

## Clearing the Air on Personal Interventions to Reduce Exposure to Wildfire Smoke

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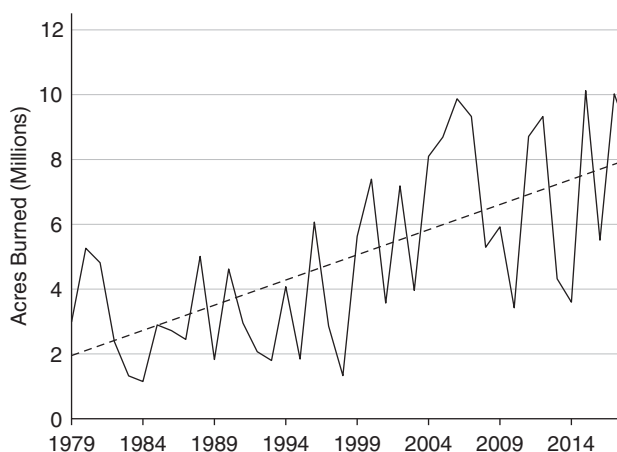
Wildfires are a growing threat to public health in the United States and around the world, as evidenced by the recent catastrophic fires in California, the Pacific Northwest, and Greece. Due to climate change, hotter and drier weather in the western United States and other areas of the globe is likely to accelerate this trend (1). Greater frequency, intensity, and duration of wildland fires have combined with an expanding wildland–urban interface to cause widespread impacts on air quality and public health, as well as devastating local losses of life, health, and property (2) (Figure 1). Rapidly increasing and shifting concentrations of wildfire smoke causing unhealthy levels of air pollution downwind of wildfires demand effective responses at the individual, family, community, and population levels (3).

Smoke from large fires can spread over thousands of square kilometers, potentially affecting the air breathed by millions of people. Annual global mortality from wildfire smoke has been estimated to be over 300,000 persons (4). With increasing frequency of wildfires has come increasing awareness of adverse health effects of wildfire smoke. What are effective actions that individuals, especially those at higher risk, can take to reduce personal exposure to ambient air pollution, including wildfire smoke? What is the balance of potential benefits and harms that may result from

individual actions to reduce exposure? A May 2018 American Thoracic Society workshop, “Personal Interventions for Reducing Exposure and Risk from Air Pollution,” sought to begin to answer these questions, with a report anticipated in 2019.

Wildfire smoke is a complex mixture of fine and coarse particulate matter (PM) and gases, including carbon monoxide, nitrogen oxides, volatile organic compounds, and air toxics. The chemical composition of wildfire smoke particles and gases varies with the types of fuel, moisture, intensity of the fire, and other factors. Systematic reviews have found strong evidence of associations between wildfire

smoke and all-cause mortality and exacerbation of asthma, chronic obstructive pulmonary disease, and respiratory infection (5, 6). Individual components of wildfire smoke (e.g., PM, carbon monoxide, and nitrogen oxides) have established links to cardiovascular and respiratory mortality and morbidity, and more recent evidence suggests associations with adverse reproductive, developmental, and neurodegenerative diseases (7). Groups that are considered more susceptible to smoke and other air pollutants include those with pre-existing respiratory and cardiovascular disease, pregnant women and their fetuses, young children, and older adults (8).



**Figure 1.** Total acres burned in wildfires in the United States, 1979 through 2018, with linear regression trend line (dashed). Source: National Interagency Fire Center. ([https://www.nifc.gov/fireInfo/fireInfo\\_stats\\_totalFires.html](https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html)).

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Personal Interventions

Options for personal action to reduce exposure to wildfire smoke include evacuation, staying indoors, limiting physical activity, air filtration, and wearing respiratory protective devices (respirators, a.k.a. “masks”; Table 1). Each of these interventions has important limitations, and may have unintended adverse effects. No large-scale

observational studies or clinical trials have tested the efficacy, effectiveness, or potential harms of these interventions when recommended by public health officials or health care providers for wildfire smoke exposure. Evidence is largely limited to small-scale studies of efficacy and/or effectiveness of air filtration or use of respirators for reducing exposure to ambient air pollution in experimental settings.

Avoiding wildfire smoke by evacuating may be the most prudent action, depending on the severity of the conditions, balanced against the stress of evacuation, which has been associated with increased mortality in vulnerable people (9). Staying indoors, where levels of outdoor pollutants are typically lower if windows and doors are closed, and limiting physical activity, which decreases inhaled doses of pollutants (10), have been the mainstays of advice from the U.S. Environmental Protection Agency and others for

“bad air” days. Applied over relatively short durations and in the absence of indoor air pollutant sources, these recommendations are unlikely to cause unintended adverse effects on health and well-being. Indoor air filtration with properly sized, high-efficiency particulate air filters can further reduce indoor concentrations of PM by up to about 80% (11). The effectiveness of portable filters for reducing indoor concentrations of wildfire smoke PM depends on the clean air delivery rate and rate at which smoke PM infiltrates the indoor space. Air filtration in a designated “clean room” with the fewest doors and windows can further ensure exposure reduction (12). Air-purifying respirators certified by the National Institute for Occupational Safety and Health (NIOSH) can reduce inhalation exposure, but respirators have significant limitations and may present additional health risks, especially with prolonged use.

**Table 1.** Summary of personal actions for reducing exposure to particulate matter from wildfire smoke, in order of priority according to the hierarchy of controls

Tier in Hierarchy of Controls	Exposure Control Action	Estimated Exposure Reduction	Considerations
1. Elimination	Relocation	100%	Stress of relocation may be harmful, especially for vulnerable populations Exposure to air pollution and other unsafe conditions while in transit May not have feasible places to go
2. Engineering	Reduce indoor infiltration by closing doors and windows Filter air with portable air filters, central air filters, or air conditioners in recirculation mode	20–80%	Effectiveness varies greatly with ventilation and filtration rates. Portable HEPA filters generally more effective, if properly sized and used Central forced-air filtration is generally less effective due to lower-efficiency filters and shorter run times. Upfront costs, but may provide year-round benefit by reducing indoor PM from other sources
3. Administrative	Stay indoors Avoid heavy or prolonged physical activity	~50% on average, but varies widely Lowers inhaled dose of pollutants	Without added filtration, the building envelope limits infiltration to a widely variable extent depending on tightness Especially important for outdoor activity Pulmonary ventilation rates may increase 10- to 20-fold during heavy exertion If temporary, little risk of harmful reduction in beneficial physical activity
4. Personal protective equipment	Wear a NIOSH-approved N95 or P100 filtering facepiece respirator	90% or greater, depending on quality of fit. Near 0% if poorly fitted	Should be used only when outdoor activity cannot be avoided Performance depends on fit Fit testing and medical clearance are not generally available Physiological stress due to increased work of breathing, heat, discomfort Populations vulnerable to wildfire PM may also be more vulnerable to adverse effects of wearing a respirator

Definition of abbreviations: HEPA = high-efficiency particulate air; NIOSH = National Institute for Occupational Safety and Health; PM = particulate matter.

## Prioritizing Personal Interventions

How can one prioritize interventions to maximize potential benefits and minimize potential risks of personal actions in complex and changing wildfire circumstances? Making decisions about how to control personal exposure to air contaminants has a long history in occupational/industrial settings. In particular, the traditional “hierarchy of controls” for workplace hazards, dating back at least to the mid-20th century, provides a useful framework for controlling individual exposure to wildfire smoke (13). The underlying principle is to control the hazard as close to the source as possible. Controls are prioritized in descending order of: 1) elimination of the hazard at the source (fire prevention, fire suppression, relocation); 2) engineering controls (filtration by the building “envelope” and added mechanical air filtration); 3) administrative controls (staying indoors, reducing physical activity): and, finally, 4) personal protective equipment (respirators). According to established principles and practices of workplace health and safety, respirators are only to be used when higher-level controls are not feasible or are not yet implemented, or in emergencies (13).

The rationale for using respirators temporarily and as a last resort in occupational settings among workers also applies to the use of respirators for air pollution among members of the general public. Respirators place significant burdens for control of exposure on the individual, and they have important limitations. Filtering-facepiece respirators (N95 or P100) that have been tested and approved by NIOSH can be effective against PM, the component of wildfire smoke most clearly related to adverse health effects, but they do not provide protection against gasses. The protection afforded by these respirators depends on a tight seal between the respirator and the face. During inhalation, the wearer generates a negative pressure inside the respirator facepiece to drive air through the filter material. If there are any breaks in the face seal, contaminated air will tend to pass through these openings, bypassing the filter material. Facial hair, large scars, and other

facial irregularities may prevent a tight seal, and no respirators are approved for use by children. Fit testing is generally not available for members of the general public. A poorly fitted respirator may provide little more than a false sense of protection.

Respirators place additional burdens on the wearer. They increase the work of breathing and create a dead space under the facepiece, contributing to discomfort and potentially to heat stress (14). Although a few studies have indicated that respirators may prevent increased blood pressure associated with short-term exposure to urban PM (15), other studies have suggested that respirator use itself may cause acute increases in blood pressure (16). Due to the potential adverse respiratory and cardiovascular effects of respirator use, the Occupational Safety and Health Administration requires medical clearance for occupational respirator use. The evidence basis for medical clearance for use of respirators among workers is limited (17), and there are no guidelines for clearing members of the general public. Moreover, individuals with respiratory and cardiovascular disease who may benefit most from reductions in exposure to wildfire PM are also likely to be those most at risk of adverse health effects from wearing respirators. For these reasons, respirators for control of exposure to wildfire PM are generally recommended only for short periods of unavoidable outdoor activity. Caution in the use of respirators is especially advised for individuals who may be vulnerable to the increases in cardiovascular and respiratory stress involved in use of tight-fitting, air-purifying, negative-pressure respirators.

## Information Needs

Effective personal action to reduce risk from wildfire smoke requires knowledge of current or future anticipated levels of personal exposure in different microenvironments (outdoors, indoors, transportation, etc.). Sensory cues, such as visible haze, odor, and irritation, are not calibrated to provide sensitive, quantitative assessments of pollutant concentrations or attendant risk. Individuals can follow the Environmental Protection Agency’s AirNow website and Air Quality Index (18), or similar indices in other countries, for current and predicted

ambient air quality effects of wildfires. Limitations of available air quality data for guiding personal actions to reduce exposure include error in estimating personal exposure from central site and satellite data combined with modeling. Rapid changes and fewer air monitors in nonurban areas increase this error in locations where fires are more prevalent. To address these challenges, low-cost sensors that can be widely deployed for assessing personal or community-level air pollution levels are in development (19). Low-cost, commercial air sensors that purport to measure PM with a diameter of less than 2.5  $\mu\text{m}$  (PM<sub>2.5</sub>) are widely available, but their accuracy and reliability varies widely (20).

In wildfire-prone areas, individuals may benefit from increased awareness and proactive preparation, including plans to control exposure to wildfire smoke air pollution. Having portable or central air filtration and respirators on hand can ensure availability and ready access to these control measures when needed. Improvements in indoor air quality from increased filtration of indoor air may have year-round benefits, depending on local air quality, other conditions in the home, and susceptibility of the occupants to PM-related health effects.

One thing is clear: more research is needed to understand the effectiveness of personal interventions to reduce exposure to air pollution and improve health outcomes related to episodic wildfire events, as well as longer-term poor air quality. Interventions, such as air filtration and respiratory protection, can be studied with controlled trials to evaluate both short-term and long-term health outcomes. Innovations in building science and respirators may improve these controls. In the meantime, cautious application of a hierarchical approach to exposure reduction should guide advice to patients and the general public regarding personal actions to reduce exposure to wildfire smoke and other episodic ambient air pollution events. ■

**Author disclosures** are available with the text of this article at [www.atsjournals.org](http://www.atsjournals.org).

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