CONTROL TECHNOLOGY AND EXPOSURE ASSESSMENT FOR OCCUPATIONAL EXPOSURE TO CRYSTALLINE SILICA: Case 21 – NON-RESIDENTIAL CONSTRUCTION

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), working under an inter-agency agreement with the Office of Regulatory Analysis of the Occupational Safety and Health Administration (OSHA), is conducting a study to survey occupational exposures to crystalline silica and to document engineering controls and work practices affecting those exposures. The performance of a thorough industrial hygiene survey for a variety of individual employers provides valuable and useful information to the public and employers in the industries included in the work. NIOSH will be conducting approximately 30 case study assessments to document engineering controls and the associated worker exposures to crystalline silica. The principal objectives of this survey are:

1. To identify and describe the control technology and work practices in use in operations associated with occupational exposures to crystalline silica, as well as determining additional controls, work practices, substitute materials, or technology that can further reduce occupational silica exposures.

2. To measure full-shift, personal breathing zone, respirable particulate exposures to crystalline silica. These samples provide examples of exposures to crystalline silica among workers across the many industries where silica is encountered. These exposure data, along with the control data described above, provide a picture of the conditions in the selected industries.

One of the industries selected for surveying was non-residential construction industry, (SIC code 1541).

The field studies for this project are directed by NIOSH research personnel and are conducted by Battelle Centers of Public Health Research and Evaluation and their subcontractor, Prezant Associates.

Silica is widespread in industry in the United States. Silica exposures have been identified in at least 47 different four-digit SIC codes. These SIC codes contain more than 230,000 establishments employing more than 3.5 million workers. The current OSHA Permissible Exposure Limit (PEL) for respirable dust containing quartz is calculated from the following formula:

The current NIOSH Recommended Exposure Limit (REL) for quartz is 0.05 mg/m^3, while the current American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®) is 0.1 mg/m^3. A review of OSHA's Integrated Management Information System (IMIS) database shows that many workers are exposed to crystalline silica at concentrations exceeding the OSHA PEL, the NIOSH REL, and the ACGIH TLV. There is a need to understand the nature of these silica exposures, what is causing the exposures, and what steps are being taken or could be taken to reduce the exposures (e.g., engineering controls, work practices, and personal protective equipment).

METHODS

This field study was conducted in accordance with 42 CFR 85a, the NIOSH regulations governing the investigation of places of employment. The first day at the site was spent meeting with company personnel (company management, employees) to arrange sampling on the subsequent day, and to walk through the plant to begin the industrial hygiene assessment of exposure and control technology. Employees with the highest potential silica exposures in each process area or operation were the major focus of the site visit. Workers selected for sampling were briefed on the sampling procedures to be conducted. Because the goal of this study is to assess the effects of engineering controls and work practices on crystalline silica exposures, samplers were placed outside of any respiratory protective equipment worn by the worker. Two days of sampling were conducted at this site, allowing up to two samples per worker to be collected.

Personal respirable particulate samples, approximately eight hours in duration (minimum sample duration of seven hours), were collected for each silica process worker. Respirable particulate samples were collected at a flow rate of 1.7 liters/minute using a 10-mm nylon cyclone (a Dorr-Oliver cyclone) and a pre-weighed, 37-mm diameter, 5-μm pore-size polyvinyl chloride filter supported by a stainless steel filter support in a two-piece filter cassette sealed with tape or a cellulose shrink band, in accordance with NIOSH Method 7500. In addition to the personal samples, a bulk sample of settled dust was collected in accordance with NIOSH Method 7500. All samples were analyzed by the OSHA Salt Lake Technical Center laboratory.

Sample data sheets were filled out by the field survey team to document all of the samples collected. Information contained on the sample sheets included: facility name, facility location, process name, worker identifier (included only to allow the "matching" of samples from the same worker on different days), job title and task performed, years of experience, pump number, pump flow rate, start times, stop times, and filter number. In addition, any unusual conditions, work practices, and use of personal protective equipment were also noted on the sampling sheets.

During the site visit, information pertinent to process operation and control effectiveness (e.g.. control methods, ventilation rates, work practices, use of personal protective equipment, etc.) was also collected. A thorough description of the process is essential to understanding the role of engineering controls and work practices. The work practices and use of personal protective equipment were also recorded for each worker sampled. Information was obtained from conversations with workers to determine if the sampling day was a typical work day. This information helped place the sampling results in proper perspective. Plant and process layout diagrams were also obtained.

The summary of engineering control information includes such items as ventilation flow rates and distance measurements. The proximity of the control systems to open doors or windows, general ventilation intakes and exhausts, and other interacting equipment (i.e., pedestal fans) were also noted. The age and history of the control systems, cost of control installation, maintenance practices, and operation and maintenance costs were determined from facility management, when possible. Any silica sampling data collected by the company showing the effectiveness of the controls were also collected and evaluated (for example, sampling data from before and after the control was installed).

Pertinent data on the employer and the industry were also collected. This information included the number of employees by job title, products produced, processes used, and work schedules. Information gathered about the facility or building(s) included the type of building construction, descriptions of general ventilation present, and age of the facility. This information is helpful for understanding the operations and processes being sampled.

NIOSH researchers calculated the exposures from the analytical results. For each employee sampled, an eight-hour time weighted average (TWA) exposure to respirable dust and respirable crystalline silica was calculated. The TWA was calculated assuming that exposure remained constant during the unsampled period.

Because the samples were single, full-shift samples, when the analysis of a sample results in a value less than the limit of detection (LOD) of the analytical method, the LOD was used to calculate the TWA, and the value(s) are reported as "at or below" the calculated value for individual samples (e.g., ≤ 0.05 mg/m^3). Only descriptive statistics for this site were generated. These included measures of central tendency, such as the mean, median, standard deviation, and the range. For the samples that were below the LOD, LOD derived concentrations were also used to calculate the descriptive statistics.

FACILITY AND PROCESS DESCRIPTION

On May 14, and 17, 1999, an industrial hygienist from Battelle Centers for Public Health Research and Evaluation (Battelle) and a technician from Prezant Associates (Prezant) conducted a site visit at the construction of a metropolitan retail mall (hereafter referred to as Facility 21). The purpose of the study was to identify and describe the control technology and work practices used in operations associated with occupational exposures to crystalline silica, and measure full-shift, personal breathing zone, respirable particulate exposures to crystalline silica.

Site 21 involves a general contractor and specialty subcontractors who are constructing a shopping mall. The building is a steel and concrete structure, with current construction activities including the installation of the brick exterior, and other interior finish work. The project began in May 1997, and the first retail outlet will be opened in the early fall of 1999. The project will be completed in the spring of 2000. Upon completion the mall will rise 12 stories encompassing 4 million square feet. The mall design features a brick facade exterior and an open interior atrium with pedestrian walkways, and panoramic glass window views. Tenants will include department stores, retail outlets, theaters, and food and beverage services. Infrastructure systems include HVAC systems, parking garages, escalators, and elevators. At the time of the site visit, construction of the steel framed and concrete slab garages was 90% complete. The mechanical systems, finishing for the facade and interior finishing were 50% complete.

Other Facility 21 features over the 20 acres included:

- general and subcontractor administrative trailers
- paved areas for the parking lot, and roadways to the mall
- yard storage for equipment and materials prior to use
- adjacent road construction

Facility personnel work 40 hours per week. Approximately 5% of the personnel at the site work in areas with some potential for silica exposure at the time of the visit. All personnel sampled were subcontractors of the general contractor for the facility.

Process area identification numbers for Facility 21 are as follows:

Area 1 Parking garage scaffolding
Area 2 Parking garage top deck
Area 3 First floor fireproofing batch mixer

Two Process Area 1 employees worked outside the parking structure, on scaffolding, about six feet apart. Using pneumatic chip hammers, they removed a 4-inch wide strip of concrete from the exterior edge of a 6-inch thick parking garage slab. Approximately 100 linear feet of concrete was removed from the edge of the slab. The resulting edge was then prepared for a shelf to support the future installation of a brick facade. The worker held the chip hammer (Chicago Pneumatic Chipper model CP4123 at 90 psi or Bosch hammer model 11230EVS with a 5/8 inch carbide bit) at chest level to maintain leverage against the work surface. Little visible dust was generated during this operation.

A third Area 1 worker used a circular saw (DeWalt DW 378G with 7-inch blade at 4600 rpm) nearby to cut concrete (21 feet by 1 ½ inches by 4 inches). This employee also used a torch to cut metal, as well as removed concrete using a chip hammer.

On the top deck of a parking garage (Process Area 2), workers were repairing incidental chips or “spalls” resulting from the handling and placement of the concrete slabs. The workers first used an electric chip hammer to remove concrete from the damaged area to leave a surface amenable to the patching compound. The area was then swept with a broom and the fines removed with an electric hand-held blower. The use of the blower resulted in visible aerosol generation which moved into the breathing zone of the operator. The patching compound (labeled as being a silica-containing product) was placed in a bucket and mixed with water using a hand-held power mixer. No visible aerosol was generated. The repair areas varied in their dimensions, but approximately 15 areas, with a mean size of about 10 inches by 5 inches and 3 inches deep, were repaired each sampling day,

The laborer mixing fireproofing (Process Area 3) worked from a platform immediately adjacent to a walk-in truck. The truck was parked at the perimeter, but under the decking of the unwalled first floor of the mall. The mixing operator moved individual bags of the dry fireproofing pre-mix (a non-silica product) to the top grate of a rotary mixer. The potential source for crystalline silica exposure was the access road 60 feet away. A steady stream of concrete pumping trucks was queued for concrete delivery to the construction site. The truck traffic, while slow, did generate visible dust that could be carried to the workstation, depending upon the wind direction. The mixer operator had no option for moving his workstation to mitigate exposure from the traffic. Significant non-silica dust exposure may have resulted from the worker opening the bags of the pre-mixed patching compound. The patching compound was mixed to two consistencies, fine and coarse. Of the 35 batches (5000 pounds) prepared each day, 20 were coarse and 15 were fine. A 4-foot high personal comfort fan was positioned behind the worker, pushing the dust generated by the mixing operation away from the worker.

RESULTS

Air Sampling

Medians, means, ranges and standard deviations are given in Table 1 for the respirable silica concentration measurements and Table 2 for the respirable dust concentration measurements. The individual sampling results are given in Attachment I.

In addition to air sampling, three bulk samples of settled dust were taken to determine the presence of quartz, tridymite, and cristobalite. The bulk analysis showed the sample to contain 30%, 30%, and 40% quartz and no tridymite, or cristobalite. The percentage of crystalline silica in personal samples ranged from 12% to 14% for those samples with a detectable mass of silica.

Table 1
Facility 21 TWA Respirable Silica Concentration Summary Data by Job Title (mg/m^3).

Job Title	n	Mean	Median	Standard Deviation	Range	Number Non-Detected
Pump Tender	1	0.015	0.015	0	≤0.015-0.015	1
Cement Mason	2	0.014	0.014	0.001	≤0.013-0.015	2
Laborer	4	0.719	0.496	0.572	0.317-1.567	0

Table 2
Facility 21 TWA Respirable Dust Concentration Summary Data by Job Title (mg/m^3).

Job Title	n	Mean	Median	Standard Deviation	Range
Pump Tender	1	5.143	5.143	0	5.143-5.143
Cement Mason	2	0.140	0.140	0.079	0.084-0.196
Laborer	4	5.346	3.408	5.270	1.512-13.057

Control Technology and Associated Costs

Several method were utilized to help ensure the health ad safety of the workers at this site. The primary means of controlling silica exposures at Facility 21 was to minimize the number of employees in the area where the crystalline silica aerosols were being generated. This involved the scheduling of construction activities to minimize the exposures of workers not directly involved with silica-generating activities. In addition, the general contractor provided two on-site safety personnel to conduct safety and health inspections and evaluations. The subcontractors performing the concrete repair work (Process Area 2) employed a safety specialist who made site safety inspections, performed fit tests, and implemented a safety plan for the subcontract employees.

Employees have been informed and were knowledgeable about the sources and health effects of silica exposure. Conventional work practices to minimize exposure were understood. The union and the employer were cited by the workers as sources of training regarding silica.

Respirator wearers had some experience in being fit-tested, although the extent among the subcontractors was not assessed. Medical surveillance was not universally provide to the employees at this site. Respirators were not required during the activities performed by subcontractor's employees, but filtering-face piece respirators were worn by all process area personnel if their task involved the generation of an airborne aerosol. The pump tender, who mixed the fire-proofing material, wore a half-face piece respirator during mixing.

Work Practices

Table 3 gives a summary of the job locations within Facility 21, job titles and work activities. The percentages given for each work activity are for that particular sampling day.

Table 3
Summary of Job Locations, Job Titles, and Activities

Process Area	Job Title/Description	Activities
2	Laborer 1	One sampling day only – 100% of time spent patching concrete floor. This involved sawing (Milwaukee 7¼-inch #6365 saw), chipping (Makita #HR4000C chipper) and drilling (Bosch #11224VSR drill) of the concrete surface. Followed by sweeping and blowing (Makita #4014NV hand-held blower) of the debris. The area was patched with a cement mixture. Approximately 80% of the shift is spent performing silica dust generating activities. Worker wore a GPT F-950 filtering-face piece respirator when mixing cement, about 15% of the time.
1	Laborer 2	One sampling day only – 65% of time spent cutting concrete with a Dewalt DW378G saw with 7-inch blade operating at 4600 rpm. Worker wore filtering-face piece respirator (Gerson #2737, N95) during cutting operation. 25% of time spent using a torch to cut metal. !0% of time spent chipping concrete using a Bosch 11230EVS hammer with 5/8-inch bit.
1	Laborer 3	One sampling day only – 100% of time spent chipping concrete using a Chicago Pneumatic CP4123 chipping hammer. Worker wore filtering-face piece respirator (Gerson #2737, N95) 50% of the time.
1	Laborer 4	One sampling day only – 100% of time spent chipping concrete using a Chicago Pneumatic CP4123 chipping hammer. Worker wore filtering-face piece respirator (Gerson #2737, N95) 50% of the time.
Process	**Job**	**Activities**

Area	Title/Description	
2	Cement Mason	Both sampling days – 100% of time spent patching concrete floor. This involved sawing (Milwaukee 7¼-inch #6365 saw), chipping (Makita #HR4000C chipper) and drilling (Bosch #11224VSR drill) of the concrete surface. Followed by sweeping and blowing (Makita #4014NV hand-held blower) of the debris. The area was then patched with a cement mixture. Approximately 80% of the shift is spent performing silica dust generating activities. Worker wore a GPT F-950 filtering-face piece respirator when mixing cement, about 15% of the time.
3	Pump Tender	One sampling day only – 100% of time spent mixing fireproofing material. After mixing the material is pumped to other levels of the building where other employees apply it. The material is poured into the hopper and mixed with water. Worker wore 3M 8210 filtering-face piece respirator during mixing of the course material and a 3M half-face piece respirator with dust filters during the mixing of the fine material. Worker wore a respirator about 15% of the total time.

CONCLUSIONS AND RECOMMENDATIONS

The air sampling results indicated that four of the seven personal exposures exceeded both the NIOSH REL for crystalline silica and the OSHA PEL for respirable dust containing crystalline silica. All four of the exposures exceeding the exposure limits were laborers performing cutting and chipping activities. The use of water for dust suppression is a recognized method for controlling dust exposures during many operations, particularly for cutting. Wet-cut saws are currently on the market, and the use of water, both as a dust suppressant and as a coolant, may increase the life of the blades in use. Consideration should be given for the use of water for reducing these workers' exposures

In addition, given the exposures measured, a formal respiratory protection program should be established and employees should be required to wear appropriate respiratory protection. Because of the extent of the exposures, filtering-face piece respirators and half-face piece respirators are not protective enough. For crystalline silica exposures less than or equal to 50 times the NIOSH REL of 0.05 mg/m^3, NIOSH recommends at a minimum, the use of an approved full-face piece air purifying respirator with high efficiency (N100) filters. The issue of filter efficiency is being reviewed, and may be revised by NIOSH at a later date. An effective respiratory protection program includes, but is not limited to, respirator fit-testing, medical monitoring to ensure workers are capable of wearing a respirator, and training on the proper use and care of the respirator.

Attachment I
Individual Sampling Results
Facility 21

Sample Date	Sample Time (HH:MM)	Resp. Conc. (mg/m^3)	Percent Silica	Silica Conc. (mg/m^3)	Job Title
5/17/99	**7:27**	**4.321**	**12**	**0.519**	**Laborer 1**
5/17/99	7:26	0.084	nd	≤0.013*	Cement Mason
5/14/99	**7:31**	**13.057**	**12.0**	**1.567**	**Laborer 2**
5/14/99	**7:30**	**1.512**	**21**	**0.317**	**Laborer 3**
5/14/99	6:40	5.143	nd	≤0.015*	Pump Tender
5/14/99	6:15	0.196	nd	≤0.015*	Cement Mason
5/14/99	**7:35**	**2.496**	**19**	**0.474**	**Laborer 4**

* - Not Detected. [LOD/(respirable dust mass)] x 100% was used for percent silica calculation. Samples exceeding the NIOSH REL are shown in bold.