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SHORT COMMUNICATION

Respirable Silica Dust Suppression During Artificial Stone Countertop Cutting

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ABSTRACT

Purpose: To assess the relative efficacy of three types of controls in reducing respirable silica exposure during artificial stone countertop cutting with a handheld circular saw.

Approach: A handheld worm drive circular saw equipped with a diamond segmented blade was fitted with water supply to wet the blade as is typical. The normal wetted-blade condition was compared to (i) wetted-blade plus 'water curtain' spray and (ii) wetted-blade plus local exhaust ventilation (LEV). Four replicate 30-min trials of 6-mm deep, 3-mm wide cuts in artificial quartz countertop stone were conducted at each condition in a 24-m^3 unventilated tent. One dry cutting trial was also conducted for comparison. Respirable cyclone breathing zone samples were collected on the saw operator and analyzed gravimetrically for respirable mass and by X-ray diffraction for respirable quartz mass.

Results: Mean quartz content of the respirable dust was 58.5%. The ranges of 30-min mass and quartz task concentrations in mg m^{-3} were as follows—wet blade alone: 3.54–7.51 and 1.87–4.85; wet blade + curtain: 1.81–5.97 and 0.92–3.41; and wet blade + LEV: 0.20–0.69 and <0.12–0.20. Dry cutting task concentrations were 69.6 mg m^{-3} mass and 44.6 mg m^{-3} quartz. There was a statistically significant difference ($\alpha = 0.05$) between the wet blade + LEV and wet blade only conditions, but not between the wet blade + curtain and wet blade only conditions, for both respirable dust and respirable silica.

Conclusions: Sawing with a wetted blade plus LEV reduced mean respirable dust and quartz task exposures by a factor of 10 compared to the wet blade only condition. We were unable to show a statistically significant benefit of a water curtain in the ejection path, but the data suggested some respirable dust suppression.

KEYWORDS: countertop cutting; engineering controls; respirable silica

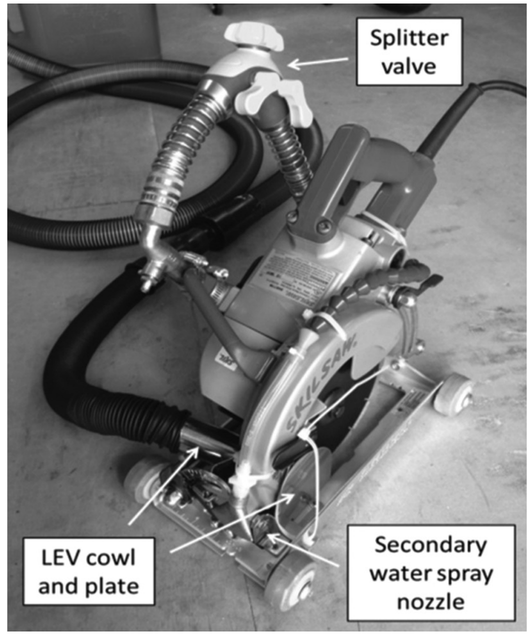
INTRODUCTION

Workers fabricating countertops from granite and other quartz-rich stone using hand tools can be exposed to extremely high levels of respirable silica if good engineering controls are not used (Simcox *et al.*, 1999; Phillips *et al.*, 2013). Outbreaks of silicosis have been reported in Spain (Garcia *et al.*, 2011; Pérez-Alonso *et al.*, 2014), Israel (Kramer *et al.*, 2011), and Italy (Bartoli *et al.*, 2012) among workers making countertops from quartz composite artificial stone.

Stone saws are commonly equipped with water stream attachments to cool the blade and suppress dust. Local exhaust ventilation (LEV) attachments for saws are also commercially available. However, no peer-reviewed studies have been reported regarding the effectiveness of LEV alone, blade wetting alone, or the two in combination when cutting stone countertop material with a handheld saw. The purpose of this work was to compare respirable silica dust exposures during simulated stone countertop cutting with a handheld worm drive circular saw under conditions of wetted blade only (the baseline condition), wetted blade + supplemental water curtain, and wetted blade + LEV.

MATERIALS AND METHODS

A worm drive circular saw (Skil Model SHD77M-RT, Robert Bosch GmbH, Germany) with a 17.8-cm diameter diamond segmented stone cutting blade (Model 035CU1340, Regent Stone Products, Virginia Beach, VA, USA) was used. In accordance with usual practice, the saw was mounted to a roller carriage (Blade Roller Part No. BR7001C, Pearl Abrasive Company, Commerce, CA, USA). In the first cutting scenario (normal 'wetted blade only'), an add-on water line (Abrasive Water Kit, Part No. BRWK001, Pearl Abrasive Company) directed a stream of water at the blade's front edge at the point where it entered the stone. The first comparison scenario involved an additional water line fitted with a brass nozzle as shown in Fig. 1 that created a thin curtain of water directed normal to the saw's cutting path, intended to intercept dust as it was ejected by the blade. This attachment was utilized in conjunction with the normal wetted-blade operation, accomplished by mounting a hose splitter valve to the saw. Water flow rates were 2 l min^{-1} for the blade and 8 l min^{-1} for the curtain. The second comparison scenario involved an LEV cowl attached to the saw (Stainless Steel SawVac, Pearl Abrasive Company), as also shown in Fig. 1. The cowl mounted to the guard surrounding the wetted saw blade, placing it 2.5–5 cm from the cutting zone. A plate added on the opposite side of the blade directed the air flow. The LEV cowl and plate were removed when not needed for the experiment. The cowl was connected via a pre-separator to a high efficiency particulate air (HEPA) filtered vacuum (RIDGID ShopVac, Model No. 9662611, Emerson Electric Co., Elyria, OH, USA) using 5-cm diameter hose. The pre-separator, which was fabricated from an 18.9-l plastic jerrican, prevented captured water from reaching the vacuum's pre-filter bag and HEPA filter. With the HEPA filter in place, the LEV air flow was 2.3–2.4 m^3 min^{-1}, which was slightly below the cowl manufacturer's recommended 2.83 m^3 min^{-1}. This flow produced a capture velocity >5.43 m s^{-1} near the point of dust ejection from the cut, as measured using a heated wire anemometer (Alnor Model CF8585, TSI Inc., Shoreview, MN, USA).



1 A secondary water flow provided a fan-shaped water curtain sprayed normal to the path of the ejected stone dust. The secondary flow could be shut off during LEV and wetted-blade-only trials. The LEV cowl was attached only during LEV trials.

Quartz-based artificial stone was used because it has a more uniform composition than granite. The stone slab was 19 mm thick and contained 85% quartz in a resin matrix. The slab was pre-cut into 1.4 m by 0.8 m pieces. Trials were conducted inside a 3.1 m × 3.1 m outdoor tent with 2.1-m high fabric side panels and a 2.7-m high vaulted roof; the tent volume was ~24 m^3. With the door panel zipped closed, there was essentially no air movement into or out of the enclosure during trials. The stone slab was supported on saw horses, and the area was well drained due to a gently sloping floor. Each trial included 27 successive cuts spaced 6 mm apart. Each cut was 3.2 mm wide, 6.4 mm deep, and ~120 cm long. The total volume of stone removed was ~645 cm^3 per trial. Four replicates of the three cutting scenarios were conducted, plus a single dry cutting trial, for a total of 13 trials. The order of trials was randomized within each replicate block. The mean duration of trials was 29.9 min (range 26.5–32.9 min). Three to five trials were conducted per day, with periodic rinsing of the area to remove accumulated dust and chips.

The study design was approved by the Institutional Review Board. The saw operator wore hearing protection, steel-toed boots, and a powered air purifying respirator (OptimAir 6A, Mine Safety Appliances Inc., Cranberry Township, PA, USA) with HEPA filter cartridges (MSA OptiFilter XL HE) and a hood (MSA Model No. 7-790-1). A ground fault circuit interrupter (GFCI) was utilized to protect against electric shock.

A single breathing zone respirable dust sample was collected during each trial. The saw operator wore a personal air sampling pump (Model PCXR4, SKC Inc., Eighty Four, PA, USA) connected to a GS-3 conductive plastic respirable dust cyclone (SKC Model 225-100) worn on the shirt collar. Samples were collected on matched-weight (within 25 µg) 5-µm pore size polyvinyl chloride filters in 37-mm diameter three-piece cassettes (SKC Model 225-8202). The air pump flow rate was calibrated before and after each trial using a bubble tube primary standard. The sampler flow rate was 2.75 l min^{-1}, which provided a 4 µm 50% cut-point. Three to six trials were conducted on each of 4 days of sampling; one field blank was submitted for each day of sampling. Gravimetric analysis was performed in accordance with NIOSH Analytical Method 0600 (NIOSH, 2003). The filter cassettes were placed in a controlled environment weighing chamber at 25°C and 50% relative humidity, with the inlet and outlet plugs removed, for 24 h before weighing. The filters were weighed inside the environmental chamber on a ±1 µg sensitivity microbalance (Cahn Model No. C-33, Orion Research, Beverly, MA, USA) supported on a vibration damping platform. Respirable dust masses were calculated as the difference between the collection filter and the matched-weight control filter behind it. After weighing, the filters were returned to their original cassettes and submitted to an accredited laboratory for silica determination by X-ray diffraction according to NIOSH Method 7500 (NIOSH, 2003).

The data were analyzed by parametric analysis of variance (ANOVA) of log-transformed concentration data after verifying their normality via the Shapiro–Wilk test and homogenous variance via the *F*-test. Associated *post hoc* pair-wise comparisons of conditions were made using Tukey's test.

RESULTS

Results of the gravimetric analysis are presented in Table 1. The limit of detection (LOD) and limit of quantitation (LOQ) of the gravimetric method were 0.061 and 0.205 mg, calculated as 3 and 10 times, respectively, the standard deviation of the weight differences of the matched filters from eight blank cassettes (the four field blanks plus four unused cassettes from the same box of 50 manufacturer-prepared cassettes). The result of the fourth wetted-blade + LEV trial should be viewed with caution, as the LEV hose partially collapsed during the trial, likely reducing the LEV effectiveness.

The wetted-blade + LEV combination consistently had the lowest respirable dust concentrations. The mean concentration for the wetted blade + LEV (excluding the suspect fourth trial) was 92% lower than the mean concentration for the wetted-blade-only scenario, whereas the mean concentration for the wetted-blade + water curtain was only 23% lower than that for the wetted-blade-only scenario. The mean exposure for the baseline wetted-blade-only condition was an order of magnitude lower than the 'dry blade' concentration.

An *F*-test of the variances was significant (P = 0.017), indicating dissimilar variances between conditions. A logarithmic transformation of the data resulted in a non-significant *F*-test, and

Table 1. Respirable dust concentrations (mg m^{-3}) averaged over nominal 30-min sampling period

Replicate	Wetted blade only	Wetted blade + water curtain	Wetted blade + LEV	Dry
1	7.511	5.116	0.689[a]	69.60
2	5.025	1.814[a]	0.321[a]	
3	3.654	5.965	0.201[a]	
4	3.546	2.357	1.204[b]	
Mean	4.934	3.813	0.604	
SEM	0.923	1.018	0.225	

[a]Measured mass from which this concentration was calculated was < LOD and LOQ.

[b]Measured mass from which this concentration was calculated was < LOQ.

Table 2. Respirable silica dust concentrations ($mg\ m^{-3}$) averaged over nominal 30-min sampling period

Replicate	Wetted blade only	Wetted blade + water curtain	Wetted blade + LEV	Dry
1	4.846	2.944	ND[a]	44.37
2	2.563	0.920[b]	0.139[b]	
3	1.874	3.405	0.201[b]	
4	2.209	1.373	0.669	
Mean	4.934	3.813	0.604	
SEM	0.923	1.018	0.225	

ND, not detected.
[a]Measured silica mass from which this concentration was calculated was < LOD.
[b]Measured silica mass from which this concentration was calculated was < LOQ.

a Shapiro–Wilk *W* test ($\alpha = 0.05$) of the log-transformed data sets for each condition failed to reject the null hypothesis of normality. A parametric one-way ANOVA of the log-transformed data yielded a significant result ($P < 0.001$), and a *post hoc* Tukey's pair-wise comparisons test (Sheskin, 2004) indicated statistically significant differences (overall $\alpha < 0.05$) between the wetted-blade-only and wetted-blade + LEV conditions and between the wetted-blade + water curtain and wetted-blade + LEV conditions, but not between the wetted-blade-only and wetted-blade + water curtain conditions.

Results of the respirable silica analysis are presented in Table 2. The quartz LOD and LOQ values were 0.010 and 0.030 mg per sample, as reported by the laboratory. Quartz content of respirable dust samples ranged from non-detect to 100%, with a mean quartz content across all scenarios of 59.6%. ANOVA and Tukey's test results for the log-transformed silica data were parallel to those for the gravimetric analysis, i.e. statistically significant differences between the wetted-blade-only and wetted-blade + LEV conditions and between the wetted-blade + water curtain and wetted-blade + LEV conditions were shown, but not between the wetted-blade-only and wetted-blade + water curtain conditions.

DISCUSSION

Wetting the saw blade resulted in a 10-fold reduction in respirable dust exposure compared to dry cutting. Supplementing this with LEV provided 10-fold further exposure reduction. These results were consistent with previous studies (Yasui *et al.*, 2003; Pocock, 2012; Beaudry et al., 2013a,b). The water curtain appeared to provide some further reduction over that achieved by blade wetting alone, but the difference was not statistically significant.

The aim of this study was to compare the efficacy of engineering controls under controlled conditions, rather than to characterize exposures under actual working conditions. The experimental conditions, i.e. a small, unventilated enclosure and prolonged cutting task, were not representative of typical stonecutting operations. Full-shift time-weighted average respirable dust exposures under actual working conditions would likely be much lower than the levels measured in our experiments.

A note of caution is in order. Although the use of water for cooling and dust suppression during stone working with handheld tools is common practice in industry, the risk of electric shock or electrocution must be recognized. The use and regular testing of a GFCI equipped power supply is absolutely essential.

CONCLUSIONS

Addition of LEV to handheld circular saws appears to be an effective, simple, and low-cost engineering intervention for reducing respirable silica exposures during stone countertop fabrication.

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