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Case Studies

Silica Exposure During Granite Countertop Fabrication

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Occupational exposure to crystalline silica has received renewed attention. The National Conference to Eliminate Silicosis in March 1997, was extensive. The conference included workshops that covered silica exposures and the risks in construction, the mining industry, quarries, and foundries.[1] The Occupational Safety and Health Administration (OSHA) launched a special emphasis program in May 1996, to inform employers and employees about the occurrence, hazards, and controls of crystalline silica.[2] Some state OSHA plans adopted the emphasis, including the state of Washington.

It is well documented that chronic and, in some cases, acute exposure to dust containing silica can cause serious health problems.[3] Silicosis is an incurable lung disease resulting in death or disability. Smokers are at an increased risk; smoking and silica act synergistically in causing chronic obstructive disease in the lung.[4–6] Silica exposure has also been associated with other lung diseases, such as tuberculosis[7–8] and lung cancer.[9–11] Washington state alone recorded 201 deaths from silicosis between 1968 and 1992.[12] The health consequences have been known for years for workers in mining and manufacturing.[13] It has been known for over 80 years that fabrication of granite produces silicosis.[14]

A specific type of granite fabrication was the focus of a number of recent industrial hygiene surveys in the state of Washington reported in this case study. The authors representing the Washington State Department of Labor and Industries and the University of Washington's Field Research and Consultation Group participated in a number of work site surveys of businesses fabricating granite products for commercial and residential structures. Workers were engaged in fabricating granite kitchen countertops, kitchen islands, tables, tiles, lathed banisters, and other customized stone pieces. Tasks that could generate visible and significant airborne granite dust include cutting, grinding, and finishing. All shops surveyed were found to work with limestone, granite, or marble. Granite may be expected to most consistently present the potential for exposure to silica.

Crystalline silica is a common but variable component of granite. The percentage typically varies by color. The lighter colors contain greater percentages of crystalline silica or quartz (e.g., white ranges 25–45%). The darker granites typically contain less (e.g., black ranges 0–15%).

This case study reports on levels of exposure to airborne crystalline silica and methods of dust control for several granite countertop businesses in the State of Washington. Exposures are likely in other regions of the country where these products are in demand. Though the literature contains reports of silica exposures for stonecutters and rock crushers,[15–18] the authors were unable to find reports specific to the granite countertop industry. Granite countertop fabrication was observed to be an emerging small employer industry in the state of Washington. This case study is also an example of several public agencies targeting an occupational health hazard in a specific industry through research, information, consultation, and enforcement.

Methods

The industrial hygiene surveys contributing to the report were performed by three different groups. The State of Washington Department of Labor and Industries consultants and the University of Washington Field Research and Consultation Group (FRCG) performed surveys during 1997 at the request of a number of employers in the granite fabrication industry. The enforcement branch of the State of Washington's Department of Labor and Industries, or state OSHA program, conducted a number of target health inspections in the same industry in 1997. Six separate businesses were surveyed. The companies visited employed from three to ten employees and are believed to be representative of the industry in the state of Washington.

Forty-three personal airborne respirable particulate samples were collected at the six work sites and analyzed for crystalline silica. Respirable particulate sampling by the FRCG was performed with SKC aluminum cyclones (catalog #225-01-02) and 37 mm 0.5 PVC pre-weighed filters with Gilian and SKC pumps calibrated at 2.5 liters per minute. Respirable particulate sampling by Labor and Industries utilized MSA 10 mm nylon cyclones and 37 mm 0.8 PVC pre-weighed filters with Gillian pumps calibrated at 1.7 liters per minute. The collection of respirable particulate by the aluminum and nylon cyclones are believed to produce similar results.[19] Samples were analyzed for crystalline silica using x-ray diffraction (XRD) for University of Washington samples and by Fourier transform infrared spectroscopy (FTIR) for the Department of Labor and Industries samples in accordance with National Institute of Occupational Safety and Health (NIOSH) Methods 7500 and 7602, respectively. Both the FRCG and Labor and Industries laboratories are AIHA-accredited. The laboratories reported the sampling results as micrograms of crystalline silica quartz per cubic meter of air. The results are presented without distinguishing the two different sampling and analytical methods used. The differing methods are accepted by the state of Washington for the evaluation of worker exposure to crystalline silica with respect to the state's permissible exposure limit.

Six samples were not included in the results because they were judged not representative of a worker's full shift exposure. Two sample filters became visibily wet from spray or mist caused by water thrown from the tool action. Analysis of these filters indicated high levels of exposure (silica concentrations were 0.48 and 0.2 mg/m^3). These high exposures were considered an artifact, and it was reasoned that the water itself contained crystalline silica. Re-sampling with more careful postioning of the sampler eliminated the water contamination. Another sample was excluded because the tool use was not known, and therefore, the process could not be classified as dry or wet (silica concentration was 0.54 mg/m^3). Three additional samples were excluded from the data set because workers did not complete their full shift (silica concentrations were 0.58 [dry], 0.13 [wet], and 0.16 [wet] mg/m^3).

Results

The fabrication of a kitchen or bathroom counter required the use of several types of tools. Smoothing or forming edges were performed by dry or wet grinding with a handheld angle grinder or by water-fed stone milling tool. Cutting holes or small pieces was performed dry or wet with a handheld circular saw. All companies used a water-fed bridge saw to cut large slabs of stone prior to fabrication.

Based on the tool use, the six work sites were divided into two types of processes for the purpose of this case study. Those that used handheld grinders and saws without water on a regular basis were identified as using *dry processes*. Those that used predominantly wet methods, such as water-fed angle grinders and milling tools, were called *wet processes*. Work sites using dry processes also used water-fed tools.

Workers were sampled to determine their eight-hour time-weighted average (TWA) exposure to respirable crystalline silica. Thirty-seven personal samples are presented in this case study. The number of samples collected during dry processes and wet processes are 19 and 18, respectively. Seventy percent of the personal samples (26/37) represent at least six hours of an eight-hour shift. Time not sampled was assumed to have zero exposure for the purposes of the time-weighted calculations. Full shift exposures were compared with the state of Washington's permissible exposure limit of 0.1 mg of respirable crystalline silica per cubic meter of air as an eight-hour TWA (PEL).

Work sites with dry processes were found to routinely have exposures above the PEL (Table I). Sixty-three percent (12/19) of personal exposures exceeded the PEL of 0.1 mg/m^3 for silica during dry grinding. Each work site had at least one personal exposure twice the PEL. The highest full shift exposure was more than seven times the limit.

TABLE I

Range and mean silica concentrations during dry processes, calculated as eight-hour time weighted averages (TWAs)[A]

Company ID	No. of workers sampled	Range (mg/m^3)	Mean (mg/m^3)
1	1	0.43	—
2	6	0.11–0.77	0.49
3	9	<0.04–0.58	0.22
4	3	<0.08–0.22	0.16

[A]Reported exposures may include several activities: grinding, cutting, and polishing. Companies used similar equipment, such as angle grinders and circular saws.

FIGURE 1
A fabricator dry grinding on granite counter top.

Though workers typically used more than one type of tool throughout the sampled shift, the use of handheld powered equipment without water was believed to contribute most to the exposure. Dry grinding and cutting were observed to release visible clouds of dust (Figure 1). Dry sweeping of dust from stone pieces and from the floor were common practices. Appropriate respiratory protection and hazard communication were lacking in most facilities.

Workers utilizing wet processes were found to have significantly lower exposures (Table II). Companies 5 and 6 were using wet processes on initial visits and had no exposures above the PEL. Company 6 was the only company using pneumatic tools, whereas all other companies used electric power tools. Companies 1–4 presented in Table I were resampled following a switch to wet processes and dramatic reduction in exposure was observed. Wet operations generated water spray or mist and no visible dust.

The types of tools used in the wet processes for the sampled shift are shown in the second column of Table II. The tools for companies 1–4 indicate the switch from a dry to wet process. One company converted handheld grinders from dry to wet operation. Others purchased water-fed hand grinders or milling machines. One company used automatic profiling machines to perform edge grinding activities. All companies used a water-fed bridge saw to cut large slabs of stone prior to fabrication.

Discussion

Worker exposure to silica is dependent on several factors, including crystalline silica content of the stone, work piece shape, equipment and tools used, length of time performing tasks, type and level of ventilation, work practices, housekeeping, and dust suppression methods. Reducing exposure to crystalline silica in this case study occurred through the use of wet processes and eliminating or severely restricting duration of dry process work. Local exhaust ventilation, though not observed in this study, may be adapted to the tools used in this industry.

TABLE II

Range and and mean silica concentrations during wet processes, calculated as eight-hour time weighted averages (TWAs)[A]

Company ID	Types of tool	No. of workers sampled	Range (mg/m^3)	Mean (mg/m^3)
1	Water-fed milling machine	3	<0.02–0.05	0.03
2	Retrofitted angle grinders, new water-fed angle grinders	2	0.06–0.06	0.06
	Water-fed bridge saw	2	0.03–0.05	0.04
3	Water-fed milling machine, new water-fed angle grinders	3	<0.03–0.09	0.06
4	Water-fed wet grinders	3	<0.05–<0.1	<0.07
5	Water-fed milling machine	2	0.05–0.06	0.06
6	Water-fed wet grinders, water curtain, automatic edge profilers	3	0.05–0.07	0.06

[A]Reported exposures may include several activities: grinding, cutting and polishing.

Wet Processes

The use of wet processes for control of dust is a well known control method. NIOSH recommends the use of water as a feasible method to control silica dust, most recently in the agency's alert to the construction and rock drilling industries.[20] The authors of this case study found that water-fed equipment specific for stonework could substitute for all the dry processes observed. A number of tools which profile stone effectively under wet conditions were found to be available from industrial supply vendors.

Given the high airborne concentrations of respirable silica and particulate matter generated during dry stonework, it was recommended to employers that all exposed workers wear respiratory protection until exposure controls were implemented. The Washington Administrative Code 296-62-07501-3 a requires that "employers implement feasible or engineering control methods" to achieve compliance for these elevated worker exposures to crystalline silica. Several shops retrofitted their existing tools to control the dust. A water feed system can be fitted to either electric or pneumatic tools; the latter avoids the hazard of water and electricity. Water can be supplied to the tool working area through flexible supply piping called Loc-Line. The commercial piping consists of a series of conical interlocking plastic parts which can be snapped together or apart and twisted into any configuration. A variety of end nozzles and fittings are available to enable users to configure a water supply system to meet their needs. As an alternative to retrofitting, handheld grinders can be purchased with a water feed to the center of the grinding wheel as shown in Figure 2.

Some shops used a wet edge milling machine for shaping edges of stone (Figure 3). Milling and grinding cycles produce clean profiles and contours along the edges of stone slabs with the use of diamond wheels. With guidance from a

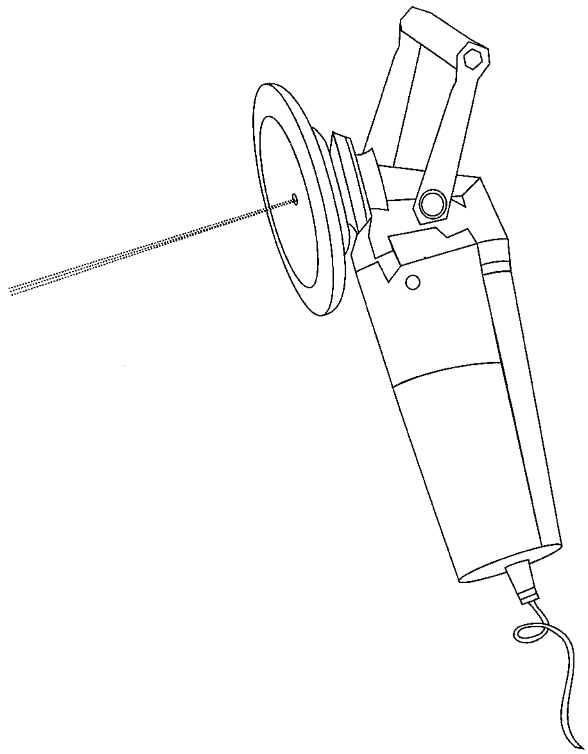

FIGURE 2
Wet grinders are designed to supply water through a hollow drive shaft.

fabricator, these machines run directly on the polished surface of the piece to be worked without scratching the polished surface and allow the tool to follow the upper edge of the slab perfectly. Companies and workers that switch from dry to wet processes should prepare to accomodate other changes. Workers switching to water-fed hand grinders need time to familiarize themselves with using water hoses attached to the tool. The visibility of the stone may be obscured with the spraying water. Appropriate clothing, floor drainage, and safe use of electrical equipment in a wet environment must be considered.

Ground fault circuit interruptors (GFCI) are necessary to reduce electrical hazards when using electrical power tools with water present. Suspension of electrical tool cords should prevent both electrical and tripping hazards. Outlet boxes should be suspended as well so workers have easy access to electrical sources. Due to the substantial amount of water used during the wet processes, particularly grinding, workers needed rain gear, rubber boots, and gloves. Eye protection was necessary for both dry and wet operations. Floor drainage, in addition to that for the bridge saw or other wet-operated equipment, may be needed. Though a switch to wet processes may have an initial cost, some shop owners indicated an increase in productivity that offset the change-over costs.

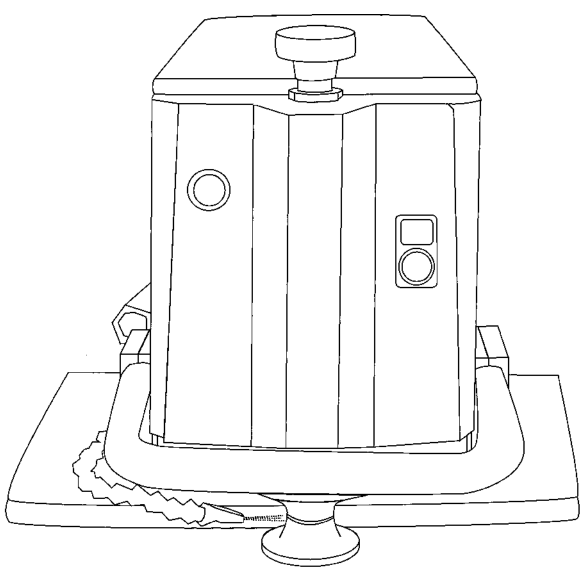

FIGURE 3
Wet edge milling machines provide clean profiles with the use of diamond wheels.

Ventilation

One company attempted to use a "water curtain" ventilation hood for additional control. The device consisted of a large, open-faced ventilated hood that used a curtain of water to capture dust drawn into the hood. Grinding operations were located near the hood. Necessary capture velocities near or at the tool were not achieved. ACGIH recommends capture velocities of 500–2000 fpm for grinding activities.[21] Reduced worker exposure to silica should be verified when water curtain systems are used as a control.

Though not observed in this project, another method of control is the use of locally exhausted tools. A number of locally exhausted grinding and cutting tools are commercially available. The use of a shrouded (suction casing) grinder connected to an exhaust source can capture the dry dust as it is being generated. The exhaust source can be an industrial-type vacuum or a high-velocity, low-pressure ventilation system.[21]

The use of locally exhausted grinders in the stone fabrication industry may have limitations. Much of the grinding activity observed was on the edge of a stone slab. The shrouds work most effectively on flat surfaces. When working on edges, there are some dust emissions, and the amount of emissions depends in part on the amount of suction produced by the vacuum system. Further, shops presented with the option were reluctant to try locally exhausted tools for fear that workers would not be able to see their work surface adequately. Proper care of equipment (casings) and dust collectors requires training.

Other ventilation concepts such as rectangular ventilated hoods constructed to enclose the grinder and stone or capture emitted dust were discussed with owners but not pursued.

Conclusion

Granite countertop fabricators were found to be at risk for silicosis, a preventable disease. Wet processes significantly reduced worker exposure to respirable crystalline silica and, in all cases, to below the state of Washington's PEL of 0.1 mg/m^3. Wet processes were adopted by the small companies in this case study because several cost-effective tool options were available that were easy to use and applicable to stone fabrication work. Hazards other than crystalline silica were found. A summary of the hazards and controls the authors observed and as published in a hazard alert[22] by the state of Washington are provided in Table III.

Because the NIOSH-recommended exposure limit (REL) for respirable crystalline silica of 0.05 mg/m^3 as a TWA during a 40-hour work week was exceeded at most of the work sites using wet processes, employers should continue to explore ways to reduce silica exposures to as low a level as possible. There is no cure for silicosis; thus, prevention of exposure is imperative.

TABLE III
Summary of hazards in stone fabrication shops

Hazards	Control recommendations
Silica dust	• Reduce or prevent silica exposures by 1) using wet processes with their varied equipment options, 2) using shrouded power tools and shop vacuums, or 3) installing a local exhaust ventilation system. • NIOSH recommends that medical examinations be available to all workers who may be exposed to crystalline silica. Such examinations should occur before job placement and at least every three years thereafter. Consult with NIOSH to learn more about recommended medical examinations. • Practice good housekeeping to prevent dust from re-suspending into the air. DO NOT DRY SWEEP OR USE COMPRESSED AIR because this re-suspends the dust and increases worker exposure. • Respirators may be used as a control for very infrequent tasks or where no feasible engineering controls can be found for a particular task. Develop and implement a written respiratory protection program for all dry grinding stone operations. • Sample for crystalline silica to ensure exposure controls are effective or whenever changes are made to the process, work flow, or ventilation system.
Water	• Use grounded equipment, ground fault circuit interruptors (GFCI), electrical cords routed overhead, and good maintenance of electrical tools. The use of air-powered tools can eliminate the electrical hazards. • When using water for dust suppression, floor drainage and appropriate clothing must be considered.
Untrained workforce	• Conduct worker training on the hazards of silica. Training should include information on health effects, work practices, protective equipment, and methods to reduce exposure to crystalline silica.
Take-home exposure	• Require that employees use disposable or commercially washable work clothes that are left at the work site. Do not contaminate cars, homes, or places outside of the work site with dusty clothes.
Materials handling	• Handling large pieces of stone nesessitates specific safe work practices to prevent back and crush injuries. Provide steel-toed boots to all employees to prevent foot injuries during material handling.
Noise	• Monitor worker exposure to noise and implement a hearing conservation program when worker exposures are equal to or exceed 85dBA.

REFERENCES

1. U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), Mine Safety and Health Administration (MSHA), U.S. Department of Health and Human Service, National Institute of Occupational Safety and Health (NIOSH), and the American Lung Association. 1997 National Conference to Eliminate Silicosis. March, 1997. Conference information and the Silicosis Cyber-Conference (July 1997) was available on the OSHA home page at

http://www.osha.gov under the technical information link.
2. U.S. Department of Labor, Occupational Safety and Health Administration (OSHA). Special Emphasis Program for Silicosis [memorandum]. May 2, 1996.
3. International Agency for Research on Cancer (IARC). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Silica, Some Silicates, Coal Dust and Para-aramid Fibrils. World Health Organization (WHO) Ed, Lyon 68: (1997).
4. Hnizdo, E.; Sluis-Cremer, G.K.: Silica Exposure, Silicosis, and Lung Cancer: A Mortality Study of South African Gold Miners. Br J Ind Med 48:53–60 (1991).
5. Hnizdo, E.: Combined Effect of Silica Dust and Tobacco Smoking on Mortality from Chronic Obstructive Lung Disease in Gold Minters. B J Ind Med 47:656–664 (1990).
6. Malmberg, P.: Hedenstrom, H.; Sundblad, B.M.; Changes in Lung Function of Granite Crushers Exposed to Moderately High Silica Concentrations: A 12 Year Follow-Up. Br J Ind Med 50(8):726–731 (1993).
7. Chen, G.X.; Burnett, C.A.; Cameron L.L.; et al.: Tuberculosis Mortality and Silica Exposure: A Case-Control Study Based on a National Mortality Database for the Years 1983–1992. Int J Occup Environ Health 3:163–170 (1997).
8. Althouse, R.B.; Bang, K.M.; Castellan, R.M.: Tuberculosis Comortality with Silicosis-United States, 1979–1991. Appl Occup Environ Hyg 10(12):1037–1041 (1995).
9. Cherry, N.M.; Burgess, G.L.; Turner, S.; et al.: Crystalline Silica and Risk of Lung Cancer in the Potteries. Occup Environ Med 55779–55785 (1998).
10. Costello, J.; Castellan, R.M.; Swecker, G.S.; et al.: Mortality of a Cohort of U.S. Workers Employed in the Crushed Stone Industry. A J Ind Med 27(5):625–640.
11. Koskela, R.S.; Klockars, M.; Laurent, H.; et al.: Silica Dust Exposure and Lung Cancer. Scan J Work Environ Health 20(6):407–416m (1994).
12. National Institute for Occupational Safety and Health: Work-Related Lung Disease Surveillance Report. DHHS (NIOSH) Pub. No. 940120. NIOSH, Cincinnati, OH (1994).
13. National Institute for Occupational Safety and Health: Criteria for Recommended Standard: Occupational Exposure to Crystalline Silica. NIOSH HEW Pub. No.75-120. NIOSH, Cincinnati, OH (1975).
14. Hamilton, A.: Exploring the Dangerous Trades. Little Brown and Company, Boston, MA (1943).
15. Guenel, P.; Breum, N.O.; Lunge, E.: Exposure to Silica Dust in the Danish Stone Industry. Scan J Work Environ Health 15:147–153 (1989).
16. Kullman, G.J.; Greife, A.L.; Costello, J.; et al.: Occupational Exposures to Fibers and Quartz at 19 Crushed Stone Mining and Milling Operations. Am J Ind Med 27(5):641–660 (1995).
17. Froines, J.R.; Wegman, D.H.; Dellenbaugh, C.A.: An Approach to the Characterization of Silica Exposure in U.S. Industry. Am J Ind Med 10:345–361 (1986).
18. Partanen, T.; Jaakkola, J.; Tech, L.; et al.: Silica, Silicosis and Cancer in Finland. Scand J Work Environ Health 21(2):84–86 (1995).
19. ACGIH. 1998 TLVs and BEIs; Threshold Limit Values for Chemical Substances and Physical Agents, Biological Exposure Indices, p. 84. ACGIH, Cincinnati, OH (1998).
20. National Institute for Occupational Safety and Health: NIOSH Alert—Preventing Silicoisis and Deaths in Rock Drillers. DHHS (NIOSH) Pub. No. 92-107. NIOSH, Cincinnati, OH (1992).
21. ACGIH: Industrial Ventilation: A Manual of Recommended Practice, 22nd ed. Cincinnati, OH (1995).
22. Washington State Department of Labor & Industries, WISHA Services: Hazard Alert: Silica Dust Poses Health Hazard in Stone Fabrication Industry. Olympia, WA (1998).

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