Field testing a low-cost passive aerosol sampler for long-term measurement of ambient PM$_{2.5}$ concentration and composition: results from the HAQAST Hi-Res Tiger Team

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Low-Cost PM Sensors

Characteristics:

- Most use light scattering to infer PM mass
- Good for short-term sampling on order of seconds-weeks; not for annual mean which drives biggest health burden
- Sensitive to humidity variations
- Calibration drift due to soiling of optics
- Require power
- Don’t measure PM composition
- No archived sample
UNC Passive Aerosol Sampler

- Collects PM on a filter in a passive manner, through gravitationally settling and diffusion
- Suitable for long-term integrated sampling (on order of weeks to months)
- Automated PM counting, sizing, and chemical characterization by electron microscopy
- ~$20/filter; ~$150/analysis
- Coarse PM data correlates well with FRM samplers
- Has not been tested extensively for PM$_{2.5}$
UNC Passive Sampler

Large particles settle by gravity

Small particles diffuse

Removable mesh cap

Filter

SEM Stub


Source RJLee Group
Samplers are placed between aluminum plates to protect from weather and turbulence.
Duplicate samplers deployed at Mass DEP site adjacent to Route 93 in Boston
Automated PM sizing and elemental analysis

- Graphical representation of grayscales in the SEM image is used for particle detection
- Individual particle images are acquired for each individual particle
- 45 Rotating Feret boxes are used to measure each particle (90 diameters)
- Elemental composition is obtained using Energy Dispersive Spectroscopy (EDS)
Estimating Airborne Concentration

\[ C = \frac{F}{V_{\text{dep}}} = \left(\frac{\#}{\text{cm}^2 \text{s}}\right) \left(\frac{\text{s}}{\text{cm}}\right) = \frac{\#}{\text{cm}^3} \]
Tiger Team PM$_{2.5}$ Field Study

- For 13 months, we co-located UNC-PAS samplers at regulatory monitoring stations (3 in Boston; 2 in NYC; 3 in San Francisco Bay area)
- At each site: Sequential 4-week and 12-week integrated samples collected + duplicates & field blanks
- Evaluated precision based on duplicates
- Examined correlations with co-located Federal Reference (FRM) and Federal Equivalent (FEM) method data
- Characterized major particle sources, including diesel vehicles, wildfires, sea salt, etc.
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**Background**
- There is an increasing need for high resolution PM data in support of health assessments, particularly for quantifying the dominant health risks related to long-term PM$_{2.5}$ concentrations.
- Low-cost sensors (LCS) for PM$_{2.5}$ are of increasing interest, but most LCS infer PM based on light scattering and may not be ideal for long term sampling due to calibration drift and humidity interferences.
- Passive samplers collect particles by gravitational settling and diffusion.
- Sampling rates as a function of particle diameter are estimated from theory.
- Calibration drift and humidity interferences.
- Passive samplers collect particles by gravitational settling and diffusion.
- PM$_{2.5}$ concentrations can be estimated from the particle size distribution (Wagner and Leith, 2001a,b,c).

**Objectives**
- Collect sequential 4-week and 12-week average PM$_{2.5}$ concentration and composition in eight urban sites in Boston, New York City and the San Francisco Bay Area.
- Implemented new methods for particle deposition calculation and microscopic analysis to improve UNC-PAS performance for submicron, carbonaceous particles typical of urban environments.
- Compute precision based on duplicate sampling.
- Compare data from the UNC-PAS and co-located federal reference and equivalent methods.
- Characterize particle composition and speciation data.

**UNC PAS**
- The University of North Carolina Passive Aerosol Sampler (UNC PAS) was developed by Wagner and Leith (2001a,b,c). Ott and Peters (2008) designed a flat plate shelter that houses the sampler.
- Collects airborne particles in a passive manner for as long as it is left open to the air.
- Has been extensively validated for coarse particles, but not for PM$_{2.5}$.
- Utilizes a deposition velocity model from the particle size distribution (Wagner and Leith, 2001b; Nash and Leith, 2010) for estimating airborne concentrations.

**Results**

**Precision**
- The correlation coefficient, R, between duplicates was 0.97 (p < 0.001). The computed precision (SD(diff)/sqrt2) was 14.2%. Good precision (25%) was also observed for PM$_{10-2.5}$. R = 0.78, p < 0.001.
- We also compared 12-week integrated samples with the mean of three sequential 4-week samples. The 12-week PM$_{2.5}$ was 12% lower on average (p = 0.01), suggesting some loss of volatile and semivolatile particles over longer sampling periods.

**Accuracy and Reproducibility**
- We also compared 12-week integrated samples with the mean of three sequential 4-week samples. The 12-week PM$_{2.5}$ was 12% lower on average (p = 0.01), suggesting some loss of volatile and semivolatile particles over longer sampling periods.

**Speciation Data**

**Conclusions**
- Overall, our results suggest that passive monitors offer a useful alternative for long-term PM$_{2.5}$ monitoring in community settings.
- Used in conjunction with remote sensing and other data, passive monitors could improve spatial data coverage, characterize source-related components, identify pollution hotspots, assess air pollution-related disease burdens, or evaluate the impact/benefit of interventions.

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