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Wildland Fire Science

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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, there is a growing threat to air and water quality, public health and ecosystems—more frequent and intense wildfires.

EPA is applying its extensive expertise in air quality science to the study of wildland fires to help states and communities that are impacted. This issue of *Science Matters* newsletter highlights some of the research projects under way by EPA and partners that are advancing the ability to assess human health and ecological impacts of wildland fires; improving tools and technologies to quantify and predict wildland fire impacts; and providing 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

Novel Air Measurement Technology Supports Smoke Management Practices

Central Kansas is home to the largest remaining tallgrass prairie in North America with five million acres in Kansas and portions of Nebraska and Oklahoma. Fires were once a natural occurrence, but now they are intentionally set during prescribed burns, primarily in the spring. The fires burn the invasive plants and rejuvenate the soil, which encourages growth of native grasses. This, in turn, benefits farmers and ranchers who graze cattle and bison on the land. However, the smoke plumes can contribute significantly to air pollution in nearby communities and farther downwind, sometimes as far as the East Coast, particularly when burning is concentrated during the short spring season.

EPA researchers are supporting best smoke management practices for prescribed burns of prairies to reduce the impact of smoke in nearby communities and those much farther away. In November 2017, the research team traveled to the rolling prairies of Flint Hills, Kan., to take air measurements during the planned fires using a novel air sampling system developed in the lab. Researchers had previously visited the area in March during peak burn season to take air samples. They will use the two data sets to see if there are any differences in smoke plume emissions from spring to fall.

"This effort used the latest advances in open fire emissions sampling technology to assist the state's agricultural and environmental interests," says Brian Gullett, lead scientist for the study.

Smoke from prescribed burning contains air pollutants, notably combustion gases and particles, that can impact health. During burns, air pollution levels can sometimes exceed federal limits. People who are most vulnerable to these pollutants, such as those with lung and heart problems, are at greater health risk. The smoke can also cause the general population to experience irritation of the eyes, nose, and throat and cause visibility problems.

The Flint Hills study is providing air emissions data needed to better predict the best times, locations, and conditions to burn. To get measurements in the smoke plume, researchers take ground measurements and use an aerial sampling system to measure levels of particle pollution, black and brown carbon, and volatile organic chemicals, as well as impacted background ozone levels. The portable box-shaped system is attached to a helium-filled balloon called an aerostat and lofted up to 500 feet into smoke plumes.

The data will provide information more specific to the Flint Hills region for prescribed grassland burning that can be used in models to better predict where smoke plumes will go and how much pollution may form downwind and impact communities. Better forecasts of smoke impacts will allow for better selection of days to do burning and better modeling tools will allow for more sophisticated understanding of regional pollution impacts from these types of burns.

"It takes broad partnerships, from ranchers and researchers to downwind-communities and regulators, to understand the benefits and challenges associated with the complex practice of the management of five million acres of tallgrass prairie in our nation's heartland," says Josh Tapp, Deputy Director for the Environmental Sciences and Technology Division in EPA's Region 7 Office in Kansas City.

"It is through these Flint Hills partnerships that common-sense practices can be refined and implemented to ensure the protection of public health while promoting sustainable agriculture and protecting an endangered ecosystem," he adds.

Advancing Sensor Technology to Monitor Wildfires

Sometimes the smallest things can make the biggest difference, even when it comes to measuring air quality. Miniature sensors that can monitor air quality near wildfires are being tapped to protect public health from smoke exposure.

EPA and other federal agencies and states recognize the need for compact and field-deployable sensor technology to measure air pollutants emitted during wildfires. Rugged but reliable and easy-to-use sensor systems can significantly increase data on air quality conditions during a wildfire or prescribed fire. Data from these small sensors complement measurements obtained from more complex regulatory-grade monitors that are stationary or not easily transported.

EPA and other federal agency partners are responding to the need for more monitoring capabilities during wildland fires through two research projects. One is the Wildland Fire Sensors Challenge that is stimulating innovations in the development of sensors specific for wildfire conditions. The second is a field study to evaluate commercially available sensors during smoke events. These projects build upon EPA's expertise in developing emissions and ambient monitoring systems that integrate sensor technologies, as well as field evaluation of commercially available sensors under ambient conditions.

"Our goal for the Challenge is to encourage innovative technology designs that are easy to use and operate as a wireless sensor network and that can be used to assess air quality conditions close to the fire as well as in downwind communities."

Wildland Fire Sensors Challenge

Developers submitted prototype proposals for the Wildland Fire Sensors Challenge in 2017, which is offering a cash prize to one or multiple winners. The ideal monitor will measure fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), ozone (O_3), and carbon dioxide (CO_2). The competition requires monitors to be portable and low maintenance, measure a wide range of pollution levels, and report real-time data continuously and wirelessly to a central data-receiving station.

"Our goal for the Challenge is to encourage innovative technology designs that are easy to use and operate as a wireless sensor network and that can be used to assess air quality conditions close to the fire as well as in downwind communities," says Gayle Hagler, an EPA researcher who is helping to coordinate the Challenge. "The target user is the Air Resource Advisor who is responsible for developing public health communications about air quality conditions and could benefit from expanded air monitoring technology options."

The Challenge received 27 submissions, ten of which have been selected for further testing by EPA and the U.S. Forest Service (USFS). The results of the Challenge are expected to be announced in 2018.

In addition to the USFS, EPA is conducting the Challenge in partnership with the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the Centers for Disease Control and Prevention (CDC).

Sensor Testing in the Field During Wildfires

In another project, EPA researchers are collaborating with the USFS and other partners to evaluate the performance of fine particle pollution ($PM_{2.5}$) sensors already available commercially for their ability to operate under real-world wildfire conditions. EPA researchers are putting the sensors into portable units, evaluating their performance in the lab, and testing them in the field during the 2018 wildfire season.

"The goal is to identify emerging air sensor technology that can enhance efforts to monitor air quality during a wildfire event and to provide guidelines for communities and government agencies on the use of these sensors," says Amara Holder, EPA principal investigator.

The sensor packages will be designed to operate for up to a two-week period with minimal maintenance and without access to power. Following the study, a performance evaluation report will be developed that can be used by states, tribes, communities, and public health officials to learn more about the potential application of sensors for wildfire smoke monitoring.

How to Reduce Emissions from Prescribed Burning

Researchers found that prescribed burning of dry piles of post-harvest Douglas-fir slash (cut timber and timber debris) exhibited significantly lower emissions than wet piles due to better combustion efficiency, according to a study funded by the Oregon Department of Forestry and the EPA through a Cooperative Research and Development Agreement. Polyethylene sheets (PE) have been used on timber slash piles to prevent moisture exposure.

Tests from this study suggest that use of PE as a biomass cover to keep slash piles dry results in lower emission factors than those from piles exposed to moisture, which reduces pollutant levels during prescribed burning. Also, burning the PE cover on the pile was found to have no distinctive effect on emissions.

These results can be used by management and regulatory communities to inform smoke management practices and limit potential hazards related to prescribed burning of slash piles. The research is published in an article titled, Emissions From Prescribed Burning of Timber Slash Piles in Oregon, in a 2017 issue of *Atmospheric Environment*.

The Danger of Wildland Fire Smoke to Public Health

As the 2017 wildfires in California, Oregon, and other western states revealed, smoke from wildfires is harmful to health. Many residents near the fires experienced respiratory distress and other health problems from breathing in toxic smoke for days and weeks during some of the fires.

Wildfires are increasing in intensity and size, contributing to impaired air quality for people living near or downwind of the fires. But while smoke from wildfires is a threat to health, and even survival in some cases, there are many unknowns about the health effects of smoke from wildfires as well as prescribed fires. Is all smoke the same or is some more toxic than others based on the type of trees and vegetation burned? What are the health effects from smoke in the flaming stage of a wildfire, compared to the smoldering stage? How does smoke "age" over time and are the health effects different? And who is most susceptible?

One of the main components of smoke is particle pollution (PM), which is a regulated air pollutant. Wildland fires, which include wildfires and prescribed fires, now account for 40 percent of the total PM emitted in the country, making it a major source of the pollutant, which causes lung and health problems.

While smoke from wildland fires is a recognized public health threat, there are very few studies that examine the specific role of the different components of smoke on disease and the severity of disease when people are exposed, says EPA's Wayne Cascio, Director of the National Health and Environmental Effects Laboratory, in an article titled, Wildland Fire Smoke and Human Health, published in a 2017 issue of *Science of the Total Environment*.

The increase in wildfires in the U.S. and worldwide makes it important to learn more about the health impacts on people living in smoke-prone areas as well as those who live farther away but still downwind of the smoke, Cascio says. The study of health effects from wildland fires is a relatively new and quickly expanding field of study, he notes. The article provides insights into the state of knowledge of what we know about a growing public health concern and describes needed research.

One area of investigation where more studies are needed is to determine what smoke emissions do to impact the cardiovascular system. While the association between PM and heart problems is well documented in the scientific literature, there have been mixed results in a small number of studies about the impacts on the cardiovascular system, Cascio states in the article.

In one study, published in 2018 in the *Journal of the American Heart Association*, dense smoke days during the 2015 California wildfire season increased emergency room visits for heart attacks by 42 percent among older adults.

There is also an interest in learning what the effects might be for a few days of exposure compared to weeks or even months as the length of time for extinguishing wildfires can put people in the path of smoke for a long time. Short-term and long-term health studies are needed, says Cascio. In the article, Cascio also encourages policy decision makers at all government levels, public health professionals, and air quality managers to explore ways to improve communications and outreach about the threat of exposure to wildland fires.

More research on wildland fires can help officials identify those most at risk from smoke exposure and provide guidance on effective public actions to decrease exposure, reduce health problems, and lower the number of visits to the doctor's office or hospital during a wildland fire.

Be a Part of Science: Use the New Smoke Sense App

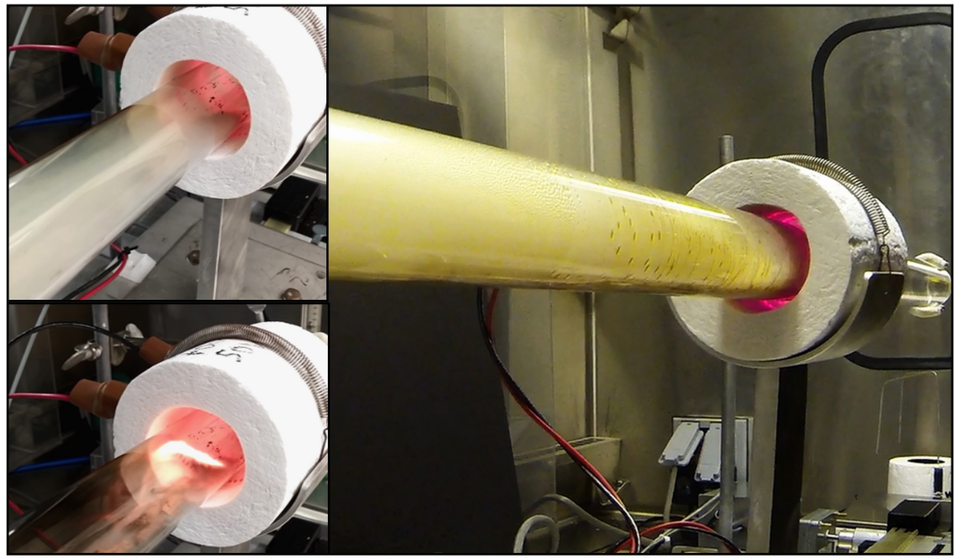
A new Smoke Sense app is being piloted in an EPA study to evaluate the health effects from wildland fires and develop health risk communication strategies for the public during smoke days. The app is available on Android and iOS devices. Smoke Sense app users' identities are anonymous and non-identifiable.

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 crowdsourcing study was launched in 2017 and will continue during the 2018 wildfire season. In 2017, the app was used by nearly 5,000 users with over 50,000 unique sessions between Aug. 1 and Dec. 14. The vast majority of users returned to Smoke Sense on multiple occasions. Other statistics on app use are available online.

Learn more and get the app at:

epa.gov/air-research/smoke-sense



The Science Behind Wildfire Smoke Toxicity

Where there is smoke, there is fire…and also air pollution.

The toxic effects of wildfire smoke when chokingly thick can cause serious health risks and even death for those caught too close. But what about the health effects of smoke from wildfires or prescribed fires when there is a noticeable haze over a community for days, weeks, and sometimes months?

In a laboratory in Research Triangle Park, NC, researchers are using an innovative furnace tube system to study the health effects of smoke in controlled conditions. They are investigating whether particles in smoke have different health effects depending on the type of wood burned and the stage of the fire such as flaming or smoldering.

In the United States, forests and woodlands vary from region to region, from chaparral type scrub on the coast of California to red oak in the Midwest and East, as well as pine across the country. The question scientists are asking is: "Does the smoke from a wildfire pose a greater health risk based on the type of wood and intensity of the combustion?"

"Smoke from wildland fires and prescribed burning is now a major component of air pollution in the United States and its characteristics and potential health effects need more thorough investigation," says EPA researcher Ian Gilmour. "The toxicity studies being conducted will provide new insights into how to protect public health from potential effects of smoke exposure."

Studies at EPA on the health effects of wildland fire smoke had their start in 2008 when a large peat fire in eastern North Carolina produced haze and air pollution that far exceeded air quality standards. Using satellite imagery and hospital records, researchers found a link between smoke from peat fires and an increase in hospital visits for symptoms of heart failure as well as respiratory problems relating to asthma, COPD, pneumonia and bronchitis. They also collected samples of the smoke and found that the particles worsened indicators of lung and heart disease in mice, to a greater degree than the same amount of particles collected after the fire was controlled.

Does the smoke from a wildfire pose a greater health risk based on the type of wood and intensity of the combustion?

While these observational studies provide important health information, the researchers wanted to study the potential toxicity of smoke under more controlled laboratory conditions. They adapted test methods from the tobacco industry and developed a furnace system that can be used to simulate smoke from wood-burning fires. Biomass fuel samples are combusted by moving an insulated furnace down a thin line of wood chips placed on the bottom of a long glass tube. The temperature of the furnace can be raised or lowered to create flaming or smoldering conditions, and the smoke is collected in chilled flasks where it is analyzed and used to assess health effects in cell and animal studies.

In a study published in the journal *Environmental Health Perspectives* in 2018, the greatest lung toxicity was from eucalyptus, which is representative of chaparral-type wood. The study also found that smoke from pine wood, which is broadly distributed across the United States, caused genetic mutations in bacteria, which is an indicator for the development of cancer. Overall, the results suggest that emissions from fires in regions rich in those type of fuels may induce greater health effects than those from fires of similar magnitude with other types of trees.

Newer results examining direct inhalation of the smoke are confirming the same general pattern of effects between different fuel types and combustion conditions, and are also showing that the smoke can affect lung function as long as 24 hours after the exposure. Additional studies examining cardiovascular effects as well as comparing the impact of single, intermittent, or longer term exposures are being planned.

The research providing more information on the toxicity of wildland fire smoke can be used by air quality managers and health professionals to protect public health. If fires from a particular forest show a greater potential for causing respiratory or heart problems, for example, advisories can be adapted to inform first responders and the general public.

Health Impacts and Economic Costs of Wildland Fires

Researchers at EPA and colleagues at NC State University, the University of Sydney, and the University of Tasmania are advancing the science of understanding the public health burden associated with wildland fires. In a published study, the team estimated the number of premature deaths and illnesses caused by pollution related to wildland fires in the United States, and the economic value of that health burden over a 5-year period. The team applied a unique set of air quality modeling simulations in combination with well-established techniques for assessing air pollution risk and found that wildland fires occurring between 2008 and 2012 posed a significant burden to public health.

This is the first study of its kind to characterize fine particle pollution ($PM_{2.5}$) from wildland fires—the pollutant of most concern for health risk from fires—over such a long period of time. Other studies have focused on single fire events or covered shorter periods of time. The team hopes that the findings will support further research into the health burdens and costs from wildland fires.

The study found between 5,200-8,500 hospital admissions for respiratory problems per year and 1,500-2,500 hospital admissions for cardiovascular problems per year.

The article, published in *Science of the Total Environment* in 2017, estimated between 5,200 and 8,500 hospital admissions for respiratory problems per year and 1,500-2,500 hospital admissions for cardiovascular problems per year. Total deaths per year were estimated between 1,500 and 2,500 as well, with 2008 having the highest rate because of wildland fire-related $PM_{2.5}$.

The wildland fires for these five years had an economic impact as well. The study estimated the cost of short-term exposures that led to premature deaths or hospital admissions at $63 billion in 2016 dollars and long-term exposures at $450 billion in 2016 dollars.

While the entire U.S. experienced increased levels of wildland fire $PM_{2.5}$ for the period (from wildfires or prescribed fires), a subset of states experienced an especially large impact—including Louisiana, California, Idaho, and Georgia.

The study lays the groundwork for future investigations into the health and economic costs of wildland fires and provides information that state and local health officials can consider now as they develop communications about wildland fires and public health.

Identifying Those at Higher Risk from Smoke

EPA scientists developed a Community Health Vulnerability Index that can be used to help identify communities at higher health risk from wildfire smoke. Breathing smoke from a nearby wildfire is a health threat, especially for people with lung or heart disease, diabetes, and high blood pressure as well as older adults, and those living in communities with poverty, unemployment, and other indicators of social stress.

Health officials can use the tool, in combination with air quality models, to focus public health strategies on vulnerable populations living in areas where air quality is impaired, either by wildfire smoke or other sources of pollution. The work was published in *Environmental Science & Technology* in 2017.

Learn more at:

epa.gov/air-research/community-health-vulnerability-index-fact-sheet

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 applying the power of computer technology.

Plumes from wildland fires can disperse in communities close to the fire, prompting local officials to issue public health advisories. But emissions also can impact air quality in communities hundreds or thousands of miles away, when the smoke rises into the upper atmosphere and is moved by wind currents and finally deposited to the ground through rain and other processes.

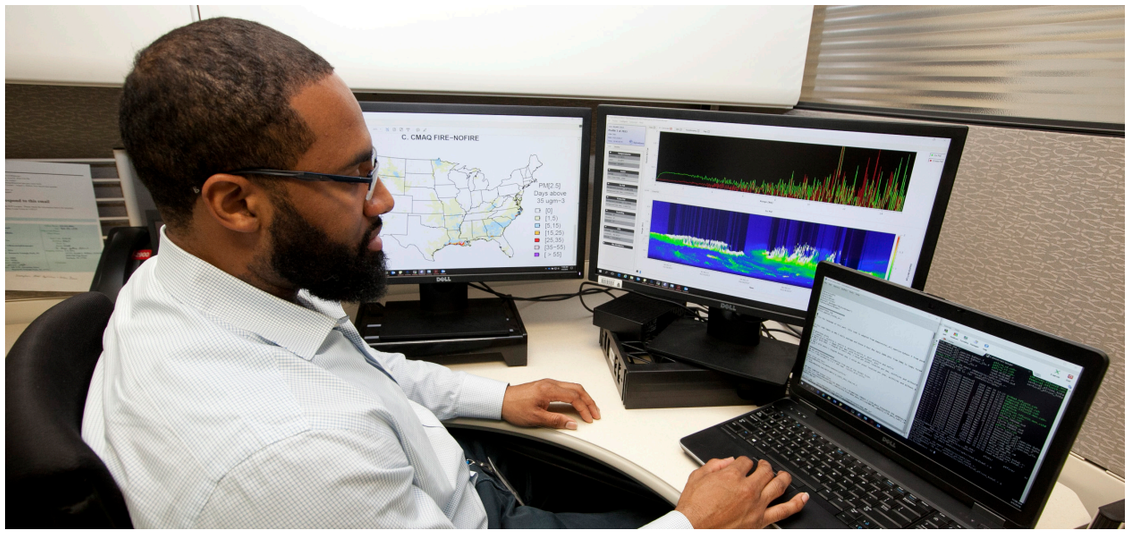
"Long-range transport of smoke emissions is well recognized and can impact air quality across regions or globally," says Tom Pierce, a modeling researcher at EPA. "We have developed a variety of tools to help predict smoke transport and impacts over an area."

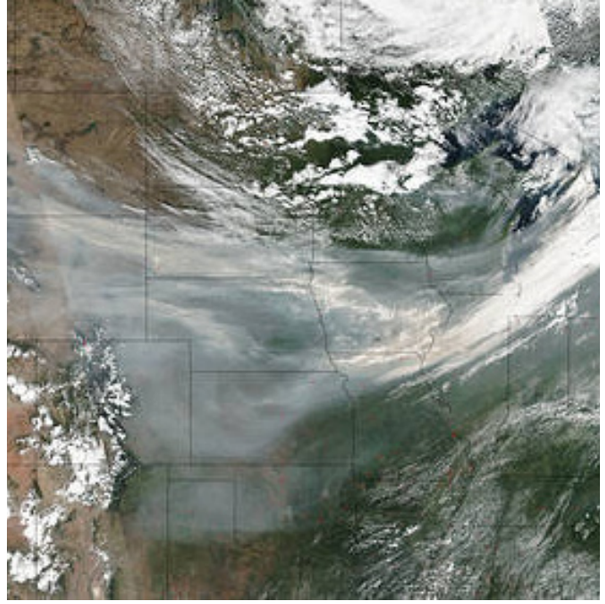
One EPA modeling study published in 2008 shows the distances smoke emissions can travel. Results demonstrated that fine particle pollution ($PM_{2.5}$) from fires in Alaska that occurred during 2004 traveled to the eastern part of the country, causing a 24 to 42 percent increase in pollutant levels for some areas.

Models are an integral part of protecting public health from wildland fire smoke. They are used by air resource advisors to better predict when smoke in an area may be harmful to health. And 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. With the increase in intensity and frequency of fires, some states impacted by wildfires are experiencing increased levels of PM and ozone.

EPA applies its CMAQ model, developed to support air quality regulations, to study wildland fire smoke and evaluate its impact on air quality. New approaches and methods developed for the model are making it possible to more accurately simulate and track emissions from smoke. As model sophistication improves, this tool could be used to help balance prescribed fire activity for land management with negative human health impacts due to smoke exposure.

"Right now we can do a reasonable job of estimating air quality impacts from fires, but there is a need to improve modeling to make them even more accurate and to better estimate health impacts so people can make informed decisions to minimize exposure," says Kirk Baker, another modeler at EPA.





Research projects are under way to further advance the capabilities of modeling wildland fire emissions. Modelers at EPA are:

- Evaluating plume rise and differences in emission composition for flaming and smoldering components of wild and prescribed fires.
- Improving understanding of the optical properties of the chemical components of smoke to allow for better representation of plume chemistry evolution.
- Developing new approaches to differentiate wild and prescribed fire impacts on air quality and populations using a photochemical grid model. This research is supported by the EPA-funded STAR grant on Particulate Matter and Related Pollutants in a Changing World.
- Estimating prescribed fire emissions using permit information to enable more accurate air quality forecasts. This research is supported by the EPA-funded STAR grant on Dynamic Air Quality Management.
- Modeling to look back at contributions of wildland fire smoke emissions to ozone and particle pollution over the United States and more recently to look at individual fires to assess emissions and how they are transported.

These and other advances are leading to the development of more robust 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.

Smoke Ready Toolbox for Wildfires

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

Airnow.gov: Current Fire Conditions
airnow.gov/index.cfm?action=topics.smoke_wildfires

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_may2016.pdf

Wildfire Smoke Exposure Infographics
airnow.gov/index.cfm?action=topics.smoke_wildfires

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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