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Evidence review:
Home and community clean air shelters to protect public health during wildfire smoke events

March 31, 2014

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Key points

- Wildfires emit several air pollutants including fine particulate matter ($PM_{2.5}$) and gases.
- Few studies have evaluated the use of air filters during wildfire smoke events. Most of the available research has evaluated use of portable air cleaners in residential settings to reduce $PM_{2.5}$ related to wood smoke, environmental tobacco smoke and general indoor air pollution.
- Use of high efficiency particulate air (HEPA) filters and electrostatic precipitators has been shown to reduce residential $PM_{2.5}$. Effectiveness, however, varies depending on the size of the room in which the air cleaner is placed, air exchange rate, as well as pollution sources in homes.
- Little information is available on the potential health benefits of air cleaner use, although some evidence suggests that use of portable HEPA air cleaners, even over the short term (days), may be linked to improvements in cardiovascular health and some asthma-related symptoms.
- Limited research evaluating induct filters in homes and other buildings suggests that use of high performance induct media filters can substantially lower indoor $PM_{2.5}$ concentrations.
- Filtration is a potentially effective intervention to reduce $PM_{2.5}$ exposures among community members exposed to wildfire smoke. Filtration can be implemented through the establishment of home clean air shelters (with the use of portable or induct filters in homes) or community clean air shelters (with the use of induct filters in larger public buildings).
- When determining the appropriateness of filtration in smoke-affected communities, several things should be considered, including the intensity of the smoke event, timing and preparation for and implementation of filtration, availability of potential community clean air shelters (i.e., large public buildings with well-maintained HVAC systems) in the community, as well as the particular needs of the community.

Evidence gaps

- Most studies of portable air cleaners report on “best case” scenarios and do not take into consideration variations in usage compliance, indoor behaviours, or housing characteristics.
- Effectiveness of portable air cleaners over longer use periods (e.g., months versus days to weeks) has not been well studied.
- There is a lack of research on the impact of induct filters in reducing infiltration of PM from wildfire smoke.

Considerations

- When recommending home clean air shelters (HCAS):
    - Poor quality housing, as well as older housing, is expected to have higher infiltration rates, making such homes less effective as home clean air shelters.
    - Availability of residential central air conditioning will encourage residents to remain indoors with windows closed because homes will remain at a more comfortable temperature. Keeping windows and doors closed will also mean lower infiltration of smoke-related particles, even when air conditioners do not have additional filtration.
    - Community members should be provided information on how to best minimize potentially negative impacts of lowering air exchange rates in the home (e.g., accumulation of indoor pollutants such as carbon monoxide or carbon dioxide).

  - More than one portable air cleaning unit may be required for large rooms or homes with high air exchange rates.
- When recommending community clean air shelters (CCAS):
  - Consider whether large air conditioned spaces such as shopping malls, libraries, or community centres are available and whether it is feasible to use these spaces in the short term (hours) and long term (days to weeks).
  - Practical considerations around the effectiveness of CCASs include effectiveness of the current HVAC system in limiting exposures, feasibility of installing higher efficiency filters in the current HVAC system, and potential for increased air exchange rates, and therefore higher infiltration of smoke, due to movement into and out of the building.
  - For communities where wildfire smoke is a frequent seasonal exposure, installation of high efficiency filters in community shelters before the fire season may be needed. For other communities, establishing an inventory of buildings with sufficient conventional induct filtration may be a more feasible approach.
  - The types of filters (e.g., high efficiency media filters, electrostatic precipitators, or HEPA filters) to be employed will depend on the needs and resources of the community as well as severity and duration of the smoke event.
  - Upgrades to buildings may be required to provide adequate electrical power, fan capacity, or structural support to handle the added airflow resistance of high efficiency induct filtration.
- When considering community versus home clean air shelters
  - Residents may be required to travel longer distances to reach CCASs, and may be exposed to smoke in transit.
  - Mobility may be limited for families with small children or elderly residents or who may not be able to walk or drive to a CCAS.
  - Community members who are trying accessing CCAS versus remaining at home may experience additional stresses.
  - The benefits of potentially more effective filtration obtained intermittently at CCASs (e.g., malls) should be weighed against less effective but more consistent filtering obtained in HCAS for extended periods of time.
  - Encouraging individuals to remain in CCASs may be a challenge if extended stays are required. If smoke events are expected to persist, HCASs might be a more viable option than encouraging prolonged stays at CCASs.
- **Vulnerable populations**, including children, the elderly, pregnant women, and those with pre-existing respiratory and cardiovascular disease, may be at higher risk of adverse health effects related to wildfire smoke, and therefore may benefit most from decreased exposures through filtration. Measures to best implement the use of filters among these groups should be considered. For example, high efficiency induct filters could be installed in long-term care and retirement facilities, as well as schools. Additionally, portable filters could be preferentially made available to homes with children or elderly occupants.

1. Introduction

Wildfires emit several pollutants, including fine particulate matter (particulate matter less than 2.5 µm in diameter; $PM_{2.5}$) and gases such as carbon monoxide, volatile organic compounds, and nitrogen oxides. These pollutants can infiltrate indoors, increasing exposures to occupants in homes and other buildings. Air filters can help to lower indoor concentrations of pollutants and potentially reduce adverse health effects. Filters can be stand alone units (portable) or installed as part of heating, air conditioning and ventilation (HVAC) system in buildings (induct filtration). Two options for providing filtration are available to communities impacted by wildfire smoke. First, residents can be encouraged to create home clean air shelters (HCAS) which would involve use of either portable or induct filtration in homes. Second, public buildings such as libraries, shopping malls, community centres, or schools can be established as community clean air shelters (CCAS). Ideally, these buildings should have a well maintained HVAC system. HVAC systems can be operated as normal (i.e., using a conventional filter that is already in place) or with added filtration (i.e., using additional portable or induct filtration). Here, we summarize evidence on the use of portable and induct filtration in homes and other buildings to reduce particulate air pollution and the associated health effects. The aim of this document is to provide information to better inform decisions around the implementation of filtration in communities impacted by wildfire smoke.

2. Methods

A search of scientific literature was conducted primarily through the Ebsco, PubMed, and SearchMedica.com databases, all of which are available through the University of British Columbia. The following terms were used: "air clean*" OR "air filt*" OR "high efficiency particulate air" OR "particulate matter" OR HEPA OR vacuum OR ventilat* OR "electrostatic precipitator" OR HVAC OR " residen* OR home OR house OR indoor OR PM2.5 OR PM10 OR commercial OR school OR office OR mall OR community centre OR wildfire/wild fire OR forest fire OR bushfire OR brushfire/brush fire OR wildland/wild land fire OR landscape fire OR fire smoke (but not household/building/urban fires), OR "air shelter", "blood pressure" OR cardiovascular OR "inflammatory disease" OR "oxidative stress" OR health OR illness OR asthma or allerg* OR respirat* OR "hypertension" OR COPD OR "chronic obstructive pulmonary disease". Searches were restricted to studies published in 2000 and onwards. Additional research studies were identified through the reference list of studies. Only studies investigating exposures to wildfire smoke, residential wood burning smoke, traffic-related pollution and general outdoor air pollution were included. Studies investigating the use of air filters on allergen-related health effects were excluded.

3. Types of air cleaners

Air filters can be categorized by their setup and operating technology. The setup of air cleaning devices can be either induct or portable (1). Induct devices are a part of the HVAC system and are designed to clean air from the entire building. Portable devices are designed to clean air from a single room in a building. Each type of setup is associated with advantages and disadvantages. Induct devices may be associated with higher operating costs and will only filter air when the HVAC system is turned on. A portable air cleaner, while having lower operating costs, is designed to clean the air in the room in which it is placed, although studies have found that, in some conditions, portable units can reduce whole house $PM_{2.5}$ levels (2). Additionally, a portable air cleaner must be sized appropriately for the room in which it is used in order to be effective.

Air filters can also be broadly categorized into three types of operating technologies: i) mechanical filter-based; ii) electrostatic precipitating or ion generating; and iii) hybrid devices using more than one type of technology (Table 1). Both mechanical filter-based and electrostatic precipitating models remove particles from air. Filter-based devices incorporate the use of flat, pleated, or high efficiency particulate air (HEPA) filters. Efficiencies to remove particles increase from flat to HEPA filters (1). To be designated HEPA, a filter must capture at least 99.97% of 0.3 µm particles. Most filter-based air cleaners also use activated carbon as a gas-phase pre-filter, which helps to remove some gases (and odours) from air. Electrostatic precipitators operate by charging the incoming stream of particles and collecting them on an oppositely charged metal plate within the device. Ion generators also charge particles, but may not collect particles within the cleaner. Instead, charged particles deposit onto room surfaces, including walls, table surfaces, and the floor (1). When charged particles attach to these surfaces, they are no longer airborne or inhalable, but can be re-entrained to air if disturbed.

Although the use of air cleaners is intended to reduce health effects associated with poor indoor air quality, some air cleaning technologies are associated with potential negative health impacts. Of particular concern are units which produce ozone (a respiratory irritant) either intentionally (e.g., ozone generators) or as a by-product (e.g., some electrostatic precipitators).The levels of ozone produced by some residential units are generally not effective at cleaning the air, and instead can cause respiratory irritation, particularly when used in homes with low air exchange rates (3). Health Canada advises against the use of ozone generators in residential settings due to the health impacts of exposure to ozone, including chest discomfort, coughing, and other respiratory symptoms (4). Ozone can also react with other compounds in indoor air to form new pollutants; for example, ozone can react with terpenes to form submicron particles and with nitric oxide to form nitrogen dioxide (5). Household cleaning products containing pine, lemon, and orange oil can be a source of terpenes, while gas stoves and unvented kerosene heaters can be sources of nitric oxide.

Table 1. Summary of major air cleaner operating technologies (1)

Design	Pollutants Targeted	How they Work	Limitations
Mechanical filters	Particles	Particles move across filter and are removed based on particle size. Filters can be flat, pleated or high efficiency particulate air (HEPA). By definition, HEPA filters remove 99.97% of particles sized <0.3 µm.	Portable HEPA filter cleaners have a limited volume of air they can clean; appropriate room sizing and reducing air exchange rates are important to air cleaner effectiveness.
Electrostatic precipitators	Particles	Charge an incoming stream of particles and collect them within the device on an oppositely charged plate.	Units may produce ozone as a by-product, and therefore pose a potential health concern.
Ion generators	Particles	Charge particles in the air to increase their deposition onto room surfaces.	Particles deposited on room surfaces can be re-suspended in the air.
Activated carbon filters	Gases	Gases move across the filter and adsorb onto the filter. Typically found in hybrid air cleaners, which incorporate the use of more than one cleaning technology, such as a HEPA filter.	Not all gases can be removed. Filters can become loaded, and need to be replaced in a timely manner.

Design	Pollutants Targeted	How they Work	Limitations
Ozone generators	Gases (including volatile organic compounds)	Release ozone into the air to react with indoor pollutants.	The levels of ozone produced are ineffective at cleaning, and pose a health concern; their use is not recommended.

4. Evaluating air cleaner effectiveness

The effectiveness of any air cleaning device depends on two factors: i) the efficiency of the device at removing a specific pollutant, and ii) the volume of air that is cleaned by the device. These factors in turn are influenced by variables such as air exchange within the room or building, the levels of pollutants in the air, the positioning of the device within the room and, most importantly for stand-alone air cleaners, the size of the room in which the device is used. Two industry rating systems have been developed to provide performance measures of cleaners: the Minimum Efficiency Reporting Value (MERV) for induct HEPA filters and the Clean Air Delivery Rate (CADR) for portable HEPA filter devices. The MERV rating system, developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), assigns a number between 1 and 16 to a filter based on a performance test comparing concentrations of particles, sized between 0.3 and 10 µm, upstream and downstream of the filter. For wildfire smoke, $PM_{2.5}$ particles concentrations are most relevant. A rating for each filter corresponds to the particle removal efficiency of the filter, based on the specific size category of particles tested. The CADR ratings are assigned to a device for three pollutants: tobacco smoke, dust, and pollen. The efficiency of the device is based on the difference between pollutant concentrations in a test chamber with and without air cleaner use. These efficiencies are then translated to CADR ratings which describe efficiencies at various room sizes (1). With use, filters become overloaded and must be replaced according to manufacturer instructions. Replacement frequency will depend on frequency and duration of use, as well as on the settings in which filters are used with respect to pollution concentrations.

5. Portable air cleaners

5.1. Exposure reduction

Few studies have investigated the use of air filters to reduce PM generated from wildfires, in part due to the unpredictable nature of fires (Table 2). Henderson et al. 2005 measured $PM_{2.5}$ levels in four homes exposed to wildfire smoke (2). Two to three electrostatic precipitators (EPs) were operated in two homes for 24–48 hours, while two homes served as controls (i.e., no filtration). Each pair of treatment and control homes was matched for age and air exchange rate. Occupants were instructed to keep windows and doors closed throughout the study period. Treatment homes had 63–88% lower $PM_{2.5}$ concentrations compared to control homes (2).

Some researchers have investigated the effectiveness of air cleaners by quantifying infiltration efficiency of particles during periods with and without filter use. Infiltration efficiency is a unit-less quantity defined as the fraction of the outdoor concentration of a pollutant that penetrates indoors and remains suspended. In the absence of indoor sources, infiltration efficiency is equal to the indoor/outdoor concentration ratio of the pollutant of interest. In settings where indoor sources are more prevalent, such as homes, infiltration efficiency takes into account the portions of indoor and outdoor generated pollution in indoor air. For example, for an infiltration efficiency of 0.60 for $PM_{2.5,}$ the indoor concentration of outdoor-generated $PM_{2.5}$ is 60% of the outdoor concentration. Barn et al. investigated the relationship between portable HEPA filter use and infiltration efficiency of $PM_{2.5}$ in homes; $PM_{2.5}$ from forest fires (summer sampling) and residential wood burning (winter sampling) was investigated (6). Sampling was conducted for 48 hours in each home (n=13), with an air cleaner operating with a HEPA filter for half of the study period. Filter use was randomly assigned to the first or second 24-hour period in each home. For homes impacted by forest fire smoke, an average infiltration efficiency of 0.19±0.20 was found for filtering periods, compared to 0.61 ± 0.27 for non-filtering periods (6).

Allen et al. conducted a randomized crossover study of portable HEPA filter air cleaner use in 25 homes affected by residential wood smoke (7). Sampling was conducted in each home during the winter season for 14 consecutive days, and air cleaners were operated with the filter in place for half of the study period. A lower average infiltration factor was found during the filtering period (0.20±0.17) compared to non-filtering periods (0.34±0.17) in all homes (7). Filtering was also associated with cardiovascular health benefits (see health benefits section). Barn et al. also found lower average infiltration with use of HEPA filters in homes affected by residential wood burning. In this study, a 24-hr period of filtering was associated with an average infiltration of 0.10±0.08 compared to 0.27±0.18 during periods with no filtration (n=19) (6). Hart et al. conducted a randomized crossover study to investigate the use of portable EPs to reduce particle concentrations in two homes with wood stoves (8).Sampling was conducted in each home for ten 24-hour periods, with EPs operating for half of each 24-hour period. Use of EPs was randomly assigned to the first or second 12-hour period (8). Particle count concentrations were reduced by 61–85% during filtering periods compared to non-filtering periods. Significant reductions in concentrations were seen for all particle size ranges investigated (0.3, 0.5, 1, 2.5, 5, and 10 µm).

A few studies have investigated the use of portable air cleaners to reduce residential concentrations of particles from traffic, tobacco smoke and general air pollution. Brauner et al. placed HEPA filters in 21 homes located in close proximity to roads. The air cleaner was operated with the filter for the first or second 48-hour period of the study; filtering periods were randomly selected (9). Researchers found that use of portable HEPA filters over 48-hour periods reduced average indoor $PM_{2.5}$ concentrations from 12.6 µg/m^3 (95% CI: 11.2,14.1) to 4.7 µg/m^3 (95% CI: 3.9,5.7) (9). HEPA filter use was also found to improve microvascular function in participants (see section *5.2 Health benefits*). In a similar study, researchers found that use of HEPA filter air cleaners was linked to reduced indoor $PM_{2.5}$ concentrations in 30 apartments located within 350 m of major roads (10). Air pollution measurements were collected in each home for 2 consecutive weeks; two air cleaners were operated with filters for half of the study period (in the main living area and a bedroom). Lower average $PM_{2.5}$ concentrations were found during periods when the air cleaners were operated with a filter (main living area: 4.3 µg/m^3 (0.2–12.2 µg/m^3)) compared to when they were operated without the filter (main living area: 8.0 µg/m^3 (3.4–20.7 µg/m^3)); similar concentrations were found in bedrooms.

Researchers have also evaluated the use of portable HEPA filters to reduce $PM_{2.5}$ concentrations related to smoking and general indoor air pollution. Butz et al. investigated use of HEPA filters to reduce environmental tobacco smoke particles in homes of asthmatic children over a 6-month period (11). Homes were assigned to one of 3 groups: control (n=44), two HEPA filters (n=41), or two HEPA filters plus a health coach who provided four asthma education sessions through the study period (n=41). Sampling was conducted in each home for 1 week at baseline (before interventions were implemented) and again after 6 months. Largest mean differences of $PM_{2.5}$ concentrations measured at baseline and the 6-month follow up were seen for the HEPA filter only group (-19.9 µg/m^3), compared to the HEPA filter plus health coach (-16.1 µg/m^3) and control (3.5 µg/m^3) groups; visits with a health coach were found to provide no additional reduction in $PM_{2.5}$ concentrations over air cleaner use. Similar results were seen for $PM_{2.5-10}$ concentrations (11). Lanphear et al. also conducted a randomized controlled trial to investigate the use of HEPA filters to reduce residential environmental tobacco smoke (ETS) exposures to asthmatic children (12). Filter use was randomized among two groups, with one receiving two active HEPA filter air cleaners (n=110) and the other receiving two sham air cleaners (n=115). Sampling of particle count concentrations (for cut-off points of >0.3 µm and >5 µm) was conducted at baseline and again at 6 and 12 months. Particle count concentrations were up to 25% lower at both follow up periods compared to baseline for all intervention homes. The largest reductions were for particles >0.3 µm, where concentrations were 4.0, 2.5 and 3.0 x $10^6/ft^3$ at baseline, 6 months and 12 months (12).

No significant differences in particle concentrations were found in the control group. Weichenthal et al. conducted a randomized case crossover study of the use of portable EP to reduce residential $PM_{2.5}$ concentrations in a First Nations community (13). One air cleaner was operated in each home for 14 days, with the filter removed from the cleaner for one half of the study period (n=20). Average indoor concentrations of $PM_{2.5}$ were substantially lower on days when the filter was used, with a mean difference between filter and non-filter periods of 37 $\mu g/m^3$ (95% CI: 10, 64) (13).

In their evaluation of portable HEPA filter air cleaners in homes of asthmatic children, Du et al. found lower PM concentrations after one week of use ($8.4 \pm 13.1\ \mu g/m^3$) compared to baseline concentrations ($26.0 \pm 23.8\ \mu g/m^3$) in all treatment homes (n=47) (14). Similarly, Eggleston et al. evaluated the use of portable HEPA filters along with other interventions (home-based education about asthma, cockroach and rodent extermination, and mattress and pillow casings) in homes of asthmatic children (15). Participants were randomized into a control (no air cleaner) and treatment (air cleaner plus other interventions) and $PM_{2.5}$ concentrations were compared at baseline, as well as 6- and 12-month follow up periods. Compared to baseline (38 $\mu g/m^3$ (95% CI: 23, 70), average $PM_{2.5}$ concentrations were lower at 6-month (23 $\mu g/m^3$ (95% CI: 10, 60)) and 12-month (24 $\mu g/m^3$ (95% CI: 10, 43)) follow up periods. No significant changes were seen in control homes (15).

Table 2. Summary of studies investigating the use of portable air cleaners to reduce residential particle concentrations

Study	Exposure	Type of air cleaner	Study Design	Study conditions & housing characteristics	Main findings
Henderson et al. 2005 (2)	Fire smoke	Portable electrostatic precipitator	Randomized controlled trial. Two to three air cleaners were operated in 2 treatment homes for 24–48 hours; the number of units used was based on the total volume of the home.	Air pollution monitoring was conducted in the main living area of the home. The location of the air cleaners was not specified. Participants were asked to keep windows and doors closed throughout the study period. All homes were 2–3 floor single family homes. The age of homes ranged from 3–39 years, and total volumes ranged from 407–1415 m^3.	Indoor $PM_{2.5}$ levels 63–88% lower in treatment versus matched control homes (n=4). The mean indoor $PM_{2.5}$ concentration was <3 $\mu g/m^3$ in treatment homes compared to 5.2–21.8 $\mu g/m^3$ in control homes.
Barn et al. 2008 (6)	Forest fire & wood smoke	Portable HEPA	Randomized crossover study. One air cleaner was operated in each home for 48 hours. Filters were removed from the units for 24 hours, with the filtering period being randomly assigned to the first or second half of the study period.	The unit was placed in the main bedroom of the home; when this wasn't possible, the unit was placed in the main living area of the home. Air pollution monitoring was conducted in the same room in which the air cleaner was placed. All rooms in which the unit was placed must have met the maximum room size requirement of 15 x15 ft^2. Residents were asked to refrain from using woodstoves during the study period.	Lower average infiltration of $PM_{2.5}$ found in homes when filter in place (0.13±0.14) compared to when filter not in place (0.42±0.27) in all homes (n=29).

Study	Exposure	Type of air cleaner	Study Design	Study conditions & housing characteristics	Main findings
Allen et al. 2011 (7)	Wood smoke	Portable HEPA	Randomized crossover study. Two air cleaners were operated in homes for 14 days. Filters were removed from air cleaners for 7 days, with the filtering period being randomly assigned.	One unit was placed in the main activity room and another in the participant's bedroom. Air pollution monitoring was conducted in the main activity room. No information on housing characteristics provided.	Lower average infiltration of $PM_{2.5}$ was found in homes when filter was in place (0.20±0.17) compared to when the filter was not in place (0.34±0.17) in all homes (n=25).
Hart et al. 2011 (8)	Wood smoke	Portable electrostatic precipitators	Randomized crossover study. One air cleaner each was placed in 2 homes for 10 days. Each day, the air cleaner was turned on for 12 hours, and off for 12 hours, with the filtering period being randomly assigned for each 24-hour period.	Homes had total areas of 125 and 122 m^2; one was a double wide mobile home and the other was a conventional wood frame home. The unit was placed in the main living area of each home. Air monitoring was conducted in the same room.	Average particle count concentrations were reduced by 61–85% for all particle cut-points (0.3, 0.5, 1, 2.5, 5, 10 µm) during periods when air cleaner was used (n=2).
Brauner et al. 2008 (9)	Traffic	Portable HEPA	Randomized crossover study. Two air cleaners were operated in each home for 96 hours (4 days). Filters were removed from air cleaners for 48 hours, with the filtering period being randomly assigned.	One unit was placed in the main living area and the other in the participant's bedroom. Participants were asked to stay indoors and keep windows closed during study duration. Air pollution monitoring was conducted in the same room in which an air cleaner was placed. No information on housing characteristics was provided.	Lower average $PM_{2.5}$ levels were found for periods when the filter was in place (4.7, 95% CI: 3.9, 5.7 µg/m^3) compared to when filters were not in place (12.6, 95% CI: 11.2, 14.1 µg/m^3) in all homes (n=21). Similar reductions were found for lower PM_{10} concentrations during the filtering (9.4, 95% CI: 8.1, 10.1 µg/m^3) versus non-filtering (4.6, 95% CI: 3.5, 6.0 µg/m^3) period.

Study	Exposure	Type of air cleaner	Study Design	Study conditions & housing characteristics	Main findings
Karottki et al. 2013 (10)			Randomized crossover study. Two air cleaners were operated in each home for 14 days. Filters were removed from air cleaners for 7 days, with the filtering period being randomly assigned.	One unit placed in bedroom and another in the main living area. Air pollution monitoring was conducted in the bedroom and main living area. All participants lived in apartments.	Effectiveness of filtration was found to be variable, although average $PM_{2.5}$ concentrations were lower during the filtering versus non-filtering period across all homes (n=29). Average $PM_{2.5}$ concentrations in main living areas during filtering and non-filtering period were 4.3 µg/m^3 (0.2–12.2 µg /m^3) and 8.0 µg /m^3 (3.4–20.7 µg /m^3), respectively. Similar concentrations were found in bedrooms.
Butz et al. 2011 (11)	Environmental tobacco smoke	Portable HEPA	Randomized controlled trial. Homes of children exposed to indoor environmental tobacco smoke were randomly assigned to one of three groups 1. control (n=44) 2. 2 HEPA filter air cleaners (n=41) 3. 2 HEPA filter air cleaners plus home visits from a health coach (n=41) over a 6-month period.	One unit was placed in the child's bedroom and another in the main living area. Air pollution monitoring was conducted in a room in which an air cleaner was placed. The mean area of homes was 54.9±18.6 m^2.	Mean differences in concentrations of $PM_{2.5}$ and $PM_{2.5\text{-}10}$, respectively (from baseline and 6-month follow up): *Control*: 3.5 µg/m^3 and 2.4 µg/m^3 *Air cleaners*: -19.9 µg/m^3 and -8.7 µg/m^3 *Air cleaners plus health coach*: -16.1 µg/m^3 and -10.6 µg/m^3 No differences were found in air nicotine or urine cotinine concentrations at baseline and 6-month follow up.

Study	Exposure	Type of air cleaner	Study Design	Study conditions & housing characteristics	Main findings
Lanphear et al. 2011 (12)	Environmental tobacco smoke	Portable HEPA filters	Randomized controlled trial. Homes of children exposed to indoor environmental tobacco smoke were randomly assigned to one of two groups: 1. control (2 sham air cleaners; n=115) 2. intervention (2 HEPA filter air cleaners; n=110) over a 12-month period.	One unit was placed in the child's bedroom and another in the main living area. Air pollution monitoring was conducted 3 rooms (main activity room, child's bedroom, and kitchen); the average concentrations for all 3 rooms were reported for each home. No information on housing characteristics was provided.	Particle counts for cut off points of >0.3 um and >5 µm, respectively, were lower at 6 and 12 month follow up periods compared to baseline levels: *Control* Baseline: 4.7 and 0.0037 $10^6/ft^3$ 6 month follow up: 4.6 and 0.0028 x $10^6/ft^3$ 12-month follow up: 4.4 and 0.0024 x $10^6/ft^3$ *Intervention* Baseline: 4.0 and 0.0033 x $10^6/ft^3$ 6-month follow up: 2.5 and 0.0029 x $10^6/ft^3$ 12-month follow up: 3.0 and 0.0027 x $10^6/ft^3$
Weichenthal et al. 2013 (13)	General indoor air	Portable electrostatic precipitators	Randomized crossover study. One air cleaner was operated in each home for 14 days. Filters were removed from air cleaners for 7 days, with the filter period being randomly assigned.	The unit was placed in main living area of home. Air pollution monitoring was conducted in same room. No information on housing characteristics was provided.	Average indoor concentrations of $PM_{2.5}$ decreased substantially when filters were used, with a mean difference between filter and non-filter periods of 37 µg/m^3 (95% CI: 10, 64); n=20. Indoor concentrations substantially elevated above outdoor concentrations due to high prevalence of smoking indoors.

Study	Exposure	Type of air cleaner	Study Design	Study conditions & housing characteristics	Main findings
Batterman et al. 2012 (16)	General indoor PM	Portable HEPA filters and air conditioners	Randomized controlled trial. Homes of asthmatic children randomly assigned to one of 3 groups: 1. Control (n=37) 2. HEPA filter air cleaner (n=47) 3. HEPA filter air cleaner and air conditioner (n=42) for 3–4 consecutive seasons.	The unit was placed in child's bedroom. Filters and pre-filters were replaced after 6 months. Air pollution monitoring was conducted in child's bedroom. All homes were 2- to 4-bedroom single-family homes. The age of homes varied from <9 to >100 years.	Average PM (total suspended particle) concentrations over all seasons (3–4 follow up home visits across all seasons) decreased in intervention groups: *control*: 32.5 μg/m^3 *air cleaner*: 21.4 μg/m^3 at baseline and 11.8 μg/m^3 with intervention *air cleaner and air conditioner*: 32.5 μg/m^3 at baseline and 14.1 μg/m^3 with intervention. Similar trends seen for particle number counts (0.3–1.0 μm and 1–5 μm). Filter use declined over time.
Du et al. 2011 (14)	General indoor PM	HEPA filter	Randomized controlled trial. Homes of asthmatic children randomly assigned to one of two groups: 1. control (visit from community health work; n=37) 2. intervention (one HEPA filter air cleaner plus visit from community health worker; n=47) for one year.	The unit was placed in the child's bedroom or in the main living area of the home. Filters were placed after 6 months of the study. Air pollution monitoring conducted in the same room in which the air cleaner was placed. Most homes were 2- to 4-bedroom single family homes, with a mean area of 47±58 m^2.	Filter used reduced PM (total suspended particle) concentrations by an average of 69–80% in all homes. PM sampling conducted for one week in each home. Air cleaner placed in each home mid-week. Average pre-air cleaner and post-air cleaner concentrations, respectively in all homes were 26.0±23.8 μg/m^3 and 8.4±13.1 μg/m^3. Similar trends were seen for particle number counts. Baseline average PM concentrations were similar in control (31.8±16.8 μg/m^3) and air cleaner homes (pre-filter).

Study	Exposure	Type of air cleaner	Study Design	Study conditions & housing characteristics	Main findings
Eggleston et al. 2005 (15)	General indoor PM	HEPA filter	Randomized controlled trial. Homes of asthmatic children were randomly assigned to one of two groups: 1. control (no air cleaners; n=50) 2. intervention (one HEPA filter air cleaner in addition to home-based education, cockroach and rodent extermination, mattress and pillow casings; n=50) for one year.	The unit was placed in the child's bedroom. Air pollution monitoring was conducted in the child's bedroom. All homes were row houses; no other information on housing characteristics was provided.	Average $PM_{2.5}$ concentrations in all homes were significantly lower at 6 and 12 month follow up visits, compared to baseline levels in the intervention group *Control* Baseline: 30 (95% CI: 20, 45) µg/m^3 6 months: 29 (95% CI: 22, 50) µg/m^3 12 months: 31 (95% CI: 20, 53) µg/m^3 *Intervention* Baseline: 38 (95% CI: 23, 70) µg/m^3 6 months: 23 (95% CI: 10, 60) µg/m^3 12 months: 24 (95% CI: 10, 43) µg/m^3

5.2. Health benefits

5.2.1. Wildfire smoke

Only one study has investigated the potential health benefits of air cleaner use during wildfires. Mott et al. investigated the effectiveness of four interventions made available to a community exposed to wildfire smoke (17). These interventions were: portable HEPA filter air cleaners, public service announcements, face masks, and evacuation from the community (in the form of hotel vouchers). Researchers surveyed 286 of 385 community residents on their respiratory symptoms before, during and after the fire. In total, 98 participants (34%) reported using an air cleaner in their home during the smoke event; persons with pre-existing respiratory and cardiovascular disease were more likely to use air cleaners over other interventions. Increased duration of use was significantly associated with decreased odds of reporting worsening respiratory symptoms (OR =0.54). The ability to recall public service announcements was also linked to decreased symptom reporting, while mask use and evacuation from the area were not associated with any such decreases (17). Study findings, while limited by recall bias and lack of exposure measurements, suggest that air cleaner use could provide some health benefits during wildfire smoke events.

5.2.2. Other sources of PM

The use of portable air cleaners has been linked to increased blood vessel health (7, 9), decreased inflammation (7), decreased blood pressure (18), and decreased asthma-related symptoms (12). Brauner et al. found that microvascular function improved among elderly subjects (aged 60–75 years) following use of a portable HEPA filter air cleaner over a 48-hour period in homes impacted by traffic related pollution (i.e., homes located less than 350 m from a major road) (9). Reactive hyperemia index (RHI), a measure of endothelial function, improved by 8.1% (95% CI: 0.4, 16.3%) among participants during filtering periods, compared to non-filtering periods (9). In a similar study, Allen et al. investigated the relationship between HEPA filter air cleaner use and RHI using a randomized crossover study where participants were exposed to 7 days of filtered air and 7 days of non-filtered air in their homes (n=45) (7). Lower exposures to $PM_{2.5}$ during the filtering period were associated with a 9.4% (95% CI: 0.9, 18%) improvement in RHI, and a 32.6% (95% CI: 4.4, 60.9%) decrease in C-reactive protein, a marker of systemic inflammation (7). In contrast, Karottki et al. found no significant differences in microvascular and lung function between periods of filtering and non-filtering among elderly participants living in apartments located within 350 m of major roads (n=48) (10). This finding might in part be due to the variability of effectiveness of the filters, which ranged between reductions of 24 $\mu g/m^3$ to an increase of 7 $\mu g/m^3$ in the living room and the bedroom, where air cleaners were placed. In this study, two HEPA filter air cleaners were operated in each home for 14 days, with the filter in place for only the first or second half of the study period (10).

Lanphear et al. found the use of HEPA filters in homes of asthmatic children exposed to ETS to be associated with an 18.5% (95% CI: 1.25, 82.75%) reduction in unscheduled asthma visits among compared to children who used a sham air cleaner (i.e., with the filter removed) over a 12-month period (12). No significant differences were found in parent-reported asthma symptoms. Finally, Weichenthal et al. conducted a randomized crossover study of the use of portable EPs in homes and acute changes in respiratory and cardiovascular health in an aboriginal community (18). Residents operated an air cleaner in their home for 14 days; the filter was in place for the first or second half of the study period. Filtering was associated with a 217 ml (95% CI: 23, 410) increase in forced expiratory volume in 1 second (FEV_1), a

7.9 mm Hg (95% CI: -17, 082) decrease in systolic blood pressure and a 4.5 mm Hg (95% CI: -11, 2.4) decrease in diastolic blood pressure (18).

Although more research on the use of air filters to reduce $PM_{2.5}$-related health effects, particularly during wildfire smoke events, findings from the studies discussed here suggest that portable air cleaner use lead to some health benefits in the short term.

6. Induct filter and air conditioners

6.1. Existing (conventional) filtration

Larger buildings may be more resistant to degradations in indoor air quality as a result of poor outdoor air quality episodes, including wildfire smoke events. Outdoor pollutants may be more easily diluted by the large volume of air in these buildings. Additionally, larger buildings typically have more controlled air exchange rates through their HVAC systems, compared to homes, which are more likely to use natural ventilation. Finally, conventional media filters (MERV 1 or 2 ratings) found in HVAC systems may also provide some filtering benefits.

Ratios of indoor to outdoor air pollution concentrations provide a good indication of infiltration efficiency for large buildings where indoor sources may provide relatively little contribution to indoor air pollution concentrations. Polidori et al. investigated indoor and outdoor ratios of pollutants ($PM_{2.5}$, elemental carbon and organic carbon) in two retirement facilities in Los Angeles (19). Indoor and outdoor air pollution sampling was conducted over two 6-week periods (summer and winter) and average infiltration factors for each pollutant were quantified. For $PM_{2.5}$, F_{inf} ranged from 0.52–0.74 for both buildings. Highest F_{inf} values were found for elemental carbon (0.70–0.98); authors suggested that because these particles penetrate more easily across the building envelope because of their small size, which typically falls in the range of 0.1–0.4 µm. Constant and low air exchange rates were found for both facilities in both sampling periods; this finding was attributed to the keeping of windows and doors closed as well as presence of central air conditioning, which limits natural ventilation. A range of indoor-outdoor ratios have also been found for schools in the US, with ratios ranging from 0.12 to 0.66 (20, 21).

6.2. Added filtration

No studies have investigated the use of induct filters to reduce infiltration of wildfire smoke into homes or buildings. Three studies have investigated their use in improving general residential indoor air quality (22-24) while an additional two have investigated use of induct filtration in schools (25, 26). Additionally, Lin et al. investigated potential health benefits of air conditioning in residential settings (27).

6.3. Exposure reduction

6.3.1. Residential settings

Myatt et al. modeled the effectiveness of high efficiency electrostatic precipitator induct filter and portable HEPA filter air cleaners in reducing levels of several asthma triggers, including ETS particles, in one and two story single family homes (22). Levels of these triggers were modeled for typical meteorological, air exchange, and pollutant emission rate configurations using empirical data from literature. Use of induct filters was estimated to result in 90–98% reductions in ETS, while use of portable HEPA filter air cleaners were estimated result in reductions of ETS between 70–80% (22). Researchers concluded that use of an electrostatic induct filter as part of a forced air ventilation system resulted in the greatest reduction of air pollutants, followed by use of multiple portable air cleaners in conjunction with conventional (1-inch media filter with MERV 2 rating) induct filtration. Similarly, Macintosh et al. concluded that high efficiency induct filters were more effective than portable filters at removing particles in a home (23). Researchers characterized particle removal rates in a test home under various air filter configurations, including induct conventional media filters, induct high efficiency electrostatic filters, and portable HEPA filters. Removal rates for $PM_{2.5}$ were 0.5 h^{-1} for baseline conditions, 1 h^{-1} for a 1-inch induct media filter, 2.4 h^{-1} for one portable HEPA filter, 4.6 h^{-1} for a 5-inch induct media filter, and 7.5 h^{-1} for a high efficiency electrostatic induct filter (28). Induct filters were expected to lead to higher removal rates of particles since they filter air in the whole building in contrast to portable filters which are designed to clean air in a single room.

6.3.2. Schools

Polidori et al. evaluated the use of three filtering systems on indoor air quality in three Southern Californian elementary schools (26). The three filtering systems were: 1) high performance (HP) induct media filter, 2) register-based (RB) air purifier, which was installed at the air supply entry to each classroom tested, and 3) large stand alone (SA) unit operating independently of the HVAC system; all of which were equipped with a high performance filter (MERV 16). Overall, the HP filter reduced indoor concentrations for all pollutants (black carbon, $PM_{2.5}$ and PM_{10}) by at least 86%. Operating the HP in conjunction with the RB system resulted in the highest removal efficiencies of 87-96% for all pollutants (26). The SA unit, while effective, was found to be the most influenced by activities within the classroom, including opening of windows. Additionally, indoor air quality was found to be heavily influenced by outdoor pollution, particularly emissions related to traffic. All tested configurations improved indoor air quality over baseline levels (with regular media filter-equipped HVAC).

McCarthy et al. tested reductions in black carbon and gaseous pollutants in three Las Vegas schools after improvements were made to building HVAC systems (25). These improvements were made as a result of a legal settlement which required the city to implement HVAC changes to counteract negative impacts to indoor air resulting from construction of a major highway next to the schools. School HVAC systems were upgraded with high performance induct media filters with MERV ratings of 11 or higher. Two schools required additional fans, filter boxes, and in one case, structural support due to the pressure changes in the system. In all schools, the improved HVAC systems were found to reduce black carbon particle concentrations by 74–97% in school classrooms (25). No improvements in gaseous pollutants were found, although authors attributed this finding to the heavy contribution of indoor sources to total concentrations.

6.4. Health benefits

Macintosh et al. modelled indoor $PM_{2.5}$ reductions in single family homes based on housing characteristics in three US cities under three scenarios: (1) all homes have natural ventilation; (2) all homes have forced air heating and cooling with conventional 1-inch induct media filter, and (3) all homes have forced air heating and cooling with a high-efficiency induct electrostatic precipitator (24). Researchers estimated median 24-hour indoor-outdoor ratios of outdoor generated $PM_{2.5}$ in homes of 0.57 for homes with natural ventilation, 0.35 for homes with conventional induct filtration, and 0.1 for homes with high efficiency induct filtration. Reductions in indoor $PM_{2.5}$ concentrations were translated to potential public health benefits. Researchers estimated that if the entire population of single family homes with conventional filtration converted to high efficiency induct filtration, 700 premature deaths, 940 hospital and emergency room visits, and 130,000 asthma attacks could be avoided every year in metropolitan US areas (24).

Lin et al. investigated the link between reductions in indoor $PM_{2.5}$ concentrations, associated with air conditioning use and potential improvements in cardiovascular health (27). Researchers measured C-reactive protein (CRP), 8-hydroxy-2′-deoxyguanosine (8-OHdG), fibrinogen in plasma and heart rate variability (HRV) during 6 home visits scheduled one week apart among 300 healthy subjects aged 20–65 years. Participants were instructed to open all windows for the first two visits, close windows during the next two home visits, and to operate air conditioners with windows closed during the last two visits. The greatest reductions in $PM_{2.5}$ concentrations were seen when air conditioners were operating with windows closed, with average decreases in concentration of 50% in all homes. Concentrations of CRP, 8-OhdG and fibrinogen also decreased by 24%, 71% and 7%, respectively, when the air conditioners were operating compared to when windows were left open (27). Previously, Bell et al. had found lower risks of cardiovascular hospitalizations in communities with a higher prevalence of air conditioning (29). However, the relationship between air conditioning and cardiovascular health is not clear since its use is linked to closing of windows, which in turns reduces infiltration, and perhaps to socioeconomic factors not specifically linked to air conditioner use (30).

7. Determinants of effectiveness

The conditions under which portable air cleaners have been investigated vary between studies, which accounts for the range in effectiveness found. Studies vary with respect to the number, type and duration of air cleaner use, baseline pollutant concentrations, and air exchange rates (AERs) within the room and home. Overall, appropriate sizing of portable air cleaners is an important determinant of effectiveness. Appropriate sizing of a unit should take into account not only size of the room in which it is being used, but also AERs. Consequently, more than one air cleaner may be needed to filter air in a larger space or in a space where AERs are high. Greater reductions in pollutant concentrations are generally seen when air exchange is limited within the room in which the portable air cleaner is used. Additionally, lower AER can reduce the influence of outdoor generated pollution on indoor air quality. On the other hand, a reduced AER can increase the impact of indoor sources by allowing indoor generated pollutant levels to build up. Under conditions where AER is lowered with the aim of reducing outdoor pollution from entering indoors, such as during periods of wildfire smoke or residential wood burning, air cleaner use may be particularly beneficial.

While high efficiency induct filters have been shown to be more effective at removing particles compared to portable filters in residential settings, their use may not be feasible in all settings. For example, most residential HVAC systems are not designed to handle the added energy demands required of HEPA filters (due to increased airflow resistance) (1). Even in larger buildings, HVAC systems may require additional modifications to accommodate high efficiency filtration. In their evaluation of induct filters in schools, McCarthy et al. reported that two of the three schools in their study had to undergo additional changes (e.g., addition of fans and structural supports) to accommodate the use of higher efficiency media filters (25). Additionally, higher efficiency filters may be more costly with respect to purchasing, maintenance and operations costs, although the energy costs of operating induct versus portable filters have not been adequately quantified (31).

8. Research gaps

Few studies have evaluated the use of filtration to limit exposure or reduce health effects during wildfire smoke events. As mentioned above, the methodologies of available studies vary substantially, making it difficult to compare findings between studies. The use of portable HEPA filter air cleaners has been most well studied. Although the effectiveness of these filters in reducing PM concentrations is generally high, most studies have investigated their use over short periods of time (days to weeks), with only a few studies investigating longer use periods (e.g., months). Despite the typically short study durations, use of portable HEPA and electrostatic filter air cleaners does appear to have some benefits with respect to reduced exposures to particles and benefits to cardiovascular and respiratory health.

In most studies, air monitoring was conducted in the same room in which an air cleaner was placed, providing “best case” results of filter effectiveness. Although most studies, particularly those involving longer periods, did not instruct residents to change their behaviours, some studies, including Brauner et al. (9) and Henderson et al. (2) asked residents to keep windows closed throughout the study period which could have resulted in higher observed efficiencies in these studies. Additionally, few studies have addressed the compliancy of air cleaner use by study participants. Some researchers note that use of portable air cleaners can decrease over time (e.g., due to lack of interest or concerns about noise or energy costs), but few studies have attempted to quantify the use of the units when investigating their effectiveness (11, 12, 16).

No studies have evaluated the use of induct filters to reduce infiltration of particles generated from wildfire smoke. The available literature suggests that high efficiency filters, such as HEPA or EPs, are effective at reducing particle concentrations in indoor air. More information is needed to consider their effectiveness, as well as the purchase, maintenance and operational costs of induct filters of varying efficiency (including conventional media filters and higher efficiency filters such as electrostatic and HEPA). Overall, determinants of effectiveness of induct filters in buildings are not well understood. Additionally, no studies have evaluated the use of multiple portable air cleaners in large spaces, making it difficult to compare the effectiveness of induct versus portable filters in non-residential settings.

9. Considerations

While the efficacy of filters is well established, their effectiveness in real life situations depends on many factors which must be considered when determining their usefulness in communities impacted by wildfire smoke. The utility of home or community clean air shelters will vary depending on the severity of the smoke event. Expected pollution concentrations and duration will help to determine whether filtration is an appropriate intervention to consider versus other interventions, including immediate or later evacuation from the area.

9.1. Home clean air shelters (HCAS)

- Housing conditions. Poor quality housing, as well as older housing, is expected to have higher infiltration rates, making such homes less effective as home clean air shelters.
- Prevalence of air conditioning in homes. Residents will be more likely to remain indoors with windows closed if they are able to keep their homes at a comfortable temperature. Additionally, because effective air conditioning requires closing of windows and doors, lower infiltration of smoke-related particles can be expected in homes when air conditioning units are operated, even those without additional filtration.
- Messaging to the public should include information on how to reduce potentially negative effects related to filtration. Effectiveness of filters is largely influenced by air exchange rates in a home or building, particularly in the case of portable filters. Reducing air exchange rates in homes can lead to increased heat exposures as well as accumulation of other indoor pollutants, such a carbon monoxide and carbon dioxide. Community members should be provided information on how to best minimize such exposures.

- Room size and AER affect the efficacy of portable air cleaners; more than one unit may be required for large rooms or homes with high AERs.

9.2. Community clean air shelters (CCAS)

- Availability of large air conditioned spaces such as shopping malls, libraries, or community centres. Consider whether it is feasible to use these spaces in the short term (hours) and long term (days to weeks).
- Practical considerations around the effectiveness of CCASs, including:
  - Effectiveness of the current HVAC system in limiting exposures.
  - Feasibility of installing higher efficiency filters in the current HVAC system.
  - Potential for increased air exchange rates, and therefore higher infiltration of smoke, due to movement into and out of the building.
- Costs and logistics of purchasing, maintaining, and storing filters, as well as the time frame of purchase and implementation of the filters. For communities where wildfire smoke is a frequent seasonal exposure, installation of high efficiency filters in community shelters before the fire season may be needed. For other communities, establishing an inventory of buildings with sufficient conventional induct filtration may be a more feasible approach. Choosing the types of filters (e.g., high efficiency media filters, electrostatic precipitators, or HEPA filters) to be employed will depend on the needs and resources of the community. For example, less efficient filters, such as conventional 1- or 5-inch media filters appear to offer some benefit with respect to exposure reduction compared to filtration. Such filters may be less costly to purchase and operate in HVAC systems, and therefore may be more practical to install in many buildings. However, while their use may be appropriate during smoke events where particulate levels are slightly elevated, conventional filters may not provide adequate protection during more severe events where particulate levels are substantially elevated.
- Ability of buildings to accommodate high efficiency filters. Upgrades may be required to provide adequate electrical power, fan capacity, or structural support to handle the added airflow resistance of HEPA filtration.

9.3 Community versus home clean air shelters

Decisions on the establishment of CCAS versus recommending HCAS require several practical considerations, including:

- The distance that residents may be required to travel to reach CCASs, and their exposures to smoke in transit.
- The mobility of residents. Mobility may be limited for families with small children or elderly residents or who may not be able to walk or drive to a CCAS.
- Added stress to community members who are trying accessing CCAS versus remaining at home.
- The benefits of potentially more effective filtration obtained intermittently at CCASs (e.g., malls) versus less effective, but more consistent, filtering obtained in HCAS for extended periods of time.
- How to best encourage community members to go to, and remain in, CCASs if the need is determined; encouraging individuals to remain in CCASs may be a challenge if extended stays are

required. If smoke events are expected to persist, HCASs might be a more viable option than encouraging prolonged stays at CCASs.

9.4 Vulnerable populations

Vulnerable populations, including children, the elderly, pregnant women, and those with pre-existing respiratory and cardiovascular disease, may be at higher risk of adverse health effects related to wildfire smoke, and therefore may benefit most from decreased exposures through filtration. Measures to best implement the use of filters among these groups should be considered. For example, high efficiency induct filters could be installed in long-term care and retirement facilities, as well as schools. Additionally, portable filters could be preferentially made available to homes with children or elderly occupants.

10. Summary

Few studies have investigated the use of filtration in reducing particulate air pollution exposures from wildfire smoke, but findings from other studies, particularly those investigating use of portable HEPA filters, suggest filters can be useful during smoke events. Use of portable HEPA filters and electrostatic precipitators have been shown to substantially reduce residential $PM_{2.5}$, as well as lead to some health benefits, including improvements in microvascular function, blood pressure and some asthma-related symptoms. Little information is available on the use of induct filters or air conditioners to reduce particulate air pollution in homes and buildings. Available evidence suggests that induct filtering may be more effective in lowering whole house particulate levels compared to portable filtering, and that even conventional induct filters which provide low efficiency filtration have benefits over no filtration in buildings.

Little information, however, exists to provide guidance on appropriate actions to take at a community level during wildfire smoke events. Several gaps exists with respect to the practicality of recommending sheltering in place versus establishing community air shelters. The benefits of installing high efficiency filtration over using conventional (i.e., existing) filtration in buildings is not clear, and may need to be determined on a case by case basis. Additionally no evidence exists on the effectiveness of using multiple portable air cleaners in large spaces to reduce exposures. Additional challenges in determining the feasibility of filtration in communities where wildfire smoke events increase short term exposures to air pollutants include the severity of the event (e.g., the level and duration of the smoke), the episodic nature of the event (e.g., once vs. multiple episodes throughout a fire season; regular episodes in wildfire seasons vs. relatively rare exposures to the community), timing of intervention (preparation required before the fire season or as the need arises), and costs (preparation, implementation, and maintenance). Finally, the potential benefits (reduced exposure and health effects related to wildfire smoke) should be weighed against potential adverse effects, including increased exposures to heat and indoor air pollutants, as well as the added stress to community members travelling to and remaining in community air shelters.

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