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Wildfire Smoke and Public Health: Science and Technology Development to Reduce Risk

Editor's Note: The National Environmental Health Association (NEHA) strives to provide up-to-date and relevant information on environmental health and to build partnerships in the profession. In pursuit of these goals, NEHA has partnered with the Office of Research and Development (ORD) within the U.S. Environmental Protection Agency (U.S. EPA) to publish two columns a year in the *Journal*. ORD is the scientific research arm of U.S. EPA. ORD conducts the research for U.S. EPA that provides the foundation for credible decision making to safeguard human health and ecosystems from environmental pollutants.

In these columns, authors from ORD will share insights and information about the research being conducted on pressing environmental health issues. The conclusions in these columns are those of the author(s) and do not necessarily represent the official position of U.S. EPA.

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Startling images of smoke-filled skies have pervaded the news and social media in recent years during major wildfires in the U.S. (Photo 1). In 2020, over 10 million acres burned from nearly 59,000 wildland fires, including wildfires and prescribed fires (National Interagency Fire Center, 2021). As wildfires burn, they generate smoke that contains substantial amounts of air pollutants (e.g., fine particulate matter [$PM_{2.5}$], carbon monoxide) that threaten the health of people nearby and sometimes at distances far from fire areas (Cascio, 2018; Jaffe et al., 2020; Reid et al., 2016). The continued growth of the wildland–urban interface amplifies risk of smoke exposure as more people relocate to fire prone areas; between 1990 and 2010, the wildland–urban interface area grew by 41% in terms of the number of new homes (Radeloff et al., 2018).

Wildfire prevalence and intensity are expected to worsen as climate change continues, with one report estimating that the Southwestern U.S. area burned by wildfire from 1984–2015 was twice what would have burned had climate change not occurred (Abatzoglou & Williams, 2016). The U.S. Environmental Protection Agency (U.S. EPA) Office of Research and Development (ORD)—in partnership with other federal agencies; states; localities; tribes; and state, local, and tribal organizations—conducts research and provides technical solutions to characterize wildfire smoke emissions and evaluate strategies to reduce health and environmental risks.

Monitoring Wildfire Smoke

To better understand how the combination of burned materials (including biomass and materials from burning structures and vehicles), fire intensity, and meteorology alter the amount and chemical composition of smoke, ORD has analyzed emissions from prescribed fire and wildfire emissions. Prescribed fire is an important land management activity that can be strategically conducted in periods that favor smoke dispersion and controlled burning rates to reduce exposures and public health risks. ORD collaborated with the U.S. Forest Service (USFS) Missoula Fire Sciences Laboratory in Missoula, Montana, to simulate burns and comprehensively measure smoke properties. ORD also collaborated with the U.S. Department of Defense, USFS, and other land managers to conduct in situ emission measurements in real-world prescribed burns, including deploying a custom developed aerial sampling platform to directly measure smoke plumes (Aurell et al., 2021). Results from this research can help local environmental health practitioners better understand the public health impacts associated with wildland fire smoke and evaluate their local conditions to predict the risk for specific harmful emissions.

Wildfire smoke production and ground-level air pollution concentrations can vary substantially as fire behavior and meteorology shift with time, complicating air quality assessment and public communications of risk during wildfire events. Through partnerships with other federal agencies, ORD has advanced strategies for wildfire smoke detection and risk communications (Table 1), including:

- Establishing a quality check and correction method for a widely used $PM_{2.5}$ air sensor (Barkjohn et al., 2021), which can help

Photo 1. *Wildland fire smoke from the Monument and McFarland Fires in California in August 2021. Photo courtesy of Ali Kamal, U.S. Environmental Protection Agency, Office of Air and Radiation.*

TABLE **1**

U.S. Environmental Protection Agency (U.S. EPA) Tools and Resources for Environmental Health Practitioners to Address Wildfire Smoke Challenges

Tool/Resource	Description
AirNow Fire and Smoke Map (AirNow, 2022)	View information on ground-level air quality monitors recording fine particulate matter ($PM_{2.5}$) from smoke and other sources, as well as information on fires, smoke plume locations, and special statements about smoke issued by various sources. This map is designed to allow users to browse current conditions and show information relevant to specific locations.
Wildfire Smoke Air Monitoring Response Technology pilot (U.S. EPA, 2021a)	Air monitoring technologies available for loan to state, local, and tribal air organizations to support supplemental air monitoring in areas affected by wildfire smoke and with observational data coverage gaps. (*Note.* The equipment is not available for general public use.)
Smoke Sense app (U.S. EPA, 2021b)	Crowdsourcing, citizen science research mobile app focused on increasing public awareness and engagement related to wildfire smoke health risks. This application is available on Apple and Android devices, and in English and Spanish.
Smoke-Ready Toolbox (U.S. EPA, 2022b)	Assortment of tools and resources for public health officials and healthcare practitioners to understand and communicate risks of smoke exposure and provide actions people can take to protect their health (Figure 1).
Wildfire Smoke and Your Patients' Health (U.S. EPA, 2021f)	Online course for physicians, nurse practitioners, nurses, asthma educators, health educators, and other medical professionals about the health effects associated with wildfire smoke and actions patients can take before and during a wildfire to reduce exposure.

ensure communities using this air sensor have a higher confidence in the data. This research supported the inclusion of this sensor's public data into U.S. EPA's AirNow Fire and Smoke Map (AirNow. 2022), vastly increasing the number of air quality observations available to inform public communications of wildfire smoke risks.

- Accelerating the development of commercially available air sensor technology suitable for wildfire smoke response. This development was achieved through a cosponsored Wildland Fire Sensors Challenge, along with five other federal agencies, with rigorous laboratory evaluation of prototypes (Landis et al., 2021) and U.S. EPA's Small Business Innovation Research Program (U.S. Environmental Protection Agency [U.S. EPA, 2022a).
- Launching the Wildfire Smoke Air Monitoring Response Technology (WSMART) pilot to increase use of new air monitoring technologies in wildfire response settings, particularly as air monitoring data might be limited in many areas affected by wildfire smoke (U.S. EPA, 2021a; The White House, 2021). The WSMART program loans quickly deployable air monitoring technologies to state, local, and tribal air organizations, as well as to air resource advisors through the Interagency Wildland Fire Air Quality Response Program. These supplemental monitoring technologies can help local governments gather timely data to assess smoke impacts and provide public health information. WSMART deployed air monitoring technologies to emergency responders at seven major wildfires in 2021.

Wildfire Smoke Risk Reduction Research

To support public health communication and health research, ORD engages the public through a crowdsourcing, citizen science research project to learn about public perception of risk and personal behavior changes during wildfire events. In 2017, ORD launched the Smoke Sense app that provides smoke data visualizations, game-based education about air quality, and allows subclinical symptom reporting for research analysis (U.S. EPA, 2021b; Table 1). Smoke Sense can be a powerful way for local environmental health practitioners to provide timely information about smoke events to communities.

Through analysis of Smoke Sense data, effective strategies for delivering health messages about smoke have been found, including:

- The need to increase health risk awareness and provide compelling evidence that protective health behaviors are beneficial, including personally relevant data that allow individuals to recognize their own personal health risk (Rappold et al., 2019).

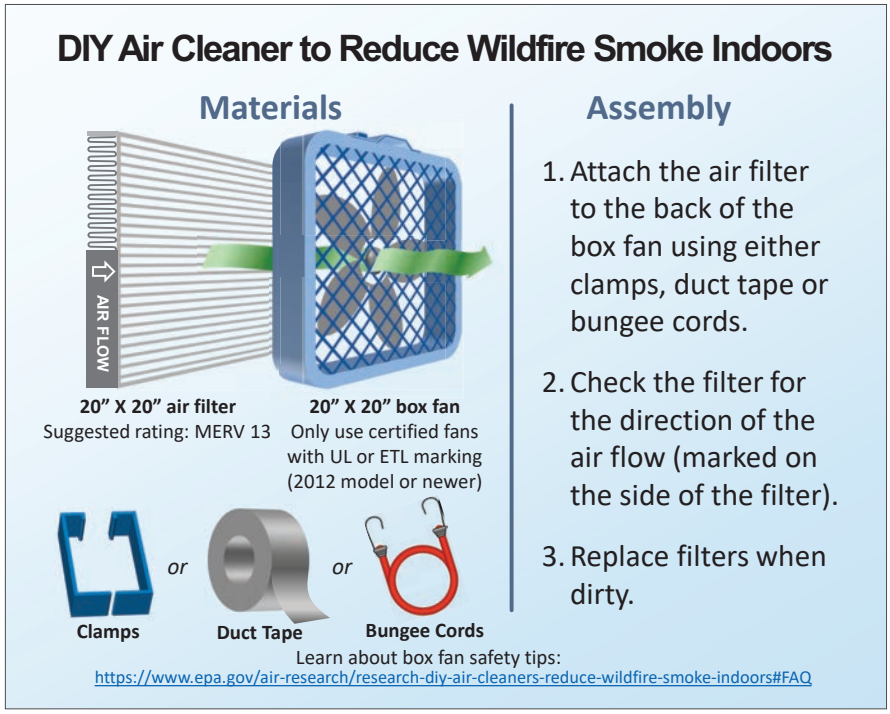
- The need to tailor health risk messaging to suit common individual traits related to perception of health risk and willingness to adopt recommended health behaviors. These traits include "protectors" (individuals who have decided to engage by adopting new health behaviors); "cautious, proactive, and susceptible" (individuals at various deciding stages); and "unengaged" (individuals who do not perceive smoke as a health issue and are unlikely to change behavior in response to messaging) (Hano et al., 2020).

Strategies that smoke-ready communities can use to reduce exposure to smoke particles during wildfire episodes have also been studied, including:

- Optimal use of face masks, including face mask type and how it is worn, to reduce exposure to airborne particles. Results from this research are relevant to airborne COVID-19 and particles of similar size in wildfire smoke (Clapp et al., 2021).
- Using HVAC filtration and portable air purifiers to reduce indoor air exposure to smoke (U.S. EPA, 2021c).
- Accelerating the availability of affordable and effective indoor air cleaning technologies through prize-based challenge competitions, such as the 2021 Cleaner Indoor Air During Wildfire Challenge (U.S. EPA, 2021d).

FIGURE **1**

DIY Air Cleaner Infographic for Reducing Wildfire Smoke Indoors



Note. Infographic is part of the Smoke-Ready Toolbox for wildfires from the U.S. Environmental Protection Agency (2021g, 2022b). DIY = do it yourself.

The Future of Wildfire Research

As the wildland–urban interface continues to expand into fire prone areas, future wildfires will likely result in the burning of more built structures, such as the recent Marshall Fire in Colorado, which increases the complexity of the wildfire smoke mixture. Looking to the future, public health practitioners will benefit from a better understanding of how smoke emissions and corresponding health risks from these types of fires vary compared to fires that are purely biomass based.

Another important unknown is the health consequences of repeated short- and long-term smoke exposure, which is becoming more common as wildfire severity and frequency increase in some areas of the U.S. As the need for prescribed fires increases, more research on prescribed fire smoke emissions (considering meteorology, biomass fuels, and burning rates) and development of risk management and communication strategies will also be needed. Toward this end, ORD recently assessed two case study fires in the Western U.S. to compare prescribed fire and wildfire emissions and public health impacts (U.S. EPA, 2021e). U.S. EPA research will continue to develop insights, methods, and tools to support environmental health practitioners as they serve their communities and adapt to a more fire prone environment.

Acknowledgements: The authors would like to acknowledge Gayle Hagler, Megan Christian, Emily Smith, and Kelly Widener for identifying supporting material and providing editorial review; Brian Gullett, Tom Long, Ana Rappold, Beth Hassett-Sipple, Jason Sacks, Amara Holder, and Matt Landis for providing scientific review; and Bruce Rodan, Bryan Hubbell, and Kacee Deener for their suggestions in framing the column.

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