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# Wildland Fire Science

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# About this Issue: Wildland Fire Science

Air quality in the United States has improved significantly over the past several decades. High air pollution days are decreasing and many more Americans are enjoying the health benefits from cleaner air.

While skies are clearer and pollution levels have dropped in many parts of the country, larger and more intense wildfires are a growing threat to air and water quality, public health and ecosystems.

EPA is applying its extensive expertise in air quality science to study wildfires and prescribed burns, referred to as wildland fires. This issue of *Science Matters* newsletter highlights research projects by EPA and partners to assess human health and ecological impacts of wildland fires; improve tools and technologies to quantify and predict wildland fire impacts; and provide information to minimize adverse public and environmental impacts and risks.

The results are leading to new air monitoring capabilities, improved emissions inventories, better modeling to forecast poor air quality days during wildland fires, and new ways to identify those at greatest risk from smoke exposure and effectively communicate the risks.

To learn more, visit:

**epa.gov/air-research/wildland-fire-research-protect-health-and-environment**

# Studies Advance Air Monitoring and Improve Forecasting of Smoke

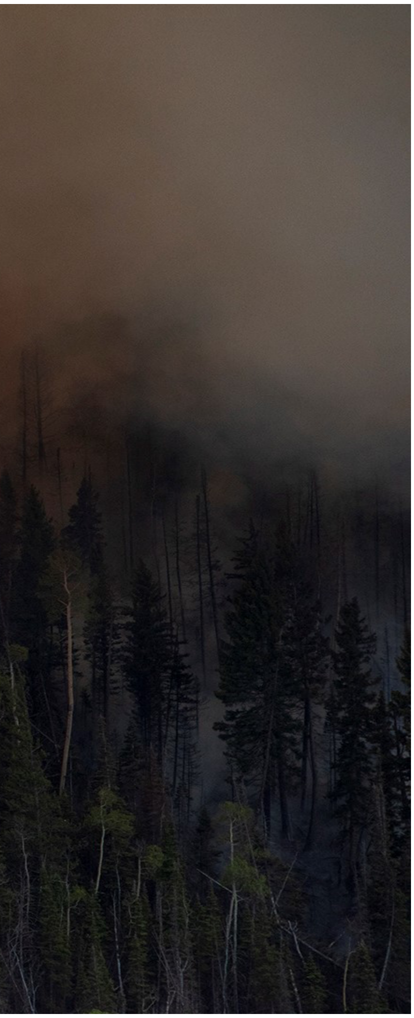
EPA is conducting field studies to advance understanding of emissions from wildfires. The goals are to elucidate the performance of air monitoring instruments during smoke events; better understand the chemical aging of smoke; and evaluate models used to forecast where smoke from wildland fires will travel.

The Mobile Ambient Smoke Investigation Capability (MASIC) study, launched May 2019, is collecting air measurements from both EPA designated reference and non-regulatory instruments, to determine their performance capabilities during impacts from wildfires. Researchers used two mobile laboratories to measure emissions near the MP-97 (Oregon) and Williams Flats (Washington) wildfires. One mobile laboratory was equipped with primarily state of-the-art research grade instruments and regulatory air quality monitors and the other with portable non-regulatory instruments.

In addition, three comprehensive fixed sites have been set up in wildfire-prone areas in Reno, Nevada, Boise, Idaho, and Missoula, Montana. Researchers are collecting air monitoring data and comparing the performance of regulatory and portable non-regulatory instruments at these sites and mobile laboratories during wildfire smoke events.

"These studies will help us to interpret data from regulatory monitoring and supplemental networks during wildfires and also provide information on the efficacy of using rapidly deployable devices for fire incident response," explains EPA researcher Matt Landis. The research will continue for three additional fire seasons in 2020-2022.

The MASIC study is also contributing to FIREX-AQ, a large interagency field study in the Northwest and Southeast, led by NASA and National Oceanic and Atmospheric Administration (NOAA). Using satellites, aircraft, and ground monitoring, researchers are studying how fuel, fire, and meteorological



conditions affect the physical and chemical characteristics, plume height development, and downwind dispersion of smoke. These factors determine the local, regional, and national impacts smoke has on ambient air quality as it undergoes photochemical chemical transformation and aging. The results of FIREX-AQ will be applied to remote sensing monitoring by satellites and models to improve predictions of the impact of smoke from wildfires and prescribed burns on ambient air quality.

## Studying Emissions and Fire Behavior

In Fishlake National Forest in Utah, EPA participated in a week-long air sampling activity during a controlled forest burn by the U.S. Forest Service in summer 2019. Over 40 scientists from the Desert Research Institute (DRI), University of Idaho, and other agencies and universities participated in the comprehensive study called the Fire and Smoke Model Evaluation Experiment (FASMEE).

The Kolibri air sensor, a lightweight sampler developed by EPA researchers, sampled chemical, particle, and biological pollutants as it was carried through the smoke in an unmanned aircraft system owned by DRI.

The prescribed burn provided wildfire-like conditions, with heavy surface fuel loads and high burn intensity, giving researchers a unique opportunity to study fire behavior, fuel consumption, smoke dispersion, and emissions. The prescribed burn will reestablish aspen stands, allowing for regrowth in what has become a mixed conifer forest.

"The Fishlake study offered us a unique opportunity to characterize near-source emissions under wildfire-like conditions," says Brian Gullett, EPA lead investigator. "The ultimate goal is to link emissions with the fuel properties, ignition methods, and meteorological conditions to enable better prediction of smoke production during wildland fires."

# Wildfires: How Do They Affect Our Water Supplies?

EPA has been exploring the impacts of both short-term and long-term exposure to wildfire smoke on human health. More recently, EPA researchers have begun to look at a less understood area of research—the impact of these fires on our water supply, the natural resource we depend on for drinking, irrigation, fishing and recreation.

> ***"How do wildfires change the amount of water and sediment flowing into a stream?"***

Just as wildfires impact air quality, they can also affect the quantity and quality of water available. Water supplies can be adversely affected during the active burning of a wildfire and for years afterwards.

During active burning, ash and associated contaminants settle on streams, lakes and water reservoirs. Vegetation that holds soil in place and retains water is burned away. In the aftermath of a large wildfire, rainstorms flush vast quantities of ash, sediment, nutrients and contaminants into streams, rivers, and downstream reservoirs. The absence of vegetation in the watershed can create conditions conducive to erosion and even flooding, and naturally occurring and anthropogenic substances can impact drinking water quality, discolor recreational waters, and may potentially contribute to harmful algal blooms.

Due to the unpredictable nature of wildfires, drinking-water utilities face a considerable challenge to develop plans and strategies for managing floods and treating polluted water. Information and tools are needed to help water storage and treatment managers better prepare for wildfire impacts.

Research conducted by Mussie Beyene, an EPA postdoctoral researcher working with EPA ecologist Scott Leibowitz, has examined pre- and post-wildfire data on streams in the western United States to understand how wildfires change the daily flow of sediment and water in streams. One of the reasons he focused on the western states is because 65% of fresh water supply in the region originates from forested watersheds, which, depending on conditions, can be highly susceptible to forest fires.

"How do wildfires change the amount of water and sediment flowing into a stream?" asks Beyene. "If you are a municipal water supply manager, you are most concerned with changes in the magnitude, frequency and timing of extreme water discharge and sediment—what are the highest and lowest amounts of water and sediment that flow into a stream after a wildfire—because your water treatment plants and your water storage systems may not be built to accommodate them."

Beyene found that there is a possible increase in stream water discharge following a wildfire. For streams in the northwest, this can be followed by fewer episodes of very low water levels. In contrast, for streams in the southwest, the increase in discharge is followed by more episodes of very high water levels. Additionally, the timing of peak flood events shifted towards late winter-early spring for regions that receive the majority of their waters from winter snowpack. In terms of water quality, Beyene also found a significant increase in the amount of suspended sediments in streams after a wildfire event.

Beyene's research is just one aspect of EPA's larger investigation into the impact of wildfires on water resources. Researchers are working to determine whether pollutants, like mercury and lead left over from the 20th century mining boom and other old industries, more easily find their way into water after wildfires. They are also exploring ways to protect water quality from wildfires through watershed management. Information generated from these studies will be used to protect the quality of our water supplies and the essential benefits they provide.

# What Can Firefighters' Breath Reveal About Chemical Exposure During a Fire?

When firefighters enter a burning building, they have more than hot flames to fight. There's also the smoke to contend with, which often contains combustion byproducts and contaminants that are harmful to human health.

During a structure fire, firefighters' respiratory tracts are protected with a self-contained breathing apparatus, while skin is shielded by specially designed clothing. But even using this protective equipment, firefighters still have a higher cancer rate than the general population, which studies have linked in part to their increased exposure to the dangerous compounds in smoke. [1, 2]

Recent research led by the National Institute for Occupational Safety and Health (NIOSH) examined firefighters' exposure to volatile organic compounds (VOCs) during structure fires by analyzing their exhaled breath before and after controlled burns. EPA scientists offered technical support, developing a method to analyze breath samples, studying the data, and authoring several reports on their findings — all in hopes of better understanding firefighters' chemical exposure.

"Breath is a relatively non-invasive biological medium compared to blood or urine, and participants have been shown to be more willing to provide these samples," M. Ariel Wallace, an EPA scientist says. She explained that exhaled breath monitoring is also a comparatively simple method, since it doesn't involve the extra post-processing steps that liquid samples require.

To assess the firefighters' exposure to VOCs, scientists collaborated with NIOSH to study 12 controlled structure burns with realistic firefighting responses at the University of Illinois Fire Service Institute. The burns were conducted in a wood framed residential structure with identical home furnishings as fuel. Each burn was assigned 12 firefighters in typical fireground positions – like attack (fire suppression) or search and rescue – to fight the fire.

Researchers collected exhaled breath samples from the firefighters before and after each burn exercise, then organized the data according to their positions in the field. They also visualized the data of individual firefighters to see which individuals conformed to group trends of increased or decreased exposure. The data offered some interesting insights.

At the group level, scientists saw statistically significant increases in post-exposure benzene concentrations in the fire attack, victim search, and outside ventilation firefighting positions.

"What surprised us about the results of this study was that some compounds showed statistically significant decreased concentrations in post-exposure samples, when we expected that all post-exposure VOC concentrations would be elevated," Wallace says. "We found that not all firefighters displayed the characteristic response of increased post-exposure VOC concentrations."

Wallace noted that this may be due to many factors, including differences in individual firefighting positions, how well the individual adhered to safety precautions, or how well their protective equipment fit and functioned during the fire. How close each firefighter was to the active fire, and other environmental exposures before and after the fire – including any off-gassing of VOCs from protective gear – may have also contributed to differences in individuals' breath data.

This research illustrates the importance of looking not only at data trends for the group, but the individual as well, since certain people may be more or less susceptible to chemical exposure than others.

By understanding which firefighting positions and individual firefighters are prone to higher VOC exposure, firefighting teams can take action to protect their health. Researchers say this information could be used to rotate firefighters through different positions during live fire responses, and to decrease future exposures of individual firefighters by making adjustments and improvements to the use of their personal protective gear.

Although this research focused on firefighting activity, scientists suggest the concept could also be applied in other exposure scenarios, like a forest fire, to study human health and ecological effects.

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2. Crawford, J.O., T. Winski, D. McElvenny, R. Graveling, and K. Dixon: Firefighters and cancer: The epidemiological evidence. *Instit. Occup. Med.* TM/17/01(2017).


# Smoke Sense App Lets you Participate in Science

EPA's Smoke Sense app is a research project to evaluate the health effects from wildland fires and to develop health risk communication strategies for the public during smoke days. The app is available on Android and iOS devices in English and Spanish. User identities are anonymous and non-identifiable.

The app can be used to get information about air quality and fire and smoke events and allows the user to anonymously log health symptoms and smoke observations weekly. Badges can be earned for each week a user participates.

The app has been available since 2017 with the start of the Smoke Sense project and grown to more than 25,000 users.

As an educational tool and informational resource, the goal of the project is to change behaviors that will lead people to become more prepared to protect their health from smoke.

Learn more and get the app at:

**epa.gov/air-research/smoke-sense**

# Advancing Technology to Study the Toxicity of Smoke

Smoke from wildfires can travel upward into the atmosphere and has the potential to cause acute and chronic health impacts, especially in small children, the elderly, and people with preexisting respiratory conditions. Researchers want to know how hazardous these exposures can be to human health for people in the path of smoke plumes, firefighters, and communities further downwind of wildfires.

In a laboratory in Research Triangle Park, NC, researchers built a tube furnace system to precisely generate different types of smoke to assess how fuel composition and combustion conditions affect the chemistry and subsequent toxicity of biomass smoke. Using this system, they reported that smoke samples injected into mouse lungs caused varying degrees of lung toxicity depending on the type of fuel, or if the fire was under flaming or smoldering conditions.

The researchers then went back to the design board and modified the system for use in animal inhalation studies so that the direct effects of smoke on lung function could be measured. The newer 2019 study published by EPA researcher Yong Ho Kim and colleagues[1] confirmed a similar profile of effect and concluded that some biomass fuels emit more polycyclic aromatic hydrocarbons, which are known carcinogens, and heavy metals than others. These toxic emissions also increase when the fire is hotter. Another paper extended the work by demonstrating that filtering the smoke particles partially reversed the effects suggesting that people can be protected to some degree by air filters that remove smoke particles[2].

"All smoke is not created equally," says lead EPA researcher Ian Gilmour. "Our findings on the differential toxicity of biomass smoke emissions will contribute to more-accurate hazard assessment of biomass smoke exposures in firefighters as well as people living in communities near or downwind of wildfires."

"Importantly, our research suggests that we should also measure the efficacy of control technologies like filters and air purifiers to see what steps can protect people from these exposures," he adds.

> ***"All smoke is not created equally."***

This study only assessed toxicity of fresh smoke from burning of wood. However, smoke can also be transported into populated urban areas that are hundreds of miles away from the fires. While this smoke moves through the atmosphere it can age, transform into other substances and interact with other pollutants. Studies have found that many people are more likely to be exposed to wildfire smoke that is aged in the atmosphere rather than fresh wildfire smoke[3,4]. Future research will assess the impact that aging of smoke in the atmosphere has on toxicity and health impacts.

Finally, since wildfires can reach the wildland-urban interface and burn homes, automobiles and their contents, the researchers are also exploring how inclusion of these materials alters the potential toxicity of wildfire smoke.

**References:**

1. Kim, Y. H., King, C., Krantz, T., Hargrove, M. M., George, I. J., McGee, J., ... & Gavett, S. H. (2019). The role of fuel type and combustion phase on the toxicity of biomass smoke following inhalation exposure in mice. *Archives of Toxicology*, 1-13.

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3. Seltenrich N. (2018). Flavors of Fire: Assessing the relative toxicity of smoke from different types of wildfires. E*nvironmental Health Perspectives,* 126 (4): 044003.

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# Understanding Indoor Air Quality During Wildfires

When communities are blanketed by wildfire smoke for days and weeks, residents want to know what steps they can take to reduce their exposure outdoors and indoors. Building owners are interested in effective actions to protect their occupants. That is what happened in Missoula, Montana, during the summer of 2017 when the community and surrounding areas experienced significant smoke impacts from nearby forest fires.

The Missoula City-County Health Department (MCCHD) was inundated with inquiries about the risks of smoke, actions to take and how to create clean air spaces indoors. Following the smoke episodes, the health department is interested in learning more about effective risk reduction strategies they can share with building owners and the public. As a result, the health department and other partners have teamed up with EPA researchers to conduct an indoor and outdoor air measurement study.

EPA researchers and partners have placed over 30 low-cost air sensors that measure fine particulate matter ($PM_{2.5}$) -- the main component of smoke that is of great health concern -- inside 18 buildings and outdoors at 16 locations throughout Missoula in summer 2019. The buildings are public or commercial buildings that range in air management methods from window-only ventilation to central air filtration and represent locations the public may visit during a summer smoke episode. Buildings include fitness centers, museums, churches, office buildings, a senior citizen center, and universities. The health department is collecting and sending the recorded data from the sensors to researchers for analysis.

*"We expect the results will help us provide our community with practical advice about creating cleaner air spaces during wildfire smoke events."*

The goal of the field study is to learn more about how air cleaning and ventilation practices impact indoor air quality during wildfire events. A complementary laboratory study in Research Triangle Park, North Carolina, will evaluate the effectiveness of portable air cleaners and air filtration systems in removing $PM_{2.5}$ under simulated pollutant concentrations typically found during wildfires.

When the lab study begins, researchers will test five portable air cleaners, ranging from a do-it-yourself (DIY) cleaner composed of a box fan with attached HVAC filter to commercial HEPA air purifiers. The cleaners will be evaluated for their effectiveness at removing $PM_{2.5}$ and other toxic pollutants, as well

*Amara Holder with air cleaner in a laboratory testing chamber.*

as their ease of use and cost to operate. Wood, tree litter, and duff collected from the forests surrounding Missoula will be burned to create the smoky conditions needed to evaluate the air cleaners. These real-world fuels will enable researchers to create emissions in the laboratory, similar to wildfires in the area. They plan to test the air cleaners at concentrations slightly above the air quality standard and at higher concentrations that can occur during wildfires.

The research has involved local partners from the beginning to identify what information they need to effectively communicate actions that building owners and the public can take to reduce public health risk during smoke episodes. In addition to the health department, the University of Montana in Missoula is participating.

Sarah Coefield, air quality specialist with MCCHD said, "We're excited to be partnering with the EPA on this study. The data from this field study will show the variability of indoor air quality in buildings across our community and will help us understand how much outdoor air comes inside under real-world conditions. We expect the results will help us provide our community with practical advice about creating cleaner air spaces during wildfire smoke events."

After the wildfire season ends in Missoula, EPA plans to conduct a similar field study of indoor and outdoor air quality associated with wildfire smoke episodes with the Hoopa Valley Tribe in northern California.

This project is part of EPA's solutions-driven research initiative, which emphasizes working directly with stakeholders to develop solutions to environmental challenges. The research findings are expected to be applied to help communities prepare for wildfire smoke and provide answers about indoor air quality and clean air devices.

Amara Holder, one of the EPA research engineers leading the project explains, "This research approach has been gratifying, as we are designing and quickly implementing studies to address time-sensitive questions about smoke episodes and how to protect the public when community members may have limited choices other than to stay indoors. This research will be impactful because of the input and support of our local partners."

# Tracking Smoke with Models to Protect Public Health

Smoke plumes rising above a wildland fire are a visible sign of air pollution. What they emit, where they go, and how they are transported are all of interest to atmospheric modelers who are working to protect public health by using the power of computer technology.

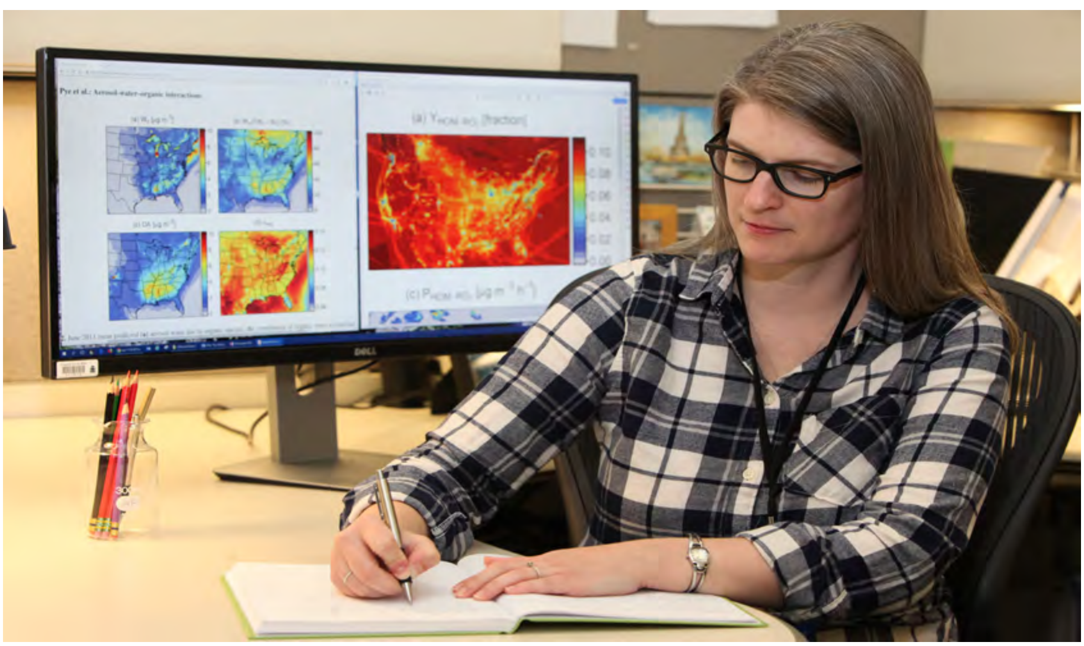
EPA's Community Multiscale Air Quality Model (CMAQ), developed to support air quality regulations, is often used to study wildland fire smoke and evaluate its impact on air quality. EPA researchers are continually improving the tool's performance and reliability to simulate the impact of fires on past, present, and future air quality and human health.

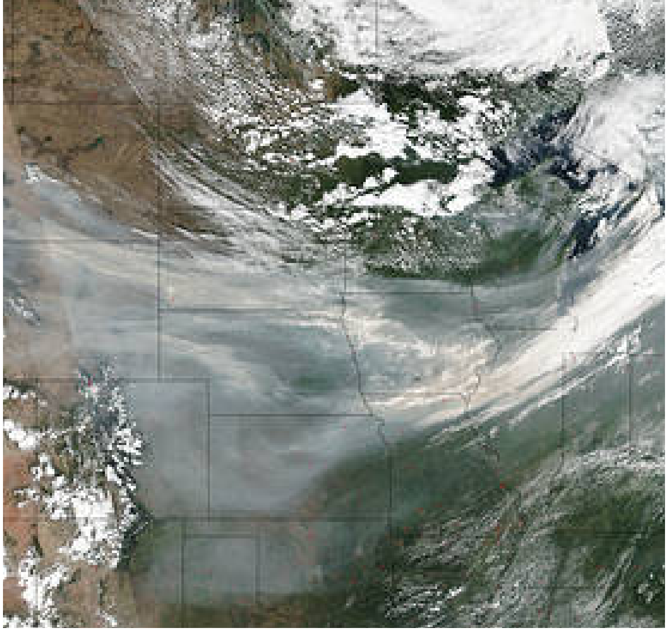
In a 2018 study by EPA[1], researchers used CMAQ to estimate the impact of wildland fires on elevated concentrations of air pollutants (e.g. fine particulate matter and ozone) in the United States from 2008-2012. The study suggests areas where CMAQ could improve its ability to model U.S. wildfires by region and fire characteristics – like an intermountain region wildfire in the West versus a prescribed fire in the Southeast – to better improve model estimation of wildfire smoke impacts on air quality.

The study found that while CMAQ excels at capturing overall time and space patterns of air pollution from wildfires nationwide, more lab and field work is needed to improve the model in areas such as characterization of "medium-size" fires under 40,000 acres, long-smoldering peat fires, and other lesser-studied fires. These types of fires exhibit different physics than larger or faster-burning fires, which could influence their effect on air quality and human health.

"Determining health impacts from models is a complex issue, and is just one example of model use," says Joseph L. Wilkins, an atmospheric modeler at EPA. He adds that some health studies have correlated CMAQ model results for pollution exposure with regional health data – like hospital visitation or mortality – to understand potential wildland fire impacts and make decisions that protect vulnerable populations.

Models like CMAQ are an integral part of protecting public health from wildland fire smoke. Air Resource Advisors use models to better predict when smoke in an area may be harmful to health. State agencies use models to account for wildland fire smoke contribution to air quality as part of their planning process to meet air quality standards for particle pollution, ozone, and regional haze.





EPA researchers are currently advancing modeling capabilities for wildland fire emissions by:

- Performing fire stage modeling to study differences in emissions from residual smoldering fires, smoldering fires, and active flaming fires
- Evaluating model perfomance in capturing surface and aloft impacts from prescribed burning events
- Advancing emissions and model approaches for controlled burn plume transport to improve regulatory modeling, forecasting systems, and smoke management programs
- Studying small and low-cost wildfire sensor technology to improve modeling
- Conducting plume rise research to improve the way CMAQ models vertical allocation of smoke
- Continuing to update CMAQ by incorporating National Emission Inventory updates, modeling platform changes and satellite detection algorithm updates

These and other advances are improving modeling tools for characterizing wildland fire emissions, transport, and air quality impacts. Ultimately, the work will be used to help protect public health from exposure to wildland fire smoke.

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## Smoke Ready Toolbox for Wildfires

epa.gov/air-research/smoke-ready-toolbox-wildfires

**Daily Air Quality Forecasts**
airnow.gov

**How Smoke From Fires Can Affect Your Health**
airnow.gov/index.cfm?action=smoke.index

**Wildfire Smoke: A Guide for Public Health Officials**
epa.gov/airnow/wildfire-smoke/wildfire-smoke-guide-revised-2019.pdf

**Wildfire Smoke Exposure Infographics**
epa.gov/air-research/how-order-infographic-card-reduce-health-risks-areas-wildfire-smoke

**Smoke Sense App**
epa.gov/air-research/smoke-sense

**Particle Pollution and Your Patients' Health Course**
epa.gov/pmcourse

**Online Healthy Heart Toolkit**
epa.gov/air-research/healthy-heart-toolkit-and-research

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