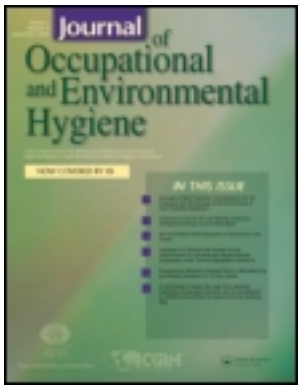

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Prevalence of Dry Methods in Granite Countertop Fabrication in Oklahoma

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Granite countertop fabricators are at risk of exposure to respirable crystalline silica, which may cause silicosis and other lung conditions. The purpose of this study was to estimate the prevalence of exposure control methods, especially wet methods, in granite countertop fabrication in Oklahoma to assess how many workers might be at risk of overexposure to crystalline silica in this industry. Granite fabrication shops in the three largest metropolitan areas in Oklahoma were enumerated, and 47 of the 52 shops participated in a survey on fabrication methods. Countertop shops were small businesses with average work forces of fewer than 10 employees. Ten shops (21%) reported using exclusively wet methods during all fabrication steps. Thirty-five shops (74%) employing a total of about 200 workers reported using dry methods all or most of the time in at least one fabrication step. The tasks most often performed dry were edge profiling (17% of shops), cutting of grooves for reinforcing rods (62% of shops), and cutting of sink openings (45% of shops). All shops reported providing either half-face or full-face respirators for use during fabrication, but none reported doing respirator fit testing. Few shops reported using any kind of dust collection system. These findings suggest that current consumer demand for granite countertops is giving rise to a new wave of workers at risk of silicosis due to potential overexposure to granite dust.

Keywords crystalline silica, stone dust, work practices

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INTRODUCTION

The association between lung disease and exposure to stone dust was recognized in antiquity.[1] The introduction of powered tools into granite quarrying and fabrication of grave monuments around the beginning of the 20th century led to an epidemic of silicosis and pulmonary tuberculosis among granite cutters who inhaled dust laden with quartz, a form of crystalline silica.[2,3] The deadly risk of silica exposure in the granite sheds was largely overcome by the implementation of effective dust control measures, including local exhaust ventilation and the use of wet methods.[4,5]

The recent popularity of granite in kitchen and bathroom countertops has fostered a proliferation of shops that fabricate custom countertops from natural granite slabs selected by the customer. In contrast to current practice in the granite sheds of the monument industry, knowledge and implementation of dust control methods does not appear to be well disseminated among many shops in the granite countertop business. A review of workplace inspections conducted by the state of Washington's Department of Labor and Industries found overexposures to crystalline silica and violation of rules on engineering controls in 9 of 18 stone countertop shops inspected.[6] The Marble Institute of America, a trade organization for the stone manufacturing industry, found in a survey of its members that 73% of shops reported being "90 to 100 percent wet" and 8% reported being "80 to 90 percent wet".[7]

A study of six granite countertop fabrication businesses in Washington State in 1997 found individual 8-hr time-weighted average (TWA) exposures ranging from < 0.04 to 0.77 mg/m^3 in workers engaged in mostly dry processes and <0.02 to 0.09 mg/m^3 in workers engaged in mostly wet processes. Four shops changed from dry to wet fabrication in the course of the study, resulting in shop-wide mean TWA exposure reduction from 0.16–0.49 mg/m^3 for dry processes to 0.03–0.06 mg/m^3 for wet processes. None of the shops used tools with local exhaust attachments, and it was noted that shops were reluctant to consider use of such tools because of concern that workers' view of the work surface might be obscured by the shrouds on the tools that help contain the dust for capture by the exhaust system.[8]

This study estimated the prevalence of exposure control methods, especially wet methods, in granite countertop fabrication in Oklahoma, to assess how many workers might be at risk of overexposure to crystalline silica.

MATERIALS AND METHODS

The study was designed to be a census of granite countertop fabrication shops in the three largest metropolitan areas in Oklahoma. Shops were surveyed on their fabrication practices and work force size. Enumeration and surveys were conducted in the first two months of 2011.

Enumeration of Countertop Shops

A complete enumeration of all granite countertop fabricators in the Oklahoma City, Tulsa, and Lawton metropolitan areas was attempted using Internet searches and listings in the Yellow Pages for the three areas. Search terms included "granite," "marble," "kitchens," "granite fabricators," and other variations. After this first enumeration, major home improvement stores and major home construction companies were contacted and asked to identify the granite fabrication shops they used. It was found that the fabrication shops identified by these firms had already been enumerated in the earlier search. Three additional shops were found by direct observation in commercial areas or by word of mouth from other granite fabricators. Screening calls were made to all shops identified in the searches to determine if they performed granite countertop fabrication in-house. Shops that did not perform their own granite fabrication or did not have currently active phone numbers were eliminated; a total of 53 granite countertop fabrication shops were enumerated: 32 in the Oklahoma City (OKC) area, 17 in the Tulsa area, and 4 in the Lawton area.

Survey Content

A questionnaire was developed in consultation with the operator of one countertop fabrication shop. The questionnaire consisted of 13 items. Six questions addressed what equipment was used in the fabrication steps of initial cuts, edge grinding, edge profiling, polishing, cutting of grooves for reinforcement rods ("rodding"), and cutting of sink openings, and the degree to which the task was performed wet or dry. Other questions addressed whether the shop had a respiratory protection program with fit testing, what type of personal protective equipment was used, how the dust was cleaned up, how the work area was ventilated, how many countertops the shop made in a given time, how many fabricators the shop employed, and the average length of employment of the shop workers. Two additional questions originally included in the questionnaire were dropped after it became apparent that survey respondents found them unnecessarily repetitive; these questions concerned what processes were performed entirely wet and what processes were performed entirely dry.

Data Collection

The University of Oklahoma Health Sciences Center Institutional Review Board determined that this research was not human subjects research; therefore, informed consent was not required.

To determine whether the manner of contact affected the willingness of shops to participate in the survey, the shops in the OKC area were randomly assigned to either on-site administration of the questionnaire (16 shops) or administration by phone (15 shops). Two shops originally assigned to the on-site contact group were moved to the phone contact group after difficulties in finding the business operators at their published addresses. A new shop that was found after the initial randomization was assigned to the on-site contact group. Of the 32 shops in the final enumeration in the OKC area, only one shop declined to participate. This shop had been contacted by phone. Two shops were dropped from the study after three unsuccessful attempts at contact, one shop was eliminated because the operators did not speak English well enough to take the survey, and one shop was eliminated because it used a thin granite veneer product rather than fabricating countertops from granite slabs. All 21 shops in the Tulsa and Lawton areas were contacted by phone. One shop in Tulsa declined to participate. The total number of shops participating in the survey was 47.

During both on-site contact and phone contact, the questionnaire was administered orally by one of the authors to the individual identified by shop personnel as the best person to talk to about the granite countertop fabrication process. Responses regarding degree of use of wet methods or dry methods in each fabrication step were noted on a five-point scale, ranging from "always wet" to "always dry." No attempt was made to verify the self-reported data collected through the survey.

Descriptions of process equipment and methods were based on a combination of direct observation by the investigators during visits to granite countertop fabrication shops, review of equipment vendors' catalogs and websites, and explanations provided by personnel in several of the shops that participated in the survey.

RESULTS

Countertop Fabrication Methods

The first step in granite countertop fabrication is cutting the granite slab into pieces of the required dimensions. The most commonly used equipment for initial cuts was a bridge saw, used in 34 shops (72%). Eight shops used a rail saw, three shops used hand-held stone saws, and two shops used a computer numerical control (CNC) machine exclusively. A bridge saw is a stationary piece of equipment with a rotating table large enough to hold an entire slab of granite, which typically measures approximately 2 m by 3 m. The saw, which is equipped with a water feed, is mounted on a gantry system that spans the slab. The bridge saw is operated from a control panel. A rail saw is a movable piece of equipment that glides along a pair of rails. Rail saws are generally equipped with a water feed. The fabricator clamps the rails to the slab and guides the saw to make the cut. A CNC machine holds an entire slab immersed in water or under a water feed while cutting or milling the stone under automated computer control. Forty-three (91%) of the shops in this survey reported that initial cutting was always performed wet. Another three shops (6%)

reported that the task was usually performed wet. Only one shop reported always making initial cuts dry; this was done with a hand-held saw.

Thirteen of the 47 shops reported performed grinding with a diamond blade or abrasive wheel to smooth out rough edges after the initial cuts. Other shops omitted this step or considered it part of the edge profiling step, described below. Edge grinding was done with either an edge grinding machine (seven shops), hand-held grinders (three shops), or both (three shops). Seven shops (15% of all shops), including some that used hand tools and some that used an edge grinding machine, reported using dry methods for edge grinding all or most of the time.

Edge profiling was most commonly performed using a stone router, a machine that uses a shaped bit or compound wheel to create the desired edge shape, such as a bevel, ogee, or bullnose profile. Stone routers are typically equipped with water feed and may be portable or supported on a stationary track system. In either case, the fabricator moves the router by hand along the edge of the stone piece to create the profile. Twenty-four of the shops used a stone router exclusively, 11 shops used hand-held grinders, 3 shops used both hand-held grinders and routers, and 9 shops used a CNC machine for edge profiling. Eight shops (17%), including 6 that used hand grinders and 2 that used stone routers, reported performing edge profiling dry all or most of the time.

Commercially available granite slabs are received from the wholesaler with one side already polished. It falls to the fabricator to perform polishing to smooth out edges or minor surface imperfections created in the fabrication process. Thirty-nine shops reported using hand-held tools for polishing, six shops used a CNC machine, one shop used both hand tools and CNC, and one shop did not specify what equipment it used. Hand-held polishing tools may include a water feed; in other cases, the fabricator may use a sponge to wet the stone during polishing. Thirty-seven shops (79%) reported using wet methods for polishing all or most of the time, three shops (6%) used about half wet and half dry polishing methods, and seven (15%) reported always dry polishing.

To reinforce the narrow sections of stone around openings for sinks or cooktops, many shops cut grooves on the underside of granite pieces and insert steel or fiberglass rods before the sink openings are cut. This step is called "rodding." Forty-one of the shops in this survey reported using hand-held tools to cut the rodding grooves, one shop used a CNC machine, and five shops reported that they did not rod. Twenty-nine shops (62% of all shops in the survey) reported that they did rodding entirely dry; two other shops (4%) reported that they did rodding half or mostly dry, and 11 shops reported that they did rodding entirely wet.

Twenty-nine shops reported using hand-held saws to cut out sink openings, 11 shops used a CNC machine, and seven shops used a specialized radial arm machine such as the Wizard (Park Industries, St. Cloud, Minn.) or Scorpion (RYE-Corp, Lenoir City, Tenn.). Twenty-one shops (45%), all of which used hand-held saws, reported that they always cut openings dry. All of the other shops reported that they always used wet methods to cut sink openings. It should be noted that sink openings are sometimes cut at the customer's site after the countertop has been installed; in these cases it is generally impractical to use wet methods.

The degree of use of wet or dry methods for a particular fabrication step tended to be reported by shops as always wet or always dry, with relatively few intermediate responses. Ten shops (21%) reported that all fabrication steps were always performed wet, and one shop reported that all steps were always performed dry. All other shops used a mixture of wet and dry methods over the course of the fabrication process. Twenty-three shops (49%) reported using dry methods all or most of the time in one or two fabrication steps. Twelve shops (25%) reported using dry methods all or most of the time in three or more fabrication steps.

Relationship Between Work Load and Fabrication Methods

Survey responses indicated that hand-held saws, grinders, and polishers were frequently used dry, while other equipment was usually operated wet, presumably under a water feed. The approximate cost of typical stone working equipment is $100–$300 for hand-held tools, $1000–$5000 for rail saws and stone routers, about $10,000 for radial arm machines, $20,000–$50,000 for bridge saws, and over $100,000 for CNC machines. A hypothesis of this study was that shops with higher work loads were more likely than smaller shops to invest in the more expensive types of equipment that are generally operated under wet conditions.

To obtain an estimate of shop work load, the survey included the question, "How many countertops do you complete in a given time period?" The question was left open to interpretation by the respondents; for example, a residential kitchen countertop order consisting of one countertop bordering the wall and one island could be considered one countertop or two, depending on the perspective of the respondent. Most respondents provided a weekly estimate of the number of countertops produced; others provided daily, monthly, or yearly estimates. Three shops did not answer the question.

The cumulative distribution of estimated shop work load, normalized to monthly production of countertops, is illustrated in Figure 1. Reported production ranged from eight granite countertops per year to 120 per month. The median monthly production across all shops was 24 countertops, or about one countertop a day. Monthly production among shops using various types of equipment is summarized in Table I. Shops with CNC machines all had monthly production numbers above the median. Radial arm machines for sink cutting were used only in shops in the second lowest quintile of monthly production. Other types of fabrication equipment, including bridge saws, stone routers, and rail saws, were used across all five quintiles of monthly production.

Some shops in this study fabricated countertops not only from granite but also from other natural stone or from composite materials. Although each respondent was told at the beginning of the survey that the questionnaire was about granite

TABLE I. Fabrication Equipment Use in Relation to Reported Typical Monthly Production of Countertops by Shop

Equipment Available	Number of Shops	Lowest Monthly Production Count	Highest Monthly Production Count
CNC	13	33	120
Bridge saw	34	4	120
Stone router	27	<1	87
Radial arm machine for sink cutting	7	13	22
Rail saw or hand tools for initial cuts	10	<1	65
Hand tools for sink cuts	29	<1	87

countertop fabrication, it is possible that some respondents might have included other materials in their estimates of countertop production.

Respiratory Protection

All 47 shops reported using some type of respiratory protection, but no shops reported having a respiratory protection program that included fit testing in accordance with the Occupational Safety and Health Administration (OSHA) respiratory protection standard (29 CFR 1910.134). Five shops reported using full-face respirators. The other shops reported using some type of half-face respirator. Most shops referred to the respirator simply as a "mask" or "dust mask." No attempt was made in the survey to distinguish between disposable respirators and cartridge respirators with elastomeric facepieces. Use of N95 respirators was reported or observed in five shops, a P100 respirator in one shop, and both N95 and P100 respirators in one shop.

Housekeeping

Methods reported for cleaning up dust were, in order of frequency: washing, sweeping, blowing the dust out of the shop with compressed air, and vacuum cleaning. Use of wet fabrication methods appeared to be associated with use of wet cleanup methods, such as washing. Seventy-eight percent of the shops that reported using entirely wet methods for the entire fabrication process also reported using wet methods for cleanup, while only 31% of shops that performed at least one step entirely or mostly dry used wet cleanup. Four shops did not respond to the question about cleanup methods.

Ventilation

Forty-three shops answered the question concerning how they ventilated the work area. All these shops reported using fans; three shops specifically mentioned ceiling fans, and 10 shops mentioned using "exhaust," "exhaust fans," or

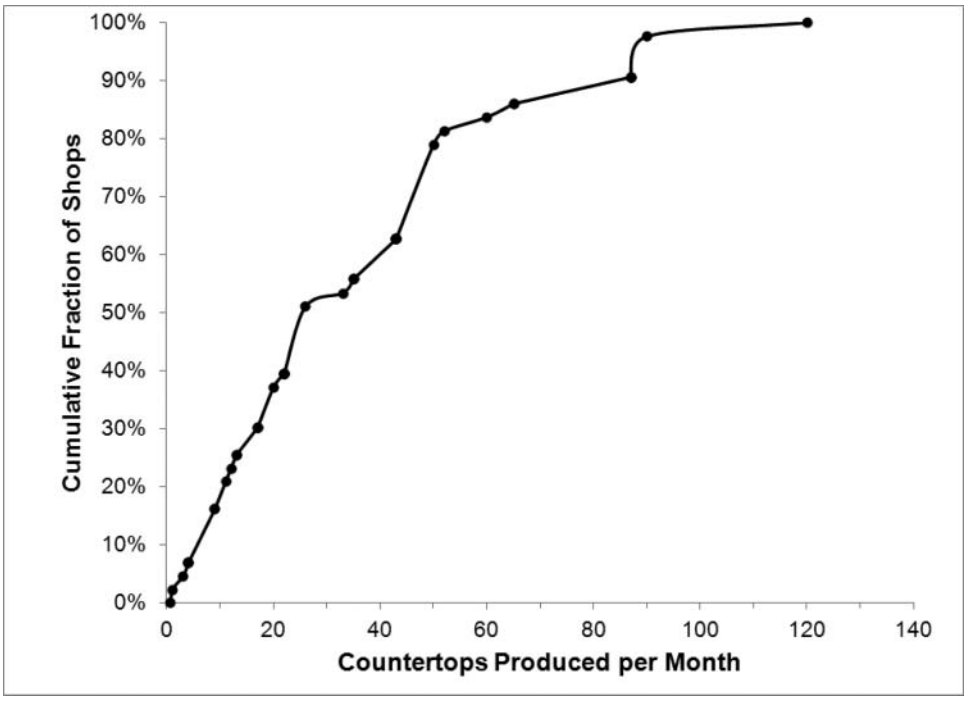

FIGURE 1. Cumulative distribution of monthly countertop production in 44 shops

"exchange." Four shops reported using some type of dust collection or dust suppression system, described respectively as a "filtration system," "fans plus filter," a "HEPA," and a "mister system." One shop reported using a shop vacuum for local exhaust; however, the vacuum hose was not attached to the tool but simply held near the point of operation by an assistant.

Work Force Size and Stability

Granite countertop fabrication in Oklahoma is conducted by small businesses. The number of countertop workers reported in the participating shops ranged from 1 to 23, with an average of 5.7 workers and a median of 4 workers per shop. The central 60% of shops in terms of work force size employed between three and six countertop workers. Work force size was weakly correlated with shop production levels ($\rho = 0.50$). Five shops did not answer questions regarding their work force.

Among the 35 shops that reported performing at least one fabrication step always or mostly dry, 31 provided information about the number of workers employed. The average number of employees in these shops was 6.3 and the median number was 5.

As a measure of stability of the work force, shops were asked to estimate "the length of employment for your average worker." Responses ranged from 1 year to 25 years, with an average of 6.0 years, a median of 5 years, and 90th percentile of 10 years. The shop reporting an average employment tenure of 25 years specialized in fabricating laminate countertops but began producing granite countertops in the past decade in response to customer demand.

DISCUSSION

Prevalence of Controls

Use of dry methods was a regular practice in the granite countertop fabrication process in a large majority of the shops surveyed in this study. Dry methods were often used during edge profiling (17% of shops), rodding (62% of shops), and cutting of sink openings (45% of shops), activities with potential for producing extremely high dust concentrations as gram-sized quantities of stone are aerosolized by powered tools within a few minutes. Shops that used dry fabrication methods also tended to use dry housekeeping methods, including sweeping and blowing of settled dust.

Wet methods can reduce exposure to respirable silica during countertop fabrication.[8] However, workers can still be exposed to silica-laden aerosol from the jet of fine spray thrown off by the rotating blade, wheel, or disk of the high-speed power tool. Mean silica exposures reported by Simcox et al.[8] during wet fabrication in six countertop shops, while below the effective OSHA permissible exposure limit of 0.1 mg/m^3, exceeded the current ACGIH® threshold limit value (TLV®) of 0.025 mg/m^3.[9]

Except for automated CNC machines and remote-controlled bridge saws, the wet process equipment used by the shops in this study must be manually guided by the fabricator, bringing the worker's breathing zone close to the point of operation of the tool. Bridge saws were widely used in shops of all sizes, but their function is limited to one step in the fabrication process, namely, cutting up the granite slab into the required dimensions for the countertop and backsplash. CNC machines can be used to perform all steps of the countertop fabrication process, but in this survey, only 28% of shops used CNC machines. All these shops had production work loads above the median. At prices up to about $500,000, CNC machines might not be affordable for smaller shops.

All shops reported the use of some type of respiratory protection, but no shops reported having a respiratory protection program with fit testing that conformed to the requirements of OSHA's respiratory protection standard. This was consistent with the findings of Lofgren[6] in his review of inspections of stone countertop shops by the State of Washington Department of Labor and Industries.

One limitation of this survey was the lack of specific questions about use of local exhaust ventilation, including exhaust attachments on tools. It is possible that respondents did not interpret the question about ventilation to include local exhaust ventilation. In any event, very few shops in this study reported the use of methods for capturing or filtering airborne dust. Further study is needed on the prevalence and effectiveness of local exhaust ventilation in granite countertop fabrication.

Estimating the Size of the Work Force

This study attempted to enumerate and survey every granite countertop fabrication shop in the three largest metropolitan areas in Oklahoma, encompassing a combined population of close to 2 million residents. Fifty-two shops were enumerated and confirmed to fabricate countertops from natural granite slabs. Ninety percent of these shops participated in the survey, and 80% provided information on the number of workers they employed in countertop production. The work force represented in this survey totaled at least 240 workers, about 200 of whom worked in shops that used some dry fabrication methods.

Extrapolating to the national population the ratio of countertop fabricators to residential population found in this study, it may be estimated that at least 36,000 workers are employed in the fabrication of granite countertops in the United States. This is probably a conservative estimate. Because the enumeration methods used in this study relied primarily on Yellow Pages listings and Internet searches, countertop fabrication shops that did not market their services through these media were likely to have been missed. The number of workers employed in such shops is unknown. It might be possible to identify shops in this less visible sector of the granite countertop business through the vendors that sell granite slabs and stone fabrication supplies.

Public Health Implications

Survey responses on length of employment suggest that 90% of granite countertop workers had worked in their shop for 10 years or less. Though radiographic changes or silicosis

diagnoses have been reported within 10 years of initial exposure to silica,[10–12] the typical latency period for radiological diagnosis of silicosis is 20 years or more after first exposure.[10,11,13] Silicosis might therefore not be detected among granite countertop fabricators for another 10 years, and then only if medical surveillance programs are implemented for this work force at risk.

Silicosis is a progressive, incurable disease.[14] Effective reduction of silica exposure through appropriate engineering controls, work practices, and respiratory protection is the only way to prevent silicosis in granite industries.

CONCLUSION

The findings in this study suggest that current consumer demand for granite countertops is giving rise to a new wave of workers at risk of silicosis due to the widespread use of dry fabrication methods and inadequate respiratory protection programs. Increased awareness and use of effective dust control measures is needed in the granite countertop industry. The self-reported use by some shops of exclusively wet methods indicates that this means of exposure control is feasible. However, the residual risk of respirable silica exposure during wet fabrication should be further assessed.

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