



## Where There's Wildfire, There's Smoke

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With the undeniable march of climate change, the danger of catastrophic wildfires is increasing around the globe, with such fires occurring in Australia, Canada,

Chile, Indonesia, Portugal, and Russia, as well as the United States, over the past decade. Large forest fires in the western United States have been nearly five times as frequent on an annual basis as they were 50 years ago. These fires are burning more land area and lasting much longer. The wildfire season has also become much longer, as exemplified by the Thomas fire near Santa Barbara, which became California's largest wildfire in modern history on December 22, 2017; the wildfire season in California typically ends in October, when autumn rains begin.

When catastrophic wildfires either come near or hit populated urban areas, as has recently occurred in both northern and southern California, large num-

bers of people are exposed to relatively high levels of smoke (see images). Wildfire smoke contains carbon dioxide, water vapor, carbon monoxide, particulate matter, complex hydrocarbons, nitrogen oxides, trace minerals, and several thousand other compounds. The actual composition of smoke depends on the fuel type (e.g., deciduous vs. coniferous trees), the temperature of the fire, and the wind conditions. Wood smoke contains many of the same toxic and carcinogenic substances as cigarette smoke, including benzene, benzo[a]pyrene, and dibenz[a,h]anthracene.

Particulate matter (PM) — typically a mixture of solid particles and liquid droplets — is the principal pollutant of health concern from wildfire smoke for the

relatively short-term exposures (hours to weeks) typically experienced by the public. Most PM in wood smoke is very small (0.4 to 0.7  $\mu\text{m}$ ), and particles of this size can be inhaled into the alveoli. The 24-hour air-quality standard set by the U.S. Environmental Protection Agency (EPA) for fine particles (PM<sub>2.5</sub>, particles smaller than 2.5  $\mu\text{m}$  in mass median aerodynamic diameter) is 35  $\mu\text{g}$  per cubic meter. For comparison, during the Sonoma-Napa wildfires in October 2017, the air quality in terms of PM<sub>2.5</sub> was the worst that has ever been recorded in the San Francisco Bay area, with 24-hour concentrations exceeding 200  $\mu\text{g}$  per cubic meter in Napa and 70  $\mu\text{g}$  per cubic meter in Oakland on October 13.<sup>1</sup>

Fine particles are regulated by the EPA because there is robust epidemiologic evidence of associations between short-term exposures to PM<sub>2.5</sub> and cardiopulmonary mortality, as well as increased risk of acute respiratory and car-



Views of the California Coast on October 8 (left) and October 9 (right, showing plumes of smoke), 2017.

Satellite images from the National Oceanic and Atmospheric Administration.

diovascular outcomes, including exacerbations of asthma and chronic obstructive pulmonary disease, acute lower respiratory tract infections, myocardial infarction, stroke, and arrhythmias.<sup>2</sup> In addition, adverse neurologic and metabolic outcomes have also been associated with chronic exposure to  $PM_{2.5}$ . There is some controversy about whether wood-smoke  $PM_{2.5}$  is as toxic as that generated by combustion of fossil fuels in motor vehicle engines and power plants. Recent reviews of the literature on community health effects from wildfire smoke found strong support for an association with respiratory morbidity, with less clear evidence of a link to cardiovascular outcomes.<sup>3,4</sup> Mental health can also be affected.<sup>4</sup> The groups most susceptible to the adverse health effects of  $PM_{2.5}$  are the very young and people with preexisting cardiovascular or respiratory disease, but older children and adults are also at risk.

Another pollutant of concern during smoke events is carbon monoxide. Carbon monoxide levels are highest during the smoldering stages of a fire. With

wildfires, the greatest danger from exposure to carbon monoxide is to wildland firefighters, because it is impractical for them to wear the self-contained breathing apparatus gear that structural firefighters wear. Community exposures to carbon monoxide can occur with rapidly spreading wildfires, such as when the recent Tubbs fire burned the Coffey Park neighborhood in Santa Rosa, California; a woman died in her husband's arms in a swimming pool where the couple had sheltered from the fire, presumably from carbon monoxide intoxication.

Other toxic pollutants, such as acrolein, benzene, and formaldehyde, are present in wildfire smoke, and though they occur in much lower concentrations than  $PM_{2.5}$  and carbon monoxide, their presence is still a concern. When many homes, other buildings, and motor vehicles burn, as they did during the fall 2017 fires in northern and southern California, fire emissions include more metal oxides and combustion products of synthetic materials. By the time the plume of a large wildfire has traveled many miles, however, most of the smoke particles are

from wood because that is the primary fuel source.

How should physicians advise their patients and the public when they're facing poor air quality due to wildfire smoke? Patients who are at greatest risk for symptoms due to smoke inhalation — those with preexisting respiratory or cardiovascular disease — should be advised to stay indoors and, if they have to go outdoors, to avoid prolonged activity. Healthy young children and older adults should follow the same advice. Because even healthy adults can have symptoms such as eye, nose, and throat irritation, the public should take some basic precautions to reduce exposure to wildfire smoke, including minimizing or stopping outdoor activities, especially those involving vigorous exercise; staying indoors with windows and doors closed as much as possible; not running ventilation devices that bring smoky outdoor air inside (e.g., evaporative coolers, whole-house fans, fresh-air ventilation systems, and some air-conditioning systems); changing ventilation-system filters to a high-efficiency particulate air (HEPA) grade; using the “recirculate” or “recycle” setting on the ventilation-system control; and avoiding smoking, frying food, or other activities that will create indoor air pollution.

Patients with respiratory or cardiovascular disease in whom wheezing, chest tightness, excessive coughing, shortness of breath, chest pain, palpitations, or other acute symptoms develop should consider evacuating to an area with better air quality. If evacuation is not possible, wearing an N95 or N100 particulate respirator provides some protection. These designations mean that the masks have been certified by the

National Institute for Occupational Safety and Health to filter out at least 95% or 100%, respectively, of very small (0.3  $\mu\text{m}$ ) test particles. The N95 mask should be familiar to U.S. hospital-based health care providers because the Occupational Safety and Health Administration requires that they be worn in rooms where patients have been isolated to prevent transmission of tuberculosis. N95 and N100 masks provide protection from inhalation of fine particles but not hazardous gases (such as carbon monoxide, formaldehyde, and acrolein). These types of masks can be found at many hardware stores, home-repair stores, and pharmacies. Care should be taken to ensure that the adjustable mask fits over the nose and mouth properly, so as to minimize leakage.

The practice of public health involves analysis of threats to a population's health followed by recommendations for efforts that communities can make to address the threats. Catastrophic wildfires are indeed an increasingly important threat to public health. In addition to global warming and

drought, a risk factor for large wildfires in the western United States is a legacy of fire suppression that has allowed overgrowth of underbrush and small trees in forests where periodic lightning-sparked wildfires are part of the natural ecosystem. Worldwide, as populations grow, housing development has created greater urban-wildland interface, straining fire-suppression resources.

In the United States, most of the Forest Service wildfire budget goes to suppression activities, leaving precious little for necessary forest-maintenance activities. At-risk communities can do more to prepare for wildfires, from basic actions such as bulldozing fuel breaks around neighborhoods, to installing new smoke-detection cameras, to improving escape routes in subdivisions. As California Governor Jerry Brown recently stated, "We're facing a new reality where fires threaten peoples' lives, their properties, their neighborhoods and cost billions and billions of dollars. We have to have the resources to combat the fires, and also have to invest in managing our vegetation and forests and all the ways we dwell in this very wonderful

place — but a place that's getting hotter."<sup>5</sup>

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 An audio interview with Dr. Balmes is available at NEJM.org

## Physician-Assisted Death for Psychiatric Patients — Misguided Public Policy

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Should physician-assisted death be available to people with psychiatric disorders? Although it was once unthinkable, physicians, primarily in the Netherlands and Belgium, have helped a small but growing number of patients with mental illness but

no terminal condition to end their lives. Such assistance is also under consideration in Canada, where physician-assisted death was recently legalized after Canada's Supreme Court held that the law prohibiting assisted suicide violated Canadians' constitu-

tional rights. Subsequent legislation passed by the Canadian parliament limited medical assistance in dying to competent adults who have a "grievous and irremediable medical condition" and whose "natural death has become reasonably foreseeable."<sup>1</sup>