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Technical note

Personal exposure to airborne particulate matter due to residential dryer lint cleaning

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ABSTRACT

Exposure to airborne particles during and after cleaning dryer lint was examined via 30 experiments involving 4 dryers in a laundry room of a Northern California home. Gravimetric and real-time air samplers measured mass and size-resolved number concentrations in close proximity to the cleaning activity. The size distributions varied greatly between loads of clothing, with particle diameters > 10 μm contributing the bulk of the airborne lint dust volume. Average 5-min exposures to PM10 varied from < 10 to > 300 μg/m^3. Cumulative frequency distributions of 1-min-averaged PM10 measurements were used to characterize the probabilities of different short-term exposure levels during and at different elapsed times after lint cleaning.

1. Introduction

The average American spends 69% of the time in their homes [1], where people are frequently in close proximity to air pollution sources such as cooking, smoking, and household cleaning. Near an indoor emission source, pollutant levels are substantially higher than further away— this "*proximity effect*" is why personal exposure levels (using a monitor worn by a person) are consistently higher than indoor background levels (from a stationary indoor monitor) [2–5]. For example, Ferro et al. [6,7] found that household vacuuming can cause 2.5–10 μm particle exposure levels to be ~2 × as high as background levels in the same room. Acevedo-Bolton et al. [8] showed that fine particle (diameters ≤ 2.5 μm; PM2.5) exposures when sitting next to a smoker averaged ~4 × as high as the background PM2.5 in two houses.

Previous studies have examined a range of indoor activities (i.e., folding clothes/rugs [7], vacuuming [9,10], walking [11,12], wiping the blackboard [13], and even body movements during sleep [14]) that suspend particles indoors, leading to elevated exposures due to the proximity effect. However, cleaning dryer lint has not been examined, even though it can quickly suspend substantial amounts of particles, in close proximity to the person performing the cleaning.

A few past studies have chemically characterized bulk lint samples for trace metals [15,16], polybrominated diphenyl ethers (PBDEs) [17,18], or poly- and perfluorinated compounds (PFCs) [19]. These studies proposed that dryer lint could serve as an indicator of the amount of chemical present in the household [15,17], as a surrogate for dermal [18,19] or hand-to-mouth [18] exposure, or as a more general indicator of exposure in the home [16]. None of these studies investigated airborne particle concentrations or inhalation exposures when cleaning the lint trap.

One clinical study [20], investigating sensitization to detergent enzymes, measured exposure during dryer lint cleaning in the lab, reporting airborne levels of 0.04–1.2 ng protein/m^3. This is the only study, to our knowledge, that directly examined human exposure to airborne lint. However, this study did not examine levels of exposures in a real residential laundry room, nor did it characterize the mass concentration or size distribution of airborne dust produced by dryer lint cleaning.

Our first goal is to investigate exposure to airborne particles

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when cleaning dryer lint in homes. We performed 30 experiments in a home laundry room, measuring particle mass concentrations gravimetrically and in real time, for 4 dryers. Our second goal is to examine the size distributions of airborne lint. A monitor logged number concentrations for 14 size ranges continuously in each experiment, for 0.3–20 μm particles.

2. Materials and methods

We conducted experiments in a small (~12 m^3) laundry room in a single-family house in Palo Alto, California. For each experiment, we used bare fingers to remove the bulk lint in the dryer lint trap produced from one load of clothing, while using gravimetric and real-time air samplers to measure exposure to airborne particles in close proximity.

The gravimetric sampler consists of a 115 V AC vacuum pump connected to two aluminum filter holders in parallel: one with a PTFE membrane filter (47 mm diameter, 1-μm pore size, Pall Corp., Ann Arbor, MI, USA) and another with a PVDF membrane filter (47 mm diameter, 0.45-μm pore size, EMD Millipore Corp., Billerica, MA, USA). (The results of analyzing these two filters for trace metals and allergens, respectively, will not be discussed here.) Each filter was downstream of a cyclone separator (URG Corp., Chapel Hill, NC, USA) removing particles with aerodynamic diameters > 10 μm at 16.7 L/min. Typically, exposure studies have focused on fine particulate matter (PM2.5). Here, we chose to collect both fine and coarse respirable particles together (PM10), because in our initial tests, we were not able to accumulate sufficient PM2.5 mass.

A real-time aerosol monitor (AM510 SidePak laser photometer, TSI, Shoreview, MN, USA) logged PM10 concentrations every 10 s. A size-resolved monitor (Portable Aerosol Spectrometer Model 1.100, Grimm Technologies, Inc., Douglasville, GA, USA) measured number concentrations of airborne lint particles for 14 size ranges (0.3–20 μm) every 1 min – this instrument is widely used for investigating size-specific airborne particle levels in residential settings [e.g., 21,22].

All the monitors were placed together on a laboratory hand truck (Fig. 1 (a)) - this allowed us to (i) collocate all air sampling inlets near the adult's breathing height while standing (1.5 m) during sampling and (ii) transport all the instruments in/out of the laundry room without changing any air sampling settings between experiments, thereby measuring concentrations in a consistent manner.

We carried out 30 lint cleaning experiments using 4 different dryers: (i) Samsung USA dryer (Model DV50F9A8EV; 12 experiments), (ii) Samsung Korea dryer (6 experiments), (iii) LG dryer (Model DLEX5680V; 6 experiments), and (iv) Whirlpool dryer (Model WED8900BC; 6 experiments). These dryers were purchased locally, except for the Samsung Korea dryer, a prototype with a newly designed lint trap which was provided directly from Samsung in Korea. This prototype dryer used an enclosed cylindrical container to collect bulk lint, different from the typical in-door filter screens used in the 3 commercially-available dryers.

We conducted 3 lint cleaning experiments per day, with gravimetric and real-time air samplers running continuously. The airborne lint particles were collected ~0.5 m horizontally from the lint trap at ~1.3 m from the floor, to approximate the breathing location of a person performing the cleaning activity. In each experiment, we closed the laundry room door and turned off the HVAC system for the house. This gave an air change rate of ~0.1–0.6/h, estimated by the slopes of the log-linear regression lines between the measured number concentrations of the smallest size range (0.3–0.4 μm) and time during the decay periods.

An investigator inside the room cleaned the lint trap for 10–30 s and then quickly exited the room after 10 min, reclosing the door. We waited ~1–2 h before the next experiment to minimize the contributions from previous cleaning activities on subsequent measurements. Each pair of PM10 filter samples represented 3 lint cleaning experiments.

Dryer loads contained clothes and bedding from 3 local houses: one with 3 cats, another with 2 dogs, and the other without any pets. Each load of clothing was washed with Tide® Original liquid detergent using a top-load Whirlpool washer for 45 min (the standard washing time) and dried (with 6 dryer balls and 1 dryer sheet, to minimize static) for 50 min with the normal temperature setting. We collected and weighed the bulk lint after each drying cycle.

The gravimetric PM10 concentration was calculated as the particle mass collected on each filter divided by the air volume sampled (air sampling flowrate × duration). For both filter samples,

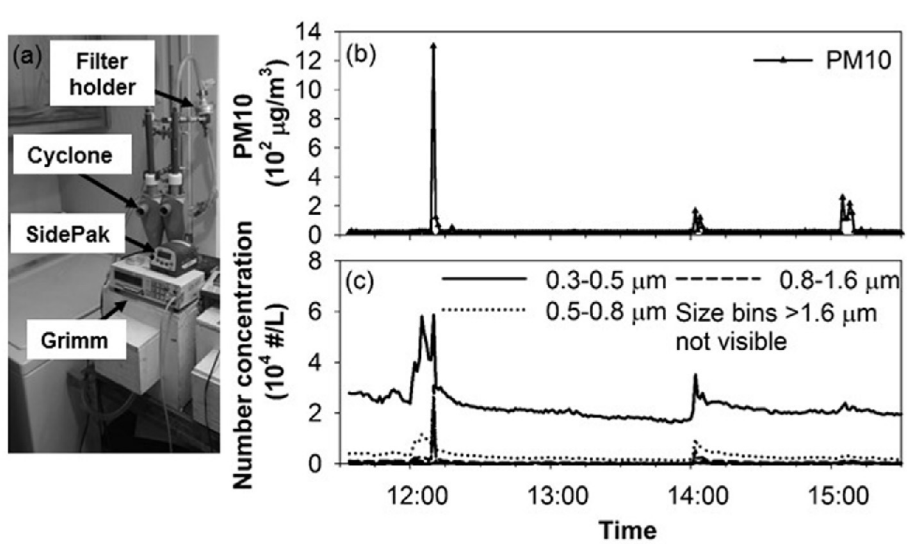

Fig. 1. (a) Air sampling setup including the gravimetric filter sampler and two real-time monitors (SidePak and Grimm). Example time series plots for (b) PM10 and (c) size-resolved particle number concentrations measured by SidePak and Grimm monitors, respectively. Each time series shows 3 concentration increases, produced by 3 successive dryer lint cleaning experiments on one day.