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Nahian, M. R., & Siegel, J. A. (2025). An in-situ test method for portable air cleaners.
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Abstract

Portable air cleaners (PACs) are widely used to reduce indoor airborne particle concentration. However, the performance of an air cleaner fluctuates over time within the same environment and varies across different environments due to factors such as room volume, ventilation, sources of particles, room mixing, background loss rates, and outdoor particle levels. This study presents an in-situ test methodology for PACs to capture the actual performance using low-cost sensors. The testing consisted of switching from air cleaner operation to placebo operation every 2.5 h for two weeks and the effectiveness was calculated from the $PM_{2.5}$ concentrations during neighboring placebo/air cleaning conditions. The median $PM_{2.5}$ effectiveness of three types of tested PACs varied from 36.3% to 94.3% in residential, 0% to 66.7% in classroom, and 11.4% to 33.3% in office environments owing to the variation of room size, clean air delivery rate (CADR), sources, and background loss rates. Although the CADR of the top performing PAC is approximately 8.8 times higher than the least performing PAC, the median effectiveness only improved by a factor of 2.4. One type of low-cost sensor predicted a similar median effectiveness when compared to a more robust instrument, while another type of low-cost sensor resulted in a lower effectiveness, likely owing to its reduced responsiveness during periods with elevated $PM_{2.5}$ concentrations. Overall, this study contributes to the development of an in-situ testing methodology for PACs, which will facilitate the adoption, use, and evaluation of PACs.

Highlights

1. We present an in-situ test methodology for portable air cleaners.
2. This methodology considers interval, speed, data truncation, duration, and environmental mixing.
3. Effectiveness of a given air cleaner varies over time in the same and different environments.
4. Variation in clean air delivery rate is not fully reflected in effectiveness.
5. Some low-cost sensors demonstrate reliability in testing portable air cleaners.

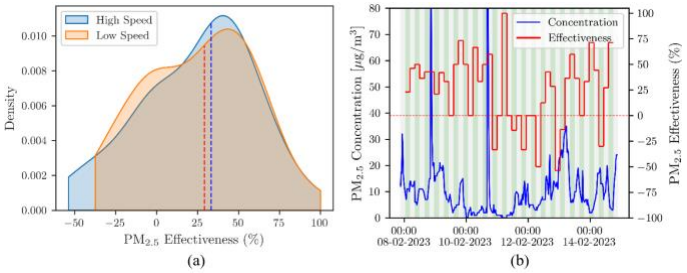

Fig. 1. Comparison of (a) PAC-01 effectiveness across low and high operating speeds: vertical dashed lines represent the median $PM_{2.5}$ effectiveness for the corresponding speeds, (b) $PM_{2.5}$ concentration and $PM_{2.5}$ effectiveness variation over time for higher operating speed: vertical green and gray shaded regions represent air cleaner and placebo conditions, respectively.

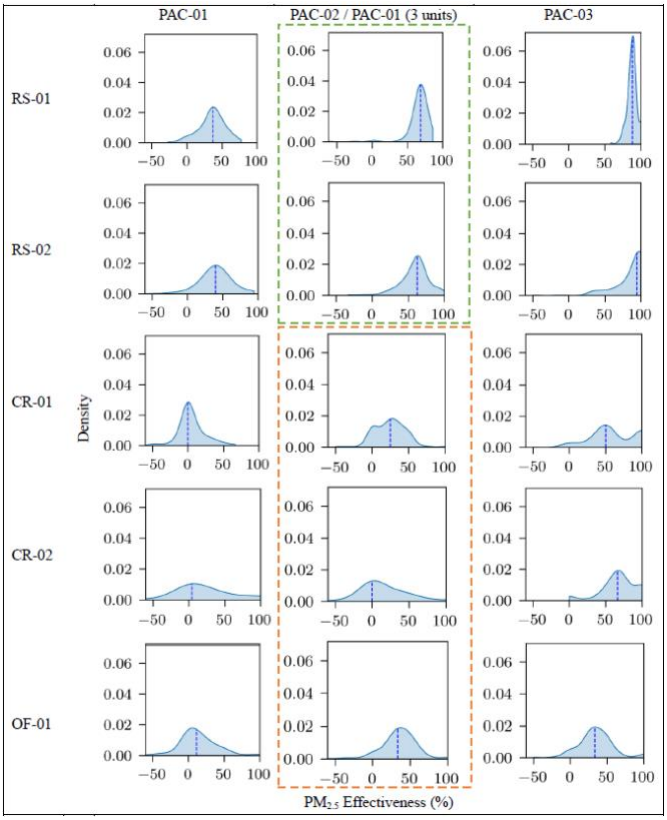

Fig. 2. $PM_{2.5}$ effectiveness of PACs in different environments: the vertical dashed lines represent the median effectiveness; RS, OF, and CR indicate for the residential site, office, and classroom, respectively; Plots within the green and red dashed lines represents PAC-02 and PAC-01 (3 units), respectively.

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