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Implications and Impacts of Mitigation Strategies for Wildland–Urban Interface Fire Smoke Exposure in Residential Environments

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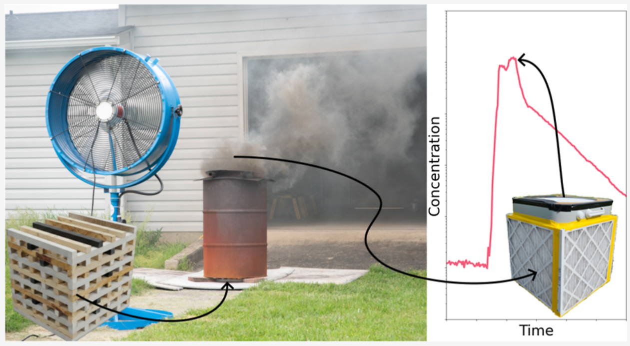
ABSTRACT: This study examines the effectiveness of various indoor air quality pollutant mitigation strategies during Wildland–Urban Interface (WUI) fire smoke events. We simulated WUI fire smoke conditions in the field by burning mixed-fuel cribs designed as surrogates outside a test house and measured particle concentrations using multiple instruments inside the house. Increasing the number of deployed portable air cleaners provided a nonlinear benefit in particle removal effectiveness, with per-unit effectiveness increasing significantly when multiple units were operated simultaneously. Filters exposed to a single heavy smoke (C_{peak} of 210 μg m^{-3} to 1300 μg m^{-3}) loading showed no significant degradation in particle removal performance compared to new filters. The effectiveness of creating a "cleaner air space" within the test house was also evaluated, demonstrating substantial reductions in peak particle concentrations. Our findings emphasize the importance of accounting for air movement and mixing throughout a home when sizing and positioning air cleaners to ensure optimal performance. If internal doors are open and a central heating and cooling system is operating, air cleaners must be sized to the entire house volume, rather than just the room in which they are located. In contrast, if internal doors are closed and heating and cooling vents are sealed, a single properly sized air cleaner can provide a "cleaner air space" during WUI fire events.



KEYWORDS: *indoor air quality (IAQ), portable air cleaners (PAC), clean air delivery rate (CADR), particle decay rate, cleaner air space, MERV filtration, air mixing*

1. INTRODUCTION

Wildland–Urban Interface (WUI) fires, occurring where human development meets wildland vegetation, present unique threats to public health.[1] Unlike wildland fires, WUI fires consume biomass alongside building materials, vehicles, plastics, and waste, producing smoke with a complex mixture of chemicals and particles.[2,3] When infiltrating into homes, this smoke elevates indoor particulate matter (PM) and chemical concentrations, potentially causing adverse health effects ranging from respiratory irritation to cardiovascular complications.[4,5]

1.1. Indoor Exposure to Wildland–Urban Interface Smoke and Mitigation Strategies

Buildings offer incomplete protection during WUI fire smoke events.[6,7] For buildings without mechanical ventilation, building protection can be described with the infiltration factor. The infiltration factor is the indoor concentration of outdoor-origin PM2.5 relative to outdoor PM2.5, which excludes indoor-generated particles that an indoor/outdoor ratio would also capture. Crowdsourced and field measurements during wildfire smoke events report infiltration factors with geometric means near 0.2 to 0.4, declining during the most polluted periods as occupants close windows and operate filtration.[8,9] This infiltration, combined with prolonged exposure durations, necessitates effective indoor air quality (IAQ) mitigation strategies.[10] Recommended approaches include enhanced central heating, ventilating, and air-conditioning (HVAC) filtration, portable air cleaners, and the creation of isolated "cleaner air spaces".[11−15]

While upgrading HVAC filters to MERV 13 (Minimum Efficiency Reporting Value) or higher has been recommen-

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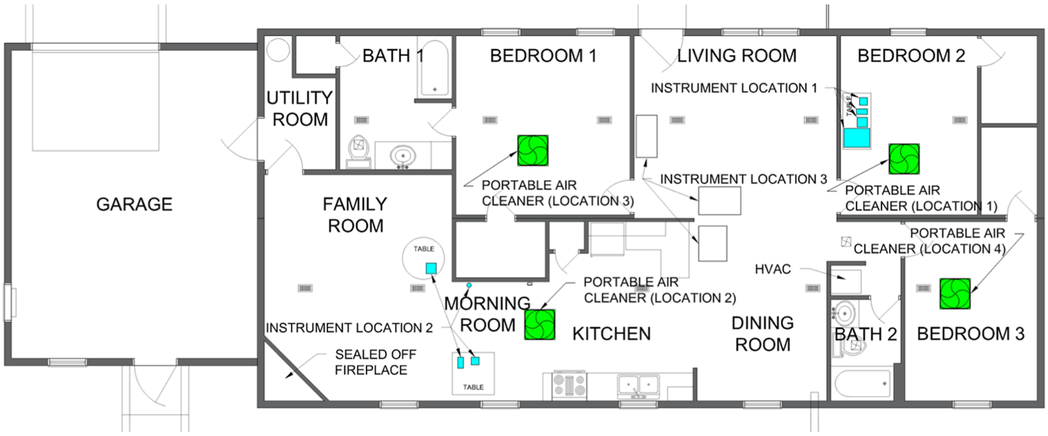

Figure 1. Test house floor plan with two instrument locations (blue) and four portable air cleaner locations (green) noted. Not to scale.

ded,[10,16−18] some residential systems, particularly older units, cannot accommodate high-efficiency filters due to increased airflow resistance, which may reduce performance or damage equipment.[19] Consequently, supplementary strategies are often required.

Portable air cleaners with high-efficiency particulate air (HEPA) or high-MERV filters are a primary intervention for reducing indoor PM.[10,16] Their effectiveness is quantified by the Clean Air Delivery Rate (CADR). The Association of Home Appliance Manufacturers (AHAM) generally recommends a CADR (ft^3 min^{-1}) of at least 2/3 of the room area (ft^2) for general-purpose air-cleaning, increasing to a 1:1 ratio for wildfire smoke.[20] However, this guidance may be inadequate for the extreme concentrations and complex particle mixtures characteristic of WUI events,[21] nor does it account for internal mixing in residential settings.

Alternative strategies include Do-it-yourself (DIY) air cleaners (e.g., box fans with filters) and "cleaner air spaces". While DIY options offer a low-cost alternative, their real-world performance during high-concentration events remains under investigation.[22−24] Similarly, creating a cleaner air space by isolating and filtering a single room is valuable when resources are limited,[12,25−27] though few studies have quantified its effectiveness under actual WUI fire smoke conditions.

1.2. Knowledge Gaps and Research Objectives

Despite the critical need for IAQ management during WUI fire smoke events, several knowledge gaps remain. First, the effectiveness of portable air cleaners has not been evaluated under the extreme outdoor PM concentrations typical of WUI fires, where outdoor 24 h PM2.5 can exceed 250 $\mu g\ m^{-3}$ and, in near-source cases, approach 1900 $\mu g\ m^{-3}$ (Table S1). Instead, most air cleaners are tested using a potassium chloride (KCl, e.g., ASTM D8625[28]) or cigarette smoke aerosol (e.g., AHAM AC-1[20]). The laboratory CADRs used for comparison in this study were measured using a KCl aerosol according to ASTM D8625-25 (Table S2). The KCl challenge aerosol and WUI surrogate smoke differ in size: the KCl distribution has a geometric mean diameter (GMD) of 33 nm, whereas the WUI surrogate smoke has a GMD of 125 nm (Supporting Information Section S2). The two aerosols also differ in chemical composition. Whether CADRs derived from a laboratory KCl challenge predict performance against the larger, chemically distinct aerosol of a WUI fire has not been established. Second, the impact of filter loading and the necessary replacement frequency during prolonged smoke exposure is poorly understood.[23,24] Third, the spatial distribution of particles within homes during mitigation efforts has received limited attention.[29]

To address these gaps, this study provides an experimental assessment of portable air cleaner performance during experimental WUI mixed-fuel smoke events. We specifically examine:

1. How well do KCl-derived CADRs measured by ASTM D8625 predict portable air cleaner particle removal performance during experimental WUI smoke events, given that the laboratory and WUI challenge aerosols differ in both size distribution and chemical composition?
2. How does the number of portable air cleaners impact the air cleaner's effectiveness in a residential home?
3. For the specific filter products tested, does a single realistic WUI smoke loading event measurably degrade particle removal performance?
4. For the specific MERV 13 and MERV 12A products tested, how does particle removal performance compare under WUI smoke conditions?
5. Is creating a "cleaner air space" indoors an effective strategy for reducing WUI smoke exposure?

2. MATERIALS AND METHODS

2.1. Experimental Facility

The experiment was conducted at the NIST Indoor Air Quality (IAQ) test house. Figure 1 shows the floor plan of this manufactured house built in 2001 to the U.S. Department of Housing and Urban Development (HUD) standard for manufactured houses. A garage was added to the house in 2007. The test house has a floor area of 140 m^2 and an internal volume of 324 m^3 when the volume of internal walls is excluded.

The house features three bedrooms, two bathrooms, and an open space that accommodates the kitchen, morning room, family room, dining room, and living room. The door between the utility and family rooms was removed during previous sampling campaigns and never reinstalled. Figure 1 also highlights the locations of all monitoring instruments throughout the house.

During the experimental period, the overall infiltration rate and HVAC system effects on the air change rate were measured using a series of tracer-decay tests (SF_6 was released inside the house and monitored in the central dining room). The resulting average air change rate was 0.19 h^{-1} ± 0.05 h^{-1}, reflecting the combined influence of natural infiltration and the ongoing operation of the recirculation fan.

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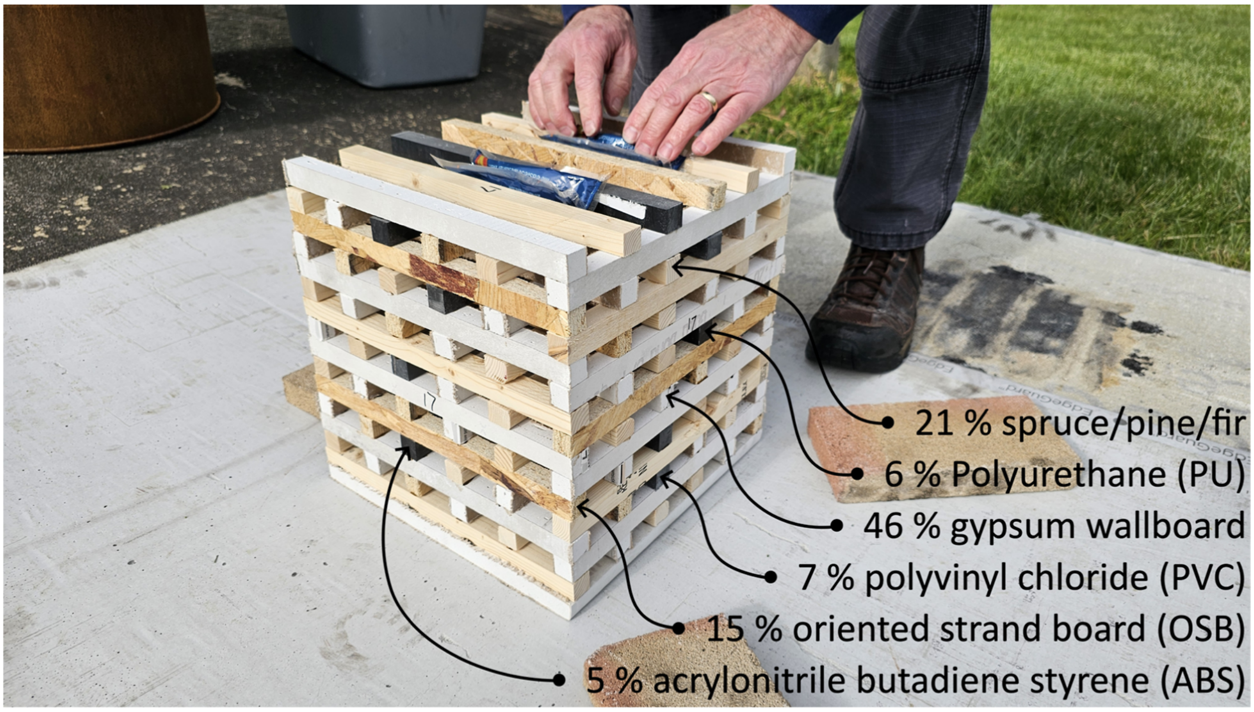

Figure 2. WUI mixed-fuel residential building surrogate. Percentage contribution to total surrogate mass are shown in text.

The HVAC system for the NIST test house is a 22 kW gas furnace, a 15 kW air conditioner, and a forced air recirculation fan with associated ductwork. The total HVAC airflow rate was 1400 m^3 h^{-1}, measured with a balometer at the supply register grills for the system. The HVAC's forced air recirculation fan (more precisely a heating and air-conditioning, or HAC, fan, as the system was not designed to provide outdoor-air ventilation) was run continuously to help mix the air throughout the volume of the occupiable space of the house during the measurement campaign. A MERV 6 equiv cut-to-fit washable polyester filter is attached to the internal side of the HVAC cabinet's return grill. This filter was not replaced during the experiments.

2.2. NIST Wildland–Urban Interface Mixed-Fuel Surrogate

We simulated WUI smoke events by burning a mixed-fuel crib designed to be a surrogate for a residential building (hereafter called "surrogates"), as shown in Figure 2 (see Figure S2 for more details) and documented in Davis et al.,[30] outside of the test house. The surrogate composition was selected to represent the composition of an idealized residential building.[30] Each surrogate weighed approximately 8 kg and was composed of a combination of:

- 21% spruce/pine/fir (representing structural lumber)
- 15% oriented strand board (OSB) (representing structural floors and walls)
- 46% gypsum wallboard (representing interior walls and ceilings)
- 5% acrylonitrile butadiene styrene (ABS) (representing plastic household goods)
- 7% polyvinyl chloride (PVC) (representing electrical conduit and plastics)
- 6% Polyurethane (PU) (representing furniture and insulation materials)

Davis et al.[30] and Link et al.[31] demonstrate consistent smoke yields from combustion of the surrogate under a hood calorimeter.

We generated smoke by placing the surrogate in an open-bottom 55-gallon steel drum (see Figure S3) located approximately 3 m from the attached garage of the test house. A 0.19 kW barrel pedestal fan (0.76 m diameter) was positioned approximately 2.5 m beyond the steel drum to direct the smoke plume toward the open garage door. Figure S4 shows the smoke plume generated during a typical WUI surrogate burn conducted at the NIST test house. Ambient meteorological conditions influenced the size and dispersion pattern of the smoke plume. Figure S5 illustrates the fan-aided smoke infiltration process. Smoke entered the test house primarily through the partially opened door between the garage and the house interior (opened 19 mm at the handle side of the door, except for Burn 01, where it was opened 12 mm). All interior doors within the house were opened completely, except during experiments examining "cleaner air spaces".

2.3. Experimental Design and Test Matrix

We burned 10 surrogates over the course of a month and a half (Table 1). All burns were conducted in the morning between approximately 8:30 A.M. and 9:30 A.M., with a burn duration between 18 and 28 min (Table S3). Prior to ignition of the surrogate, the door between the garage and the house was opened. The smoke from the surrogate was blown into the garage with a fan. After the surrogate was extinguished, the garage door and the door between the garage and the house were closed. The house remained closed and was monitored remotely for at least 48 h.

Corsi-Rosenthal (CR) boxes were used as the tested portable air cleaners. These DIY portable air cleaners do not have an AHAM-certified smoke CADR. Our laboratory-derived CADR was based on previous work using potassium chloride (KCL) particle removal.[32] The portable air cleaners utilized four commercially available 0.508 m × 0.508 m × 0.0508 m MERV-13 or MERV-12A rated filters. Flow rates of the portable air cleaners were measured using a balometer with new MERV 13 filters; the mean flow achieved was 602 m^3 h^{-1} ± 22 m^3 h^{-1}. Flow rates were not measured for the MERV-12A filters when they were new.

Burn 01 served as the house's natural decay after a WUI fire event, providing a baseline comparison for other burns, and represented a house where no mitigation strategy was employed. Burn 02 was used to demonstrate the outcomes when air cleaners are deployed using the 2/3 rule of thumb for general air cleaning, as recommended by AHAM.[20,33,34] For this Burn 02, four portable air cleaners were placed throughout the house (Figure 1). During Burn 02, one of the portable air cleaners (designated as "used") had been previously used in an office space for less than a year. Burn 03 and Burn 04 examined the effects of filtration when a household can only use one portable air cleaner in the entire house. The portable air cleaner was in Bedroom 2

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Table 1. List of Surrogate Burns and Associated Portable Air Cleaner Test configurations

burn ID	examined test configuration	number of portable air cleaners	MERV Rating	filter condition used/new	discussed in section(s)
Burn 01	**Background**: whole house	0	No filter	No filter	3.5
Burn 02	**AHAM2/3Rule of Thumb**[a]: whole house	4	13	3 New/1 Used	3.1, 3.2
Burn 03	**Used**: 1 air cleaner	1	13	Used	3.3
Burn 04	**New**: 1 air cleaner	1	13	New	3.1, 3.2, 3.3
Burn 05	**Background**: cleaner air space	0	No filter	No filter	3.5
Burn 06	**Cleaner Air Space**: new 1 air cleaner	1	13	New	3.1, 3.5
Burn 07	**Filter Rating**: MERV-A new	2	12A	New	3.4
Burn 08	**Filter Rating**: MERV-A used	2	12A	Used	3.4
Burn 09	**Filter Rating**: MERV new	2	13	New	3.2, 3.3, 3.4
Burn 10	**Filter Rating**: MERV used	2	13	Used	3.3, 3.4

[a]The AHAM 2/3 Rule of Thumb recommends that the clean air delivery rate (CADR [measured in cubic feet per minute (CFM)] of an air cleaner be equal to at least 2/3 of the room's area (in square feet).

for these burns (portable air cleaner location 1). During Burn 03, the single portable air cleaner designated "used" was one of the units operated once during the immediately preceding test (Burn 02); not the unit that had been used for under a year in an office. The single smoke loading from one prior burn is therefore a mild used-filter condition, consistent with the loading limitation noted above. Burn 04 examined a single portable air cleaner with filters. Burn 05 served as a baseline for comparing the "cleaner air space" strategy deployed in Bedroom 2. For this burn, the HVAC diffuser in Bedroom 2 was covered with tape, a towel was wedged at the base of the closed-door connecting it to the living room, and no portable air cleaners were used. Burn 06 employed the same compartmentalization mitigation strategy as Burn 05, but one portable air cleaner was located in the bedroom during the test. Burns 07 through 10 examined the degradation of filter performance. For these tests, two portable air cleaners were outfitted with either new MERV 12A filters or new MERV 13 filters and placed at locations 1 and 2 (Figure 1). They were then used in two consecutive burn events to examine the effects of WUI smoke on their performance.

2.4. Instrumentation Suite

Seven instruments employing three distinct measurement principles were utilized to monitor particle concentrations: Optical Particle Counters (OPCs), nephelometers/photometers, and a Scanning Mobility Particle Sizer (SMPS). This multi-instrument approach provided redundancy and allowed for cross-validation of results while capturing the particle size distribution relevant to WUI smoke exposure. OPCs and nephelometers were deployed in Bedroom 2 and the morning room to assess spatial concentration gradients. The SMPS was positioned in the bedroom alongside the OPC and a nephelometer.

2.5. Data Analysis

2.5.1. Decay Rates Calculation. For each test, we determined size-dependent first-order loss rate constants (k_{decay}) for particulate matter (PM) across various size fractions, including PM0.4, PM1.0, PM2.5, and PM10 (where PM and the following number represent the largest micron diameter included in the concentration), as well as other sizes. While data were collected for multiple size fractions and measurement locations, this paper's Results and Discussion section focuses on the results for PM0.4 and PM2.5. Specifically, PM0.4 was measured using a single Scanning Mobility Particle Sizer (SMPS) located in Bedroom 2, whereas other size fractions were measured using multiple OPCs distributed throughout the house. We calculate particle decay rates following eq 1

$$k_{decay} = -\ln\left(\frac{[C]_t}{[C]_{t0}}\right)\left(\frac{1}{t}\right) \tag{1}$$

where k_{decay} (h^{-1}) is the rate coefficient for the first-order loss of particles during a test, [C] is the concentration of particulate matter (PM) in appropriate units (e.g., $\mu g \cdot m^{-3}$), $[C]_t$ is the concentration at time t, $[C]_{t0}$ is the initial concentration at the start of the decay period, and t is the elapsed time (h). Uncertainties for k_{decay} were determined with a 95% confidence interval. We calculate k_{decay} from the slope of the normalized natural log of the time dependent concentration plotted versus the decay period time. The decay period began after the fire was extinguished, when indoor concentrations were two to 3 orders of magnitude higher than typical outdoor concentrations. Under these conditions, the outdoor PM concentration was assumed to be negligible.

To ensure consistent analysis across all tests, the decay start time (t_0) and the initial concentration point ($[C]_{t0}$) were defined using the following criteria:

1. t_0 must occur after portable air cleaner activation for tests with deployed air cleaners or after garage door closure for tests without air cleaners.
2. $[C]_{t0}$ must be the first data point in a linear pattern for the logarithmic decay curve, which we defined by requiring the rolling derivative of five consecutive data points to be within 10%. We excluded any decay rate for quality assurance where the decay uncertainty's relative standard deviation (RSD) exceeded 10%.

PM2.5 concentrations were reported directly by each instrument and were not derived from other size fractions; where an instrument did not output PM2.5 directly, the nearest reported fraction was used and noted (for example, one OPC reported PM3.0). Decay rates were calculated individually for each instrument. The whole-house decay rate for a given size fraction is the mean of the individual decay rates from all whole-house instruments measuring that fraction, and the reported uncertainty reflects the spread among instruments. Whole-house PM2.5 decay rates and the CADRs derived from them therefore draw on instruments located in both Bedroom 2 and the morning room, whereas PM0.4 decay rates derive from the single SMPS located in Bedroom 2.

2.5.2. Clean Air Delivery Rate Calculation. The Clean Air Delivery Rate (CADR) is a standardized metric for quantifying the volumetric flow rate of filtered air delivered by portable air cleaners, expressed in cubic meters per hour ($m^3 \cdot h^{-1}$). The metric is commonly determined in laboratory spaces with known well-mixed volumes. In a house with multiple rooms, the assumption of a single uniform volume may or may not be valid, especially for single air cleaners operating in one room of a larger house.[22]

To determine the CADR, the k_{decay} for each test was compared to the natural decay, as shown in eq 2

$$\text{CADR} = V(k_{decay2} - k_{decay1}) \tag{2}$$

where V is the volume of the space (m^3) assumed to have a uniform concentration: 324 m^3 for whole house tests (excluding internal wall volume) or 33 m^3 for Bedroom 2 during compartmentalized tests. k_{decay1} is the baseline decay rate (ventilation + deposition) constant without air cleaners (from Burn 01 for whole house tests or Burn 05 for compartmentalized bedroom tests) and k_{decay2} is the decay rate constant with active filtration under the test configurations.

For tests with multiple portable air cleaners, we calculated the CADR per portable air cleaner by dividing the total CADR by the number of devices.

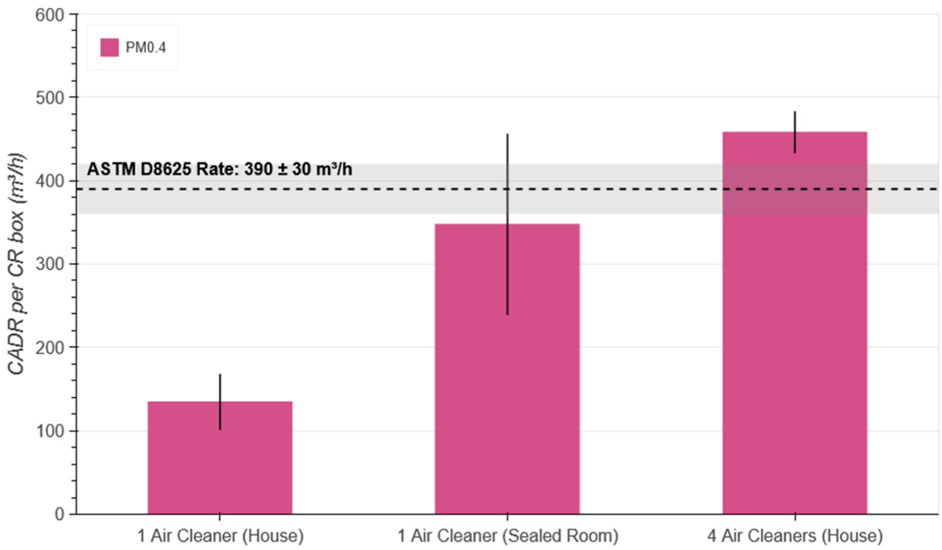

Figure 3. PM0.4 portable air cleaner CADRs measured in the lab in accordance with ASTMD8625-25 (black horizontal line) and from the test house (Pink-red vertical bars). The error bars indicate 95% confidence intervals for the associated CADR per portable air cleaner.

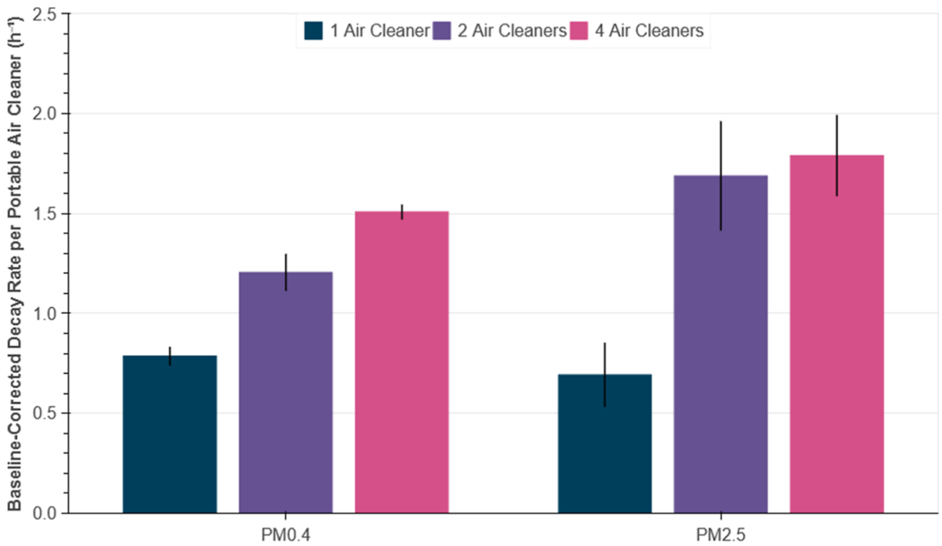

Figure 4. PM0.4 and mean PM2.5 decay rates as a function of the number of portable air cleaners. The black vertical lines indicate 95% confidence intervals for the respective vertical bars.

2.5.3. Baseline Correction. Portable air cleaner specific contributions were isolated by subtracting baseline decay rates from total decay

$$k_{\mathrm{cleaner}} = k_{\mathrm{decay2}} - k_{\mathrm{decay1}} \quad (3)$$

where k_{deacy1} and k_{decay1} have the same definitions as in eq 2.

2.5.4. Statistical Analysis. Statistical analyses were performed to evaluate the effects of the number of portable air cleaners, filter type, and filter condition on decay rates, with significance determined at α = 0.05. For PM0.4, which was measured using a single SMPS instrument, Z-tests were employed to compare conditions by propagating measurement uncertainties. The Z-statistic was calculated as $Z = (\mu_a - \mu_\beta)/\sqrt{(\sigma a^2 + \sigma\beta^2)}$, where μ represents the mean decay rate and σa^2 and $\sigma\beta^2$ represent the variances for each condition. Two-tailed p-values were calculated as $p = 2(1 - \Phi(|z|))$, where Φ is the cumulative distribution function of the standard normal distribution.

For PM1, PM2.5, and PM10, which were measured by multiple instruments, one-way ANOVA was used to compare groups, with F-statistics and associated p-values calculated for each comparison. When ANOVA indicated significant differences, pairwise t tests were performed to identify specific group differences.

Interinstrument variability was assessed using the relative standard deviation (RSD) calculations of concurrent measurements. The ratio of interinstrument variability to measurement uncertainty provided insight into the relative importance of instrument selection versus measurement precision. Statistical calculations were performed using Python with scipy.stats and pandas libraries. Uncertainty values are calculated to a 95% confidence interval unless stated otherwise. The complete results of the PM0.4, PM1, PM2.5, and PM10 statistical analysis are available in the S8. Statistical Summary: WUI Decay Rate Analysis section.

3. RESULTS AND DISCUSSION

3.1. Do Lab Quantified Clean Air Delivery Rate Agree with Field Measured Clean Air Delivery Rate for WUI Smoke?

AHAM recommends sizing portable air cleaners so that the CADR (in CFM) equals at least 2/3 of the room area (in square feet), assuming minimal air change with adjacent spaces and rooms having a 2.4 m (8-foot) ceiling.[33,34] In the case of a wildfire, a consumer may use an air cleaner sized for their bedroom while simultaneously keeping their HVAC system running to remain cool, which will mix the particulate matter between different rooms in the house, thus violating the assumptions of the AHAM 2/3 rule.

We evaluated the applicability of the AHAM 2/3 rule to the mitigation of smoke from experimental WUI fire smoke events by running one air cleaner in a bedroom with the door open to the total volume of the house, one air cleaner in a sealed bedroom, and four air cleaners with all doors open in the house. Based on the floor area of the house, we expected the CADR for Burn 02's four tested air cleaners to meet the AHAM 2/3 sizing rule recommendations. For the sealed bedroom, we expected that the CADR of a single portable air cleaner would exceed the AHAM rule requirement. The CADR value of the portable air cleaner in the sealed bedroom, using ASTM D8625[28] reported values during the Link et al.[32] study, was 2.3 times greater than the CADR required by using the AHAM 2/3 rule of thumb for general air cleaning and 1.5 times greater than the 1:1 rule of thumb for tobacco smoke. The KCl-derived CADRs from this laboratory method are broadly consistent with the manufacturer-reported AHAM AC-1 tobacco-smoke CADRs for the same devices (Link et al.,[35] Supporting Information Figure S6), indicating that the KCl challenge is a reasonable laboratory basis for rating these air cleaners' aerosol removal. This consistency holds despite the KCl size distribution not resembling either the tobacco or the WUI distribution (see Figure 3).

As shown in Figure 4, the air cleaner's measured CADR in the house met or exceeded the ASTM D8625-25 value from laboratory testing when the AHAM 2/3 rule of thumb sizing recommendation was followed. When we deployed four portable air cleaners throughout the house (324 m^3), meeting the 2/3 sizing rule, we measured a per-cleaner CADR (460 m^3 h^{-1} ± 25 m^3 h^{-1}) that was statistically greater than the predicted laboratory performance ($p = 0.04$). As in all burns, the HVAC's circulation fan was constantly on, and the door to the bedroom remained open (apart from the sealed bedroom "cleaner air space" configurations). This indicates that if an indoor space is equipped with an appropriate number of air cleaners, then CADRs measured in a laboratory test under ideal conditions can be achieved for smoke generated by the surrogates in real-world settings. Thus, although the laboratory KCl aerosol and the WUI surrogate smoke differ in both size distribution (GMD 33 nm versus 125 nm; Supporting Information Section S2) and chemical composition, the field-measured CADRs agreed with or exceeded the KCl-derived laboratory CADRs when the air cleaners were properly sized. The predictive value of the laboratory CADR, therefore, does not depend on a match between the challenge and WUI aerosols, at least over the size range tested here.

Figure 4 also illustrates that the CADR for a single air cleaner operated with the bedroom door open (135 m^3 h^{-1} ± 33 m^3 h^{-1} using the whole house as the mixing volume) is significantly less (≈1/3) than the CADR measured from the same portable air cleaner in laboratory testing (390 m^3 h^{-1} ± 30 m^3 h^{-1}).[32] When we sealed the HVAC ducts and the bedroom door (resulting in a volume of 33 m^3), the CADR for the portable air cleaner agreed (within error, $p = 0.71$) with the CADR from the laboratory test using a similar volume (31.5 m^3). This volume-dependent performance aligns with previous research demonstrating that a portable air cleaner's equivalent clean air change rate increases proportionally with decreasing room volume for a known CADR.[36] The relationship between CADR and room volume directly impacts particle removal effectiveness, as larger spaces require larger or more portable air cleaners, and longer mixing periods to produce the same particle reduction.[19]

Overall, this demonstrates the importance of accounting for air movement throughout a home when sizing an air cleaner. The volume used in the AHAM sizing calculation should be the volume for which the air mixes, not simply the room volume in which the air cleaner is placed. One possible suggestion for consumers to approximate this volume and convey the importance of air mixing is to refer to the floor area for AHAM size calculations as the floor area between closed doors.

Calculating a CADR assumes the entire volume used in eq 2 has a uniform concentration. The house did not achieve this. Despite the HVAC system's continuous operation, spatial variations in particle concentrations existed across different rooms in the test house. Figures S6, S7, and S8 present the concentration ratios of PM1, PM2.5, and PM10 between Bedroom 2 and the morning room for two portable air cleaner configurations. Each room was equipped with OPCs, nephelometers, and an air cleaner. If the house was well mixed, the concentration ratios should be at or near 1.0. However, the measured concentration ratios were consistently less than 1.0, indicating that the morning room concentration was higher than that of Bedroom 2, with no clear trend toward a 1-to-1 ratio.

These observed spatial gradients challenge the assumption that operating residential forced-air systems creates uniform contaminant distributions throughout the house for smoke. When a portable air cleaner operates in a room, it creates a local particle removal rate that can exceed the HVAC mixing rate, leading to nonuniform particle concentrations. This has important implications for both exposure assessment (instrument placement) and the evaluation of air cleaner effectiveness. Single-point measurements may mischaracterize CADRs and whole-house exposure, particularly in houses with multiple rooms. Personal exposure is strongly dependent on time-activity patterns within the home.

While CADR provides a standardized metric for comparing air cleaner performance in chambers, the volume- and mixing-dependent variations observed in field conditions highlight the need for alternative analytical approaches to assess air cleaner performance in the field. Using particle decay rates in a specific location provides a method for evaluating air cleaner effectiveness that does not rely on the assumption of a well-mixed volume. While this approach does not facilitate translation to other buildings, it enables us to address the other research objectives of this study.

To provide context on the particle decay rates, the AHAM floor area rule of thumb for sizing an air cleaner can be translated to an equivalent decay rate for a properly sized air cleaner. As detailed in Section S9, the AHAM 2/3 rule converts to an equivalent loss rate of 5 h^{-1} for volumes with 2.4 m (8-foot) ceilings. The following sections utilize decay rate analysis to provide insights into additional research questions regarding filter condition, MERV rating differences, and the effectiveness of cleaner air spaces during WUI smoke events. The decay rates below (referred to as baseline corrected, see eq 3 are presented with the decays from when no air cleaner subtracted (Burn 01 and Burn 05).

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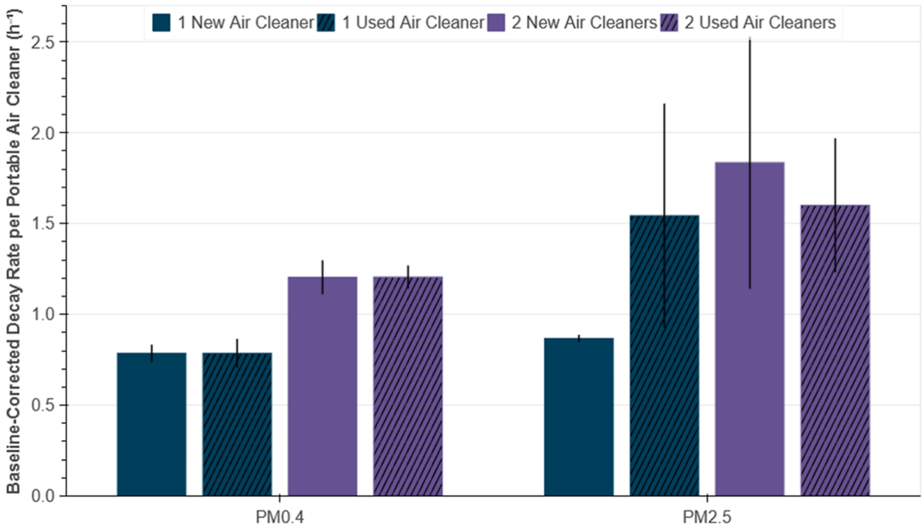

Figure 5. PM0.4 and mean PM2.5 decay rates comparing new versus used MERV 13 filter performance in portable air cleaners. The black vertical bars indicate 95% confidence intervals for the associated baseline-corrected decay rate per portable air cleaner.

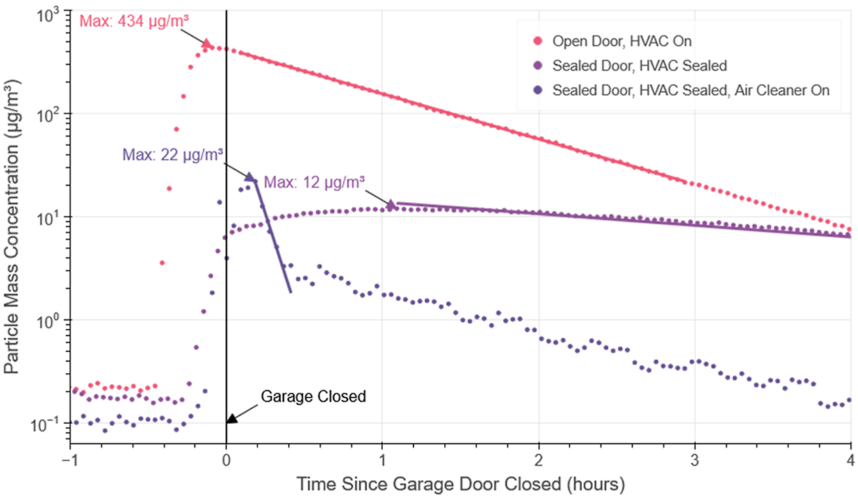

Figure 6. "Cleaner air space" concentration time series comparison. The matching color solid lines for each data series represent the decay rate for the given test configuration: Open Door, HVAC On (1.00 h^{-1} ± 0.00 h^{-1}). Sealed Door, HVAC Sealed (0.26 h^{-1} ± 0.01 h^{-1}). Sealed Door HVAC Sealed, Air Cleaner On (10 h^{-1} ± 1.6 h^{-1}). Peak measured concentration is shown for each test configuration in $\mu g \cdot m^{-3}$.

3.2. Multiple Portable Air Cleaners

Deploying multiple portable air cleaners demonstrated enhancement in particle removal effectiveness beyond simple additive effects. Figure 5 presents the baseline-corrected per-air-cleaner decay rates for PM0.4 and PM2.5 across different numbers of portable air cleaners, revealing a relationship between the number of units and the per-unit effectiveness in the same air volume. Figure S9 presents the total baseline-corrected decay rates for PM0.4 and PM2.5 across different numbers of portable air cleaners.

The number of portable air cleaners had statistically significant effects on baseline-corrected decay rates across particle sizes in most cases. For PM2.5, one-way ANOVA revealed significant differences ($p = 0.008$). The mean per-unit PM2.5 decay rate increased from 0.69 h^{-1} ± 0.16 h^{-1} with one portable air cleaner to 1.65 h^{-1} ± 0.23 h^{-1} with two units (pairwise comparison: $t = -3.45$, $p = 0.007$) and 1.79 h^{-1} ± 0.20 h^{-1} with four units (vs one unit: $t = -4.08$, $p = 0.009$). The difference between two and four units was not statistically significant ($t = -0.35$, $p = 0.739$). For PM1, ANOVA also showed significant differences ($p = 0.040$), with decay rates increasing from 0.61 h^{-1} ± 0.17 h^{-1} (one unit) to 1.52 h^{-1} ± 0.35 h^{-1} (two units, $p = 0.040$).

For PM0.4, Z-tests revealed significant differences across all configurations. Per-unit decay rates increased from 0.79 h^{-1} ± 0.05 h^{-1} (one portable air cleaner) to 1.20 h^{-1} ± 0.09 h^{-1} (two portable air cleaners, $p < 0.001$) and 1.51 h^{-1} ± 0.04 h^{-1} (four portable air cleaners, $p < 0.001$ compared to one unit). The comparison between two and four units was also statistically significant ($p = 0.002$). The consistency between PM0.4, PM1, and PM2.5 results suggests that the effectiveness of air cleaner removal increases nonlinear with the increasing number of air cleaners within the particle size ranges analyzed here.

This nonlinear scaling suggests that operating multiple units simultaneously results in a disproportionate increase in effectiveness, indicating that the combined performance of multiple units is more complex than a simple linear extrapolation of the performance of a single unit. The results demonstrate a multiplicative effect when multiple portable air cleaners are deployed. Consistent with our observations, Zhang

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et al.[37] found that, depending on the configuration, multiple air cleaning systems operating simultaneously can increase the decay rate by 15% to 32% compared to single-unit operation. We hypothesize that the enhanced performance in our study likely results from improved air mixing and circulation patterns created by multiple air cleaners operating in different locations throughout the house.

In complex partitioned residential layouts where air distribution patterns vary significantly from laboratory test conditions, dispersed multiple units are more likely to achieve the predicted AHAM designed performance compared with a single large unit due to mixing limitations. Lu et al.[38] showed that while portable air cleaners can achieve PM2.5 reductions, the effectiveness varies by room. The researchers observed 78% reductions in well-mixed air cleaner deployed rooms, but only 57% in secondary rooms with limited air change. Li et al.[22] demonstrated that PM2.5 decay rates, when a single air cleaner was used in a two-story test house, varied between 0.20 h^{-1} and 2.44 h^{-1} across seven different rooms. These disparities underscore the challenge of achieving uniform air cleaning across a home, where incomplete mixing between rooms can limit the effective coverage of a single unit. Deploying multiple air cleaners creates multiple well-mixed zones, effectively increasing the overall effect in the given mixing volume and enhancing the uniformity of air cleaning throughout.

3.3. Filter Loading Performance Degradation

Filters exposed to heavy smoke for one burn (~4 h) showed no significant degradation in particle performance compared to new filters. Table S4 summarizes the paired comparisons between new and used filters across different configurations. The statistical test results demonstrate no significant differences in any comparison (all $p > 0.05$), except for the PM2.5 results for the one portable air cleaner (blue color in figure), which will be discussed later. Figure 6 compares the decay rates for new (solid-colored bars) versus used (bars with cross-hatching) filters across 1 and 2 portable air cleaner configurations. For PM0.4, statistical analysis again revealed no significant differences between new and used filters in either configuration.

The general lack of particle performance degradation for a single heavy smoke exposure aligns with research on filter loading effects under moderate exposure conditions. As shown in Table S5, the measured flows of the portable air cleaners showed minimal change after exposure to one or two WUI smoke events. In Bedroom 2, the portable air cleaner with new MERV 13 filter delivered 640 m^3 h^{-1} of air before the first burn, 630 m^3 h^{-1} after one burn, and 710 m^3 h^{-1} after two burns, whereas the MERV 12A filter maintained 600 m^3 h^{-1} after both one and two burns. In the morning room, the MERV 13 filter showed 570 m^3 h^{-1} new, 600 m^3 h^{-1} after one burn, and 590 m^3 h^{-1} after two burns, while the MERV 12A filter changed from 550 m^3/h after one burn to 500 m^3 h^{-1} after two burns. Despite exposure to smoke, the stability in airflow through the filters correlates with the observed lack of significant degradation in particle removal performance. These results suggest that particle removal filters do not require immediate replacement after a single, ≈30 min smoke episode that produced indoor peak concentrations of 210 $\mu g \cdot m^{-3}$ to 1300 $\mu g \cdot m^{-3}$ and left elevated PM2.5 levels for more than 20 h in the absence of portable air cleaning. In studies by Rosenthal,[39] portable air filters with MERV 11 filters in commercial buildings demonstrated minimal single-pass efficiency reduction after one month of continuous general air cleaning. Substantial degradation is expected to occur after extended exposure using the ANSI/ASHRAE filter test Standards 52.1 and 52.2 Appendix J (MERV-A testing) for certain filter types. The absence of significant degradation in our study likely reflects the short-term nature of the tested WUI smoke events (several hours) compared to continuous building filtration applications. The unexpected improvement in single air cleaner PM2.5 performance with used filters was unexpected.

Particularly given the supply chain challenges that often arise during large-scale wildfire events, filter replacement recommendations after a WUI fire smoke event (and in preparation for a future one) should balance particle filtration effectiveness after prolonged exposure and replacement availability. The variability in performance changes of filters emphasizes the need for assessment based on smoke exposure intensity and duration. Additionally, this effort focused solely on particle reductions, and WUI smoke chemicals may build up on the filter and desorb back into the indoor environment over time.[14]

3.4. Performance of the Tested MERV 13 and MERV 12A Filter Products

Traditional MERV ratings assess filter efficiency using sodium chloride particles under controlled laboratory conditions, but may not accurately reflect real-world performance with wildfire smoke particles, where submicron particles predominate.[40] MERV-A ratings represent "actual" efficiency after electrostatic charge has been passivated using a potassium-chloride aerosol per ASHRAE Standard 52.2−2017 Appendix J.[41]

This study tested a single MERV 13 product and a single MERV 12A product. Because particle removal performance varies substantially among filter products that share the same MERV rating, both when new and after aging, the comparison below characterizes these specific products under WUI smoke conditions and is not a full comparison of the MERV and MERV-A rating paradigms.[42−44] The single smoke loading event applied here is also a mild challenge relative to the preloading used in dedicated longevity studies,[23] and is not a controlled probe of filter degradation.

Electrostatic filters can experience performance degradation when exposed to wildfire smoke. Research examining this phenomenon has found that single pass efficiencies for electrostatically charged melt-spun polymer media (known as electret) air filters can be significantly reduced after exposure to wildfire smoke when there is not a significant increase in pressure drop.[40] Research on pine needle smoke found that fiberglass media showed minimal change in single-pass removal efficiency after exposure to smoke. In contrast, an electret filter media sample experienced significant performance degradation after smoke loading.[40]

Figure S10 compares the particle removal effectiveness of MERV 12A and MERV 13 filters in both new and used conditions across different particle sizes.

Statistical analyses revealed significant differences between filter types for certain particle sizes and conditions. For PM2.5, one-way ANOVA showed that filter type had a statistically significant effect ($p = 0.022$), with MERV 12A filters (mean = 2.00 h^{-1}, $n = 11$) demonstrating superior performance compared to MERV 13 filters (mean = 1.56 h^{-1}, $n = 12$). This represents approximately a 28% improvement in decay rate for MERV 12A filters. For PM1, the difference between filter types was not statistically significant ($p = 0.246$), with

MERV 12A achieving mean decay rates of 1.73 h^{-1} (n = 9) compared to 1.38 h^{-1} for MERV 13 (n = 9).

For PM0.4, Z-test comparisons revealed nuanced performance differences. New filters showed no significant difference between types (MERV 12A: 1.33 h^{-1} ± 0.09 h^{-1} vs MERV 13:1.20 h^{-1} ± 0.09 h^{-1}, p = 0.324). However, used filters demonstrated a statistically significant difference (MERV 12A: 1.45 h^{-1} ± 0.10 h^{-1} vs MERV 13:1.21 h^{-1} ± 0.06 h^{-1}, p = 0.044), suggesting that MERV 12A filters may maintain their performance characteristics better after exposure to heavy smoke loads.

Two-way ANOVA examining the interaction between filter type (MERV 12A vs MERV 13) and condition (new vs used) for PM1 revealed no significant main effect of filter type (p = 0.271), no significant effect of condition (p = 0.738), and no significant interaction (p = 0.569). Similarly, for PM2.5, while filter type showed significance in the one-way analysis, the two-way ANOVA interaction term was not significant (p = 0.751), indicating that the performance patterns of the two filter types remained consistent regardless of whether they were new or used.

3.5. Effects of Utilizing a "Cleaner Air Space" Strategy

The observation that portable air cleaners create localized zones of cleaner air, even with HVAC-promoted mixing, suggests that strategic placement near occupied areas can reduce occupant exposure to smoke. This finding supports guidance for creating "cleaner air spaces" during smoke events, particularly when the number of available air cleaners is limited. The cleaner air space approach test was implemented here by sealing Bedroom 2 through door closure, taping the HVAC diffuser, and placing towels at the door base, which reduced peak particle concentrations compared to baseline conditions.

During the initial burn with no air cleaner (all doors open), Bedroom 2 experienced maximum PM0.4 concentrations of 430 $\mu g\ m^{-3}$ (Table S6). In contrast, the two cleaner air space configurations, with and without an air cleaner, reduced maximum concentrations to 22 $\mu g\ m^{-3}$ and 12 $\mu g\ m^{-3}$, respectively, representing approximately 95% to 97% reductions. These maximum values occurred before air cleaner activation, demonstrating that the cleaner air space strategy of sealing the room provides a primary barrier against initial smoke infiltration.

Analysis of PM2.5 data corroborates these findings, showing a decrease in maximum PM2.5 concentrations from 1300 $\mu g\ m^{-3}$ during baseline conditions to 28 $\mu g\ m^{-3}$ and 24 $\mu g\ m^{-3}$ in the cleaner air space configurations. Table S6 indicates that overall smoke infiltration into the house remained relatively consistent, with comparable or even higher maximum mass concentration during the cleaner air space burns compared to baseline conditions. This suggests that the effectiveness of the cleaner air space sealing strategy is not due to reduced overall smoke infiltration to the house but rather its ability to limit smoke entry into the protected room.

While the cleaner air space strategy reduces initial entry to the protected room, the PM0.4 decay rate analysis (also shown as dashed-dot lines in Figure S8) reveals the role of portable air cleaners in accelerating particle removal. The baseline configuration exhibited a PM0.4 natural decay rate of 1.00 h^{-1} ± 0.00 h^{-1}. The cleaner air space without an air cleaner exhibited a slower PM0.4 decay rate of 0.26 h^{-1} ± 0.01 h^{-1}, likely due to reduced airflow into and out of the sealed room, limiting removal mechanisms. However, adding a portable air cleaner to the cleaner air space increased the PM0.4 decay rate to 10 h^{-1} ± 1.6 h^{-1}, representing a 40-fold improvement over having no air cleaner. Note: After the initial drop in PM concentration due to the activation of the portable air cleaner, PM concentration levels are influenced by the entry of PM from the high concentration outside the room.

Sealing the bedroom (33 m^3) with a single portable air cleaner operating also yielded a statistically higher PM2.5 decay rate of (7.3 h^{-1} ± 0.5 h^{-1}) compared to a single portable air cleaner operating in the unsealed room (1.5 h^{-1} ± 0.3 h^{-1}). The sealed room with a portable air cleaner achieved 95% particle reduction within 25 min, while the unsealed configuration required over 2 h to achieve similar reductions. These differences highlight the importance of minimizing air change between the protected space and contaminated areas of the residence.

The enhanced combined effect between cleaner air spaces and portable air cleaners aligns with modeling by Li and Zhu,[26] who found that combining passive and active strategies optimizes protection and recovery time. Maintaining low indoor concentrations over time is crucial for minimizing cumulative exposure during prolonged periods of wildfire smoke. In such scenarios, a high CADR air cleaner is crucial for maintaining low concentrations.

The time-series data in Figure S8 illustrates the complementary protective mechanisms of sealing the space and operating an appropriately sized air cleaner. Sealing the space lowers the entry rate of smoke, effectively limiting peak exposures during the initial smoke intrusion. The portable air cleaner removes infiltrated smoke at a rate faster than the smoke infiltration rate, thereby maintaining a lower concentration over time. This is particularly important for prolonged wildfire events, which can last for days to months. Our results demonstrate that sealing the space and using an air cleaner is effective because the room sealing slows the entry rate, allowing the air cleaner to remove the smoke more efficiently. This two-phase protection reduces both acute peak exposures and cumulative dose that contribute to adverse health effects from wildfire smoke.[5] The configuration evaluated here implements the full set of measures recommended for a cleaner air space: closing the door, covering the supply register, and sealing the gap at the base of the door. This is a form of compartmentalization that limits not only smoke entry but also cooling and ventilation to the room. In practice, many occupants are likely to apply only a subset of these measures, for example, closing the door without covering the register or sealing the door gap. A fully sealed room may also become thermally uncomfortable over extended occupancy, particularly in summer or with more than one occupant, which constrains how completely and how long occupants can realistically maintain it. We evaluated the fully sealed configuration to bound the achievable protection; the practical compromise between sealing and thermal comfort is an operational limitation of the strategy. An intermediate configuration in which the door is closed, and a portable air cleaner operates without sealing the supply register, was not tested here. Evaluating this case, along with partial-sealing measures and the use of portable air conditioning to maintain thermal comfort in a closed room, in which the room receives smoke at the rate of interzonal exchange while the cleaner removes it, is the subject of an upcoming measurement campaign and is not estimated analytically in this work.

Health Canada[12] and the U.S. EPA[27] recommend cleaner air spaces as a primary intervention, and our results validate this approach for reducing peak exposures. Our decay rate analysis suggests that portable air cleaners should also be recommended for cleaner air spaces when available. Davison et al.[25] emphasize that the effectiveness of cleaner air spaces depends on thorough sealing procedures, while optimal air cleaner performance requires appropriate sizing for the sealed room volume. Our results suggest that even in resource-limited settings, establishing a cleaner air space provides substantial protection, with portable air cleaners offering enhanced benefit when accessible. Furthermore, when a room is effectively sealed, the required CADR of the air cleaner can be lower, as it only needs to exceed the infiltration rate of smoke into the sealed room. This means that not only can smaller, less energy-intensive air cleaners be used, but existing units can also be operated at lower fan speeds, reducing noise levels and energy consumption while maintaining effective air cleaning.

3.6. Discussion

3.6.1. Implications for Mitigating WUI Fire Smoke Exposure. Our findings indicate that deploying multiple portable air cleaners yields nonlinear benefits, favoring distributed strategies over single, high-capacity units. PM2.5 decay rates increased significantly from 0.69 h^{-1} with one unit to 1.79 h^{-1} with four units ($p = 0.008$), with a similar pattern observed for PM0.4 ($p \leq 0.002$). This suggests that distributed placement provides more uniform protection, particularly in homes with complex layouts or limited interzonal mixing.[22,37,38]

Regarding maintenance, emergency filter replacement appears unnecessary during acute smoke events. We observed no significant degradation in particle removal performance after heavy smoke loading across all tested sizes (PM0.4, PM1, PM2.5; $p > 0.05$). This stability likely reflects the short duration of WUI fire smoke events relative to continuous use lifecycles, a finding supported by recent studies on MERV 11 and DIY filters.[23,39] Consequently, given the results of this study on short-term WUI exposure, loaded filters may still remain effective for particle capture. However, this applies strictly to particulate matter; gas-phase contaminants may still necessitate earlier replacement or supplementary mitigation.[14]

Furthermore, creating a "cleaner air space" is a highly effective resource-limited strategy. A sealed room equipped with a portable air cleaner achieved a 95% particle reduction within 25 min, compared to over 2 h in an unsealed room. Even imperfect sealing combined with a modest portable air cleaner provides substantial protection, validating EPA and Health Canada recommendations.[12,25,26] As noted by Holder et al.,[45] the specific design configuration of the air cleaning device significantly impacts its performance, reinforcing the need for proper deployment within these isolated zones.

3.6.2. Measurement Considerations for Smoke Studies. Single-point measurements fail to capture whole-house exposure due to persistent spatial heterogeneity. We observed notable PM2.5 concentration gradients between rooms even with HVAC operation (see Figures S7), confirming that active mixing does not guarantee uniformity.[29] This challenges the reliance on single-location monitoring to characterize residential exposure.[21] Future research should employ multi-zone monitoring to accurately assess the efficacy of mitigation. While chamber studies (e.g., Holder et al.[45]) provide essential controlled data, field validation with spatial resolution is critical for translating these findings into practical guidance.

3.6.3. Engineering Design Considerations. Current portable air cleaners typically operate independently, but our results suggest that networked controls or strategic placement near occupants could enhance protection by creating localized clean zones. This reinforces the utility of portable air cleaners for creating "cleaner air spaces" when adequate whole-house filtration is impractical.[46]

Regarding filter selection, the specific MERV 12A product tested showed a higher mean PM2.5 decay rate than the specific MERV 13 product tested (2.00 h^{-1} versus 1.56 h^{-1}, $p = 0.022$ in the one-way analysis), although the two-way analysis showed no significant filter-type effect once condition was included ($p = 0.75$ interaction). This difference was specific to PM2.5; the two products did not differ significantly for PM1 or PM10. The difference also cannot be attributed to lower airflow resistance: the measured airflows for the MERV 12A units were equal to or lower than those for the MERV 13 units (Table S5), so a lower-pressure-drop explanation is not supported by our data. Because performance varies among products with the same MERV rating, this single-product result should not be interpreted as a general advantage of one rating over the other. For emergency response, filter selection should prioritize availability and system compatibility, provided the filter meets at least the intended MERV grade.

Finally, we observed a discrepancy between laboratory and field performance, which was attributed to differences in room conditions. In sealed rooms, lab-derived CADRs accurately predicted performance. However, in open layouts with HVAC operation, sizing based solely on room area is insufficient because the effective treatment volume expands to the whole house (or the total mixed volume). Therefore, AHAM sizing calculations or other such recommendations should account for the volume of air mixing, not just the physical dimensions of the room where the unit is placed. Without adjusting for internal mixing and open internal doors, standard metrics may overstate real-world protection.[24,45]

3.7. Limitations

Several limitations warrant consideration when interpreting our results. First, our experiments utilized controlled burns of standardized surrogates, which may not fully represent the complex and variable composition of actual WUI smoke. WUI fires consume a diverse range of materials, depending on the structural contents and local vegetation, potentially producing different particle size distributions and chemical compositions.

Second, our experiments were conducted in a single test house with specific geometry and air change characteristics. Homes vary widely in size, layout, construction tightness, and HVAC systems. While our findings provide insights into relative performance across configurations, particle decay rates vary across homes, and the absolute decay rates measured here will not transfer directly to other residential settings.

Third, our experimental design involved a short-term pulse input of WUI smoke, simulating a single burn event. However, actual WUI fire smoke events can persist for extended periods, often lasting days or even weeks. The prolonged exposure to smoke may lead to different filter loading characteristics, potentially affecting the long-term performance of portable air cleaners. In addition, because outdoor concentrations returned to low levels after each burn, outdoor air change rate served as a net removal pathway following the introduced pulse. During

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an actual prolonged wildfire smoke event, infiltration through the building envelope and operation of the central system with duct leakage and a low-grade filter would instead act as continuing sources of indoor particles. The decay rates reported here should therefore be interpreted as removal under a decaying source, not as steady-state performance against sustained outdoor smoke.

Fourth, the filters evaluated in this study were limited to a specific set of commercially available products: Synthetic electret/mechanical MERV-13 filters from Manufacturer One and synthetic mechanical MERV-12A/MERV-13 filters from Manufacturer Two. Particle removal performance varies substantially among filter products that share the same MERV rating, both when new and after aging.[42−44] The performance observed here is specific to the tested products and does not represent all MERV 12 or MERV 13 filters on the market.

Fifth, the central system operated with a MERV 6 equiv filter throughout. This represents less central filtration than the MERV 8 or MERV 11 filters that most residential systems can accommodate, and considerably less than MERV 13. Because central-fan cooling is common during wildfire conditions, a higher-rated central filter would remove particles, thereby reducing the marginal benefit attributed here to portable air cleaners. Recent work shows that operating central filtration systems during smoke events, including automated control via smart thermostats, can reduce indoor PM2.5 levels, with additional benefits from upgrading to MERV 13 filtration.[18]

Sixth, smoke was introduced through a door gap opened to 19 mm, delivering fresh smoke to the house with no filtering by the building envelope. Infiltration through the more circuitous leakage paths of a building envelope may remove some particles before they reach the interior. In exhaust-ventilated homes, the envelope of a tighter home has been reported to provide supply air filtering comparable to that of a MERV 13 filter.[21] The challenge aerosol reaching the interior in our experiments is therefore fresher and may have a different size distribution than smoke entering a typical home by infiltration, which should be considered when interpreting the absolute concentrations and decay rates reported here.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsestair.6c00137.

> Aerosol size distributions for the WUI surrogate smoke and KCl challenge aerosol; a summary of the top ten recorded 24 h PM2.5 concentrations from U.S. WUI and wildfire events (477 $\mu g\ m^{-3}$ to 1900 $\mu g\ m^{-3}$); the AHAM AC-1 count-to-mass conversion; the experimental facility floor plan, Burn 08 images, and the full burn log for the 10 burns (April 26 to May 31, 2024); a statistical summary of baseline-corrected PM decay rates; the equivalent loss rate calculation for an AHAM-sized air cleaner; spatial concentration gradients for PM1, PM2.5, and PM10; results for multiple portable air cleaners; filter loading and airflow measurements; and a MERV 13 versus MERV 12A comparison. Python analysis scripts are available at 10.18434/mds2-4025 (PDF)

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Notes

The following information can be found in the Supporting Information.

The authors declare no competing financial interest.

Disclaimer Specific commercial equipment, instruments, or materials are identified in this paper to ensure the experimental procedure is adequately specified. Such identification is not intended to imply recommendation or endorsement by NIST or imply that the materials or equipment identified are necessarily the best available.

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