Performance evaluation of twelve low-cost PM2.5 sensors at an ambient air monitoring site

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Highlights

- Low-cost sensors can be useful tools for monitoring $PM_{2.5}$ in ambient environments.
- Performance varies between different models of low-cost sensors.
- Intra-model variability within a PM sensor triplicate is typically low.
- Bias error can be impacted by changes in local environmental conditions.

Abstract

A variety of low-cost sensors are now available on the consumer market for measuring air pollutants. The use of these low-cost sensors for ambient air monitoring applications is increasing and includes fence-line or near-source monitoring, community monitoring, emergency response, hot-spot identification, mobile monitoring, epidemiological studies, and supplemental monitoring to improve the spatial-temporal resolution of current monitoring networks. Evaluating and understanding the performance of these devices is necessary to properly interpret the results and reduce confusion when low-cost sensor measurements are not in agreement with measurements from regulatory-grade instrumentation. Systematic and comprehensive field and laboratory studies comparing low-cost sensors with regulatory-grade instrumentation are necessary to characterize sensor performance. This paper presents the results of 12 particulate matter (PM) sensors measurement of $PM_{2.5}$ (particles with aerodynamic diameter less than 2.5 μm) tested under ambient conditions against a federally equivalent method (FEM) instrument at an ambient air monitoring station in Riverside, CA spanning over a 3-year period from 02/05/15 to 03/27/18. Sensors were evaluated in triplicate with a typical time duration of 8-week. Performance evaluation results found 6 of the 12 sensor triplicates with average R^2 values ≥ 0.70 for $PM_{2.5}$ concentrations less than 50 $\mu g/m^3$. Within this subset, the Mean Absolute Error (MAE) ranged from 4.4 to 7.0 $\mu g/m^3$ indicating the need for caution when interpreting data from these sensors. Additional analysis revealed that the impact of relative humidity on sensor performance varied between models with several models exhibiting increased bias error with increasing humidity. Results indicate that a number of these sensors have potential as useful tools for characterizing $PM_{2.5}$ levels in ambient environments when data is interpreted and understood correctly with regard to existing ambient air quality networks. The performance evaluation results are specific for Riverside, CA under non-repeatable ambient weather conditions and particle properties with the expectation that performance evaluation testing at other locations with different particle properties and weather conditions would yield similar but non-identical results.

Citation:

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