Li T, Siegel JA. 2021. Assessing the impact of filtration systems in indoor environments with effectiveness. *Building and Environment*, **87**, 107389. DOI: 10.1016/j.buildenv.2020.107389

Abstract

Effectiveness is commonly used to evaluate the particle removal performance of residential filtration systems. Previous investigations have used various effectiveness metrics to assess system performance through modeling efforts. However, the model assumptions often lead to an overestimation of effectiveness. Further, none of the studies considered the impact of realistic residential heating, ventilation, and air conditioning (HVAC) system operation patterns. In this investigation, we evaluated the strength and limitations of various effectiveness metrics. We identified exposure reduction as the most appropriate metric for modeling analyses because it does not rely on any steady-state assumptions. A time-varying mass balance model that accounts for system operation parameters including runtimes and cycle on-times, and the impact of indoor emission sources is used to simulate the changes in indoor particulate matter smaller than 2.5 µm ($PM_{2.5}$) concentration with and without system operation. The effectiveness results show that runtime has the biggest impact on exposure reduction. At a fixed runtime, short cycle on-times and the coincidence of system operation with emission events can further improve the removal performance of the system. Thus, the particle removal performance of a filtration system can be optimized by changing its operation pattern while still maintaining similar fan energy use.

Main findings

- Existing effectiveness metrics could **overestimate** HVAC filtration performance.
- We present a **time-varying framework** with an appropriate metric (**exposure reduction**) to directly assess filtration performance.
- The simulation results suggest **runtime** has the biggest impact on effectiveness.
- At a given runtime, filtration performance can be optimized by **reducing cycle on-time length** and **synchronizing system operation with the emissions events**.

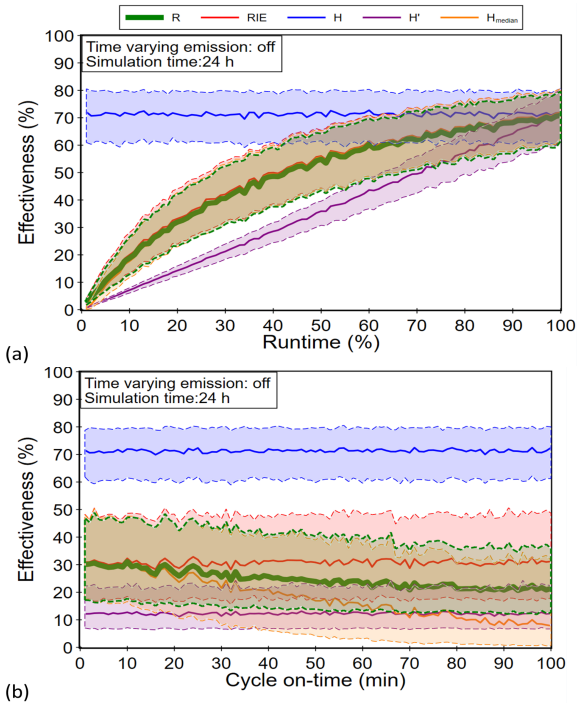

Figure 1. Effectiveness results from five effectiveness metrics: exposure reduction (*R*), theoretical effectiveness (*H*), runtime influenced effectiveness (*RIE*), runtime factored effectiveness (*H'*) and median effectiveness (H_{median}) as a function of (a) system runtime; and (b) cycle on-time, over 24-hour simulation with time-averaged emission source.

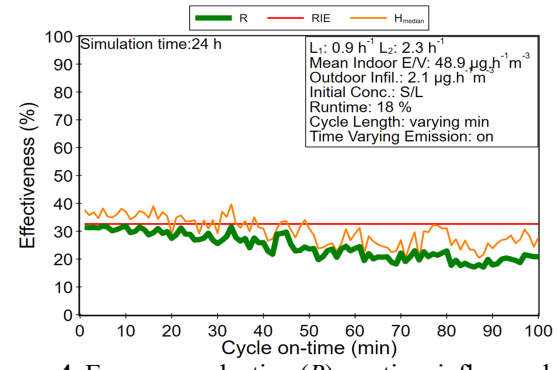

Figure 4. Exposure reduction (*R*), runtime influenced effectiveness (*RIE*), and median effectiveness (H_{median}) as a function of cycle on-time over 24-hour simulation with time-varying emission events.

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