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Short Communication

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A temporal evaluation of respirable crystalline silica exposure for construction tasks

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Abstract

Personal air monitoring using a TSI SidePak AM520 personal aerosol monitor was performed on a northern Colorado construction site during five tasks from the *OSHA* Table 1*: Specified Exposure Control Methods When Working With Materials Containing Crystalline Silica* to estimate silica dust concentrations in real time. Photometric measurements were modified using a gravimetric correction factor and a % respirable crystalline silica adjustment. Each task was sampled once; sample time ranged from 14 min to 40 min, with a mean sample time of 27 min. The mean silica dust concentration estimates (μg/m^3) (standard deviation [SD]) for the five tasks computed from the TSI SidePak AM520 respirable dust measurements were core drilling 12 μg/m^3 [2.46], grinding 918 μg/m^3 [1134.08], cutting with a walk-behind saw 36 μg/m^3 [79.67], jackhammering 27 μg/m^3 [23.24], and dowel drilling 66 μg/m^3 [77.65]. Silica exposure estimates from real-time monitoring can be used to identify exposures that may be related to inadequate controls or worker behaviors that contribute to peak exposures. Respirable crystalline silica exposure estimates presented here are likely not generalizable to other construction sites or tasks.

Key words: construction; OSHA Silica Permissible Exposure Limit; OSHA Table I; real-time dust monitoring; silica exposure.

What's Important About This Paper?

This paper describes a methodology to estimate respirable silica exposure using a real-time monitoring instrument. Real-time measurement of silica exposure can be important to determine if workplace controls are functioning effectively.

Introduction

Activities within the construction industry can generate high concentrations of dust, including respirable crystalline silica (RCS). The Occupational Safety and Health Administration (OSHA) issued a new permissible exposure limit (PEL) of 50 μg/m^3 and an action level (AL) of 25 μg/m^3 for silica dust in the construction industry in 2016 (OSHA 2016a). The standard provides construction companies with the OSHA Table 1 (OSHA 2016c), a guideline that allows employers to forego air monitoring if they implement task-specific dust control measures and work practices. Researchers have evaluated dust control measures and found that the controls did not reduce silica concentrations below published exposure limits (Flanagan et al. 2003; Akbar-Khanzadeh et al. 2010).

One option to evaluate the effectiveness of silica dust controls is to use a photometric, real-time monitoring instrument. However, in an evaluation of the relationship between particulate matter measured by photometric instruments and silica dust measured by standard gravimetric samplers, Pahler et al. (2018) found poor

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agreement between data from the TSI SidePak (i.e. real-time monitor) and traditional gravimetric samplers. To calculate a calibration factor to apply to real-time monitoring results that more accurately predict RCS concentrations, the authors wrote that a larger sample size with a known silica content would be necessary. However, the researchers ultimately concluded that calibration factors could be determined to predict RCS concentrations using direct-reading instruments. Due to the variability of silica content among construction materials, Shafie (2020) concluded that a calibration factor must be calculated for each task monitored based on the silica content of the specific material used.

The specific aim of the current evaluation was to determine the utility and feasibility of using a real-time monitoring instrument to estimate RCS air concentrations during the performance of select OSHA Table 1 tasks to evaluate the effectiveness of OSHA-mandated dust controls and employee work practices. Real-time RCS monitoring results may be used in employee exposure profiles, in conjunction with integrated sampling results, to determine if employees experience excursions above exposure limits.

Methods

The TSI SidePak AM520 (Shoreview, MN) with a Dorr Oliver 10 mm nylon cyclone (operated at 1.7 LPM) was co-located on a large construction site with an SKC disposable respirable parallel particle impactor (PPI) (Eighty Four, PA) and a Zefon Escort ELF (Ocala, FL) personal air sampling pump (operated at 4.0 LPM) to estimate area dust concentrations. The area dust monitoring was performed for 334 minutes and one field blank was collected for quality control. Pre- and post-calibration of the SidePak and the Escort ELF personal air sampling pump were performed according to manufacturer instructions. The SidePak was set to log data every minute. The construction site was an active wastewater treatment plant undergoing expansion, and there were hundreds of construction workers onsite during the evaluation. Construction activities included painting, framing, concrete work, steel work, and others. Silica-generating (and non-silica generating) tasks were ongoing simultaneously throughout the worksite, and workers were frequently in close proximity to each other while doing separate tasks, including the workers performing the five OSHA Table 1 tasks evaluated in this study. While the tasks evaluated in this evaluation occurred at different times of the day (i.e. did not occur simultaneously), they were performed in one general area of the site that was under construction that day.

The area dust monitoring results from the co-located samplers were used to determine a correction factor by dividing the PPI gravimetric respirable dust concentration by the mean SidePak photometric dust concentration. The SidePak and cyclone were then used to estimate respirable dust during the performance of five tasks from OSHA Table 1, with the SidePak attached to the worker's belt and the cyclone attached to the worker's collar in the breathing zone. Each personal respirable dust data point was then multiplied by the correction factor and then by the proportion of crystalline silica, as determined from the fines, resulting in an estimate of RCS mass concentration at each time period. The percent silica for each task was determined by taking bulk material samples from the fines created from each of the five tasks. Wind velocity, temperature, and relative humidity were measured every 30 min during the sampling day using a TSI VelociCheck air velocity meter, Model 8330 (Shoreview, MN) and a Fluke, Model 971 (Everett, WA), temperature and humidity meter.

The real-time personal air monitoring was conducted while workers performed the following five tasks on concrete outdoors, except grinding, which was performed on mortar within a partially enclosed structure:

- Rig-mounted core drilling with an integrated water delivery system;
- Grinding using a handheld grinder with a shroud and a high-efficiency particulate air (HEPA) filtration vacuum dust collection system used in a partially enclosed structure [~250+ ft^2 (23 m^2)] with four, seven-foot (2 m) high walls and no roof; employee wore a half-mask air-purifying respirator with an assigned protection factor of 10;
- Cutting with a walk-behind saw with an integrated water delivery system; an additional employee occasionally sprayed water on the concrete in front of the saw;
- Jackhammering with an integrated water delivery system; an additional employee occasionally sprayed water on the concrete at the point of operation;
- Dowel drilling used with a shroud around the drill bit with a HEPA filtration vacuum dust collection system used outdoors.

The gravimetric area and bulk samples were analyzed by the Wisconsin Occupational Health Laboratory using the National Institute for Occupational Safety and Health (NIOSH) method 7500 for RCS (all forms) (NIOSH 2003) and NIOSH method 0600 for respirable dust (NIOSH 1998). NIOSH method 7500 was also used to determine the percent silica in the bulk samples. Descriptive statistics for each of the five tasks were computed using Microsoft Excel 2013.

Results and discussion

The estimated airborne concentrations of respirable dust measured by the co-located PPI sampler and the SidePak monitor showed disagreement between the two sampling methods (gravimetric sample = 300 μg/m^3, photometric sample = 121 μg/m^3). The SidePak underestimated respirable dust by a factor of 2.48 as compared to the PPI sampler. In determining the calibration factor, only one area sample was obtained by the PPI sampler and the SidePak real-time monitor. This one-sample limitation could have resulted in a relatively less accurate calibration factor as compared to a calibration factor derived from a statistically significant number of area samples.

Based on the descriptive statistics for each of the five tasks (Table 1), the estimated mean RCS concentrations ranged from 12 μg/m^3 for core drilling to 918 μg/m^3 for grinding. Although not directly comparable to the eight-hour OSHA PEL of 50 μg/m^3, the results suggest that dust controls were inadequate for grinding (918 μg/m^3) and dowel drilling (66 μg/m^3) if the OSHA PEL is used as a reference concentration for dust control performance. Further, jackhammering (27 μg/m^3) and cutting with a walk-behind saw (36 μg/m^3) were below the PEL, but both exceeded the OSHA AL of 25 μg/m^3. Of note, those tasks that employed a wet method for dust control (core drilling, walk-behind saw cutting, and jackhammering) were all below the OSHA PEL. Alternatively, those tasks (i.e. grinding and dowel drilling) that employed a shroud and HEPA dust filtration vacuum system exceeded the OSHA PEL. The authors of the current study did not assess the performance of the dust control methods, only that they were employed by the construction company; however, the results of the estimated means of the RCS concentrations indicate the need for employers to assure that ventilation dust controls are maintained and performing as designed. The corrected respirable dust concentrations are included in Table 1 to demonstrate the significant concentration differences between respirable dust and RCS. During the five tasks, the mean windspeed was 0.94 m/s (0.34–1.74 m/s), the mean temperature was 26.8°C (22–29°C), and relative humidity was 29.45% (23.20–40.15%). Relative humidity was not included in a calculation of the correction factor.

Real-time personal sample estimated RCS concentrations were plotted to demonstrate the variability of exposure during task performance. For example, Fig. 1 demonstrates evident fluctuations in estimated silica exposure throughout the jackhammering activity, which was likely due to the stop and go nature of the task (the employee would frequently stop to reposition or stretch his fingers). Importantly, although the mean RCS concentration was 27 μg/m^3, Fig. 1 illustrates several excursions above the OSHA PEL, with one peak at 1.8 times (90 μg/m^3) the PEL. The authors noted the following employee behaviors during sampling that could have contributed to exposure variability observed in the data by changing the distance from the source to the worker's breathing zone:

- Core drilling: Worker was observed (i) leaning over the drill in a hunched position, (ii) kneeling directly beside the core drill, and (iii) pausing to stand up and stretch.
- Grinding: Worker was observed (i) holding the grinder above his head to reach higher areas on the wall, (ii) kneeling down while grinding near the bottom of the wall, and (iii) pausing operation to check the grinding surface.
- Cutting with the walk-behind saw: Worker would stop cutting when he reached the end of a row, then re-position the machine to start another cut.
- Dowel drilling: Worker observed (i) hunching over the dowel drill and (ii) pausing to readjust his hands and stretch his back.

Table 1. RCS and corrected respirable dust by task.

	Core drilling	Grinding	Cutting with a walk-behind saw	Jackhammering	Dowel drilling
Sample time (minutes)	14	40	24	30	26
% Silica	12	33	12	12	23
Mean RCS concentration (μg/m^3)	12	918	36	27	66
Standard deviation RCS concentration (μg/m^3)[a]	2.46	1,134.08	79.67	23.24	77.65
Range RCS[a]	10–20	116–6,416	6–393	6–92	13–406
Mean corrected respirable dust (μg/m^3)	98	2,782	302	227	288
Standard deviation corrected respirable dust (μg/m^3)[a]	20.49	3,436.59	663.91	193.68	337.62
Range respirable dust[a]	82–166	352–19,443	52–3,274	47–764	57–1,763

[a]Standard deviation and range are reported for a single real-time monitoring period for each task.

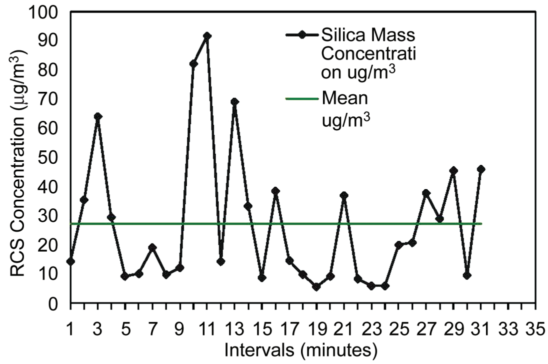

Fig. 1. Estimated RCS concentration (µg/m^3) in real time during a Jackhammering activity.

Real-time monitoring should not be used to determine OSHA compliance; however, the information can be used by employers to identify temporal spikes in exposure and to evaluate the performance of control methods and worker behaviors, as well as identifying dust controls that are no longer operating effectively. It should be noted that if OSHA Table 1 specified controls are not operating at design standards (e.g. specified flow rate), then the employer is considered to not be fully and properly implementing the control and subsequently must employ alternate exposure control methods to assess employee RCS exposure.

It is unclear if RCS estimates for the five construction tasks measured in the present study are due solely from the task itself or also due to background construction site dust concentrations. A previous study (Cothern et al. 2023) indicated that background silica concentrations measured on construction sites may contribute to employee silica overexposures when engaged in task-based silica-generating activities with OSHA Table 1 mandated controls in place. Further, Cothern et al. (2023) examined the same five tasks evaluated in the current study and found that the OSHA PEL was exceeded (as mean 8-h silica concentrations in µg/m^3) for dowel drilling (99.9), sawing with a walk-behind saw (126), and grinding (172). Similarly, in the current study, when the OSHA PEL is used as a reference value for real-time monitoring, grinding (918) and dowel drilling (66) exceeded the PEL—further indicating that real-time monitoring can be useful in identifying the effectiveness of controls and work practices.

Conclusions

The current study provides additional evidence that direct-reading instruments can be useful in illustrating the variability of silica exposure over the task duration and provide information relevant to the task and exposure potential in a manner that is more time effective than integrated sampling methods, which require substantial turnaround time for results. The authors found that the plotted concentrations of silica dust as it fluctuates over the sample period may allow the observer to identify peaks in exposure and relate those RCS concentrations to worker behaviors or inadequate controls that may have contributed to the peak exposures.

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Conflict of interest

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Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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