Evaluating Airborne Exposures to Microplastic Particles

Inhaled Particles XIII – NanOEH Conference
May 16, 2023
**Manchester, UK**

Alison Elder
Department of Environmental Medicine
University of Rochester Medical Center

Plastics are Ubiquitous in the Environment: Airborne Microplastics (MPs)

- Indoor and outdoor air sampling have demonstrated the presence of plastic particles that have a range of compositions, morphologies, and sizes
  - Submicrometer (incl. nanoscale) up to several mm in length and/or diameter (*Rahman et al., 2021; Wright et al., 2019; Zhang et al., 2020*)
  - Fibers, fragments, spheres (beads) (*Xie et al., 2022*)
  - Polypropylene, polyethylene, polyester, polyvinyl chloride, nylon (*Vianello et al., 2019; Xie et al., 2022*)
- Plastic particles can be distinguished from other airborne particulates
  - Available literature suggests that 4-50% by mass of sampled particles are composed of synthetic polymers (*Brahney et al., 2020, 2021; Dris et al., 2017; Prata et al., 2020*)
- Polymeric particles have been identified in digested excised human lung tissue *(Jenner et al., 2022)*

Broad Characteristics of Airborne MPs
(indoor and outdoor)

Physical dimensions

Xie et al., 2022
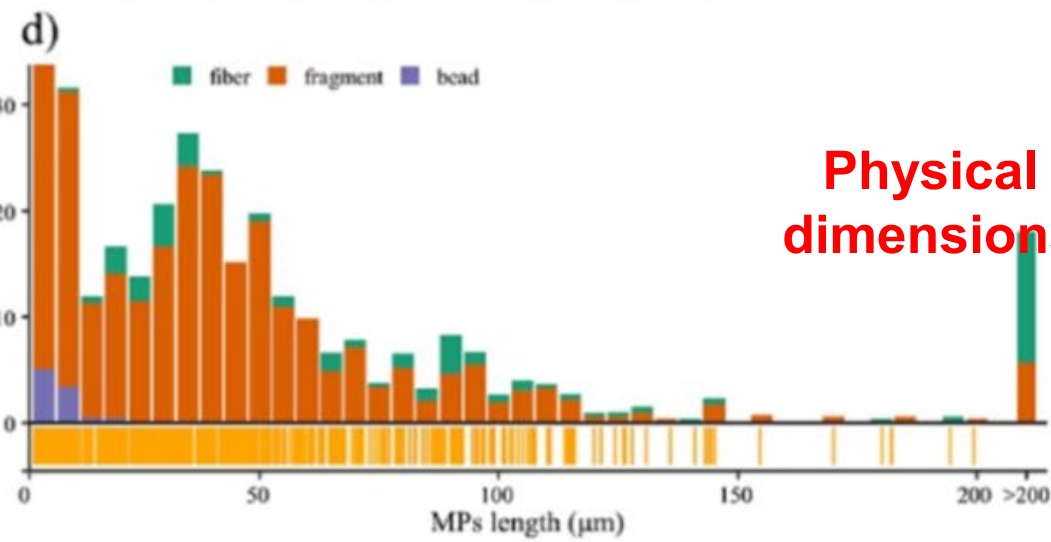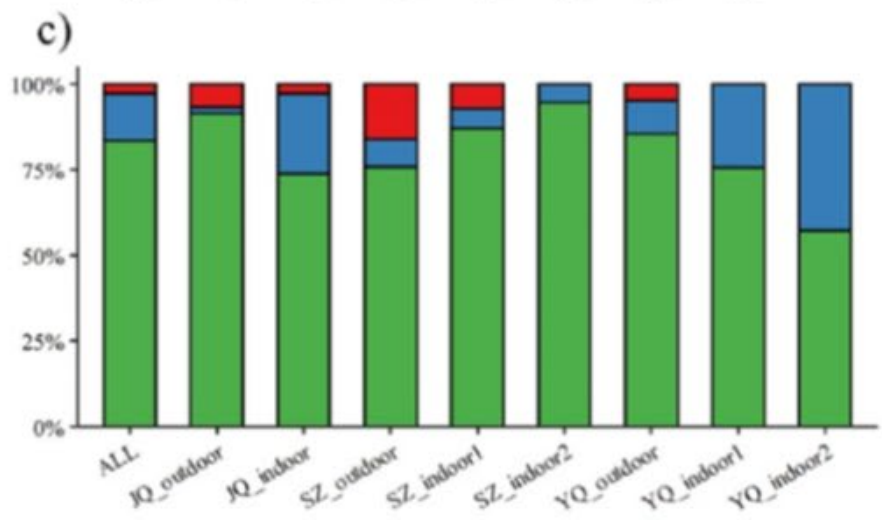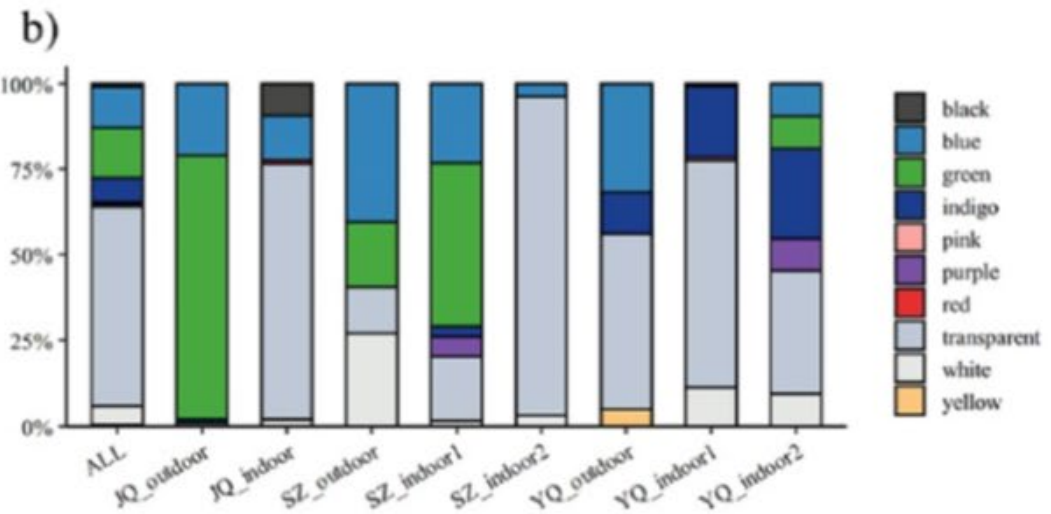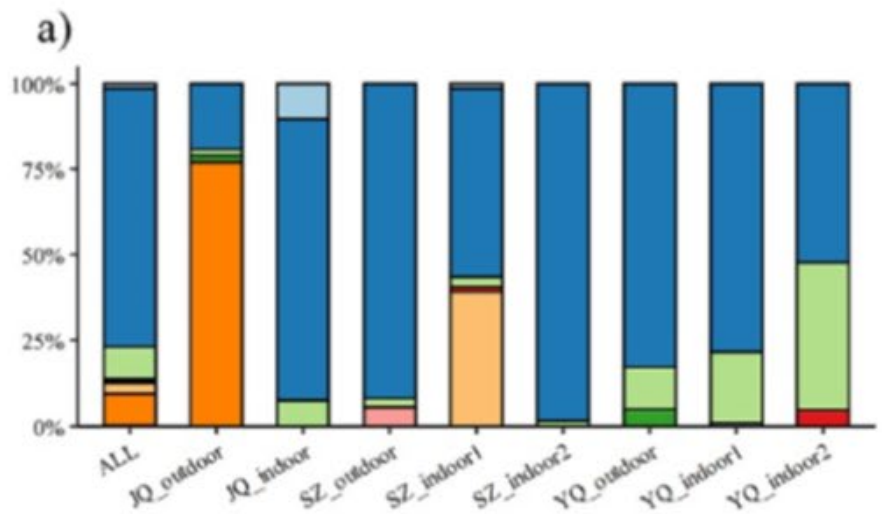
Challenges in the Characterization of Airborne MPs Exposure

- Size detection limits of analytical tools used for imaging and identification
  - Raman, FTIR spectroscopies; GC-MS; thermogravimetric analysis; enhanced darkfield hyperspectal imaging (*Nel et al., 2021; Rahman et al., 2021*)
  - Can dyes (or coatings) interfere with identification? (*Xie et al., 2022*)
- Distinguishing polymeric from other sampled particles
  - What is their contribution to overall airborne PM mass and number concentrations?
  - Is this fraction constant across all particle size fractions?
  - Use of dyes (e.g., Nile red) is commonly used (*Nel et al., 2021; Xie et al., 2022*)
- Suite of tools is needed to fully characterize polymeric particles (chemical identity, morphology, size/size distribution)
- Distinction between physical dimensions and aerodynamic diameters*

Fractional Deposition of Inhaled Particles in the Human Respiratory Tract *(nose-breathing)*
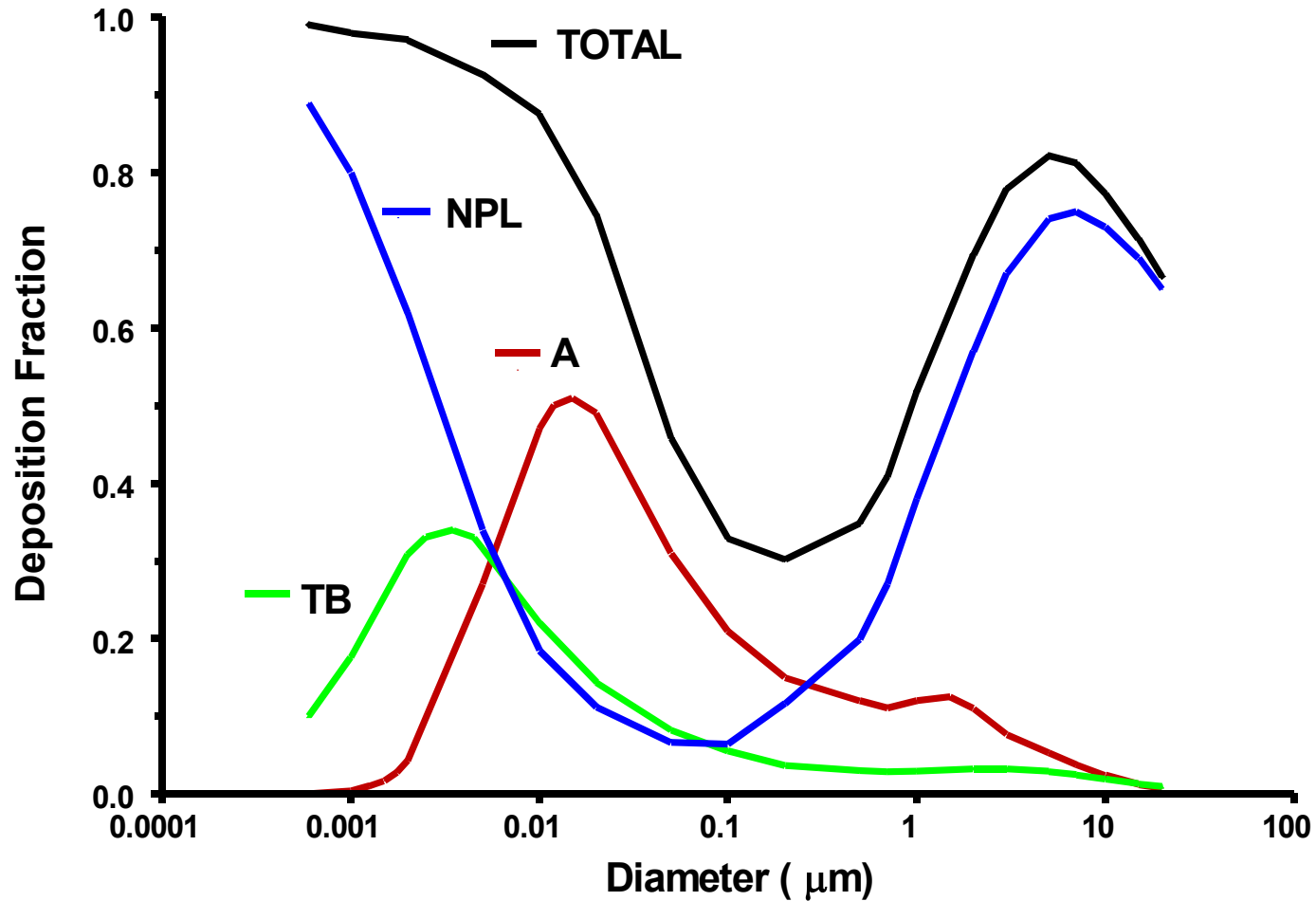
Inhalable particulate matter (human) <100 μm

Respirable particulate matter (human) <4 μm

PM$_{2.5}$ <2.5 μm

ICRP, 1994

Conceptual Overview of Project

Indoor airborne particulates

↓

Respirable particulates

↓

Respirable microplastics

Morphology?
Concentration?
Composition?

Respirable Particle Sampling Devices

Cyclone type Cutoff

Impactor type Cutoff (2.5 μm)

CYCLONE OPERATION

- ▶ Air enters through a slit on the side of the sampler which creates cyclonic action.
- ▶ Large particles fall into the cap (grit pot) at the bottom and are discarded.
- ▶ Small particles are thrown up onto the filter for analysis.
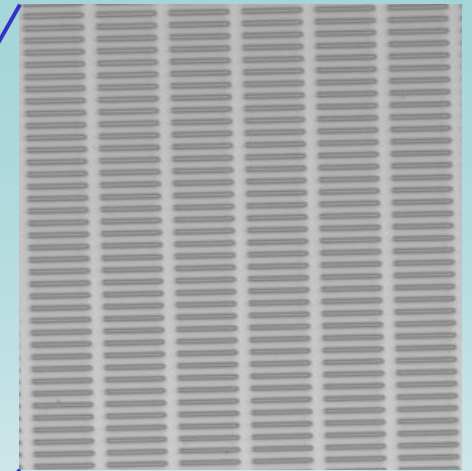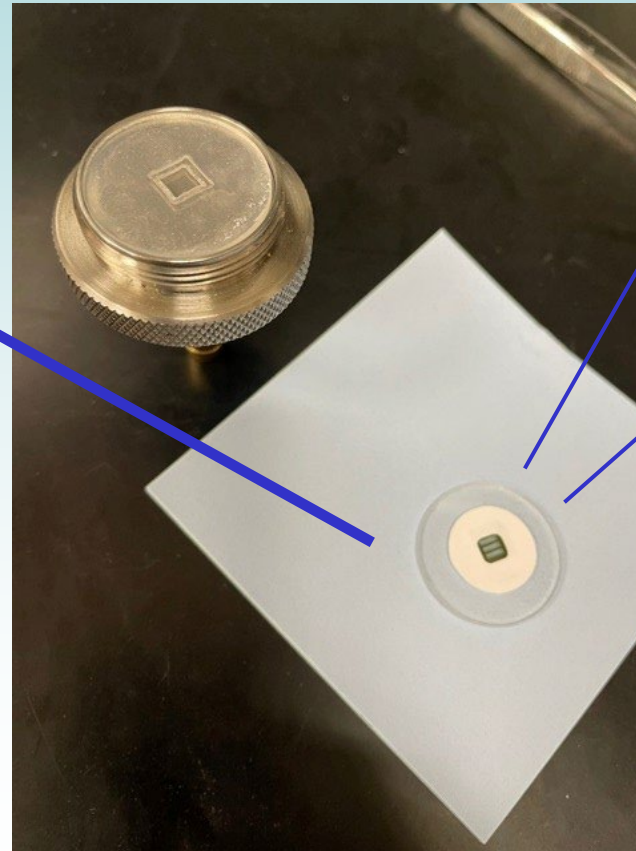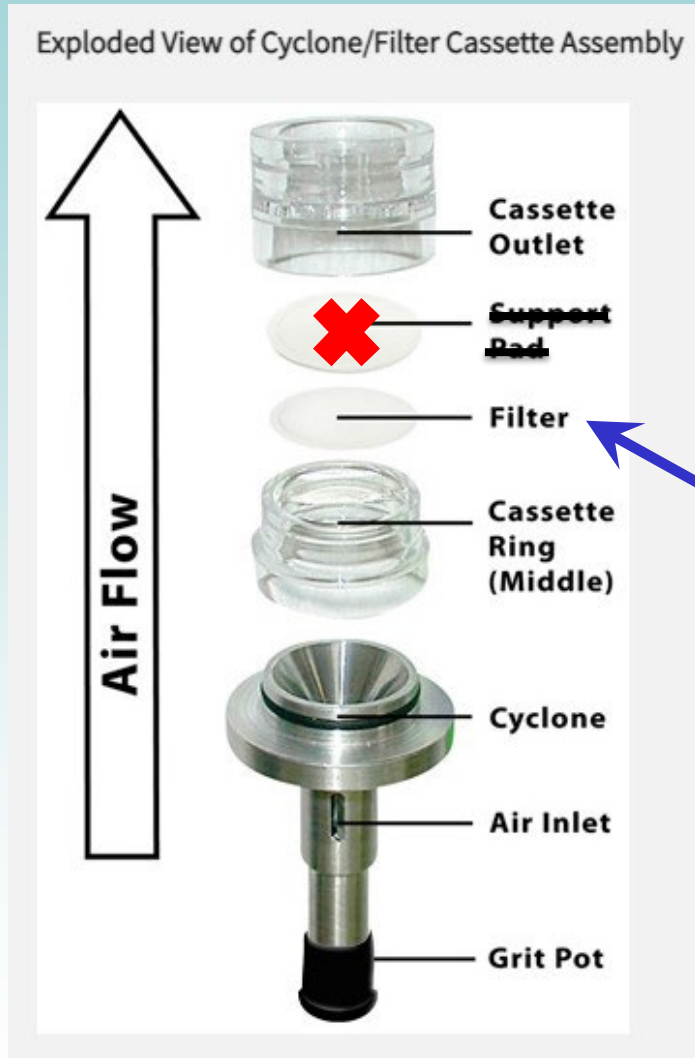
Cap (grit pot) must be in place during sampling.

TABLE 3. Respirable Fraction

Particle Aerodynamic Diameter (μm)	Respirable Particulate Matter (RPM) Fraction Collected (%)
0	100
1	97
2	91
3	74
4	50
5	30
6	17
7	9
8	5
10	1

ACGIH, 2020

Respirable Cartridge: SiMPore Substrate Substitution

Exploded View of Cyclone/Filter Cassette Assembly

Air Flow

- Cassette Outlet
- ~~Support Pad~~ ❌
- Filter
- Cassette Ring (Middle)
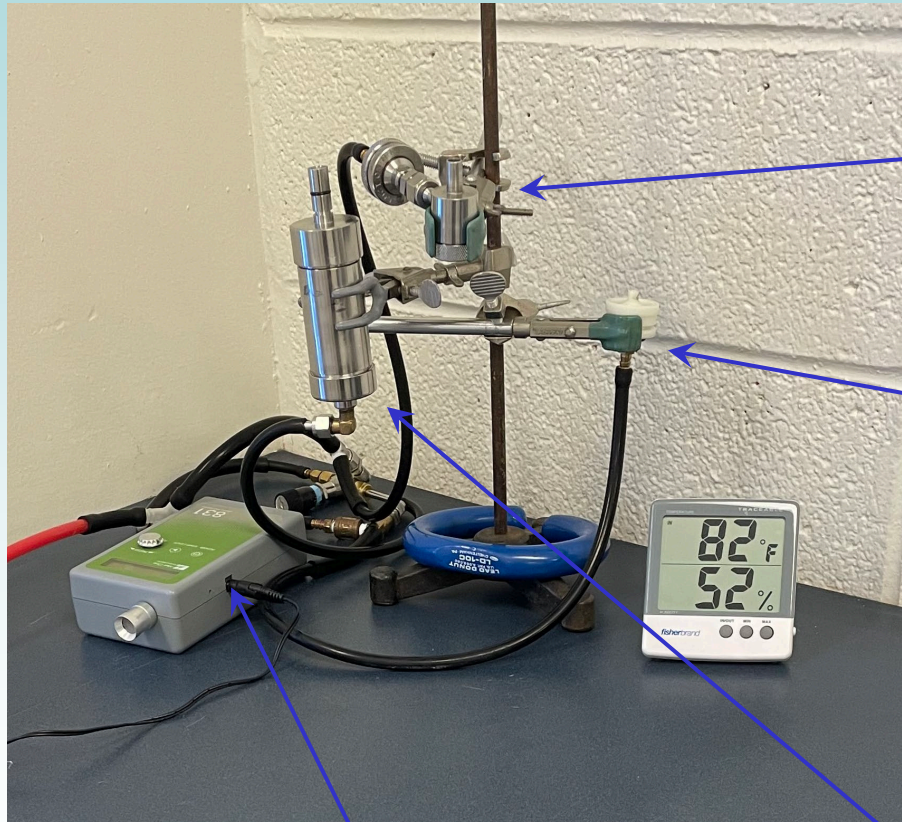- Cyclone
- Air Inlet
- Grit Pot

Ultrathin SiN membrane

Each pore = 1 x 50 μm
(8, 4, 2, 1 μm)

>3000 pores across 3 membrane windows, highly permeable

Imaging and analysis take place directly on the membrane
- No extraction
- Optically thin
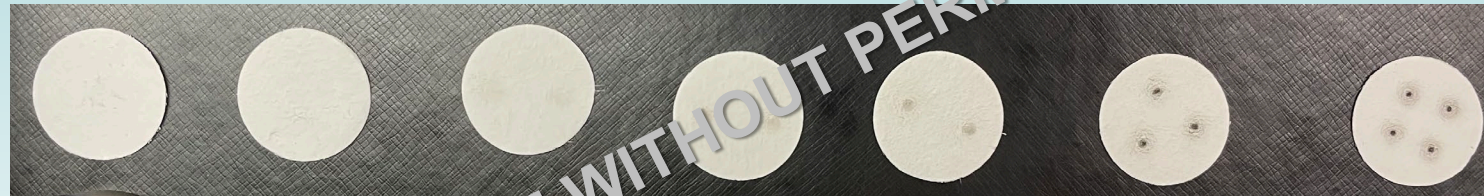
Indoor Air Sampling for Respirable Microplastics

Sampler (impactor) with ~2.5 μm cutoff

Respirable PM sampling with SiMPore membrane (pore size 1 μm x 50 μm)

Cascade impactor with 7 stages (cutoff range from 10 μm to 0.5 μm)

Optical particle counter

University laundromat air sampled with the cascade impactor
(arranged from largest to smallest cutoff)

Effective Cut-off Diameters

| 10 µm | 6.1 µm | 3.7 µm | 2.2 µm | 1.4 µm | 0.8 µm | 0.5 µm |

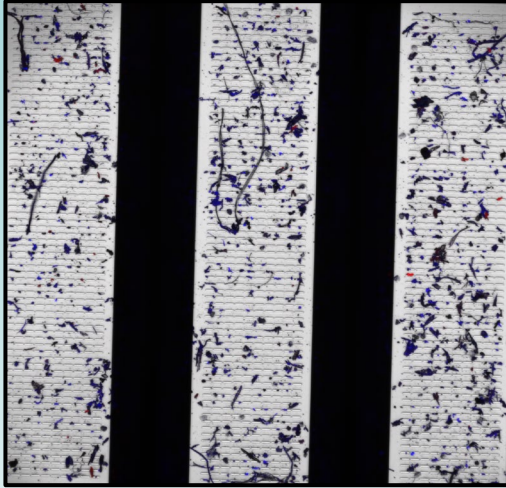* **96% of the mass belonged to the particles found in the bottom four stages**
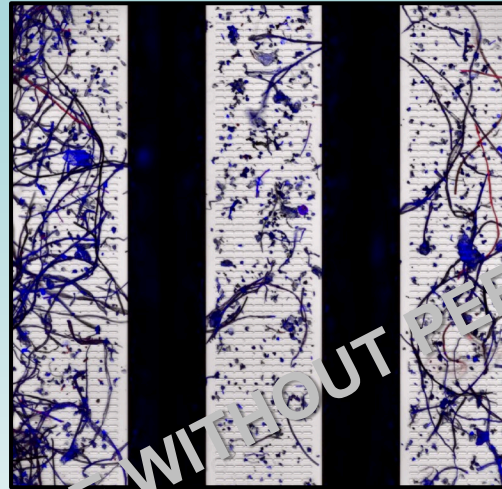
MMAD: 0.44 µm
GSD: 4.59

TSP: 9.8 µg/m³
With PM$_{2.5}$ Inlet: 11.6 µg/m³
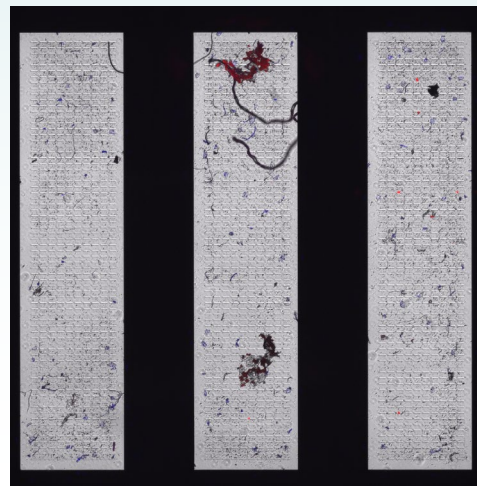
Air and Surface Dust Samples

Machine Shop (air)

Campus Office (surface dust)

Household Laundry Room (open-face)

Air

Household Laundry Room (2.5 μm impactor)

+ Nile Red
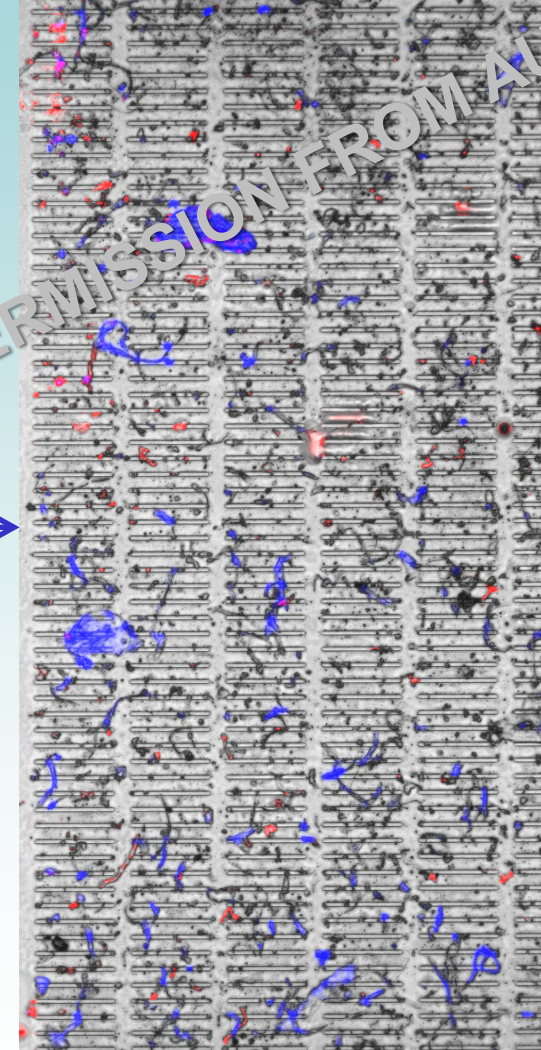+ Trypan Blue

Plastic
Cellulosic
Proteinaceous

Staining and imaging done by S.S. Romanick, G. Madejski, *unpublished*

4-hr Indoor Air Respirable PM Sample:
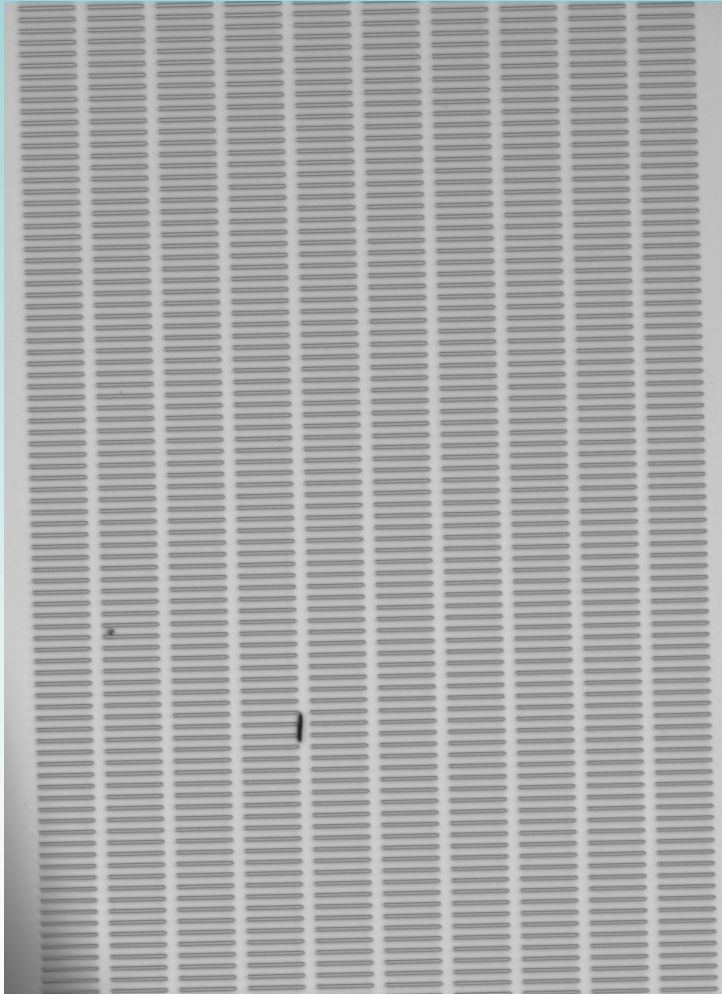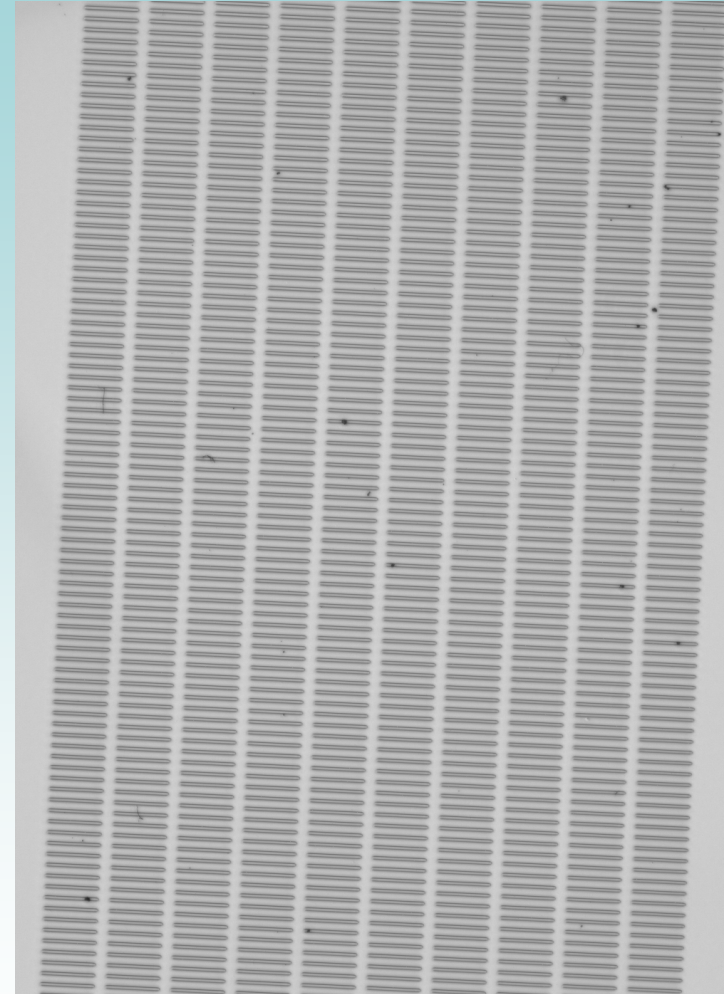## SiMPore Membrane, 1 μm pore

+ Nile Red
+ Trypan Blue

Plastic
Cellulosic
Proteinaceous

Unpublished, S.S. Romanick
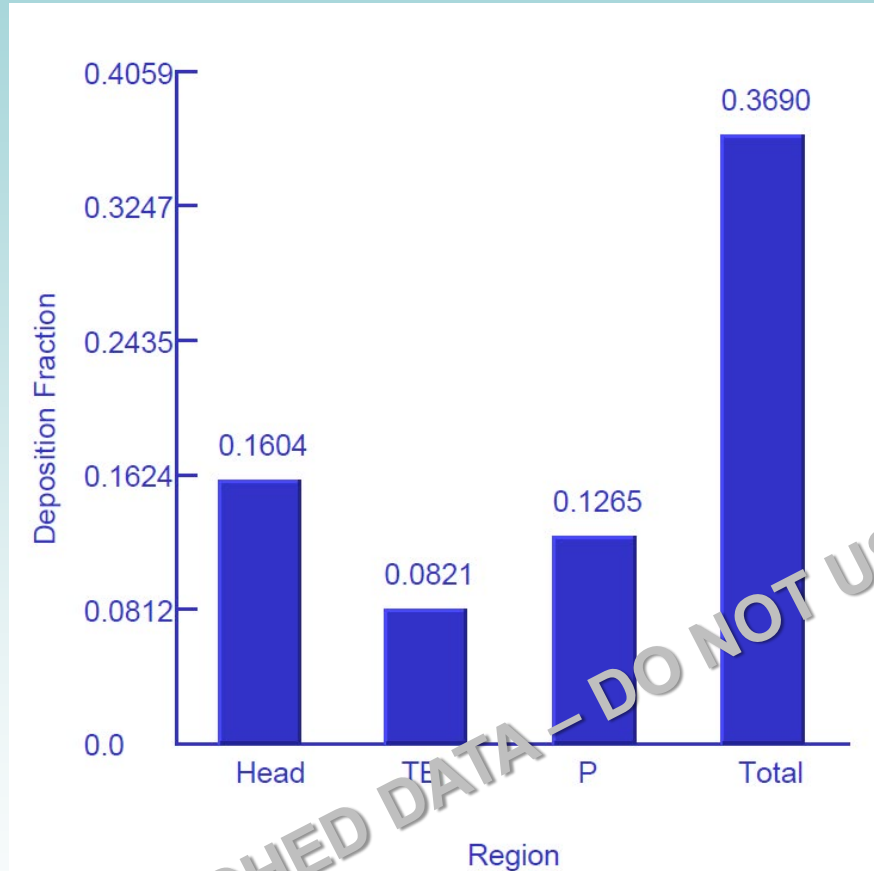
Sampling Controls

Field Blank
(SiMPore membrane in sampler)

Sample from Clean Room

Estimated Deposited Dose of Respirable Microplastic Particles

~1% of the particles were Nile Red-stained

Estimated deposited dose in the tracheobronchial and pulmonary regions is **0.26 µg** for a modeled 24-hour exposure

Deposited Dose = airborne concentration x exposure time x tidal volume x respiratory rate x deposition fraction

minute ventilation

inhaled dose

Multiple-Path Particle Deposition Model
Input parameters: human symmetric airway morphometry, oro-nasal normal augmenter breathing mode, tidal volume = 625 mL, and breathing rate of 12 min^{-1}, MMAD = 0.44 µm, GSD = 4

Conclusions and Future Directions

1. Microplastics were present in all indoor air samples collected thus far (~1% of sampled PM was Nile red-positive).

   a. Identification of specific polymers

   b. Are the polymer types equally distributed across all particle size classes?

2. Sampling revealed the presence of <u>respirable</u> microplastics.

   a. More work is needed to determine the broad applicability of these findings (is this true for all indoor environments?).

   b. How do indoor and outdoor environments compare?

3. Using the sampling data from the university laundromat, we estimated a deposited mass dose in the tracheobronchial plus pulmonary regions of ~0.26 µg (for a modeled 24-hour exposure scenario).

Acknowledgements