Development of Personal Aerosol Collector and Spectrometer (PACS): Part I: Design and Theory

Changjie Cai1,*, Jae Hong Park1, Geb W. Thomas2, Sivaram P. Gogineni3 and Thomas M. Peters1

1Department of Occupational and Environmental Health, University of Iowa
2Department of Mechanical and Industrial Engineering, University of Iowa
3Spectral Energies, LLC

Background

- People are exposed to a variety of particles with a wide range of sizes.
- Current personal samplers cannot measure real-time exposures to all particle size ranges simultaneously.
- Need to simultaneously measure particle number, surface area, and mass concentrations by size and collect particles for subsequent chemical analysis from 10 nm to 10 µm.

Objective

- Describe the Personal Aerosol Collector and Spectrometer (PACS).
- Describe and test the algorithm used to fit tri-modal distributions with PACS data.

Methods

PACS hardware

- Combines three devices: selector, photometer and condensation particle counter (CPC).
- Detects particle number and mass concentrations after passing through selector stages.

PACS software

- Fits a tri-modal, log-normal distribution to the number and mass concentrations measured after the size selector as shown below:

  **Inputs:** Measured number and mass concentrations in each stage (6 sets)

  **Step 1:** Iterate geometric standard deviation (GSD) and count median diameter (CMD) for each mode to obtain initial values (using parallel computing and low iteration resolution could decrease the computation time)

  **Step 2:** Use Hatch-Choate equations to find average mass diameter (AMD), mass median diameter (MMD) and surface area median diameter (SMD) for each mode

  **Step 3:** Acquire the number concentrations by solving the constrained linear least-square problem, which could dramatically decrease the computation time

  **Step 4:** Save all calculated CMDs, GSDs and number concentrations that satisfy the following condition: the difference between calculation and measurement is less than 10% for each stage

  **Step 5a:** Calculate the averaged value of each parameter in Step 4

  **Step 5b:** Calculate each parameter in Step 4 by finding the minimum squared sum of relative error (SSRE)

  **Condition 1:** If the results exit

  **Condition 2:** If the results do not exit

**Tests for pre-defined aerosols**

- NMB was used to evaluate the tendency of the algorithm to over-estimate or under-estimate variables; \( R^2 \) was used to indicate how well data fit a statistical model.
- For number concentrations: NMBs = 0%, \( R^2 \) = 0.98 to 0.99.
- For surface area concentrations: NMBs = 0% to 7%, \( R^2 \) = 0.93 to 1.00.
- For mass concentrations: NMBs = 0%, \( R^2 \) = 0.85 to 0.95.

Conclusions

- The PACS introduced:
  - Selector differentiates particles by size and collect particles for chemical analysis
  - Software fit a tri-modal, log-normal distribution to number and mass concentration data measured downstream of selector
  - Software fit the size distributions well for diverse pre-defined aerosols.
- Software computation time was decreased to ~110 seconds using the optimization method, low resolution iteration and parallel computing.

References


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