Significance of Sources and Size Distribution on Calibration of Low-Cost Particle Sensors: Evidence from a Field Sampling Campaign

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INTRODUCTION

- Low-cost sensors (LCS) are gathering the interest of researchers and monitoring agencies worldwide due to their compact size and economic feasibility.
- LCS have several disadvantages such as calibration dependencies and subject to biases which makes their data unreliable (Crilley et al., 2018; Dubey et al., 2022; Giodano et al., 2021).
- Typically, low-cost optical particle sizers are calibrated using PSL particles of known aerosol properties (refractive index and density), size, and concentration. This introduces errors in the LCS measurements when aerosols of unknown properties are sampled.
- To our knowledge, previous studies have not investigated the impact of aerosol composition (source mixture) and particle size distribution on the performance of LCS and their importance in the calibration models developed to improve their data quality.

OBJECTIVES

This study focuses on identifying the fundamental issues associated with low-cost particle sensors that need to be addressed for their development. It aims to address the following objectives:

- Effect of emission sources on the mass and number concentrations recorded by LCS.
- Effect of the particle sizes with dominant mass fractions on the LCS mass concentration data.
- Highlighting the discrepancies in LCS mass and number concentration measurements.

SITE SELECTION

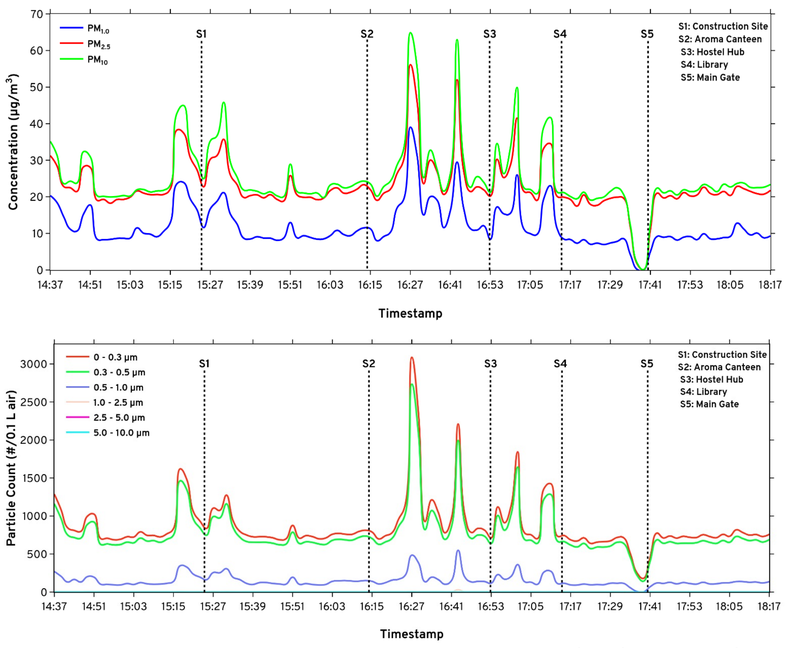

Figure 1. (a) Mass concentration and (b) Number concentration measurement results during site recce activity at different sampling locations

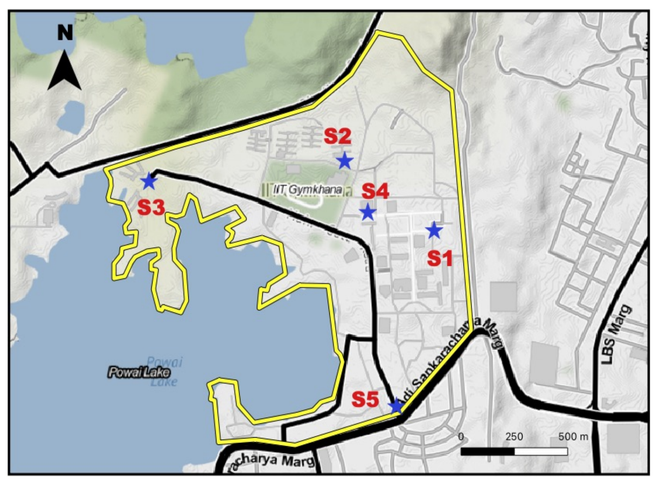

Figure 2. Sampling sites inside the IIT Bombay campus. The five sites are S1: Construction site, S2: Aromas, S3: Hostel Hub (H-12/13/14), S4: Central Library, and S5: Main Gate

SAMPLING RESULTS

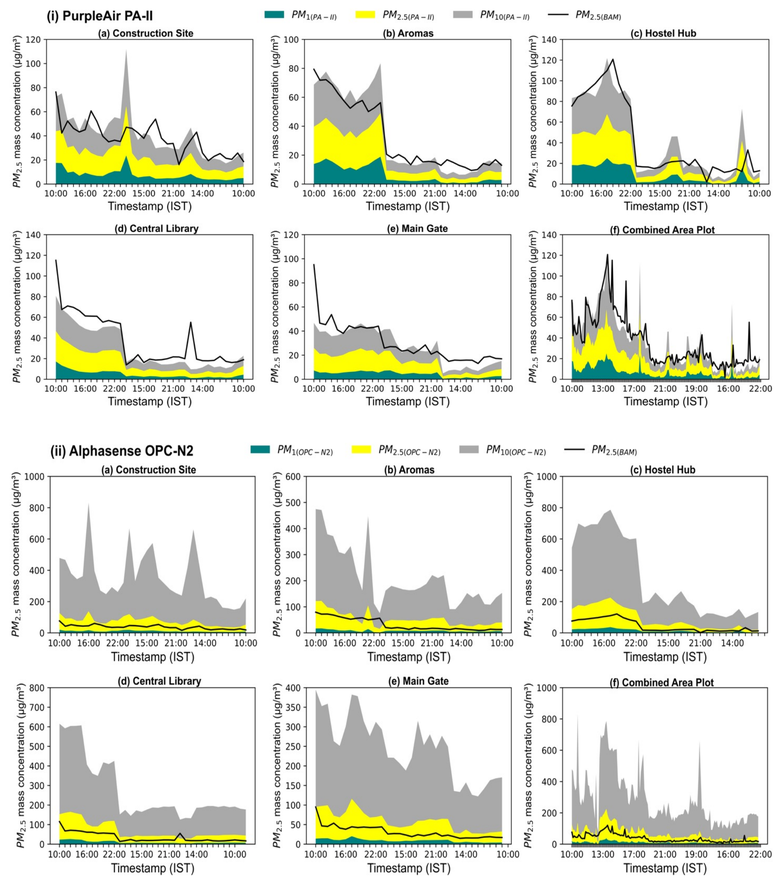

Figure 4. Averaged (1-h) PM_1 (teal), $PM_{2.5}$ (yellow), and PM_{10} (grey) mass concentration measured by (i) PurpleAir PA-II LCS and (ii) Alphasense OPC-N2

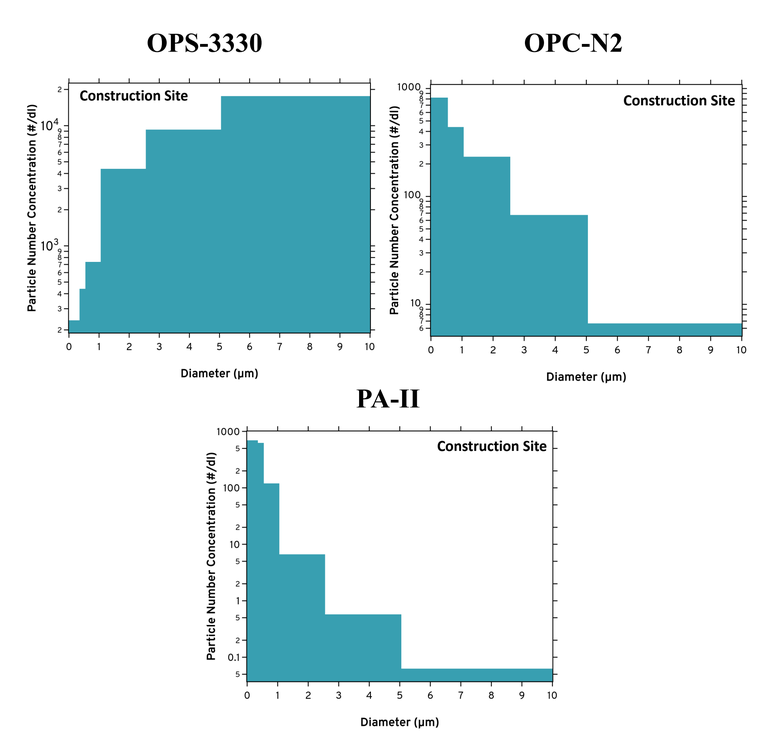

Figure 5. Size distribution of particles at different sampling locations recorded using (a) OPS-3330, (b) Alphasense OPC-N2, and (c) PurpleAir PA-II LCS

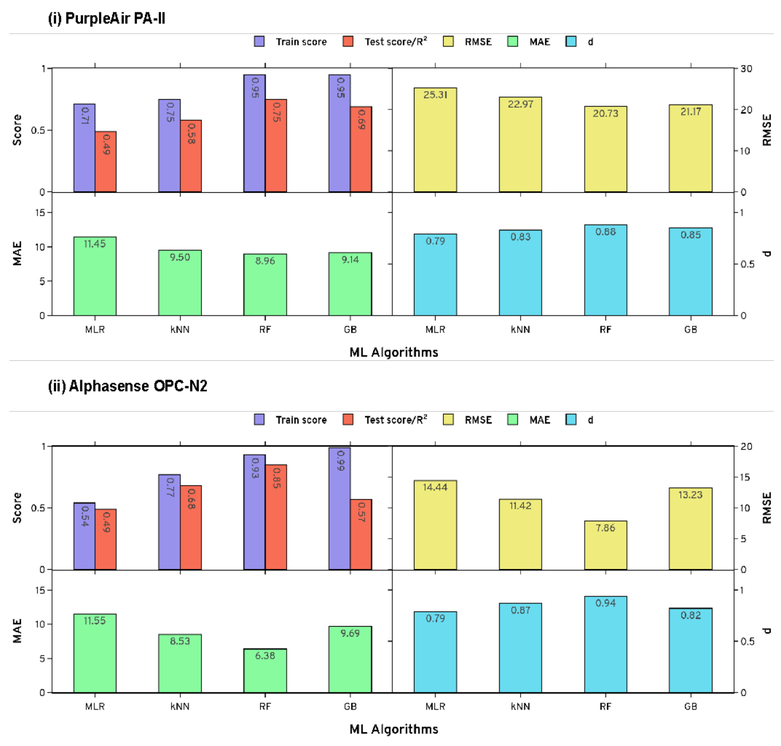

Figure 5. Comparison of (a) train and test/R^2 scores, (b) RMSE, (c) MAE, (d) d of the general calibration model for (i) PurpleAir PA-II LCS and (ii) Alphasense OPC-N2

CALIBRATION RESULTS

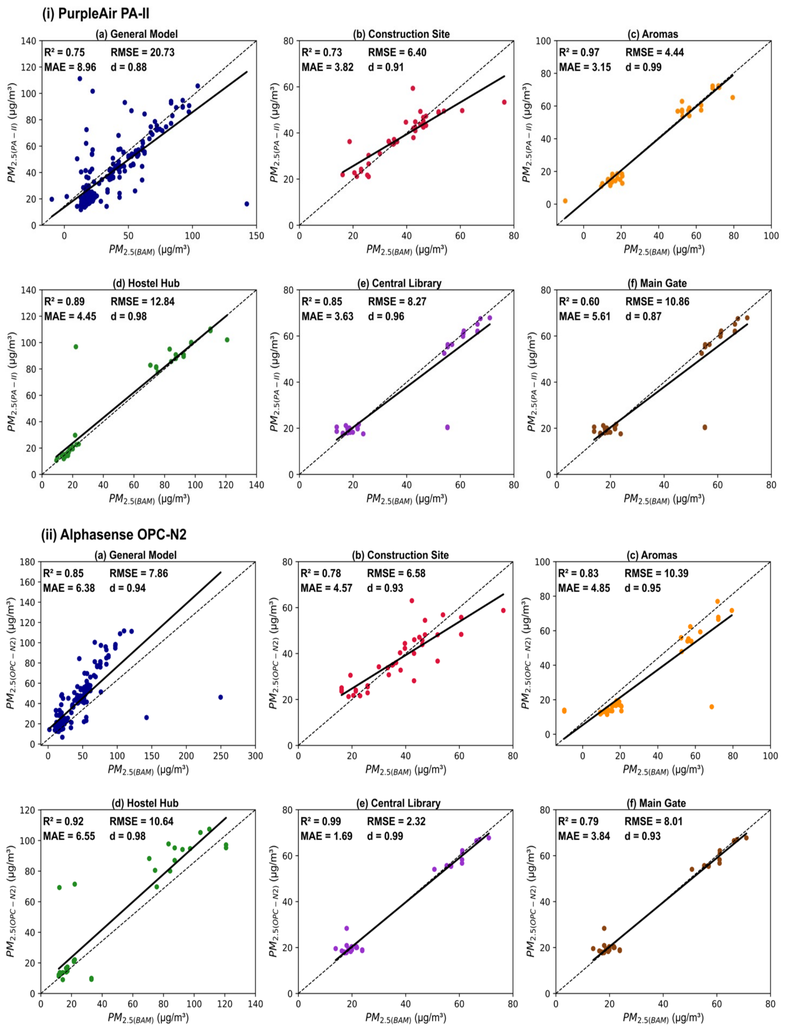

Figure 6. Calibration of (i) PurpleAir PA-II and (ii) Alphasense OPC-N2 with BAM-1020

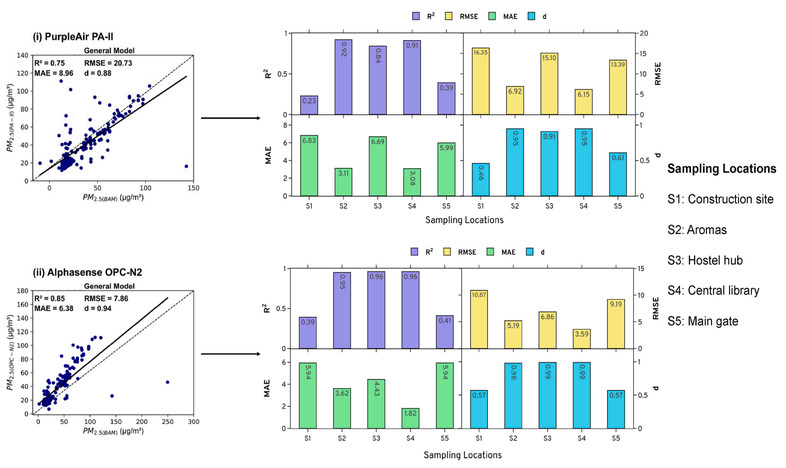

Figure 7. Performance assessment of general calibration model developed for the PurpleAir PA-II and Alphasense OPC-N2 LCS at different sites

CONCLUSION

- The performance of LCS decreased with an increase in mass fractions of PM_1 and PM_{10}.
- RF gives the best results with improved R^2 values of 0.75 for PurpleAir PA-II ($R^2_{uncalibrated}$ = 0.72) and 0.85 for Alphasense OPC-N2 ($R^2_{uncalibrated}$ = 0.73) sensors.
- Evidence for the need of site-specific robust calibration of LCS based on the particle size distribution and the dependence of the LCS performance on the source mixture present at the site under observation.
- This work is intended to provide a direction in developing low-cost sensors and make them robust to span the monitoring networks for spatiotemporally high PM measurements

PUBLICATION

The results of this study are published in Malyan, V., Kumar, V., & Sahu, M. (2022). Significance of sources and size distribution on calibration of low-cost particle sensors: Evidence from a field sampling campaign. Journal of Aerosol Science, 106114. https://doi.org/10.1016/j.jaerosci.2022.106114