A Personal Sampler to Estimate Particle Deposition in the Human Respiratory Tract

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Colorado State University
Knowledge to Go Places

Introduction

Emission → Exposure → Intake → Deposition → Dose → Health Outcome

Current PM methods ($PM_{2.5}$, IOM)

Goal of this work: to develop a sampler to estimate aerosol deposition in the human respiratory tract.

∗Measurement of aerosol deposition is a better surrogate for dose, risk assessment.

Advantages of Estimating Deposition vs. Exposure

∗**Not all inhaled particles deposit in the respiratory tract.**

∗**Filter based samplers measure all particles (inhaled and exhaled).**

- ∗**This results in error**
  - ∗**Deposition vs. Inhalability**
  - ∗**Deposition vs. $PM_{2.5}$**

∗**A sampler that mimics lung deposition may minimize this error.**

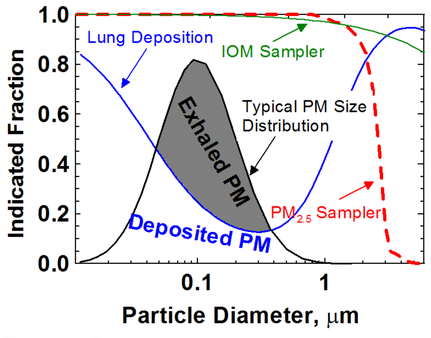
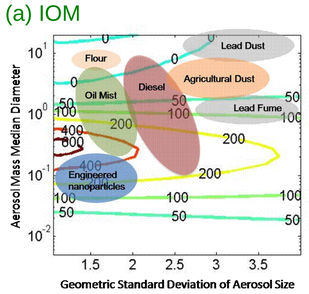


Figure 1: Schematic showing error between an inhalable sampler and a deposition sampler for a typical aerosol size distribution. The inhalable sampler captures all the particles, including those exhaled.

Figures 1 and 2 exemplify the difficulty in relating inhalability (or PM exposure) with deposition, dose, and risk.

Measurement Error: Exposure vs. Deposition

(a) IOM



(b) $PM_{2.5}$

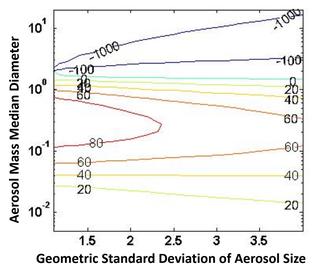


Figure 2: Error between common filter-based samplers and total respiratory deposition. (a) IOM sampler. Ovals represent particle size ranges reported in the literature for occupational exposures. (b) $PM_{2.5}$ sampler.

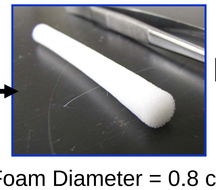
Aerosol Deposition Model

Lung deposition sampler engineered from porous foam.

$$D = 1 - \exp\left(-\frac{t}{d_f}\{a(St)^b + c(Ng)^d + e(Pe)^{-f}\}\right)$$ Clark et al. (2009)

Foam Properties | Impaction | Settling | Diffusion

4 L min^{-1}



Foam Diameter = 0.8 cm

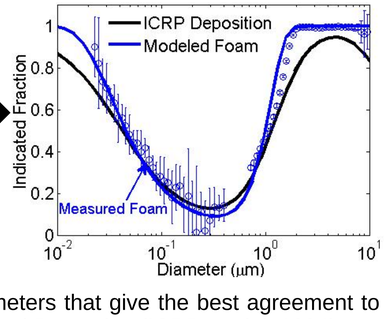


Figure 3: Particle deposition fraction for the foam sampler compared to ICRP (1994) total deposition and inhalable fraction. The red line represents modeled data; the symbols represent experimental data. Error bars represent one standard deviation.

∗We inverted the model to find foam parameters that give the best agreement to deposition fractions given by the International Commission on Radiological Protection (ICRP model, 1994).

∗We have verified that loadings of up to 20 mg have no effect on deposition efficiency.

Designing The Foam Sampler

Design Guidelines

	Pump	Foam	Battery	Total
Inexpensive	$50	$1	$30	$81
Lightweight	150 g	0.05 g	185 g	335 g
Reliable	Figure 6	Pressure drop constant with aerosol loading	Figure 6	

Using off-the-shelf parts the deposition sampler was built for < $100 and weighs about 0.3 kg (0.5 lb).

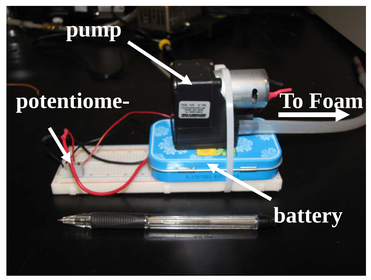


Figure 4: Pump, battery and control electronics of the sampling system. The entire unit is small enough to fit in a fanny pack.

Figure 5: The sampler can be worn on the shoulder near a workers breathing zone.

Battery Operated Pump Performance

∗Tested variation in flow over a typical 8-hr exposure period.

∗Linear decrease in flow rate with running time, due to the battery.

∗The ~10% decrease in flow has a negligible effect on the deposition efficiency of the foam.

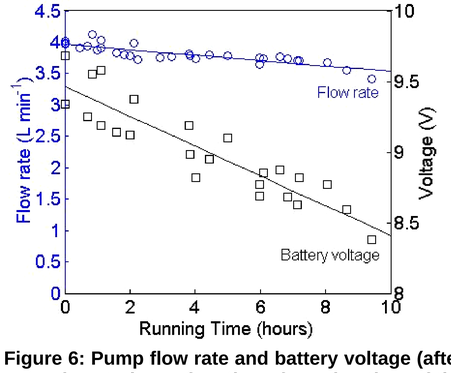


Figure 6: Pump flow rate and battery voltage (after potentiometer) as a function of running time of the battery.

Real-Time Exposure Monitoring

∗Can apply on a real-time basis using a condensation particle counter or nephelometer (here, Personal DataRam, pDR, Thermo Scientific, Inc.).

∗Unmodified pDR gives the total aerosol concentration in mg/m^3.

∗pDR with the foam insert measures the exhaled portion.

∗Deposited Aerosol = Total Aerosol – Exhaled Aerosol.

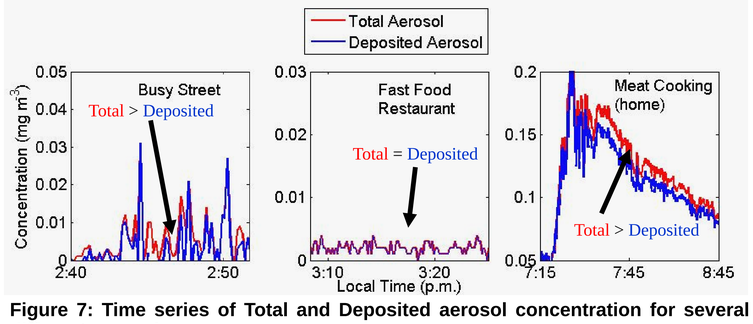


Figure 7: Time series of Total and Deposited aerosol concentration for several different aerosol exposures.

Known Limitations

∗Gravimetric analysis influenced by humidity, electrostatics.

Conclusions

∗**A foam sampling system was developed that mimics the aerosol deposition in the human respiratory tract and is expected to provide a more physiologically relevant estimation of risk.**

∗**This sampler presents a significant reduction in cost because inexpensive pumps can be used to control flow.**

∗**Some difference in total and deposited aerosol concentration are noted for common exposures.**

Acknowledgements

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References:

ICRP. (1994) Human Respiratory Tract Model for Radiological Protection. Oxford, UK:Elsevier Science, Ltd.
Clark, P. et al. An improved model for particle deposition in porous foams, J. Aerosol Sci., 2009; **40**(7): 563-572.

More details on this work can be found in Koehler et al. (2009):
Development of a Sampler for Total Aerosol Deposition in the Human Respiratory Tract, Ann. Hyg., 2009; 53: 731-738.

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