles that are 10 μm or less in diameter. Particles 10 μm and smaller are considered respirable particles and have the potential to reach the lower portions of the human lung (alveolar region).

Although particle sizes 10 μm and smaller are considered respirable, some of these particles can be deposited before they reach the alveolar region [Hinds 1999].

Symptoms of silicosis usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and nonspecific chest illnesses. Silicosis usually occurs after years of exposure (chronic) but may appear in a shorter period of time (acute) if exposure concentrations are very high. Acute silicosis is typically associated with a history of high exposures from tasks that produce small particles of airborne dust with a high silica content [NIOSH 1986]. Even though the carcinogenicity of crystalline silica in humans has been strongly debated in the scientific community, the International Agency for Research on Cancer (IARC) in 1996 concluded that there was "sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources" [IARC 1997]. Several other serious diseases from occupational exposure to crystalline silica include lung cancer and 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 2024]. The OSHA AL for RCS is 25 $\mu g/m^3$ [OSHA 2016]. An OSHA AL is the level at which the employer must provide periodic medical surveillance and air monitoring.

Section E: References

Discussion

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HHE Report No. 2023-0072-3403