# Wildfire Smoke:
## Opportunities for Cooperation Among Health Care, Public Health, and Land Management to Protect Patient Health

*Gail Robarge, Stacey Katz, Wayne E. Cascio*

**Preventing the adverse health impacts of wildfire smoke involves helping people understand if they are at risk, and the actions they can take to limit exposure. Cooperation between land managers, public health officials, and the health care system could alert the public to take actions that reduce wildfire smoke-related health risks.**

### Introduction

Wildfires occur regularly in North Carolina, ranging from western forest fires to eastern peat fires, and over the last 25 years, they consumed anywhere from 9,500 to 77,000 acres each year [1]. Fire on the North Carolinian landscape is natural, and has attendant ecological benefits for fire-adapted ecosystems such as long-leaf pine forests that provide habitat for the red-cockaded woodpecker. Prescribed fires, or "controlled burns," are used by land managers and owners in North Carolina to mitigate the risk of catastrophic wildfire and to support forestry and the health of forests. Yet, the environmental benefits of wildland fires (both wildfires and prescribed fires) can be counterbalanced by imposing hazards and adverse health effects from smoke that impair air quality on neighboring communities both locally and far from the fire. Fortunately, we now understand the patient populations most at risk from smoke. We also have readily available public health guidance to help these patients avert exposure and mitigate adverse health effects. Health care professionals have an important role to play in conveying this information to their patients.

While this is a pressing concern now, in the future exposure to wildfire smoke is expected to increase as changing climate conditions predispose North Carolina to more wildfires [2]. Vulnerability is also expected to increase as the North Carolina population continues to grow and expand into the wildland-urban interface. This commentary describes the relevance of wildfire smoke and wildland fire management to human health and clinical care in North Carolina, provides sources of public health and clinical guidance for health care professionals and patients, and offers opportunities to expand transdisciplinary professional cooperation to maximize the benefit of fire on the landscape while minimizing the risks to human health.

### Health Effects of Wildfire Smoke and Who's at Risk

Wildfire smoke is a mixture of air pollutants, of which particulate matter (PM) is the principal public health threat. Extensive scientific evidence has demonstrated health effects in response to particulate matter exposure ranging from respiratory tract irritation to more serious effects, including increased risk of premature mortality and aggravation of preexisting respiratory and cardiovascular disease [3, 4]. Recently, studies have focused more specifically on the health effects of wildfire smoke exposure and the toxicity of specific fuel sources. Systematic reviews of the effects of smoke conclude that exposure to wildland fire smoke or wildfire-related PM is associated with respiratory morbidity including asthma, chronic obstructive pulmonary disease (COPD), bronchitis, and pneumonia [5, 6, 7]. For example, exposure to wildfire PM in North Carolina during the 2012 Pains Bay peat fire increased respiratory and other chest symptoms, as well as upper respiratory infections [8].

The epidemiological data linking wildfire smoke exposure to non-accidental mortality and cardiovascular mortality and morbidity are mixed, although some recent studies provide evidence of effects [9-11]. A study of emergency department visits in California in 2015 found wildfire smoke exposure was associated with cardiovascular and cerebrovascular emergency department (ED) visits for all adults, particularly for those over age 65 [12]. Similarly, increases in ED visits for cardiovascular health effects were observed during the 2008 and 2012 peat fires in North Carolina [8, 13]. In Australia, wildfire PM exposure was associated with several cardiovascular outcomes, including out-of-hospital cardiac arrests, hospitalizations due to ischemic heart disease, and myocardial infarction in older adults and women [14].

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Address correspondence to Wayne Cascio, U.S. EPA (B305-01), 109 T.W. Alexander Dr, Research Triangle Park, 27711 (Cascio.wayne@epa.gov).

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People at risk from wildfire smoke exposure include children, pregnant women, older adults, and those with chronic disease. Evidence indicates that the risk of fine-particle-related health effects varies throughout one's lifetime. Risk is generally higher during childhood, lower in young adulthood, and greater in middle age through old age as the prevalence of heart and lung disease, hypertension, and diabetes increases (Table 1).

Limited toxicological data are available to provide mechanistic insights for epidemiological observations. However, an *in vivo* study in mice using PM collected during the 2008 Pocosin Lakes National Wildlife Refuge fire in North Carolina found that the smallest particles were related to cardiovascular effects, while the larger particles produced lung and systemic effects [15]. These findings provide some biological plausibility for the increase in ED visits and the cardiovascular and pulmonary health outcomes among those exposed to emissions from the 2008 fire [13].

## Knowledge Gaps and Research Needs

More evidence is needed on the risks from wildfire smoke on mortality, birth outcomes, other susceptible populations, and effects such as post-traumatic stress disorder, anxiety, and mood disorders. For firefighters and those who live in fire-prone regions, the cumulative health impacts of repeated, multiday smoke exposures or multiple fire seasons warrant concern. Additional questions include: Do toxicological effects of biomass combustion differ by fuel type and conditions of combustion? Is the smoke from wildfires occurring in the wildland-urban interface more toxic because of the involvement of structures when compared to wildfire smoke from rural areas?

Greater certainty of the risks of exposure to wildland fire smoke and of costs and benefits of methods to reduce risks is needed. Current modeling appropriately relies on concentration-response functions for ambient PM from all sources, including wildfire smoke [16]. As research and certainty in the data increases, cost-benefit models can be modified to provide more accurate estimates of the hazards and benefits of fires in the environment. One recent study with a national scope showed that exposure to fine particles in wildfire smoke increased asthma-related hospitalizations to a greater extent than non-wildfire PM [17].

## Preventing Adverse Health Effects From Wildland Fires Now and in the Years to Come

There are at least six key approaches to limiting the adverse health impacts of smoke exposure among people at greater risk. These include: 1) improving the overall health of the population to minimize the number of individuals at risk, 2) optimizing medical therapy for patients with conditions that put them at risk, 3) prioritizing intervention among those at risk, 4) educating patients and their caregivers on actions they can take to reduce exposure to smoke, 5) helping communities prepare for smoke, and 6) encouraging greater cooperation among land managers, public health, and health care systems and professionals to lower exposure and protect health.

## Resources to Help Prepare for Smoke

The Air Quality Index (AQI) is a nationally uniform index promulgated by the US Environmental Protection Agency (EPA) for reporting and forecasting daily air quality, including presence of wildfire smoke, across the country. The AQI health advisory information is based on the National Ambient Air Quality Standards. AirNow is a multiagency web site run by EPA that reports air quality using the AQI [18]. AQI data are available to the public via an interactive map and through email notifications, widgets, and smartphone apps. The Fire and Smoke Map on AirNow has data layers with information from ambient PM monitors, satellites (smoke plumes and fire detects), and smoke advisories, and also can provide information about the location of the nearest air monitors, smoke plumes, and fire detects (within a 150-mile radius) [18].

Numerous wildfire smoke-related educational resources that use the AQI are available for health care professionals. *Wildfire Smoke: A Guide for Public Health Officials* is designed to help local public health officials prepare for smoke events, take measures to protect the public when smoke is present, and communicate with the public about wildfire smoke and health [4]. Downloadable factsheets associated with the *Guide* cover a wide range of topics including preseason preparedness, reducing smoke exposure, indoor air quality, children's health, protecting yourself from ash, and protecting pets and livestock [19].

The online course, *Wildfire Smoke and Your Patients' Health*, is intended for physicians, registered nurses, asthma educators, and others involved in clinical or health education [19]. Developed by EPA and the Centers for Disease Control and Prevention (CDC) to inform health professionals about the health effects of smoke and actions for patients to take before and during a wildfire to reduce exposure, it offers CME, CNE, and CEU credit from the CDC.

The *Smoke Sense* mobile app developed by EPA [19] is helping to evaluate the health effects of wildfires and testing whether health risk information can be communicated effectively through the app. The free app is available to any individual who would like to participate in this citizen science project.

## The General Concept of a Wildland Fire Smoke Public Notification System

Our current knowledge of who is at greatest risk suggests that notification to patients before and during fire events would offer them the opportunity to prepare for and avoid wildland fire smoke exposure. Preparations might include securing prescribed medications, obtaining an air purifier, and planning to limit outdoor activities [4]. Two population-based modeling studies conclude that wildfire smoke interventions might result in fewer ED visits, hospi-

**TABLE 1.**
**Summary of Life Stages and Populations Potentially Sensitive to Wildfire Smoke Exposures**

| Sensitive Life Stage/Population | Rationale and Potential Health Effects from Wildfire Smoke Exposure |
|---|---|
| **People with asthma and other respiratory diseases** | ***Rationale:*** Underlying respiratory diseases result in compromised health status that can lead to the triggering of severe respiratory responses by environmental irritants, such as wildfire smoke. |
| | ***Potential health effects:*** Breathing difficulties (e.g., coughing, wheezing, and chest tightness) and exacerbations of chronic lung diseases, such as asthma and COPD, leading to emergency department visits and hospital admissions. |
| **People with cardiovascular disease** | ***Rationale:*** Underlying circulatory diseases result in compromised health status that can lead to the triggering of severe cardiovascular events by environmental irritants, such as wildfire smoke. |
| | ***Potential health effects:*** Triggering of ischemic events such as angina pectoris, heart attacks, and stroke, leading to emergency department visits, hospital admissions, and even death. |
| **Children** | ***Rationale:*** Lungs are still developing, and there is a likelihood of increased exposure to wildfire smoke due to more time spent outdoors, engagement in more vigorous activity, and inhalation of more air per pound of body weight compared to adults. |
| | ***Potential health effects:*** Coughing, wheezing, difficulty breathing, chest tightness, decreased lung function in all children. In children with asthma, worsening of asthma symptoms or heightened risk of asthma attacks may occur. |
| **Pregnant women** | ***Rationale:*** Physiologic changes associated with pregnancy (e.g., increased breathing rates) may increase vulnerability to environmental exposures, such as wildfire smoke. In addition, there may be certain periods during pregnancy when the fetus experiences increased vulnerability to these exposures. |
| | ***Potential health effects:*** Limited evidence of air pollution-related effects on pregnant women and the developing fetus, including low birth weight and preterm birth. |
| **Older adults** | ***Rationale:*** Higher prevalence of preexisting lung and heart disease and decline of physiologic processes, such as defense mechanisms. |
| | ***Potential health effects:*** Exacerbation of heart and lung diseases leading to emergency department visits, hospital admissions, and even death. |
| **People with low socioeconomic status** | ***Rationale:*** Less access to health care, which could lead to higher likelihood of untreated or insufficient treatment of underlying health conditions (e.g., asthma, diabetes), and less access to measures to reduce exposure (e.g., air conditioning). |
| | ***Potential health effects:*** Greater exposure to wildfire smoke due to less access to measures to reduce exposure, along with higher likelihood of untreated or insufficiently treated health conditions could lead to increased risks of experiencing the health effects described above. |
| **Outdoor workers** | ***Rationale:*** Extended periods of time exposed to high concentrations of wildfire smoke. |
| | ***Potential health effects:*** Greater exposure to wildfire smoke can lead to increased risks of experiencing the range of health effects described above. |

Source: US EPA, Wildfire Smoke: A Guide for Public Health Officials (Revised 2019) [4]

talizations, and deaths, and be worth the investment. One study based on North Carolina's health characteristics and exposure-response functions estimated the potential value of smoke plume forecasting and public health communication to reduce smoke exposure among the most vulnerable [20]. The other study demonstrated the benefits of in-home air filtration interventions during periods of wildfire smoke among older adults and those at highest risk [21]. Such actions might be particularly helpful in the Southeastern and mid-Atlantic United States where the at-risk population is larger [22].

Smoke forecasts could be used as the basis for notifying at-risk patients about potential smoke exposure. For example, the BlueSky wildfire smoke model was evaluated in British Columbia, Canada, and the forecasts of PM compared favorably with measurements of PM obtained from air quality monitors and NOAA remote sensing data [23]. Moreover, this study confirmed that the forecast also predicted associated respiratory illnesses. More work is needed to improve modeling and predictions of smoke from both wildfires and prescribed fires.

Currently, significant efforts are being made to reduce the health impacts of wildland fire smoke. On a national scale, the US Forest Service Interagency Wildland Fire Air Quality Response Program provides on-site Air Resource Advisors at large wildfires to communicate smoke plume information to firefighters, air quality regulators, public health officials, and the public. In North Carolina, certified federal or state professionals plan prescribed fire to minimize emissions and impacts on communities, and they notify nearby residents and businesses of the planned burn. North Carolina participates in EPA's AirNow program and provides data on current wildfires, but as is generally the case, there is no statewide wildfire or prescribed fire smoke notification system.

To develop a wildland fire smoke notification system, the US Forest Service, state foresters, other fire managers, and air quality agencies will need to provide wildfire smoke forecasts to the public health system. City and county public health agencies would then contact those at highest risk or work with health care systems, who could utilize their electronic health record system to notify those individuals at higher risk from exposure to wildland fire smoke.

Notification of the health care network would then initiate communication between the health care system or provider and the individual at risk, reminding them of the actions they can consider taking to limit exposure to smoke. These actions would reduce the personal burden of exposure and the burden on health care utilization and cost.

## Concluding Comments

As North Carolina's population and the wildland-urban-interface continue to grow contemporaneously with climate conditions favoring wildfire, air quality will periodically be impacted by both wildfire and the prescribed fire necessary to manage accumulating biomass. Health care professionals have an opportunity to educate themselves and their patients using readily available materials about the health impacts of wildfire fire smoke and ways to reduce exposure. By increasing awareness of this issue with their patients and the public at large, health care professionals can reduce the risk wildland fire poses to public health. Importantly, greater coordination and cooperation among forest managers and the public health and health care systems offers a greater opportunity to protect those most at risk from wildland fire smoke emissions, and this cooperation could help maintain prescribed fire as a viable landscape management practice to prevent catastrophic wildfire. Such a partnership is anticipated to have a positive impact on the health of communities impacted by smoke and make prescribed fire safer, contributing to the effective management of forestlands and the preservation of ecosystems. NCMJ

**Gail Robarge, MS** environmental scientist, Center for Public Health and Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.
**Stacey Katz, MPH** environmental scientist, Center for Public Health and Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.
**Wayne E. Cascio, MD, FACC** director, Center for Public Health and Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

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