A Comparative Study of Estimating Particle Resuspension Rate using a Consistent Test Mechanism

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1 Introduction

Human walking influences indoor air quality by resuspending dust particles that have deposited on the floor. Previous research shows that particle resuspension rates vary over several orders of magnitude because of several influencing factors, such as flooring type, particle type, particle size, absorbing time, and shoe type (Hu et al. 2008; Qian and Ferro, 2008; Zhang et al. 2008). Qian and Ferro (2008) found that person-to-person variability was too large to determine effects of other factors, which indicated that a consistent test mechanism is integral to characterizing particle resuspension effectively.

2 Materials and Methods

Experiments in this study were conducted using a mechanical resuspension device to improve experimental reproducibility and eliminate the variability caused by walking style on resuspension. Developed by the Lawrence Berkeley National Laboratory, the resuspension mechanism is comprised of heel and toe plates controlled by electric actuators to simulate the human foot step. Two single element force sensors were used to test the stepping frequency of the mechanism equipped with a man size ten tennis shoe. Sensors were taped firmly to the outsole at the central of toe and heel part, respectively. The mechanical resuspension device is located in a temperature and relative humidity controlled 25 m^3 residential chamber at Clarkson University.

The objective of the study is to estimate particle resuspension rate as a function of particle type, particle size, shoe type, particle load absorbing time, flooring type and flooring condition using the resuspension mechanism. A Taguchi parameter experimental design with flooring type as the primary factor and others as robustness factors was employed. Four types of flooring, including vinyl, hardwood, high density carpet (HD-carpet) and low density carpet (LD-carpet), were selected, while robustness factors were set with two levels each, as shown in Table 1. Based on the experimental design, 64 experiments in total will be conducted with duplicates.

Table 1. Robustness factors

Factor	Low level	High level
Particle type	ATD*	House dust
Shoe type	Flat	Sneaker
Absorbing time	1 day	14 days
Flooring condition	Cleaned	Seeded

*: A1 ultrafine Arizona test dust

We conducted a pilot study to prepare for the full experimental design. For the pilot study, a portable dust monitor was used to measure particle number size distribution from 0.25 µm to 10 µm. Resuspension rate coefficients (1/h) were estimated based on the change in concentration of airborne particles following stepping motion of the resuspension mechanism using the method described in Qian and Ferro (2008).

3 Results

Figure 1 provides the real-time stepping force measured at central heel and toe parts during one representative experiment. Pressure results show that the time between heel peak pressures to toe peak pressure is 0.52±0.05 s. The mechanism steps down at a constant frequency 0.55±0.03 Hz. Previous work showed that the resuspension mechanism provides consistent and comparable heel and toe pressure loadings on various flooring samples (Tian et al. 2010).

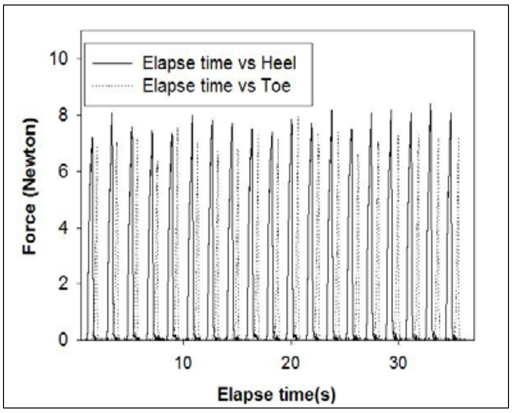

Figure 1. The real-time stepping force vs. time.

The effect of the primary factor, which is flooring type, was tested in the pilot study and preliminary results are presented in Figure 2. The results of the pilot study provide an order of magnitude response for the resuspension rate coefficient, but should be viewed as preliminary. Resuspension rate coefficients and factor comparisons will be determined by the results of the full experimental design.

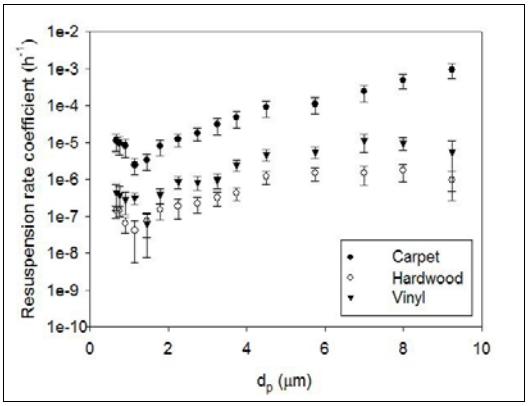

Figure 2. Preliminary results of resuspension rate coefficients for ATD in 15 size ranges from 0.6 μm to 10 μm under identical environmental conditions for 30 steps.

Preliminary results indicate that carpet is associated with higher resuspension rates than vinyl flooring, which is associated with higher resuspension rates than wood flooring. These results are consistent with previous resuspension studies using ATD (Goldasteh et al. 2010; Manthena et al. 2008; Qian and Ferro, 2008). Resuspension rate coefficients for ATD were found to vary from 10^{-6} $h^{-1}$to 10^{-4} h^{-1} for HD-carpet, 10^{-8} h^{-1} to 10^{-7} h-^{1} for hardwood and 10^{-8} h^{-1} to 10^{-6} h^{-1} for vinyl flooring. These results are 2 to 3 orders of magnitude lower than previous studies with actual humans walking (Manthena et al. 2008; Qian and Ferro, 2008). We hypothesize that the resuspension rates are lower because the mechanical foot steps in the same location each time, pushing the particles into the flooring and increasing the adhesive force of the particles for subsequent steps. Also, the resuspension mechanism cannot mimic the walking forward motion of a human which generates air currents that contribute to re-entrainment once the particles are detached.

4 Conclusions

The mechanical resuspension device provides a means for comparing various factors of resuspension and determining their importance in contributing to indoor particle levels. Preliminary results are consistent with previous experiments with humans walking when comparing the primary factor of flooring type.

5 References

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