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Characterizing Dust from Cutting Corian®, a Solid-Surface Composite Material, in a Laboratory Testing System

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Abstract

We conducted a laboratory test to characterize dust from cutting Corian®, a solid-surface composite material, with a circular saw. Air samples were collected using filters and direct-reading instruments in an automatic laboratory testing system. The average mass concentrations of the total and respirable dusts from the filter samples were 4.78±0.01 and 1.52±0.01 mg cm^{-3}, respectively, suggesting about 31.8% mass of the airborne dust from cutting Corian® is respirable. Analysis of the metal elements on the filter samples reveals that aluminum hydroxide is likely the dominant component of the airborne dust from cutting Corian®, with the total airborne and respirable dusts containing 86.0%±6.6% and 82.2%±4.1% aluminum hydroxide, respectively. The results from the direct-reading instruments confirm that the airborne dust generated from cutting Corian® were mainly from the cutting process with very few particles released from the running circular saw alone. The number-based size distribution of the dusts from cutting Corian® had a peak for fine particles at 1.05 μm with an average total concentration of 871.9 particles cm^{-3}, and another peak for ultrafine particles at 11.8 nm with an average total concentration of 1.19×10^{6} particles cm^{-3}. The small size and high concentration of the ultrafine particles suggest additional investigation is needed to study their chemical composition and possible contribution to pulmonary effect.

Keywords

Corian®; aluminum hydroxide; dust; pulmonary fibrosis; solid-surface composite

Introduction

Corian®, a solid-surface composite composed of acrylic polymer and aluminum hydroxide, has been increasingly used as a countertop material. However, inhalation of the respirable dust released from working with this material may pose an occupational health concern. Exposure to metal dust, including aluminum, is significantly associated with pulmonary

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SUPPLEMENTARY DATA
Supplementary data can be found at http://annhyg.oxfordjournals.org.

fibrosis (Taskar and Coultas, 2006). Raghu *et al.* (2014) recently reported a pulmonary fibrosis case associated with inhaled aluminum hydroxide (aluminum trihydrate) dust in a worker who had ground, machined, drilled, and sanded Corian®. However,McKeever *et al.* (2014) questioned whether the reported case was caused by the aluminum hydroxide from Corian®, or the aluminum oxide from sandpaper. This uncertainty calls for additional studies on the amount of dust generated from Corian®, how much aluminum hydroxide is contained in the dust, and the health effects of inhaling aluminum hydroxide dust. Particles with an aerodynamic diameter smaller than 10 μm are of particular interest as they are more likely to reach the gas-exchange regions of the lung (ISO, 1995). Furthermore, inhaled ultrafine particles, (i.e., diameters <100 nm), have been demonstrated to cause greater pulmonary effects than larger particles per given mass (Oberdörster, 2001). In this article, we describe the characterization of the dust, including the ultrafine particles, from cutting Corian® using a circular saw in a laboratory testing system.

Methods

Laboratory testing system

We conducted the laboratory characterization in the same testing system described in an earlier publication (Qi *et al.*, 2015). Supplementary Fig. 1, available at *Annals of Occupational Hygiene* online, illustrates a diagram of the system and all the instruments used. It included a filter section to remove all the particles from the room air entering into the system, a tool testing chamber where Corian® boards (12.7 cm wide and 1.2 cm thick) were cut automatically, a funnel section connected to a duct where samples were taken for dust characterization, and an air handling unit to move air through the system and collect all the particles from the exhaust. We operated the system as in the previous study (Qi *et al.*, 2015), which demonstrated high repeatability and representative dust sampling. In this study, we mounted a Makita circular saw (Model 5057KB, Makita USA, Inc., La Mirada, CA, USA) in the chamber and operated it automatically. A 60-tooth, 18.4 cm diameter Triple Chip Grind saw blade specifically designed for aluminum cutting (Model 072560, Oshlun, Inc., Henderson, NV, USA) was used for the saw. The traverse speed of the saw cutting through the Corian® board was set at 0.635 cm s^{-1}. Since the evaluated work task was cutting instead of sanding, it avoided the potential interference of aluminum oxide from sandpaper.

Sampling methods

Samples were collected from one duct sampling port (see Supplementary Fig. 1, available at *Annals of Occupational Hygiene* online) at a flow rate of 9.0 l min^{-1} using a Leland Legacy ® pump (SKC Inc., Eighty Four, PA, USA) connected via Tygon® tubing to a pre-weighed PVC filter (47-mm diameter, 5-μm pore-size) supported by a backup pad in a conductive three-piece filter cassette. The mass of the collected dust on the PVC filters was obtained by post-weighing the filters and subtracting their pre-weights. Three total dust samples and three respirable dust samples were collected. Respirable dust samples were collected with a GK4.162 RASCAL cyclone sampler (BGI, Waltham, MA, USA) upstream of the filter cassettes. At a flow rate of 9.0 l min^{-1}, that sampler conforms to the respirable sampling convention defined in European Committee for Standardization EN 481 (CEN,

1993) and the International Organization for Standardization 7708 (ISO, 1995; Health and Safety Laboratory, 2011). A sampling probe was designed to provide isokinetic sampling at 9.0 L min^{-1} by matching the flow velocity at the probe inlet with that in the duct. Total dust samples were collected at the same flow rate without using the cyclone sampler. It should be noted that both total dust and respirable dust samples may underestimate the actual dust mass due to the particle loss in the sampling probe, which was not straightforward to compensate.

All the filter samples were prepared and analyzed in accordance with NIOSH Methods 0500 (NIOSH, 1994) and 0600 (NIOSH, 1998). The average mass concentration of the total and respirable dust was equal to the mass loadings on filters divided by the corresponding sampled air volumes. In addition, we calculated the generation rate of the dust from cutting Corian® board and summarized the calculation method and results in the Supplementary Data, available at *Annals of Occupational Hygiene* online. Three bulk dust samples were also collected from the dust settled on the floor of the chamber. Elemental analysis of the filter and bulk samples was performed following NIOSH Method 7303 (NIOSH, 2003).

Besides taking filter samples, we used an Aerodynamic Particle Spectrometer (APS, Model 3321, TSI Inc., Shoreview, MN, USA) and a Fast Mobility Particle Sizer Spectrometer (FMPS, Model 3091, TSI Inc.) to provide real-time size distribution measurement of the dust from cutting Corian® with a 1-s time resolution. The 1-s time resolution allowed both instruments to capture the entire dust cloud profile for each individual cut, and avoided overlaps of measurement between two adjacent cuts. The details on the sampling and data processing for the two instruments are included in the Supplementary Data, available at *Annals of Occupational Hygiene* online. Depending on the density and shape of the particles, their aerodynamic diameter and mobility diameter may be different. However, the results from the two instruments provide an overall picture on the size distribution of the airborne dust in the size range from 6 nm to 19.8 μm. Ten repeated cuts were conducted for these measurements. In addition, a baseline test with just the saw running and without actually cutting Corian® was conducted to investigate the particles released from the running saw alone.

Results and Discussions

The average mass concentration of total and respirable dust on the filter samples was 4.78±0.01 (arithmetic mean ± standard deviation of the three replicates, the same goes to the data hereafter) and 1.52±0.01 mg cm^{-3}, respectively. It should be noted that these concentrations and the concentrations reported from the direct-reading instruments later were results obtained in the laboratory, which can be very different from exposures experienced during actual work practice, although the shape of the particle size distribution is expected to be similar. These results also suggests that about 32% of the total airborne dust mass from cutting Corian® board was respirable.

Metal element analysis of both filter and bulk dust samples confirmed that aluminum was the most abundant metal element in the dust, constituting about 12.0% of all three bulk dust samples, 29.8±2.3% of the total airborne dust, and 28.4±1.7% of the respirable dust. The next abundant metal element was calcium, 0.14% of the bulk dust. Since aluminum hydroxide is a known component of Corian® and the running saw contributed very few particles (see the results in Fig. 1), we assumed all the elemental aluminum found in these samples were contributed by aluminum hydroxide. Based on the molecular weights of aluminum and aluminum hydroxide, the bulk dust, total airborne dust, and respirable dust would thus contain 34.7, 86.0±6.6, and 82.2±4.1% aluminum hydroxide by mass, respectively. These results reveal that aluminum hydroxide is likely the dominant component of the airborne dust generated by cutting Corian®. The bulk dust apparently contains much lower percentage of aluminum than the airborne dust. This is probably because a large fraction of the bulk dust is large plastic-like chips (the Corian® equivalent of saw dust) possibly resulting from the interaction between the saw blade and acrylic polymer, which is another major component of Corian®. Supplementary Fig. 2, available at *Annals of Occupational Hygiene* online, shows a picture of the bulk dust on the floor of the chamber.

The average particle size distributions measured by APS and FMPS during cutting Corian® and the baseline test are plotted in Fig. 1. The mass-based size distributions from FMPS show bimodal lognormal distributions. It is not shown clearly in Fig. 1b for the result of baseline test due to the lower concentration compared to the result from cutting Corian®. All the other data show single-mode lognormal distributions. These distribution data were then curve-fitted accordingly, and the total concentration, geometric mean diameter (d_{pg}), and geometric standard deviation (σ_g) from the curve fitting for each mode are summarized in Table 1. The results in both Fig. 1 and Table 1 show considerably higher particle concentrations from cutting Corian® than from the baseline test. The particles observed from the baseline test may mainly from the saw's motor under the no-load mode. The comparison verified that most dusts observed by APS and FMPS and those collected on the filters during the cutting test were those from Corian® itself and possibly some additional particles from the motor under load. For these dusts, the averaged APS data shows a peak at 1.05 μm with a total concentration of 871.9 particles cm^{-3} based on number, and a peak at 4.19 μm with a total concentration of 2253.3 μg cm^{-3} based on mass. The averaged number-based FMPS data shows a peak at 11.8 nm with a total concentration of 1.19×10^6 particles cm^{-3}. The small size and high number concentration of ultrafine particles observed by the FMPS might raise concern about their possible contribution to any pulmonary effects from cutting Corian®. The chemical composition of these ultrafine particles, however, is unknown based on the current data.

Conclusions

The airborne dust generated from cutting Corian® in a laboratory testing system were composed mainly of aluminum hydroxide, and the respirable fraction of these dusts was about 32% of the total airborne dust mass. The number-based size distribution of these dusts had a peak for fine particles at 1.05 μm and another peak for ultrafine particles at 11.8 nm. The ultrafine particles had a total concentration of 1.19×10^6 particles cm^{-3}, suggesting that additional study is needed to confirm their chemical composition and investigate their possible contribution to any pulmonary effect.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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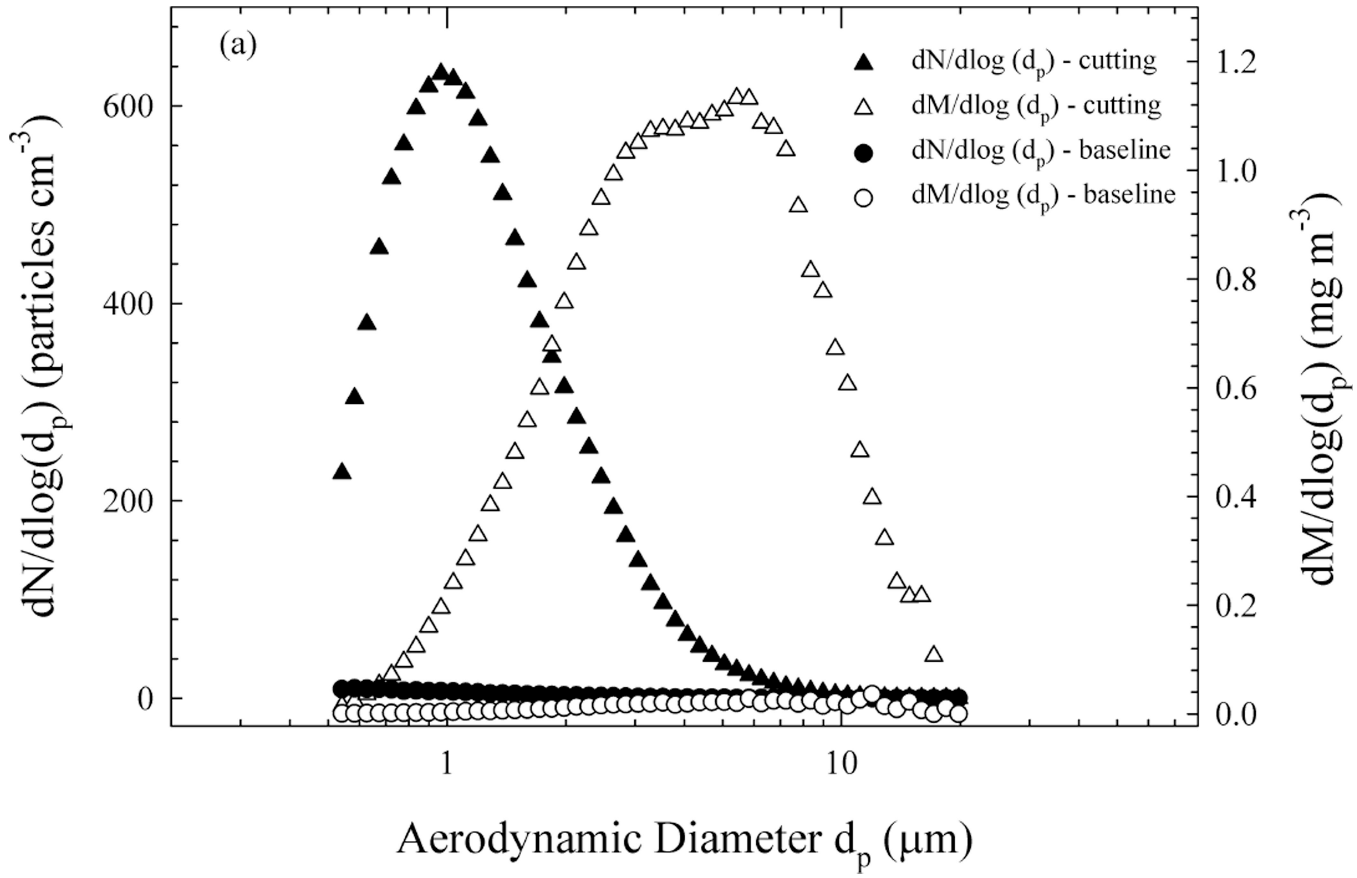
(a)
▲ dN/dlog (d$_p$) - cutting
△ dM/dlog (d$_p$) - cutting
● dN/dlog (d$_p$) - baseline
○ dM/dlog (d$_p$) - baseline
dN/dlog(d$_p$) (particles cm^{-3})
0
200
400
600
dM/dlog(d$_p$) (mg m^{-3})
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1
10
Aerodynamic Diameter d$_p$ (μm)

Figure 1a

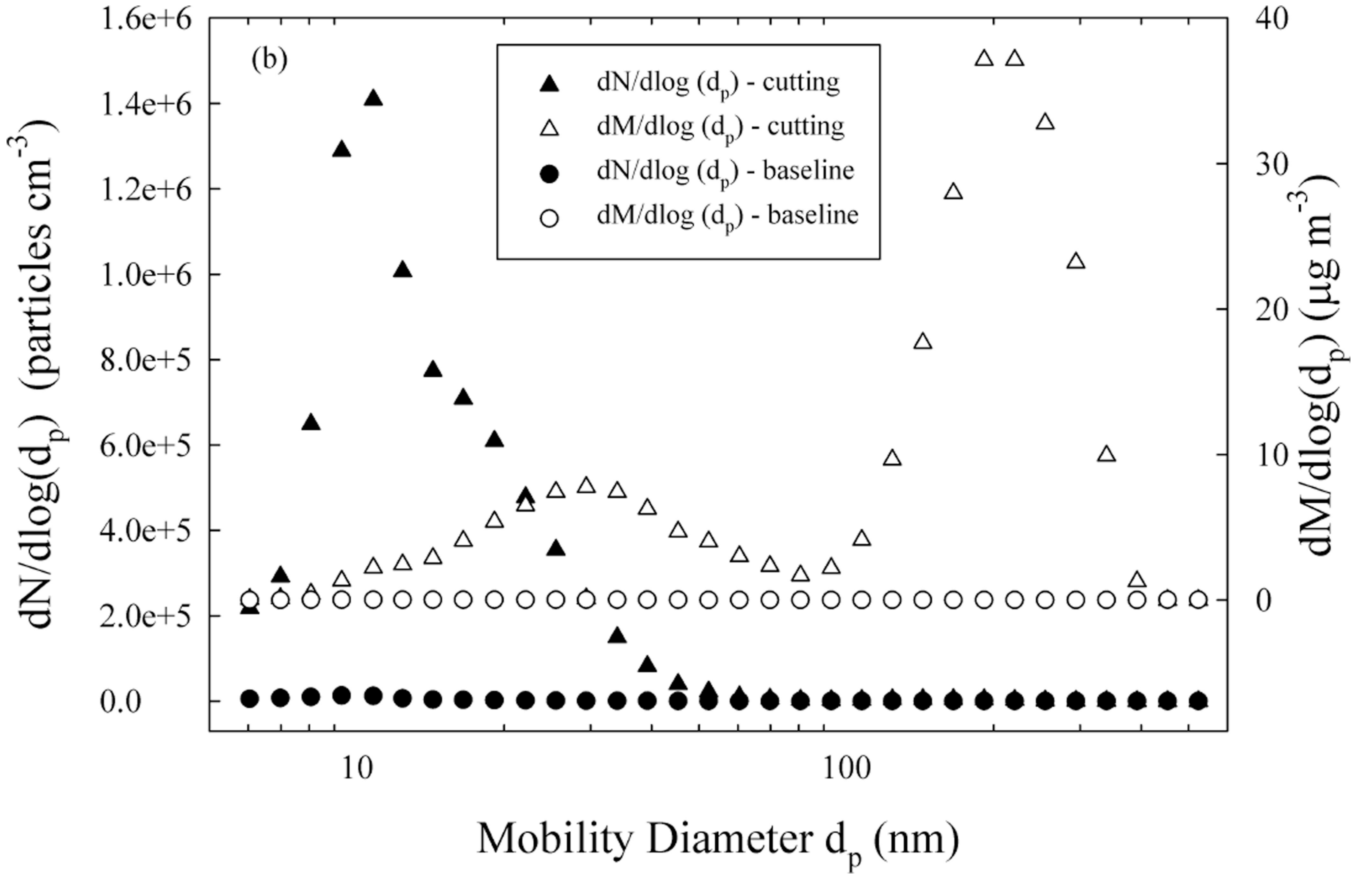

Figure 1b

Figure 1.

Number-based and mass-based size distributions of the dust from cutting Corian® and the baseline test (a) APS data; (b) FMPS data.

Table 1

The total particle concentration, geometric mean diameter (d_{pg}) and geometric standard deviation (σ_g) for each mode of the APS and FMPS data (from lognormal curve fitting)

		Number based			Mass based		
		total concentration (particles cm^{-3})	**Geometric mean diameter**	**Geometric standard deviation**	**total concentration (μg cm^{-3})**	**Geometric mean diameter**	**Geometric standard deviation**
Baseline Test	APS	24.7	0.42 μm	2.64	52.3	5.80 μm	2.41
	FMPS	9.00×10^3	9.3 nm	1.35	0.013	19.08 nm	1.87
					0.005	558.19 nm	1.21
Cutting Corian®	APS	871.9	1.05 μm	1.78	2253.3	4.19 μm	2.15
	FMPS	1.19×10^6	11.8 nm	1.51	10.28	28.89 nm	1.74
					29.54	209.87 nm	1.35