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Successful Reduction of Silica Exposures at a Sanitary Ware Pottery

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Researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted a joint survey with the New Jersey Department of Health (NJDOH) to measure crystalline silica exposures and evaluate the adequacy of the existing control measures for reducing these exposures at a sanitary ware pottery. This survey found that 95% of the personal and area samples from the Slip House, Casting, Glaze Spray, and Glaze Preparation Departments exceeded the NIOSH Recommended Exposure Level (87% exceeded the Occupational Safety and Health Administration Permissible Exposure Level) for crystalline silica. Three years later, a follow-up survey found statistically significant reductions in respirable crystalline silica exposures in two of four plant departments, and statistically significant reductions in area concentrations in all four plant departments. These reductions were accomplished through a combination of automating and enclosing the batching system in the Slip House and by replacing the mold parting compound with a nonsilica material, altering the method of dry sweeping, cleaning of castings while damp, improving exhaust ventilation at the spray booths, and improved housekeeping.

It was estimated that in the United States, 1 697 075 workers were potentially exposed to respirable crystalline silica dust in 1986. The pottery and related products industry accounted for about 30 000 of these potential exposures.[1] The National Center of Health Statistics estimates that annually 250 workers nationwide are diagnosed as having silicosis; of this number an estimated 135 will die of the disease.[2] It is possible that the estimated number may be low (New Jersey[3] alone reports 60 silicosis cases per year).

The National Institute for Occupational Safety and Health (NIOSH) has identified the Ten Leading Work-Related Diseases and Injuries[4] and has focused its prevention and research efforts toward the goal of their prevention; occupational lung disease heads this list. As part of these efforts, NIOSH is engaged in providing assistance to improve existing surveillance systems, develop new approaches to identify occupational illness, and monitor trends of occupational disease and injury. This includes a five-year program entitled the "Sentinel Event Notification System for Occupational Risks" (SENSOR), which was initiated in 1987.[5] SENSOR is a cooperative state-federal program designed to develop local capability for the recognition, reporting, and prevention of selected occupational disorders. New Jersey is one of 10 states currently participating in this program and one of 3 states involved in a silicosis surveillance program. The New Jersey Department of Health (NJDOH) SENSOR Silicosis Surveillance Program, through morbidity (hospital discharge) data, mortality (death certificate) data, and physician reporting has identified the pottery industry as a high silicosis risk industry in their state.[3]

Through the New Jersey Silica Surveillance Program, NJDOH identified a sanitary ware pottery plant where cases of silicosis had been reported in two former employees. A preliminary site visit by NJDOH revealed potential worker overexposure to respirable crystalline silica throughout the

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC).

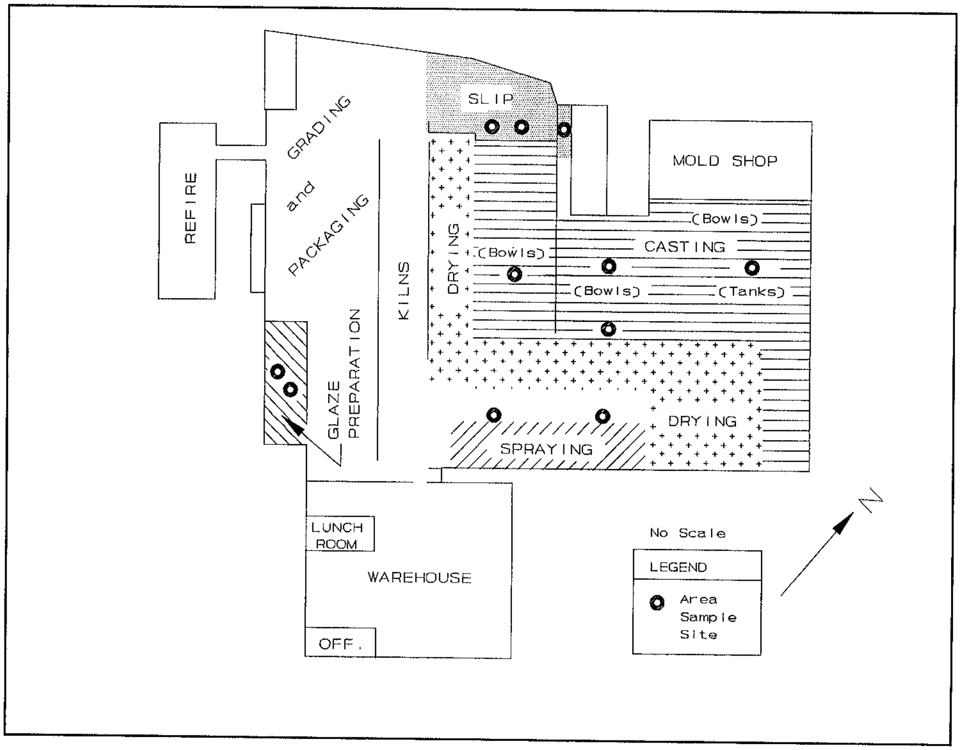

FIGURE 1. Floor plan

tanks, etc). After the slip has been allowed to harden for an hour or more, the molds are removed, dusted with a parting compound, and near the end of the shift, these molds are reassembled in preparation for the next day's pouring. Most of the castings dry for a few hours after being removed from the molds before being smoothed and trimmed, using an assortment of hand tools. However, castings poured on a Friday dry over the weekend before being smoothed and trimmed. (Pieces that have dried only a few hours prior to smoothing and trimming are known as "green" castings. Those that have dried for two or more days are known as "white" castings.) After trimming and smoothing, the pieces are dried for an additional one to two days before delivery to the Glaze Spray Department.

In the Glaze Spray Department, the pieces are inspected and then sprayed with one or more coats of glaze in ventilated booths. These products are then fired in a tunnel kiln, inspected, packaged, and shipped. The glaze is produced in the Glaze Spray Department by emptying bags of raw materials in one of several pebble mills (blenders) to be mixed.

plant.[6] Engineering controls, respiratory protection, and medical surveillance were found to be inadequate or nonexistent. To determine specifically which operations required control, researchers from NIOSH and NJDOH conducted a joint survey in this facility to identify and quantify the respirable crystalline silica sources. Specific control recommendations for reducing crystalline silica exposures were made based on the identified exposure sources. A follow-up survey was conducted three years later. The purpose of this article is to identify the dust-control measures that were implemented and document the reduction in the exposure to respirable crystalline silica.

OPERATION DESCRIPTION

This facility, employing 150 workers, operates five days a week, manufacturing 9500 units of sanitary ware—vitreous china products, such as lavatories and toilet bowls. Figure 1 describes the plant layout. A flow chart of the operation is presented in Figure 2. The principal raw materials used include clay (hydrated aluminum silicates), feldspar (alkaline aluminum silicates), and flint (crystalline silica). In the Slip House, the dry materials are combined with water to form a liquid clay slip that is pumped to the Casting Shop.

The Casting Shop consists of approximately 50 workstations with one worker per station. The worker pours the slip into plaster molds with each worker producing from 24 to 80 pieces per day, depending on the number of hours the employee works and the type of fixtures being cast (bowls,

HEALTH EFFECTS

Exposure to respirable dust containing crystalline silica is associated with silicosis, an occupational lung disease. In its earliest stage, silicosis can be seen on x-rays as scarring on the lungs; there are no physical symptoms. As the disease progresses, the symptoms include frequent dry coughing, shortness of breath, wheezing, and increased tiredness. These symptoms will become worse in the advanced stages until death results from respiratory failure, heart failure, pneumonia, or other complications.

The rate at which silicosis develops can vary. In chronic silicosis, the duration of exposure before the disease is first diagnosed is usually 20 or more years. In accelerated silicosis, duration of exposure is usually between 5 and 15 years. Acute silicosis is usually associated with a very high exposure to silica for less than 5 years.[7]

NIOSH has classified crystalline silica as a potential occupational carcinogen.[8] The NIOSH Recommended Exposure Limit (REL)[9] for crystalline silica is 50 $\mu g/m^3$ as a Time-Weighted Average (TWA) for periods up to 10 hours, based on a 40-hour work week. The OSHA Permissible

Exposure Limit (PEL)[10] for crystalline silica (quartz) is 100 $\mu g/m^3$ as an 8-hour TWA.

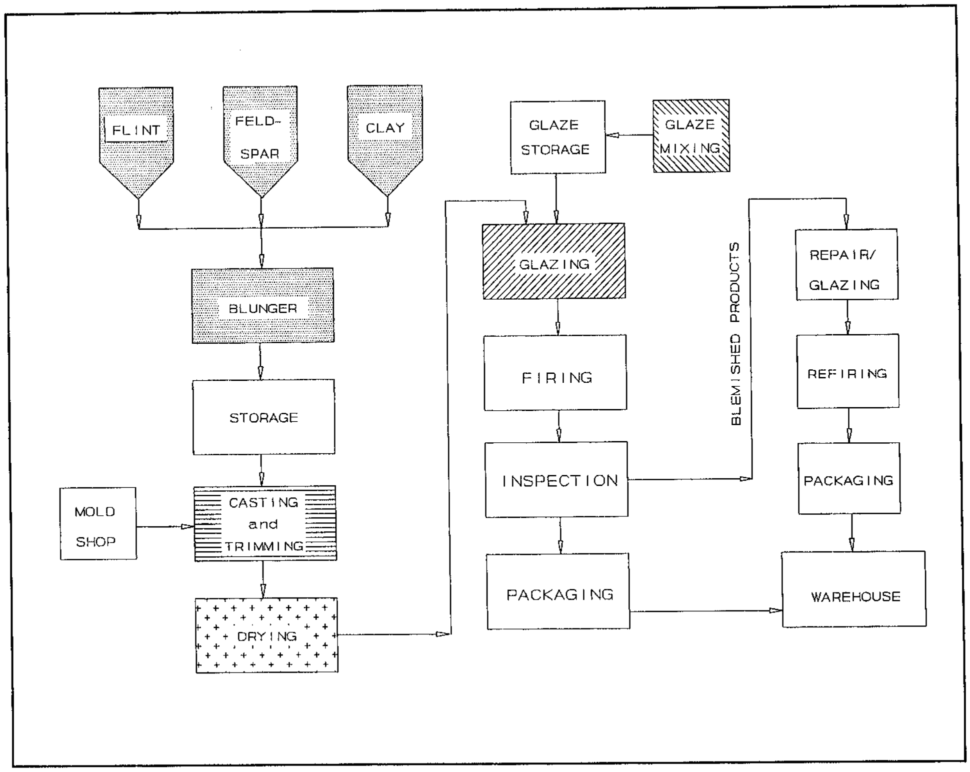

FIGURE 2. Flow chart

METHODOLOGY

Exposures to respirable crystalline silica were evaluated initially and three years later, after several of the dust control measures recommended initially had been implemented. The data collecting methodology used during the initial survey was duplicated as much as possible in the follow-up survey. This was accomplished by sampling employees performing the same job descriptions (bowl caster, tank caster, glaze sprayer, etc.) in each department, and using the same site locations for the area samples. Samples were collected over 3-day periods for both surveys. The company-reported production levels, 9500 units per (5-day) week, and the number of employees, approximately 150, were similar during both studies. Also, the environmental conditions were similar for both studies (same time of year, June; similar temperature and wind conditions; and all operations performed in an enclosed building).

Personal and area samples for respirable dust were collected on preweighed, 37-mm diameter, 5-μm pore size, PVC membrane filters. The filters were preceded by a nylon cyclone to separate the respirable mass; the sampling pumps were operated at 1.7 L/min. All samples were analyzed for respirable mass according to NIOSH Method 0500, and crystalline silica by NIOSH Method 7500, using X-ray diffraction.[11]

In the initial survey, 30 personal and 22 area samples were collected in the Slip House, Casting, Glaze Spray, and Glaze Preparation Departments. In the follow-up survey, 50 personal and 33 area samples were collected in the same four departments. Control measures installed since the initial survey for the purpose of reducing airborne crystalline silica concentrations were documented.

TABLE I. Comparison of the Geometric Means (GM) of the Respirable Crystalline Silica Personal Exposures and Area Concentrations

	Respirable Crystalline Silica ($\mu g/m^3$)						
	Base (Initial Survey)			After Implementing Controls (Follow-up Survey)			% Change
Department	*GM*	*UCL*[A]	*LCL*[B]	*GM*	*UCL*[A]	*LCL*[B]	*in GM*
PERSONAL SAMPLES							
Casting	130	150	110	27	41	17	−79%
Glaze Spray	220	290	170	34	49	24	−85%
Glaze Prep	150	270	88	179	870	37	+17%
AREA SAMPLES							
Slip House	250	730	84	21	37	12	−92%
Casting	98	140	67	11	16	8	−89%
Glaze Spray	73	140	39	15	25	9	−79%
Glaze Prep	160	1000	25	12	23	7	−93%

[A]UCL: Upper 95% confidence level
[B]LCL: Lower 95% confidence level

RESULTS

Tables I, II, and III show the results of these two surveys. Table I lists the geometric means and the upper and lower 95% confidence levels[12] of the respirable crystalline silica data. Table II lists the same information for the respirable mass data. The percent of samples exceeding the NIOSH REL and the OSHA PEL for silica is listed in Table III.

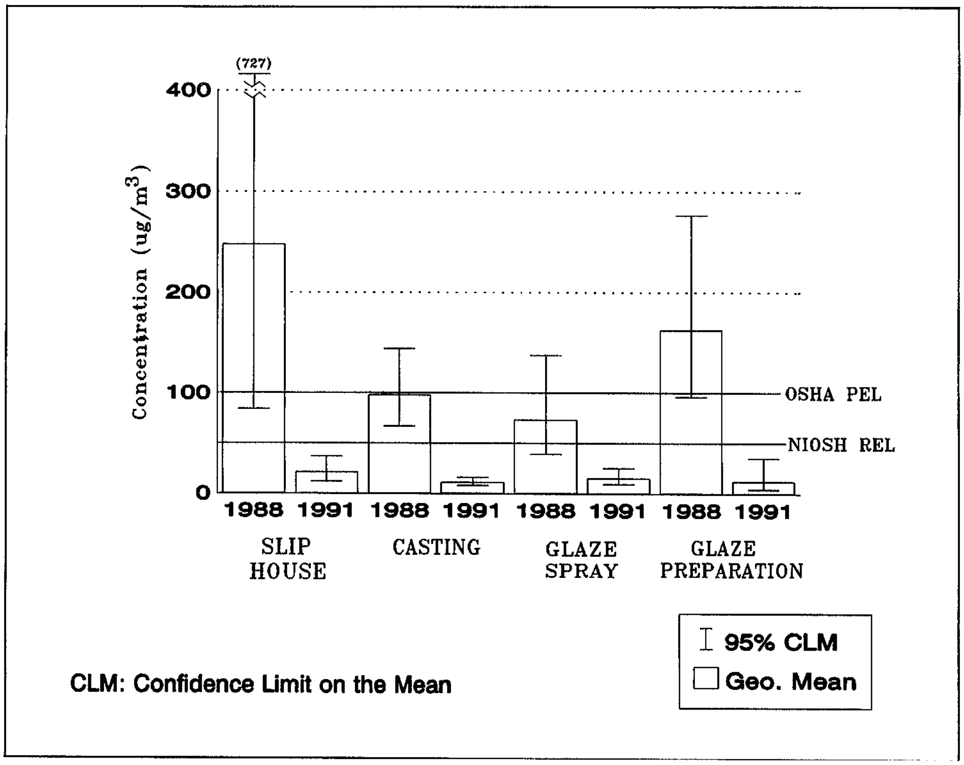

FIGURE 3. Geometric means and 95% confidence limits of the area concentration

Figure 3 shows a comparison of the mean area concentrations of respirable crystalline silica of the initial and follow-up surveys. All four departments show statistically significant (95% confidence level) reductions: Slip House (92%), Casting (89%), Glaze Spray (79%), and Glaze Preparation (93%). Figure 4 shows a comparison of the mean personal exposures to respirable crystalline silica of the initial and follow-up surveys. Statistically significant reductions in mean exposures occurred in Casting (79%) and Glaze Spray (85%).

The sampling results for respirable mass are similar to those for respirable crystalline silica. Comparing the respirable mass results in the follow-up survey with those in the initial survey, statistically significant reductions of the mean area concentration occurred in all four departments: Slip House (79%), Casting (53%), Glaze Preparation (80%), and Glaze Spray (85%). There were also statistically significant reductions in the mean personal exposure to respirable mass in Casting (48%) and Glaze Spray (85%).

TABLE II. Comparison of the Geometric Means (GM) of the Respirable Mass Personal Exposures and Area Concentrations

	Respirable Mass (μg/m³)						
	Base (Initial Survey)			*After Implementing Controls (Follow-up Survey)*			*% Change*
Department	*GM*	*UCL*[A]	*LCL*[B]	*GM*	*UCL*[A]	*LCL*[B]	*in GM*
PERSONAL SAMPLES							
Casting	580	780	420	300	490	180	−48%
Glaze Spray	1900	2700	1400	300	470	190	−85%
Glaze Prep	540	1100	280	750	3100	180	+37%
AREA SAMPLES							
Slip House	800	2300	280	170	280	100	−79%
Casting	300	490	190	140	190	100	−54%
Glaze Spray	250	1000	61	51	130	20	−80%
Glaze Prep	470	5300	41	65	160	26	−72%

[A]UCL: Upper 95% confidence level
[B]LCL: Lower 95% confidence level

Discussion of Implemented Controls

Slip House

In the initial survey, powders were transferred manually from the silos to the blungers (slurry mixing tanks) by means of an open bucket on a front-end skip loader. A slide gate was opened and the powdered raw material flowed by gravity from a silo into the bucket. The loader traveled approximately 50 feet and emptied the powder into one of four blungers. Dust clouds were visible during both the filling and emptying of the bucket of the loader. The mean respirable crystalline silica concentration was 250 μg/m³. The mean respirable mass concentration was 800 μg/m³. (Since workers spent very little time in this area, no personal samples were collected.) At the time of this survey, the company was developing plans to modernize the material-handling operation in the Slip House by installing an enclosed, automated system to move the dry materials from the silos to the blungers.

An automated, enclosed, batching system was installed and was operating during the follow-up survey. Powders were automatically weighed out and pneumatically conveyed to the blungers. Respirable crystalline silica concentrations were reduced 92% to a mean of 21 μg/m³. None of the nine samples collected in the follow-up survey exceeded the NIOSH REL or the OSHA PEL for silica. (Respirators were not required by the plant in this area.)

Casting Department

The major crystalline silica exposure source was during the dusting of the molds with a parting compound. In the initial survey, the parting compound consisted of reclaimed glaze overspray, which contained from 20 to 25% crystalline silica. When applied from a powder-type bag dispenser, a visible cloud of dust surrounded the worker. Another silica exposure source was the cleaning (wiping and scraping) of “white” castings. Real-time measurements made during this operation indicated that the worker’s dust exposure was about 4.5 times greater while cleaning “white” castings than when cleaning “green” castings. A third silica source was reentrainment of dust from scrap and dust that had accumulated on the floor throughout the plant. Mean respirable crystalline silica exposure was 130 $\mu g/m^3$. Mean respirable mass exposure was 580 $\mu g/m^3$. The following recommendations were made: (1) substitution of a noncrystalline silica parting compound for the glaze overspray, (2) reduction of the number of “white” castings to be cleaned by better scheduling or remoistening “white” castings by wiping with a damp sponge before cleaning and trimming, and (3) improved housekeeping to reduce reentrainment of dust from scrap and waste on the floor.

During the follow-up survey, a nonsilica parting compound (perlite) had been substituted for the high crystalline silica reclaimed glaze overspray. Dust clouds still existed around the worker; however, this powder is silica-free. While it was not possible to completely eliminate cleaning “white” castings, practices have been modified so that the worker now wets “white” castings with a damp, nonabrasive sponge prior to cleaning. To reduce the effects of cross contamination from other operations, curtains were hung from the ceiling to the floor in one area of Casting. From these changes, respirable crystalline silica concentrations were reduced 89% to a mean level of 11 $\mu g/m^3$. Mean personal exposures were reduced 79% to 27 $\mu g/m^3$. Seven of twenty-four personal samples exceeded the NIOSH REL and two exceeded the OSHA PEL. None of the 12 area samples exceeded the NIOSH REL or the OSHA PEL. (Respirators

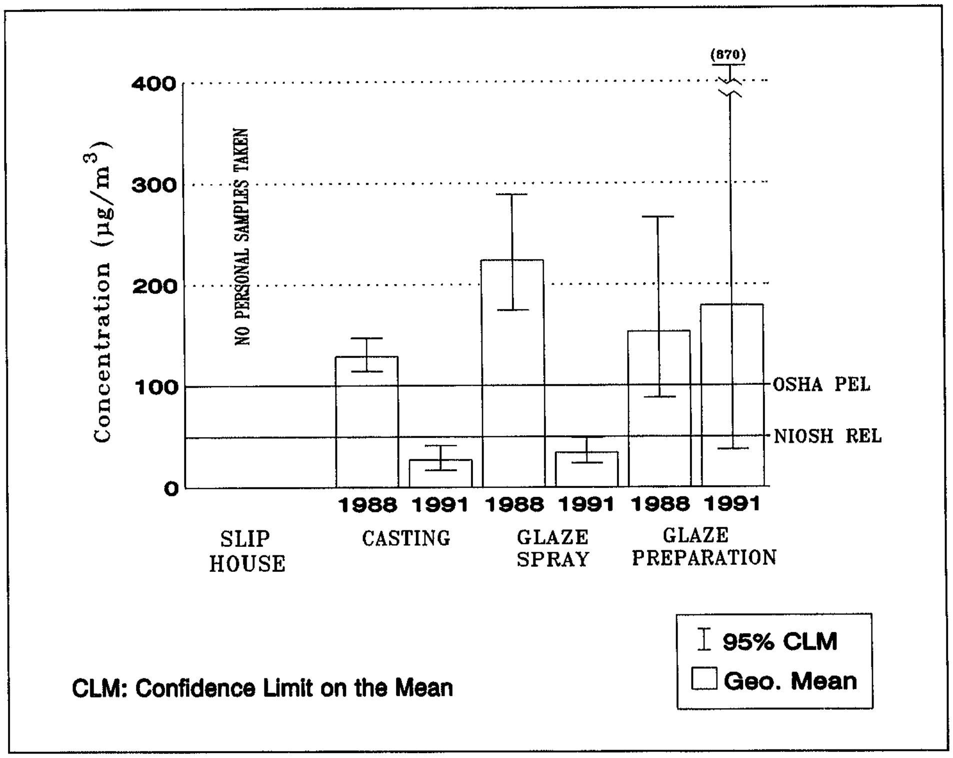

FIGURE 4. Geometric means and 95% confidence limits of personal exposures

TABLE III. Comparison of Number of Samples Exceeding the NIOSH REL and the OSHA PEL for Crystalline Silica

	Respirable Crystalline Silica					
	Base (Initial Survey)			*After Implementing Controls (Follow-up Survey)*		
Department	*No. of Samples*	*% > REL*[A]	*% > PEL*[B]	*No. of Samples*	*% > REL*[A]	*% > PEL*[B]
PERSONAL SAMPLES						
Casting	15	100	95	24	29	8
Glaze Spray	18	100	100	20	25	5
Glaze Prep	6	100	83	6	83	50
AREA SAMPLES						
Slip House	6	100	83	9	0	0
Casting	7	88	88	12	0	0
Glaze Spray	6	66	17	6	0	0
Glaze Prep	3	100	66	6	0	0

[A]50 $\mu g/m^3$ TWA, up to 10 hrs/day for 40-hr week
[B]100 $\mu g/m^3$ TWA, 8 hrs/day for 40-hr week

are required during certain operations in this area such as dusting and cleaning of castings.)

Glaze Spray Department

Glaze was sprayed onto pieces in either a semi-automatic, an automatic, or one of three manual spray booths. In the initial survey, the capture velocities at the face of most of these booths were low, averaging 40 to 65 ft/min. (The recommended control face velocities for these types of booths range from 100 to 150 ft/min when the operator works outside the booth.[13] Also, there were holes in the walls of some of the booths. "Man-cooler" fans aimed toward these booths further reduced their effectiveness because the airflow patterns at the booths' face were disrupted. Respirable crystalline silica exposures averaged 220 $\mu g/m^3$. Respirable mass exposures averaged 1900 $\mu g/m^3$. Recommended changes were: (1) upgrade and repair the spray booths, (2) eliminate the use of "man-cooler" fans, and (3) reduce the atomizing air pressure used in the spray guns to minimize overspray.

During the follow-up survey, all the "man-cooler" fans had been removed and the holes in the booths repaired. In addition, one manual spray booth was eliminated. Booth ventilation was increased, with face velocities ranging from 85 to 260 ft/min. No change was made in the pressure to the spray guns. Mean respirable crystalline silica concentrations were reduced 79% to 15 $\mu g/m^3$. Personal exposures were reduced 85% to a mean exposure of 34 $\mu g/m^3$. Five of twenty personal samples exceeded the NIOSH REL and one exceeded the OSHA PEL. None of the six area samples exceeded the NIOSH REL or the OSHA PEL. (Respirators are required while applying glaze spray.)

Glaze Preparation Department

During the initial survey, bags of powdered material were manually cut open and emptied, one at a time, into one of several pebble mills (blenders). Visible dust escaped from the blender as each bag was emptied and from the empty bags when the operator manually compressed these bags prior to disposal. A charged fogger was being used to suppress the dust. Measurements with a real-time dust monitor indicated that this fogger had no noticeable effect on the dust levels. The mean respirable crystalline silica exposure was 150 $\mu g/m^3$, the mean respirable mass exposure was 540 $\mu g/m^3$. Recommended changes were to (1) improve the method for filling the pebble mills (e.g., install a ventilated dump station), and (2) eliminate the charged fogger, since it was ineffective.

During the follow-up survey, except for the elimination of the ineffective charged fogger and improved housekeeping, no changes had been made in the method for opening and emptying bags of powdered materials into the pebble mills and disposing of the empty bags. Personal exposures, due primarily to poor work practices and a lack of dust controls, remained high with five of six personal samples exceeding the NIOSH REL and three of six personal samples exceeding the OSHA PEL. However, the respirable crystalline silica concentration was reduced 94% to a mean of 12 $\mu g/m^3$. This appears to be due mainly to improved housekeeping practices in this area and throughout the plant, since no other changes had been made in Glaze Preparation. None of the six area samples exceeded the NIOSH REL or the OSHA PEL. (Respirators are required during bag emptying and disposal operations.)

Housekeeping

During the initial survey, housekeeping throughout the plant was poor. Accumulations of scrap on the floor and dust on surfaces of the equipment was evident throughout the plant. Dry sweeping with bristle-type brooms and the use of hand-scoop shovels were the primary method for removing debris from the floor. The mean respirable crystalline silica concentration in these four departments was 140 $\mu g/m^3$. The mean respirable mass concentration was 450 $\mu g/m^3$. It was recommended that housekeeping be improved throughout the plant such as eliminating dry sweeping and improving methods for cleaning scrap material (e.g., using a HEPA-equipped vacuum cleaner).

During the follow-up survey, housekeeping had improved. Squeegee-type brooms replaced the bristle-type brooms. A HEPA-equipped vacuum had been tried but was underpowered, resulting in frequent motor burnouts in the unit. One employee is now permanently assigned to cleaning throughout the plant. When other employees are available, they also assist in cleaning. Area concentrations of both respirable mass and crystalline silica were reduced in all departments, which can be partly attributed to improved housekeeping. (Respirators are required while cleaning in most areas of the plant.)

CONCLUSION

An occupational illness, silicosis, was identified in the pottery (sanitary ware) industry. Through a cooperative state-federal effort (SENSOR), dust sources were identified, control measures recommended, and a follow-up study made to determine the effectiveness of these changes. Many of the controls recommended and used were both simple and available. Since the operations in this plant are similar to those seen elsewhere in this industry, an analogous approach should also reduce worker crystalline silica exposures and subsequent risk of silicosis in other plants. Silicosis is a disease that can be eliminated from the workplace.

At this facility, obvious changes have been made, such as modernization of powder handling systems, substitution of a nonsilica parting compound, elimination of "man-cooler" fans, repair of spray booths, together with increased ventilation rates, modification of work practices in cleaning "white" castings, and improved housekeeping practices. It was not possible to determine how much each of these changes contributed individually, but the end result of the combination of changes was a significant reduction in respirable crystalline silica exposures.

Mean exposures to respirable crystalline silica were reduced to below the NIOSH REL in the Casting and the Glaze Spray departments, the two areas of the plant employing the largest number of employees. Even in the Glaze Preparation Department, where no engineering changes had been made, improved housekeeping reduced general work area concentrations of respirable mass and crystalline silica. The company has plans to redesign this department and install a material-handling system to contain the dust during bag emptying and disposal, which should reduce the worker's exposure in this department.

Even though there were significant reductions in the respirable crystalline silica concentrations in all departments, worker exposures continue to exceed the NIOSH REL (29% of the personal samples in Casting and 25% in the Glaze Spray Department). Additional improvements are needed such as those already recommended: lowering the pressure in spray guns and further improved housekeeping such as eliminating dry sweeping and using a suitable HEPA-equipped vacuum cleaner. Until the exposure of all workers to crystalline silica can be maintained below the NIOSH REL, the plant needs to continue its respirator program.

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