WILDFIRE SMOKE

A Guide for Public Health Officials

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The Wildfire Smoke Guide for Public Health Officials, first published in 2002, was developed in part as a result of a workshop held at the University of Washington in June 2001, under the auspices of the U.S. Environmental Protection Agency, Region X, and the Department of Environmental Health, School of Public Health and Community Medicine of the University of Washington. It was written by Harriet Ammann (Washington Department of Health); Robert Blaisdell and Michael Lipsett (California Office of Environmental Health Hazard Assessment), Susan Lyon Stone (U.S. Environmental Protection Agency); and Shannon Therriault (Missoula, MT County Health Department), with input from individuals in several other state and federal agencies, in particular Jed Waldman (California Department of Health Services) and Peggy Jenkins (California Air Resources Board).

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The 2016 version of this document was updated by a team of experts from the same agencies that developed the current, 2019 version. The goal of the 2016 revision was to quickly update the 2008 version by incorporating the expanded scientific evidence base, and then take more time expanding the Guide by adding new sections and fact sheets. Since 2016, eight factsheets have been developed, with links available in Appendix A. More will be coming, including translations of the currently available ones, so watch for them.

This 2019 version of the Guide is the product of an inter-agency collaboration that includes: California Air Resources Board; California Office of Environmental Health Hazard Assessment; U.S. Centers for Disease Control and Prevention; U.S. Forest Service; and U.S. Environmental Protection Agency. Team members, authors, contributors and reviewers are listed below.

For More Information

Project Lead: Susan Lyon Stone, stone.susan@epa.gov

Chapter 1 Health Effects: Jason Sacks, sacks.jason@epa.gov

Chapter 2 Air Quality Impacts: Peter Lahm, peter.lahm@usda.gov

Chapter 3 Exposure Reduction Strategies: Alison Clune, clune.alison@epa.gov

Respirators: Lewis Radonovich, mto5@cdc.gov and Maryann D'Alessandro, bpj5@cdc.gov

Chapter 4 Air Quality Communication: Miki Wayland, wayland.michelle@epa.gov

Chapter 5 Public Health Actions: Maria Mirabelli, zif7@cdc.gov

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Disclaimer

The viewpoints and policies expressed herein do not necessarily represent those of the various agencies and organizations listed. Mention of any specific product name is neither an endorsement nor a recommendation for use.

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TEAM, AUTHORS, CONTRIBUTORS, REVIEWERS

Team Members

Susan Lyon Stone MS, Senior Environmental Health Scientist, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. Project Lead

Martha Berger MPA, Program Analyst, Office of Children's Health Protection, U.S. Environmental Protection Agency, Washington, DC, 20460.

Cory R. Butler MS, Occupational Safety and Health Specialist, Western States Division, National Institute for Occupational Safety and Health, U.S. Centers for Disease Control and Prevention, CO 80215.

Wayne E. Cascio MD, Director, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Alison Clune MPH, Biologist, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, DC, 20460.

Scott Damon MAIA, Health Communication Lead, Asthma and Community Health Branch, National Center for Environmental Health, U.S. Centers for Disease Control and Prevention, Atlanta, GA 30341.

Phillip G. Dickerson BS CPE, Supervisory Environmental Protection Specialist, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Paul Garbe DVM, Retired, Air Pollution and Respiratory Health Branch, National Center for Environmental Health, U.S. Centers for Disease Control and Prevention, Atlanta, GA 30341.

William E. Haskell MS, Retired, National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, U.S. Centers for Disease Control and Prevention, MA 01810.

Sumi Hoshiko MPH, Research Scientist, Environmental Health Investigations Branch, California Department of Public Health, Richmond, CA 94804.

Ali Kamal PhD, Physical Scientist, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Peter Lahm MEM, Air Resource Specialist, Fire & Aviation Management, U.S. Forest Service, Washington, DC 20250.

Barbara Materna PhD, CIH, Chief, Occupational Health Branch, California Department of Public Health, Richmond, CA 94804.

Maria C. Mirabelli PhD, MPH, Senior Service Fellow, Asthma and Community Health Branch, National Center for Environmental Health, U.S. Centers for Disease Control and Prevention, Atlanta, GA 30341

Tracey Mitchell RRT, AE-C, Environmental Protection Specialist, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, DC, 20460.

Karen Riveles PhD, MPH, Staff Toxicologist & Emergency Response Coordinator, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, CA 95812.

Jason Sacks MPH, Epidemiologist, National Center for Environmental Assessment, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Michelle Wayland BSE, Environmental Engineer, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

John E. White BSM, Environmental Protection Specialist, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Jeffery R. Williams PhD, Air Pollution Specialist, Research Division, California Air Resources Board, Sacramento, CA 95812.

Authors

Susan Lyon Stone MS, Senior Environmental Health Scientist, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. Project Lead, health, health communication, public health policy.

Laura Anderko PhD, RN, Director, Mid-Atlantic Center for Children's Health and the Environment, School of Nursing and Health Studies, Georgetown University, Washington DC 20057. Children's health.

Martha Berger MPA, Program Analyst, Office of Children's Health Protection, U.S. Environmental Protection Agency, Washington, DC, 20460. Children's health.

Cory R. Butler MS, Occupational Safety and Health Specialist, Western States Division, National Institute for Occupational Safety and Health, U.S. Centers for Disease Control and Prevention, CO 80215. Occupational health.

Wayne E. Cascio MD, Director, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. Health, health research.

Alison Clune MPH, Biologist, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, DC, 20460. Indoor air quality, filtration, air cleaning.

Scott Damon MAIA, Health Communication Lead, Asthma and Community Health Branch, National Center for Environmental Health, U.S. Centers for Disease Control and Prevention, Atlanta, GA 30341. Health communication.

Paul Garbe DVM, Retired, Air Pollution and Respiratory Health Branch, U.S. Centers for Disease Control and Prevention, Atlanta, GA 30341. Health, epidemiology.

Marissa Hauptman MD, MPH, Pediatric Environmental Health Fellow, New England Pediatric Environmental Health Specialty Unit, Boston Children's Hospital, Boston, MA 02115. Children's health.

William E. Haskell MS, Retired, National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, U.S. Centers for Disease Control and Prevention, MA 01810. Personal protective technology.

Sumi Hoshiko MPH, Research Scientist, Environmental Health Investigations Branch, California Department of Public Health, Richmond, CA 94804. Health, epidemiology.

Peter Lahm MEM, Air Resource Specialist, Fire & Aviation Management, U.S. Forest Service, Washington, DC 20250. Chapter 2 lead, air quality, smoke emissions, smoke forecasting, smoke management.

Barbara Materna PhD, CIH, Chief, Occupational Health Branch, California Department of Public Health, Richmond, CA 94804. Occupational health, respirators.

Maria C. Mirabelli PhD, MPH, Senior Service Fellow, Asthma and Community Health Branch, National Center for Environmental Health, U.S. Centers for Disease Control and Prevention, Atlanta, GA 30341. Chapter 5 Lead, health, epidemiology.

Narasimhan (Sim) Larkin PhD, Climate Scientist, Air Fire Team, U.S. Forest Service, Pacific Northwest Fire Station, WA 98103. Air quality, smoke emissions, smoke forecasting.

Susan O'Neill PhD, Research Air Quality Engineer, AirFire Team, U.S. Forest Service, Pacific Northwest Fire Station, WA 98103. Air quality, smoke emissions, smoke forecasting.

Janice Peterson MS, Air Resource Specialist, U.S. Forest Service, Pacific NW Region, Seattle, WA 98103. Air quality, smoke emissions, smoke forecasting.

Karen Riveles PhD, MPH, Staff Toxicologist & Emergency Response Coordinator, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, CA 95812. Smoke, ash, school closure, toxic air contaminants, risk communication.

Jason Sacks MPH, Epidemiologist, National Center for Environmental Assessment, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. Chapter 1 Lead, health, epidemiology.

Michelle Wayland BSME, Environmental Engineer, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. Chapter 4 Lead, air quality communication.

Jeffery R. Williams PhD, Air Pollution Specialist, Research Division, California Air Resources Board, Sacramento, CA 95812. Chapter 3 Lead, indoor air, filtration, portable air cleaners, personal exposure, asthma, cleaner air shelters, ozone.

Contributors

Ann R. Brown BA, Communications Lead Air and Energy National Research Program, National Health and Environmental Exposure Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Sarah Coefield MS, MA, Air Quality Specialist, Missoula City-County Health Department, Missoula, MT 59802.

Maryann M. D'Alessandro PhD, Director, National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, Pittsburgh, PA 15236.

Gayle S.W. Hagler, PhD, Environmental Engineer, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC 27709.

Laura Kolb, Office of Radiation and Indoor Air, Indoor Environments Division, U.S. Environmental Protection Agency, Washington, DC, 20460.

Lewis Radonovich MD, Chief of Research, National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, U.S. Centers for Disease Control and Prevention, Pittsburgh, PA 15236.

Reviewers

California Air Resources Board: Peggy L. Jenkins; Lori Miyasato, PhD; Hye-Youn Park, PhD; Charles Pearson; Feng-Chaio Su, PhD; Barbara Weller, PhD;

California Department of Industrial Relations, Division of Occupational Safety and Health: Eric Berg MPH; Amalia Niedhardt MPH.

California Office of Environmental Health Hazard Assessment: Rupa Basu, PhD, MPH; Heather Bolstad, PhD; Dharshani Pearson, MPH; Xiangmei Wu, PhD.

U.S. Centers for Disease Control and Prevention: Josephine Malilay PhD, MPH; Kanta Sircar PhD, MPH.

U.S. Environmental Protection Agency: Kirk Baker PhD; Pat Dolwick MS; Janice Dye DVM; Michael P. Firestone PhD; Benjamin Gibson MPP; Joanna Gmyr MEM; Elizabeth D. Hilborn DVM, MPH, Dipl. ACVPM; Stacey Katz MPH; Laura Kolb; Gail Robarge; Karen Wesson MS.

U.S. Forest Service: Melanie Pitrolo MS; Leland Tarnay PhD.

U.S. National Park Service: Mark Fitch MS.

EXECUTIVE **SUMMARY**

Wildfire smoke events can occur without warning – but we can be prepared. This Guide is intended to provide state, tribal, and local public health officials with information they need to be prepared for smoke events and, when wildfire smoke is present, to communicate health risks and take measures to protect the public. Although developed for public health officials, the information in this document could be useful to many other groups including health professionals, air quality officials, and members of the public. The document is divided into five Chapters and five Appendices. Guide authors and contributors will post up-to-date guidance, documents, and other new evidence-based information here between revisions for use by public health officials.

Health Effects of Wildfire Smoke

Wildfire smoke is a mixture of air pollutants of which particulate matter is the principal public health threat. The initial basis for understanding wildfire smoke health effects was derived primarily from studies of ambient air pollutants, specifically particulate matter. Extensive scientific evidence has demonstrated health effects in response to short-term (i.e., daily) particulate matter exposure ranging from eye and respiratory tract irritation to more serious effects, including reduced lung function, pulmonary inflammation, bronchitis, exacerbation of asthma and other lung diseases, exacerbation of cardiovascular diseases, such as heart failure, and even premature death. Recent studies examining the health effects of wildfire smoke provide evidence of health effects consistent with those reported for particulate matter. However, there is only limited evidence about the potential health impacts due to cumulative exposures from repeated, multi-day wildfire smoke exposures or multiple, consecutive fire seasons.

Although a large population can be exposed to smoke during a wildfire event, most healthy adults and children will recover quickly from wildfire smoke exposure. Certain lifestages and populations may, however, be at greater risk of experiencing health effects, including people with respiratory or cardiovascular diseases, children and older adults, pregnant women, people of lower socioeconomic status, and outdoor workers.

Wildfire Smoke and Air Quality Impacts

The science of wildfire behavior and management is complex and highly technical. Wildfire smoke produced from combustion of natural biomass contains thousands of individual compounds, including particulate matter, carbon dioxide, water vapor, carbon monoxide, hydrocarbons and other organic chemicals, nitrogen oxides, and trace minerals. Wildfires can move into the wildland urban interface (WUI), burning homes and structures and thereby consuming man made materials in addition to natural fuels. More research is needed to understand potential health impacts of breathing this complex mix of natural and man made material emissions.

Wildfire behavior will vary depending on natural fuel type; fires in forest fuels can range from mild to severe and can spread very slowly or extremely rapidly depending on weather and fuel conditions. Wildfires in forests can last for weeks or months and are often the type that results in the most severe and longest duration air quality impacts. Smoke levels in populated areas can be difficult to predict.

Most of the tens of thousands of wildfires in the United States are suppressed when they first start. Those that continue past the initial suppression attempt can become large, of long duration, and a significant source of smoke. On these types of fires, an Incident Management Team (IMT) is usually engaged, which is then guided by the land owner/manager/agency administrator and pre-existing land management plans.

Specific Strategies to Reduce Exposure to Wildfire Smoke

In areas where the public is experiencing wildfire smoke, public health and air quality agencies should provide advice on strategies to limit exposure, which include staying indoors; limiting physical activity; reducing indoor air pollution sources; effectively using air conditioners and air filters or cleaners; creating cleaner air shelters; and using respiratory protection appropriately.

The most common advisory during a smoke episode is to stay indoors, where people can better control their environment. Whether at home or in a public space, indoor environments that have filtered air and climate control can provide relief from smoke and heat. High-efficiency heating, ventilation, and air-conditioning (HVAC) filters (rated MERV 13 or higher) in systems that can accommodate them can help reduce particle concentrations indoors.

Appropriately sized room air cleaners can also reduce particle concentrations in individual rooms. It is important to choose a room air cleaner that produces little or no ozone. The California Air Resources Board provides a list of air cleaners that meet the ozone emissions limit. High-efficiency filters and room air cleaners are more effective with more frequent operation. Individuals can use a room air cleaner in a designated room in the house to create a protected environment called a "clean room" at home. Public cleaner-air shelters and spaces can provide relief from smoke for individuals who do not have adequate air filtration or cooling equipment at home. When traveling between indoor locations with cleaner air, people can reduce particle levels in vehicles by keeping windows and vents closed and operating the air conditioning in "recirculate" mode.

Properly wearing a NIOSH-certified N95 or P100 particulate respirator that fits closely to the face can help reduce personal exposure to wildfire smoke and ash. Adults who must remain outdoors in unhealthy air for extended periods due to work or other factors may particularly benefit from using this strategy. People should avoid using masks that do not provide proper protection, such as single-strap dust masks or surgical masks. Respirators are not made to fit children and will not protect them from breathing wildfire smoke.

Smoke levels can vary throughout the day, so people may be able to plan necessary trips outside during times when the air is less smoky or minimize their time in smoke impacted areas. Smoke outreach and forecasting tools can help people make decisions about when and where they can go to minimize their smoke exposures. When smoke levels are especially high, local officials may take actions such as closing schools or canceling public events. Where evacuation is necessary because of fire danger, public health officials should consider appropriate strategies to reduce smoke exposure during the evacuation, at evacuation centers, and after allowing evacuees to return home.

Communicating Air Quality Conditions during Smoke Events

The goal of air quality monitoring during a wildfire smoke event is to relay information to the public in a timely manner so people can make decisions about how to protect their health. Tools for measuring and estimating air quality conditions and conveying them to the public include the Air Quality Index (AQI; available on AirNow), visual range scale, or other approaches. The Current Conditions Map provides a one-stop place for the public on current wildfire and air quality information. School-focused guidance addresses outdoor activities, and the Air Quality Flag Program uses a visual flag alert for schools and organizations to take health protective actions. When requested by the land manager responding to a large wildfire, the Interagency Wildland Fire

Air Quality Response Program will deploy an Air Resource Advisor (ARA) to the IMT. These technical specialists are trained to monitor air quality, analyze smoke impacts, model future smoke impacts, and provide smoke outlooks for impacted communities which will help public health officials in advising the public.

Areas without continuous PM monitors may be able to get temporary, portable monitors through their federal, state, tribal, or local air quality agencies or the U.S. Forest Service, especially when associated with a wildfire incident with an assigned ARA. Emerging technology has expanded sources for air quality information, including miniaturized $PM_{2.5}$ sensors, mobile air quality monitoring systems, and data fusion products. However, there are many unknowns regarding their precision, accuracy, and reliability, especially under wildfire conditions. Therefore, sensor data and data fusion products should be considered supplemental information, but they need to be put into context with the help of nearby regulatory monitors or short-term monitors, AQI estimates, satellite data, and daily ARA Smoke Outlooks.

Recommendations for Public Health Actions

Communications planning for recommendations should address not only messages and actions during a wildfire event, but preparations to make before fires occur and as well as guidance for cleaning up after a fire. Many factors must be considered, so these recommendations should be adapted to each specific situation. Areas with established air quality programs typically have a communication plan for wildfire smoke events. One approach used by states and most communities across the country is to refer the public to the AirNow website (www.airnow.gov).

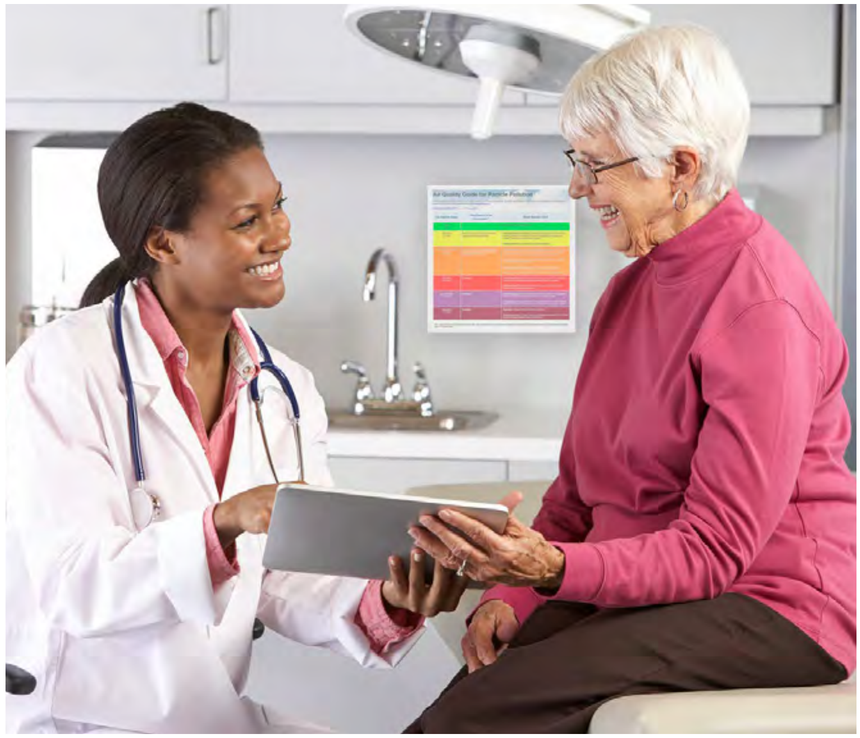
In areas where fires are likely to occur, state and local public health agencies should consider running pre-season PSAs or news and social media announcements to advise the public on preparing for the fire season. During smoke periods, public advisories based on air quality levels should address special needs of at-risk lifestages and populations (in the Air Quality Index, the term "sensitive groups" is used), including people with heart or lung disease, older adults, children, pregnant women, and people of lower SES. Other concerns include advisories for outdoor workers, prolonged smoke events, and protections for pets and livestock.

Preparation is key. Recommendations to the public at risk for smoke exposure include advising preparations in advance of wildfire season, e.g. maintaining nonperishable groceries not requiring cooking. People with chronic diseases should check with their health care provider about precautions ahead of smoke events and have an adequate supply of medication available; asthmatics should have a written asthma action plan.

Recommended steps for public health officials to take before fires start include: check fire risk in monthly outlooks at National Interagency Fire Center (NIFC) website and, especially if high, communicate risk to the public; consider how to implement the recommended actions in the Guide; prepare a communication plan; and form partnerships with important partners or stakeholders (e.g., air quality agencies, local health providers, the media).

Even after the worst of the fire and smoke is over, exposure to lingering smoke and ash from a wildfire can cause significant health effects in both healthy and at-risk populations, such as respiratory irritation, heat-related illness and emotional stress, as well as physical stress or injuries from cleanup activities. In post-fire situations in which air quality is poor due to smoke and ash residue in or near affected structures, ventilation and other protective measures are advised during cleanup.

I. HEALTH EFFECTS OF WILDFIRE SMOKE



Wildfires expose populations to multiple environmental hazards, from combustion due to the fire itself to air pollution from smoke and byproducts of combustion such as ash. In addition, when wildfires move into communities, chemicals in plastics and other chemicals can be released into the air from burning structures and furnishings. Wildfires also cause mental health concerns and psychological stress. Recently, epidemiological (e.g., Reid et al. 2016, Tinling et al. 2016, Wettstein et al. 2018) and toxicological (e.g., Kim et al. 2018) studies have focused broadly on the health effects of wildfire smoke exposure and the toxicity of specific fuel sources, respectively. These studies consistently demonstrate a variety of respiratory-related health effects with more recent studies also providing some evidence of cardiovascular-related health effects in response to short-term (i.e., daily) wildfire smoke exposures. Although the body of literature specifically examining the health effects attributed to wildfire smoke exposure has grown, the initial understanding of potential health effects was derived from studies focusing on components of ambient air pollution, primarily in urban settings, that are also found in wildfire smoke (e.g., fine particulate matter and carbon monoxide).

Particulate matter is the principal public health threat from short-and longer-term exposure to wildfire smoke and is the focus of most of this document. While particles from wildfire smoke can vary in size (see Section II. Wildfire Smoke and Air Quality Impacts), approximately 90% of total particle mass emitted from wildfires consists of fine particles (i.e., $PM_{2.5}$, particles 2.5 µm in diameter or smaller) (Vicente et al. 2013; Groβ et al. 2013). The scientific evidence does not indicate that particles generated from wildfire smoke are more, or less, toxic than particles emitted from other sources (U.S. EPA 2009; DeFlorio-Barker et al. 2019). The effects of particulate matter exposure range from eye and respiratory tract irritation to more serious disorders including reduced lung function, bronchitis, exacerbation of asthma, heart failure, and premature death. Short-term exposures (i.e., days to weeks) to fine particles, a major component of smoke, are associated with increased risk of premature mortality and aggravation of pre-existing respiratory and cardiovascular disease. In addition, fine particles are respiratory irritants, and exposures to high concentrations can cause persistent cough, phlegm, wheezing, and difficulty breathing. Exposures to fine particles can also affect healthy people, causing respiratory symptoms, transient reductions in lung function, and pulmonary inflammation. Particulate matter may also affect the body's ability to remove inhaled foreign materials, such as pollen and bacteria, from the lungs. Specific lifestages and populations may potentially be at increased risk of health effects due to particulate matter exposure (see next section) and actions should be taken to reduce their exposure to wildfire smoke.

Ground-level ozone, though less of a concern from wildfires than particulate matter, can cause effects such as reductions in lung function, inflammation of the airways, chest pain, coughing, wheezing, and shortness of breath – even in healthy people. These effects can be more serious in people with asthma and other lung diseases. Respiratory effects attributed to ozone exposure can lead to increased use of medication, school absences, respiratory-related hospital admissions, and emergency room visits for asthma and chronic obstructive pulmonary disease (COPD). Although the evidence of ozone's effects on the cardiovascular system (the heart, blood, and blood vessels) is more limited than the evidence of effects on the respiratory system, it indicates that short-term exposure to ozone may cause effects such as changes in heart rate variability and systemic inflammation. Additionally, evidence indicates that short-term ozone exposures can lead to premature mortality, as demonstrated by recent epidemiologic studies that consistently report positive associations between short-term ozone exposures and total non-accidental mortality, which includes deaths from respiratory and cardiovascular causes (U.S. EPA, 2013).

Carbon monoxide is also present in wildfire smoke. Typically, exposures to carbon monoxide from wildfire smoke do not pose a significant hazard to the public, except to some at-risk populations and firefighters very close to the fire line. This is because carbon monoxide does not travel far from the point of combustion. Carbon monoxide enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. People with cardiovascular disease may experience health effects such as chest pain or cardiac arrhythmias from lower levels of carbon monoxide than healthy people. At higher levels (such as those that occur in major structural fires), carbon monoxide exposure can cause headache, weakness, dizziness, confusion, nausea, disorientation, visual impairment, coma, and death, even in otherwise healthy individuals.

Wildfire smoke also contains significant quantities of respiratory irritants that can act in concert to produce eye and respiratory irritation and potentially exacerbate asthma. Additionally, Hazardous Air Pollutants (HAPs) (also referred to as Toxic Air Contaminants [TACs] by the California Environmental Protection Agency [CalEPA]) are also present in wildfire smoke (Reinhardt and Ottmar, 2010). HAPs may contribute to adverse health effects in infants, children, pregnant women and their fetuses, elderly persons, those with existing lung, heart, or liver diseases, and persons engaging in physical activity. Among the extensive list of HAPs, acetaldehyde, acrolein, formaldehyde and benzene, are of concern because of their differential impact on infants and children compared to adults. These HAPs overall contribute to the cumulative irritant properties of smoke and are present in concentrations that may be above regulatory health guidance values (e.g. OEHHA Reference Exposure Levels and U.S. EPA Reference Concentrations).

While most of the focus on health effects of wildfire smoke is on those attributed to short-term exposures (i.e. over a few days to weeks), it is also important to consider the health effects people may experience from cumulative exposures, whether due to repeated, multi-day exposures or multiple consecutive fire seasons. For example, there is concern that long-term exposures to chemicals in wildfire smoke at sufficient concentrations and durations might be a contributor to overall lifetime risk for heart disease, lung disease, and cancer. Unfortunately, there is little information on potential health effects from these types of exposures. The limited number of epidemiologic studies that have specifically examined the cumulative effect of wildfire smoke exposure on health have been studies of wildland firefighters. There is initial evidence that continuous occupational wildland fire smoke exposure (i.e., over multiple days) may have a cumulative effect on lung function, with some studies observing a progressive decline during burn seasons. However, it is unclear if this decline persists across off-seasons and it is difficult to compare a wildland firefighter's occupational exposure and resulting health effects to those experienced by the general population (Adetona et al. 2016).

Overall, it is important to recognize that not everyone who is exposed to smoke from wildfires will experience health effects. The level and duration of exposure, age, individual susceptibility, including the presence or absence of pre-existing lung (e.g., asthma, COPD) or heart disease, and other factors play significant roles in determining whether someone will experience smoke-related health problems.

At-risk lifestages and populations

Most healthy adults and children will recover quickly from smoke exposure and will not experience long-term health consequences. However, certain at-risk lifestages and populations may be at greater risk of experiencing severe acute and chronic symptoms (See Chapter 5 for strategies to reduce exposure for at-risk lifestages and populations). Key risk factors that shape whether a population or individual is at increased risk of health effects from wildfire smoke have been identified primarily from epidemiologic studies examining exposure to fine particulate matter in urban settings. These studies provide evidence indicating the risk of health effects due to fine particulate exposures can vary based on lifestage (i.e., children, < 18 years of age; and older adults, ≥ 65 years of age), health status, and socioeconomic status. However, studies suggest that the health effects due to wildfire smoke exposure are likely to be similar to those of urban particle pollution (Adetona et al. 2016, Liu et al. 2015, Naeher et al. 2007, Reid et al. 2016).

It appears that the risk of fine particle-related health effects varies throughout a lifetime, generally being higher during early childhood, lower in healthy adolescents and younger adults, and increasing during middle age through old age as the incidence of heart and lung disease, hypertension, and diabetes increases. Therefore, certain lifestages (e.g., children) and populations (e.g., people with pre-existing respiratory and cardiovascular disease) should be particularly diligent about taking precautions to limit exposure to wildfire smoke. The following sections provide more specific information on subsets of the population that may be differentially affected by exposure to wildfire smoke.

While the focus of this section is on those groups at greatest risk of experiencing health effects from exposure to fine particles, as noted previously, pollutants emitted from wildfires can undergo atmospheric reactions and form secondary pollutants, such as ozone. Some of the same groups that are at increased risk of health effects due to fine particles are also at increased risk of health effects from exposure to ozone. This includes people with asthma and other lung diseases, children, older adults, and people who are active outdoors (e.g., outdoor workers).

Therefore, the lifestages and population groups considered as being at greatest risk of a health effect from exposure to fine particles and ozone should be aware of the potential effect of these pollutants on their health during wildfire events by checking the Air Quality Index (AQI) forecast each day and following recommendations to reduce fine particle and ozone exposure.

People with asthma and other respiratory diseases. More than 25 million people in the United States, including more than 6 million children, experience chronic lung diseases such as asthma with another 16 million experiencing COPD (CDC 2017, CDC 2018). Air pollution, such as wildfire smoke, can lead to breathing difficulties for people with chronic lung diseases, such as asthma and COPD, and potentially trigger exacerbations of their disease. Extensive evidence from epidemiologic studies focusing on exposure to fine particles demonstrates increased risk of emergency department visits and hospital admissions for asthma and COPD (U.S. EPA, 2009).

Asthma is a condition characterized by chronic inflammation of the bronchi and smaller airways, with intermittent airway constriction, causing shortness of breath, wheezing, chest tightness, and coughing, sometimes accompanied by excess mucus production. During an asthma attack, the muscles tighten around the airways and the lining of the airways becomes inflamed and swollen, constricting the free flow of air. Because children's airways are narrower than those of adults, irritation, such as from wildfire smoke, that might create minor problems for an adult may result in significant obstruction in the airways of a young child. Additionally, minority and impoverished children and adults bear a disproportionate burden associated with asthma and other diseases, which may increase their susceptibility to the health effects of wildfire smoke (Brim et al. 2008, CDC 2014). However, these diseases affect all age and sociodemographic groups.

A significant fraction of the population may have airway hyper responsiveness; an exaggerated tendency of the large and small airways (bronchi and bronchioles, respectively) to constrict in response to respiratory irritants including cold air, dry air, and other stimuli, including wildfire smoke. While airway hyper responsiveness is considered a hallmark of asthma, this tendency may also be found in many individuals without asthma for example, during and following a lower respiratory tract infection. In such individuals, wildfire smoke exposure may cause asthma-like symptoms.

Individuals with COPD -- generally considered to encompass emphysema and chronic bronchitis -- may also experience worsening of their conditions because of exposure to wildfire smoke. Patients with COPD often have an asthmatic component to their condition, which may result in their experiencing asthma-like symptoms. However, because their lung capacity has typically been seriously compromised, additional constriction of the airways in individuals with COPD may result in symptoms requiring medical attention. Researchers have reported that individuals with COPD run an increased risk of requiring emergency medical care after exposure to particulate matter or wildfire smoke. In addition, because COPD is usually the result of many years of smoking, individuals with this condition may also have heart and vascular disease and are potentially at risk of health effects due to wildfire smoke exposure from both conditions.

People with cardiovascular disease. Cardiovascular diseases are the leading cause of mortality in the United States, comprising approximately 30 to 40 percent of all deaths each year (Xu et al. 2018). Most of these deaths occur in people over 65 years of age. Diseases of the circulatory system (e.g., high blood pressure, heart failure, vascular diseases such as coronary artery disease, and cerebrovascular conditions) can put individuals at increased risk of cardiovascular-related events triggered by air pollutants.

Following exposure to particulate matter, people with chronic heart disease may experience one or more of the following symptoms: palpitations, unusual fatigue, or lightheadedness; shortness of breath, chest tightness, pain in the chest, neck, or shoulder. Chemical messengers released into the blood because of particle-related lung inflammation may increase the risk of blood clot formation, angina episodes, heart attacks, and strokes. Studies have linked fine particulate matter to increased risks of heart attacks, and sudden death from cardiac arrhythmia, heart failure, or stroke (U.S. EPA, 2009). Despite this evidence regarding fine particulate matter effects and cardiovascular effects, wildfire-related cardiovascular studies have been inconsistent, although several recent investigations have identified elevated risks of specific health outcomes (Wettstein et al. 2018, Deflorio-Barker et al. 2019).

Children. All children, even those without pre-existing illnesses or chronic conditions, are considered at-risk of experiencing a health effect due to air pollution, including wildfire smoke. Compared to adults, children spend more time outside, tend to engage in more vigorous activity, and inhale more air (and therefore more smoke constituents) per pound of body weight — all of which can affect the developing lungs (Sacks et al. 2011). For these reasons, it is important to try to limit children's vigorous outdoor activities during wildfire events. Although the focus of this document is wildfire smoke, children may encounter other environmental hazards including air pollutants from burning structures and furnishings, and exposure to fire ash if children are present during fire clean up.

Wildfire smoke can persist for days or even months, depending on the extent of the wildfire. Symptoms of wildfire smoke inhalation, which can include coughing, wheezing, difficulty breathing, and chest tightness, are supported by evidence from epidemiologic studies of particulate matter that report increased respiratory symptoms and decreased lung function (U.S. EPA, 2009). Air pollution from wildfires can exacerbate asthma symptoms and trigger attacks. Research has shown a higher rate of asthma emergency department visits and hospital admissions for children, especially infants and very young children, during and after wildfires (Hutchinson et al., 2007). Even children without asthma could experience respiratory symptoms, resulting in school absences and other limitations of normal childhood activities.

In addition to the overt health effects and underlying physiologic differences between children and adults, children may also experience significant emotional distress, resulting from anxiety and grief following a wildfire. It is important to consider not only the potential physical health implications of wildfire smoke on children, but also the potential longer-term psychological implications.

See factsheet Protecting Children from Wildfire Smoke and Ash.

Pregnant women. During pregnancy, physiologic changes, such as higher respiratory rates and increases in blood and plasma volumes, increase a woman's vulnerability to environmental exposures. Additionally, during critical windows of human development, a mother's exposure to wildfire smoke may harm the developing fetus. A few studies have examined potential health effects of wildfire smoke exposure during pregnancy. Holstius et al. (2012) examined the effect of wildfire smoke on pregnancy outcomes in Southern California and reported some evidence indicating a potential reduction in birth weight due to *in utero* exposure to wildfire smoke. In addition, psychosocial stress exacerbated by wildfires is another mechanism through which wildfire events may affect the health of pregnant women and their fetuses (Kumagai et al. 2004). While there are few studies examining the health effects of exposure to wildfire smoke on pregnancy outcomes, there is some available evidence of health effects due to exposures to other combustion-related air pollutants. Specifically, there is substantial evidence of low birth weight due to repeated exposures to cigarette smoke, including both active and passive smoking and an emerging, but still inconsistent body of literature on the health effects of prenatal exposure to ambient air pollution. Specifically, studies examining chronic maternal exposure to ambient particulate matter (U.S. EPA 2009) and indoor biomass smoke (e.g., Amegah et al. 2014) from wood-fired home heating devices have provided some evidence of adverse birth and obstetrical outcomes (e.g., decreased infant birth weight, preterm birth).

Older adults. The number of U.S. adults 65 years of age and older will nearly double between 2012 and 2050 (Ortman et al. 2014). Older adults are at increased risk of health effects from short-term exposures to wildfire smoke because of their higher prevalence of pre-existing lung and heart diseases, and because important physiologic processes, including defense mechanisms, decline with age. Epidemiologic studies of short-term exposures to fine particles have reported greater risks of emergency department visits and hospital admissions and mortality, in older adults (U.S. EPA, 2009). Additional evidence from animal toxicological studies and human clinical studies provides biological plausibility and further support that older adults should limit exposures to fine particle pollution, such as wildfire smoke.

Low socioeconomic status (SES). SES is often defined in epidemiologic studies using a variety of indicators such as educational attainment, median household income, percentage of the population in poverty, race/ethnicity, and location of residence. It is well-recognized that SES is a composite measure that encompasses multiple individual indicators along with other factors and is often measured at the population- or community-level. Epidemiologic studies of fine particulate matter using indicators of SES provide initial evidence that individuals of low SES may be at increased risk of mortality due to short-term exposures. With respect to wildfire smoke the evidence is much more limited, although Rappold et al. (2012) and Reid et al. (2016) reported some evidence that locations classified as having the lowest SES were at the greatest risk of health effects attributed to wildfire smoke.

In addition, SES may contribute to differential exposures to wildfire smoke across communities. For example, access to air conditioning reduces infiltration of particle pollution indoors. Less access to air conditioning may lead to greater exposure to wildfire smoke and greater sensitivity to extreme heat and, subsequently, health disparities across communities. People of color and impoverished children and adults bear a disproportionate burden of asthma and other respiratory diseases and therefore they may be at increased risk of health effects due to wildfire smoke exposure (Brim et al. 2008, CDC 2014). As a result, additional outreach activities and support may be required to properly communicate the actions that people of low SES should take to both reduce and protect themselves from wildfire smoke exposures.

Outdoor workers. Working outdoors during periods of wildfire smoke exposure could result in a range of health effects depending on the underlying health status of the worker. Effects of exposure to wildfire smoke range from eye and respiratory tract irritation to the triggering of an asthma exacerbation or cardiovascular event. For workers that encompass a previously identified at-risk population or lifestage, and workers who are negatively impacted by smoke exposure, some of the same recommendations listed in this document for the general public apply when working outdoors in a smoky environment. See Chapter 5 (Protecting Outdoor Workers) for more information.

Summary

Particulate matter is the principal public health threat from exposure to wildfire smoke. The effects of particulate matter exposure range from eye and respiratory tract irritation to more serious disorders including reduced lung function, bronchitis, exacerbation of asthma and heart failure, and even premature death. Although exposure to fine particles can lead to a range of health effects, certain lifestages and populations are at greatest risk of health effects due to fine particle exposures (Table 1). While evidence about the implications of repeated or prolonged smoke exposures on health is very limited, when smoke exposure is expected to be prolonged, public health officials should consider all options in communicating the importance of actions that can be taken to reduce smoke exposure.

Table 1. Summary of lifestages and populations potentially at-risk of health effects from wildfire smoke exposures.

At-risk Lifestage/ 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 result in 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 (e.g., asthma and COPD) leading to increased medication usage, emergency department visits, and hospital admissions.
People with cardiovascular disease	Rationale: Underlying circulatory diseases result in compromised health status that can result in 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; worsening of heart failure; or abnormal heart rhythms could lead to emergency department visits, hospital admissions, and even death.
Children	Rationale: Children's lungs are still developing and there is a greater likelihood of increased exposure to wildfire smoke resulting from 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: Pregnancy-related physiologic changes (e.g., increased breathing rates) may increase vulnerability to environmental exposures, such as wildfire smoke. In addition, during critical development periods, the fetus may experience increased vulnerability to these exposures. Potential health effects: Limited evidence shows air pollution-related effects on pregnant women and the developing fetus, including low birth weight and preterm birth.
Older adults	Rationale: Higher prevalence of pre-existing lung and heart disease and decline of physiologic process, such as defense mechanisms. Potential health effects: Exacerbation of heart and lung diseases leading to emergency department visits, hospital admissions, and even death.
People of low socioeconomic status	Rationale: Less access to health care could lead to higher likelihood of untreated or insufficient treatment of underlying health conditions (e.g., asthma, diabetes). Less access to measures to reduce exposure (e.g., air conditioning) could lead to higher levels of exposure to wildfire smoke. 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.

II. WILDFIRE SMOKE AND AIR QUALITY IMPACTS

Composition of wildfire smoke

Smoke from combustion of natural biomass is a complex mixture of particulate matter, carbon dioxide, water vapor, carbon monoxide, hydrocarbons and other organic chemicals, nitrogen oxides, and trace minerals. The individual compounds present in smoke number in the thousands. Most research on wildland fire emissions has centered on natural biomass fuels—the vegetative materials comprised of trees, needles, leaves, branches, litter, duff, stumps, grasses, shrubs, and downed trees. Wildfires may also move into the WUI burning homes and structures in the process and thus consuming man made materials in addition to natural fuels. More research is needed to understand potential health impacts of breathing this complex mix of natural and man made material emissions.

The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. EPA has set NAAQS for six principal pollutants, including three pollutants that may be of concern during wildfire smoke events: particulate matter (regulated in two size categories: PM_{10} and $PM_{2.5}$), ground level ozone (O_3), and carbon monoxide (CO).

In wildfire smoke, **particulate matter**, especially the smallest size component $\mathbf{PM_{2.5}}$, is the principal air pollutant of concern for public health. Particulate matter is a generic term for particles suspended in the air, typically as a mixture of both solid particles and liquid droplets. The size of the particles (Figure 1) affects their potential to cause health effects. Particles larger than 10 micrometers in diameter do not usually reach the lungs though they can irritate the eyes, nose, and throat. Particles with diameters less than 10 micrometers (PM_{10}) can be inhaled into the lungs and affect the lungs, heart, and blood vessels. The smallest particles, those less than 2.5 micrometers in diameter ($PM_{2.5}$) are the greatest risk to public health because they can reach deep into the lungs and may even make it into the bloodstream. Most of the effort to quantify, describe, and monitor smoke and health effects from wildfires focuses on $PM_{2.5}$. Particles from smoke tend to be very small, with a size range near the wavelength of visible light (0.4–0.7 micrometers), and therefore efficiently scatter light and impact visibility, which can pose a serious safety risk when smoke crosses roads or impacts airports.

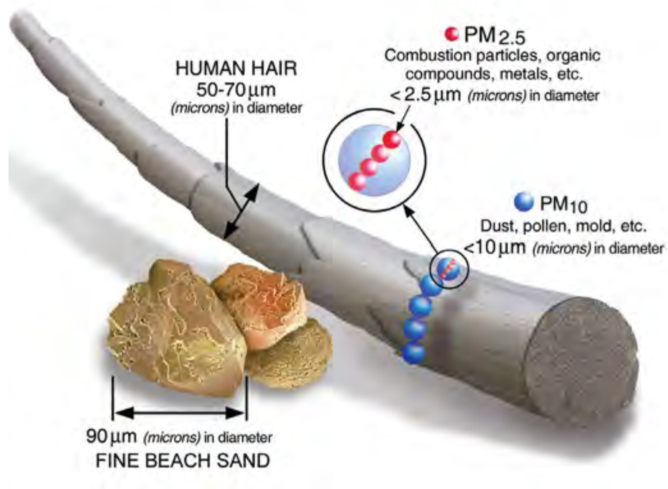


Figure 1. Fine, inhalable particulate matter ($PM_{2.5}$) is the air pollutant of greatest concern to public health from wildfire smoke because it can travel deep into the lungs and may even enter the bloodstream.

Two other pollutants that may be of concern during wildfire smoke events are carbon monoxide and ozone. **Carbon monoxide** is a colorless, odorless gas produced by incomplete combustion of wood or other organic materials. Carbon monoxide dilutes rapidly so is rarely a concern for the general public, or people with heart disease who are at-greater risk from exposure, unless they are in very close proximity to the wildfire (generally within three miles of the fire line and when smoldering fuels are present). Carbon monoxide can be a concern to firefighters close to the fire line. Smoke episodes can also be associated with elevated levels of **ozone**. Ozone is not emitted directly from a wildfire but forms in the plume as smoke moves downwind. It can be further enhanced if given the opportunity to mix with urban sources of nitrous oxides. Note that ozone is not always enhanced downwind of a fire as the formation and breakdown of ozone is a complex photo-chemical process.

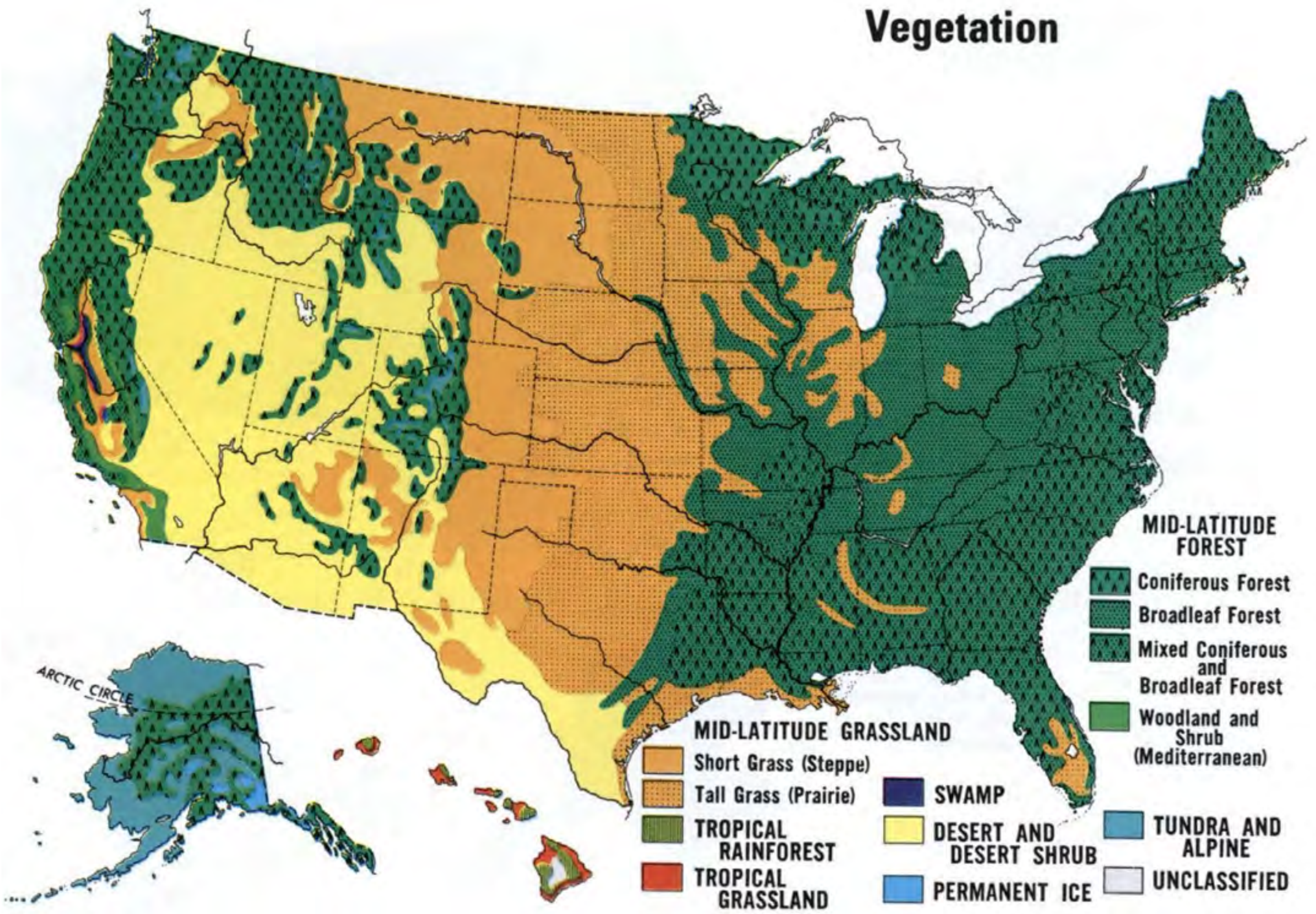


Figure 2. Wildfire rate of spread, fuel consumed, smoke produced, and duration are all influenced by vegetation type. Fires in grass fuels tend to spread quickly and burn out quickly. Fires in brush fuel types can burn hot and spread fast if weather conditions are right. Fires in forest fuel types can range from slow moving to rapidly spreading; long lasting fires in this fuel type tend to produce the most serious and prolonged smoke impacts but smoke can cause problems from wildfires in all fuel types.

Many other chemicals are present in wildfire smoke but at much lower concentrations than particulate matter, ozone, and carbon monoxide. These include an extensive list of HAPs that can be potent respiratory irritants and carcinogens. Given that the specific effects of these pollutants are hard to quantify and measure during an active smoke incident, $PM_{2.5}$ is typically the pollutant that is tracked and monitored, and the pollutant that is used to estimate public health effects from wildfire smoke

Characteristics of wildfires

Wildfires need three conditions to start—fuel, oxygen and a heat source—these three together are known as the fire triangle. Fuel is anything that can burn such as grass, brush, trees and even homes and other structures. The more fuel there is to burn, the more intense a fire can be. Fire needs oxygen to grow and winds increase oxygen supply and fire intensity. Plus, winds can push heat from the fire into new areas, preheating and drying fuels and moving the fire rapidly forward. Heat sources spark the fire and bring fuel temperatures hot enough to ignite and burn. The sun, lightning, burning campfires, cigarettes, sparks, and hot winds are all examples of heat sources

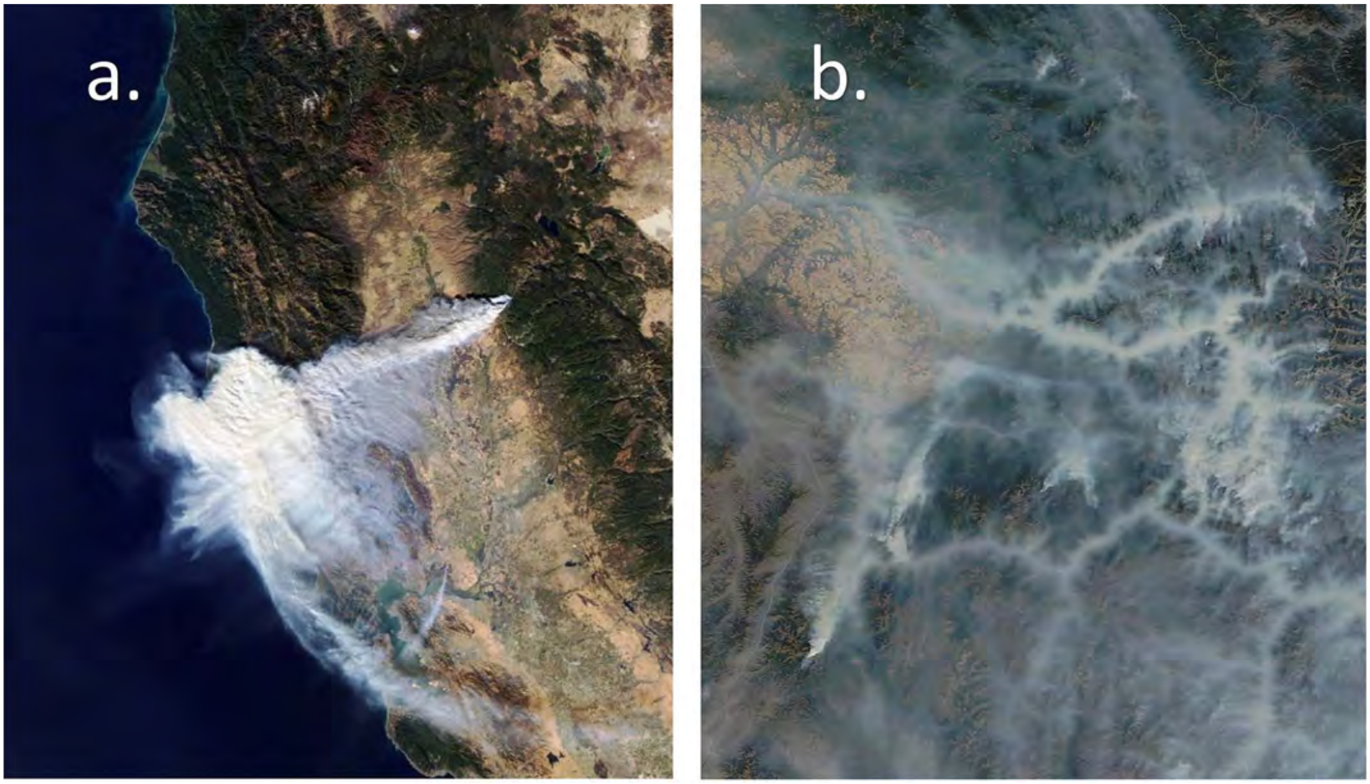


Figure 3. Strong winds can cause rapid fire spread and move smoke into communities far from a wildfire. In 2018, smoke from the Camp fire caused weeks of poor air quality in the San Francisco Bay area (a). Light winds and stable atmospheric conditions cause smoke to pool near a wildfire and flow down valleys to nearby communities as seen in central Idaho in 2012 (b).

necessary to start and promote growth of wildfires. Once ignited, fuels, weather. and topography govern fire behavior and determine how fast the fire spreads, how intensely it burns, and how much smoke it will put into the air on a given day. The changing climate is also influencing the frequency, duration, and severity of wildfires due to a warming climate, longer fire seasons, and increases in drought conditions (Westerling et al. 2003; USGCRP 2018).

Wildland fuels

The general characteristics of wildland fuels help predict some of what will happen during a wildfire smoke incident. Very generally, natural fuel fires can be described in three large and diverse categories: grass, brush, and forest (Figure 2). Wildfires in grass typically spread very rapidly but generally burn themselves out and are brought under control within hours to days of ignition. Brush-type fuels, for example chaparral, gallberry, and ceanothus often contain volatile compounds that result in hot, fast moving fires that are very difficult to control especially if the brush is growing on slopes or in dense clusters. Wildfires in forest fuel types can range from mild to severe in intensity and can spread very slowly or extremely rapidly depending on weather and fuel conditions. Fires in forests can last for weeks or months and are often the wildfire type that results in the most severe and longest duration air quality impacts. Fires in forest fuel types are more likely to be in remote and inaccessible areas making firefighting more difficult. Wildfires of course often burn over multiple fuel types and may start in one fuel type before moving into another.

The amount and type of fuel and its moisture content affect smoke production, as does the stage of combustion (flaming and smoldering). The smoldering phase of a fire when large rotten logs and duff or peat are consumed, can sometimes result in high particle emissions due to less complete combustion than when flames are present. Smoldering fuels are the sign of a cooler fire so smoke generally stays closer to the source and closer to the ground, and air quality impacts are often closer to the fire, especially at night and downslope of smoldering activity.

Meteorology and smoke

Weather conditions such as wind, temperature, and humidity contribute to fire behavior and smoke accumulation. Winds brings a fresh supply of oxygen to the fire and pushes the fire into new fuels. Strong, hot, and dry winds can cause a wildfire to grow very rapidly or "blow up". Winds also move smoke away from the fire and contribute to atmospheric mixing meaning smoke impacts to the public may be lessened near the fire although winds can move smoke long distances into communities far from where the wildfire is burning (Figure 3).

Once smoke enters the atmosphere, its concentration at any one place and time depends on mechanisms of transport and dispersion. Transport refers to whatever process may carry a plume vertically or horizontally in the atmosphere. Vertical transport is controlled by the buoyancy of the smoke plume and stability of the atmosphere. Horizontal transport is controlled by wind. The larger the volume of space that smoke is allowed to enter and the farther it can be transported, the more dispersed and less concentrated it will become.
The intense heat generated by an active wildfire drives smoke high into the air where it remains until it cools and begins to descend. As smoke moves downwind, it becomes more dilute and often more widespread, eventually reaching ground level. Terrain also affects localized weather. For example, as the sun warms mountain slopes, air is heated and rises, bringing smoke and fire with it. After sunlight passes, the terrain cools and the air begins to descend. This creates a down-slope airflow that can alter the smoke dispersal pattern seen during the day. These daily cycles sometimes help predict repeating patterns of smoke impacts in communities.

In the evening, especially in mountain valleys and low-lying areas, temperature inversions in which the air near the ground is cooler than the air above are common. Temperature inversions prevent upward air movement. The lid effect of inversions, coupled with a drop in wind speed, can favor smoke and pollutant accumulation in valleys close to the fire at night. Strong inversions can also allow for smoke to accumulate in an area for days or weeks with little opportunity for clean air to help improve smoke concentrations.

Smoke levels in populated areas can be difficult to predict and will often depend on a suite of local terrain, weather, and fire-behavior-based factors. A wind that usually clears out a valley may simply blow more smoke in or may fan the fires, causing a worse episode the next day. Smoke concentrations change constantly. Sometimes, by the time officials can issue a warning or smoke advisory, the smoke may already have cleared.

Wildland fire management

Most of the tens of thousands of wildfires in the United States are suppressed during initial attack efforts. For many jurisdictions, from federal to private lands, there are specific plans in place addressing fire suppression efforts and response. For federal land managers, land management plans are created with annually updated fire management plans that help guide the appropriate response to a wildfire in a specific area. When these land management plans are revised, they undergo public review, which provides an opportunity for input on how the land is managed by a federal agency.

When there is an ignition, whether human caused or from lightning, the first order of business is always protecting the safety of the public and fire fighters. Some wildfires continue past the initial attack or occur in areas where the risks of attack are high or the likelihood of suppression success is low. Such fires can become large, of long duration, and a significant source of smoke. When these wildfires elude initial attack efforts, exceed local firefighting capabilities, or become large quickly, the land owner or, for federal lands, the agency administrator, has the opportunity to engage external assistance for additional resources to assist their local efforts. On these types of fires, an Incident Management Team (IMT) is usually engaged. The land owner/manager/agency administrator where the wildfire is burning advises the IMT on strategies, constraints, and priorities so that fire management and suppression efforts align with other land management goals in the area.

Fire management strategies designed for a remote wildfire in a wilderness area will be much different from tactics used on lands adjacent to or in communities. Wildfires in remote areas with no risk to public resources may be monitored and largely left to take a natural course and eventually burn themselves out, especially when firefighting resources are scarce. Similarly, only sections of a wildfire may be suppressed due to resource capabilities or threats to public and private resources. Wildfires that threaten homes or other infrastructure will be attacked aggressively. This may include retardant drops from aircraft, bulldozers, fire engines, and multiple 20-person fire crews. Public and firefighter safety is considered above all else in determining the fire management or suppression approach that will be implemented.

Incident Management Teams

An IMT is a group of trained professionals that respond to national, regional, or local emergencies. IMTs are used to manage large-scale, complex wildfire incidents. Team members have expertise in finance, logistics, operations, information, safety, planning, public information, and other areas needed to manage a wildfire. Every incident management team has an incident commander to oversee and control the infrastructure of the team. IMTs work, eat, and sleep in a safe location near the wildfire frequently in camps or nearby public facilities. The IMTs hold both public and cooperator meetings where updates about the fire, upcoming fire tactics, and concerns are discussed. These are important opportunities for engagement on smoke issues.

If smoke and air quality issues become a concern, the IMT can order a technical specialist called an Air Resource Advisor (ARA). ARAs come from a variety of backgrounds but have specialized training in health effects of fine particles, air quality monitoring, smoke dispersion modeling, predicting future air quality, and communicating this information to the public in an understandable and consistent way. Much of the work of an ARA fits well with the work of public health officials because ARAs produce a "Smoke Outlook" that tells when and where smoke levels will be high during the next couple of days. Further discussion and an example outlook can be found in Chapter 4.

III. SPECIFIC STRATEGIES TO REDUCE EXPOSURE TO WILDFIRE SMOKE

In areas where the public is experiencing wildfire smoke exposure, public health and air quality agencies should provide advice on actions that can be taken to reduce smoke exposure. The following strategies to reduce wildfire smoke exposure can be used individually or in combination by individuals and communities, as feasible and appropriate for the smoke event they are experiencing. Recommendations for communicating these strategies to the public are provided in Chapter 5 and summarized in Table 4.

Individuals with heart or lung disease who are concerned about the potential health implications of exposure to wildfire smoke and actions they can take to limit exposures, should be advised to discuss this with their primary health care provider. They should also check the Air Quality Index (AQI, discussed below) each day for the air quality forecast and for information about ways to reduce exposure.

Stay indoors

The most common advisory issued during a smoke episode is to stay indoors. The effectiveness of this strategy depends on how well the building limits smoke from coming indoors, and on efforts to minimize indoor pollution sources. Staying indoors will provide some protection from smoke, especially in a tightly closed, air-conditioned home in which the air conditioner recirculates indoor air. Generally, newer homes are "tighter" and keep ambient air pollution out more effectively than older homes.

Staying inside with the doors and windows closed can reduce the entry of outdoor air into homes, in some cases by a third or more (Howard-Reed et al., 2002). Homes with central air conditioning generally recirculate indoor air, though some smoky outdoor air can still be drawn inside (e.g., when people enter or exit or when the central system can be set to bring in outdoor air). In homes without air conditioning, indoor concentrations of fine particles can approach 70–100% of the outdoor concentrations; however, it is more common that the indoor concentrations of fine particles that come from outdoors are 50% or less of outdoor concentrations when windows and doors are closed (Allen et al. 2012, Chen and Zhao 2011, Singer et al. 2016). In very leaky homes and buildings, outdoor particles can easily infiltrate the indoor air, so guidance to stay inside may offer little protection. In any home, if doors and windows are open, particle levels indoors and outdoors will be about the same.

Sometimes smoke events can last for weeks or even months. These longer events are usually punctuated by periods of relatively clean air. When air quality improves, even temporarily, residents should "air out" their homes to reduce indoor air pollution. People who wish to clean their residences after or between wildfire smoke events should use cleaning practices that reduce re-suspension of particles that have settled, including damp mopping or dusting and using a high-efficiency particulate air (HEPA) filter-equipped vacuum.

Staying indoors is a recommended strategy for avoiding both heat and smoke exposure, as long as the indoor air environment is protected. In high-heat conditions, people are advised to stay cool, stay hydrated, and stay inside. An important caveat about advising people to stay inside and close windows and doors of homes without air conditioning is the increased risk of heat stress. Even without smoke exposure, extreme heat poses a substantial health risk, especially for at-risk groups, including young children, the elderly, those with chronic diseases or disabilities, and pregnant women. These at-risk groups largely overlap with those at higher risk from smoke exposures. Heat-related illnesses include heat exhaustion, heat stroke and death. Warning signs include heavy sweating, muscle cramps, weakness, headache, nausea, vomiting, paleness, confusion, fainting (passing out), and dizziness. To prevent overheating, use cool compresses, misting, showers, baths, and drink plenty of water. In some high-heat conditions, windows and doors will need to be opened to allow cooling even if smoke enters.

People who do not have air conditioning at home should be advised to visit family members, neighbors, or public buildings with air conditioning and appropriate air filtration (such as a shopping mall, library, cooling center, or movie theatre) during high smoke conditions to cool off for a few hours each day. Public health officials should get information about cooling and filtration status of buildings before recommending where people can seek shelter from heat or smoke. Some public buildings may have older heating, ventilating, and air-conditioning (HVAC) systems that use low-efficiency filters (see section below on air conditioners and filters).

In preparation for the fire season or a smoke event, it is a good idea to have enough food on hand to last several days, to minimize driving and trips outdoors. Foods stored for use during the fire season should not require frying or broiling, since these activities can add particles to indoor air. It is also important to have at least a several-day supply of medication for the same reason.

Guidance on protecting office and other indoor workers from wildfire smoke has been developed by the California Division of Occupational Safety and Health (Cal/OSHA), in consultation with technical staff from several other California agencies (Appendix D) . This guidance describes how to maximize the protection provided by HVAC systems common in public and commercial buildings, as well as other steps to protect occupants.

Reduce activity

Reducing physical activity lowers the dose of inhaled air pollutants and reduces health risks during a smoke event. When exercising, people can increase their air intake 10 to 20 times over their resting level. Increased breathing rates bring more pollution deep into the lungs. People tend to breathe through their mouths during exercise, bypassing the natural filtering ability of the nasal passages and delivering more pollution to the lungs. They also tend to breathe more deeply, modifying the usual patterns of lung particle deposition. This guidance addresses outdoor exercise during smoky periods; residents need not be discouraged from indoor exercise in an environment with acceptable air quality.

Reduce other sources of indoor air pollution

Indoor sources of air pollution such as smoking cigarettes, using gas or wood-burning stoves and furnaces, spraying aerosol products, frying and broiling meat, burning candles and incense, and vacuuming can all increase indoor particle levels. Some of these same pollutants are also present in wildfire smoke. Reducing indoor air pollutant emissions during smoke events can decrease indoor particle levels.

Cigarette smoke significantly increases levels of particles and other pollutants. For instance, in a closed room of 125 square feet, it takes only 10 minutes for the smoke of four cigarettes to generate hazardous levels of particles (644 micrograms per cubic meter of air or $\mu g/m^3$ $PM_{2.5}$). The second largest source of indoor air pollutants is indoor combustion sources without proper ventilation to the outdoors. "Room-vented" or "vent-free" appliances such as unvented gas or propane fireplaces, decorative logs, and portable heaters can contribute substantial quantities of particles to indoor air and are of significant concern. Frying or broiling some foods also can produce high levels of particles in the kitchen and dining areas. These sources can also increase the levels of polycyclic aromatic hydrocarbons (PAHs), carbon monoxide, acrolein, and nitrogen oxides, all of which are potentially harmful to health. In addition, small sources such as candles and incense burning can produce surprisingly large quantities of particles and should not be used during wildfire smoke events. To avoid re-suspending particles, do not vacuum during a smoke event, unless using a HEPA-filter-equipped vacuum. When cleaning, use a damp mop or damp dust cloth to minimize re-suspending settled particles.

Use air conditioners and filters

When wildfire risk rises, and before the smoke arrives, public health agencies can help their communities prepare by developing public service announcements with information about upgrading the filters in their central air systems. The message should include information about different filter types, the importance of stocking up on filters ahead of wildfire season, and how to turn off fresh air intakes. Highlight the importance of creating clean air spaces in homes with individuals in at-risk groups and encourage residents to install high-efficiency filters (MERV 13 or higher), if possible. Engage with local health care professionals and provide information they can pass on to their patients. A fact sheet on indoor air filtration and air cleaners is available at: https://www3.epa.gov/airnow/smoke_fires/indoor-air-filtration-factsheet-508.pdf

Homes with central air conditioners generally have lower concentrations of particles from the outdoors compared to homes that use open windows for ventilation. Much less is known about the effect of using various types of room air conditioners (e.g., window units) and their air filters on smoke concentrations in homes. Most air conditioners are designed by default to recirculate indoor air. Those systems that have both "outdoor air" and "recirculate" settings need to be set on "recirculate" during smoke events. Other types of air conditioners, such as swamp coolers, can actually bring in large quantities of outdoor air. Below is a brief overview of common types of cooling systems.

Central air systems

Central heating and air conditioning systems (and some room air conditioners) contain filters that remove some airborne particles with different degrees of efficiency. The most helpful parameter for understanding the efficiency of HVAC filters is the fractional removal efficiency. The most widely used test method for HVAC filters in the United States is the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 52.2, which evaluates the removal efficiency for particles 0.3 to 10 µm in diameter. Results are reported as a Minimum Efficiency Reporting Value (MERV) ranging from MERV 1 to MERV 16 based on the average removal efficiency across three particle size ranges: 0.3–1 µm, 1–3 µm, and 3–10 µm (Table 2). Other commercially common proprietary rating systems for in-duct air filters include the Microparticle Performance Rating (MPR) and Filter Performance Rating (FPR). In general, the higher the filter rating, the higher the filter's removal efficiency for at least one particle size range.

If possible, the HVAC filter should be replaced with a pleated medium- or high-efficiency particle filter. Higher-efficiency filters (e.g., filters rated at MERV 13 or higher) are relatively inexpensive and preferred because they can capture more of the fine particles associated with smoke and can reduce the amount of outdoor air pollution that gets indoors. However, caution must be taken to ensure that the central system is able to handle the increased airflow resistance from a higher-efficiency filter. Consultation with an HVAC technician or the central air system manufacturer may be necessary to confirm if or which high-efficiency filters will work with an individual system. Filters need to be replaced regularly and should fit the filter slot snugly. Filters only remove particles while the system fan is operating and passing air through the filter. Regardless of whether a filter upgrade has been performed, during a wildfire smoke event, the central system's circulating fan can be set to operate continuously (i.e., fan switch on the thermostat set to "ON" rather than "AUTO") to obtain maximum particle removal by the HVAC filter, although this will increase energy use and costs (Fisk and Chan 2017). The thermostat can be reset back to "AUTO" after the wildfire smoke clears.

In addition to high- and medium-efficiency filters, electrostatic precipitators (ESPs) or other electronic particle air cleaners can sometimes be added by a technician to central air conditioning systems to keep particle levels in indoor air within acceptable levels during a prolonged smoke event. However, **ESPs may produce some amount of ozone as a byproduct**, so only ESPs that have been independently tested and produce little or no ozone should be used.

For newer air conditioners with a "fresh air ventilation system" that brings in outdoor air continuously or semi-continuously, the "fresh air" setting for the system should be turned off during smoke events. This may require closing the outdoor air damper or sealing off outdoor air intakes, setting the system on "recirculate" only, or turning off the energy- or heat-recovery ventilator or exhaust fans that are part of the system. If the control system instructions are not clear or accessible, residents should contact their builder or heating and cooling contractor to help temporarily adjust the system. However, residents should also place a reminder tag in a visible spot so that they reset the system once the smoke clears.

Many newer homes currently have whole-dwelling mechanical ventilation systems that intentionally bring outdoor air inside, often designed to meet the requirements of ASHRAE Standard 62.2. This can be achieved through dedicated supply ductwork (creating positive pressure in the building), controlled exhaust ventilation (creating negative pressure in the building), or "balanced" ventilation strategies that typically employ a heat recovery or energy recovery ventilator (HRV/ERV). Mechanical ventilation in new homes is now required by building codes in some jurisdictions. These systems may need to be turned off or adjusted during periods of high outdoor air pollution from wildfires to avoid entry of outdoor air pollutants, especially exhaust ventilation systems. Mechanical ventilation systems used in public and commercial buildings differ and are discussed further in appendices B and D.

Swamp coolers

Many older homes use evaporative coolers, known as "swamp coolers," to condition the air in the home. A cooler unit operates by evaporating water off large pads located in the cooler housing. The unit also contains the fan motor, fan, water tray, and pump and is usually located on the roof of a house. The coolers rely on bringing large volumes of outside air into the home and they will not cool effectively if the home is sealed up and the incoming air cannot be exhausted from the home. Although a laboratory study has shown that evaporative coolers can reduce PM_{10} up to 50%, and $PM_{2.5}$ by 10–40% (Paschold et al., 2003), other outdoor pollutants such as ozone are not filtered out and can reach indoor levels that are nearly equal to the outdoor levels. Therefore, unless there is a heat emergency, evaporative coolers should not be used during periods when there is heavy smoke outside.

Ductless mini-split systems

Some new or recently renovated homes may have ductless mini-split heat pumps or air conditioning systems. Ductless mini-split systems, which use an air handling unit mounted inside the home's pressure boundary, will still cool effectively in a home that has been sealed up to minimize smoke infiltration and generally do not compromise indoor air quality. These systems have the advantage of not requiring

Table 2. Particle size efficiency for select MERV ratings*

MERV Rating	Average Particle Size Removal Efficiency (%)		
	Particle Size (μm)		
	0.3–1.0	1.0–3.0	3.0–10.0
Low (1–4)	n/a	n/a	<20
Medium (5–8)	n/a	>20+	20 to >70
Medium (9–12)	20 to >35++	35 to >80	75 to >90
High (13–16)	50 to >95	>85	>90
HEPA (17–20)**	≥99.97		

*Adapted from ANSI/ASHRAE Standard 52.2

**Not part of the official ASHRAE Standard 52.2 test but added for comparison purposes

n/a: Not applicable to MERV rating (not tested)

+ Not applicable for MERV 5–7

++Not applicable for MERV 9–10

ductwork throughout the attic or basement space. From an air-balance standpoint, these systems do not significantly affect the air pressure in the home and do not result in extra air being brought into or exhausted from the home. Some mini-split systems include ducts connected to a low-profile air handler, which may be installed in an unconditioned area and may be susceptible to outdoor air exchange issues, depending on the effectiveness of the duct sealing during installation.

Window-mounted and portable air conditioners

Some residences are cooled or heated using window-mounted air conditioners. To function properly and efficiently, these units must form a tight seal with the window frame in which they are mounted. People who have window units should be advised to check the quality of the seal by looking around the perimeter of the window unit for any visible gaps. Light or air leaking in from the outside is an easy way to determine whether the seal is tight. Also, window units can be operated in recirculation mode or fresh air mode. During a high smoke event, people should be advised to set the window AC unit to operate in recirculation mode.

Use of a single-hose portable air conditioner might result in outdoor smoke being drawn into the home. Portable air conditioners are usually used to condition the air in a single room of the home. These units have a cooling capacity that can range from 6,000 to 15,000 BTU and many of these units also have a heating mode of operation. Depending on the make and model, a portable air conditioner will have either a single- or dual-hose configuration. The single-hose configuration expels hot exhaust air to the exterior of the home, but the supply air is taken from the home itself, so the net effect is that the room is placed under slight negative pressure. This means that air is drawn into the home through any leaky points in the building envelope. This is not a problem with dual-hose configurations, because they draw and deliver supply air from the outside so the air pressure inside the room remains balanced.

Use room air cleaners

Choosing to buy an air cleaner is a decision that ideally should be made ***before*** a smoke emergency occurs, particularly in homes with occupants in at-risk groups. During a smoke emergency, it may be hazardous to go outside or drive, and appropriate devices may be in short supply. It is unlikely that local health officials or non-governmental organizations will be able to buy or supply air cleaners to those who might need them. Note that air cleaners are frequently referred to as "air purifiers" by retailers and the general public.

Choose an air cleaner appropriate for the size of the indoor environment

Air cleaners can help reduce indoor particle levels, provided the specific air cleaner is properly matched to the size of the indoor environment. Room air cleaners are available as portable units designed to clean the air in a single room ($90–$900). Central air cleaners, which may be large portable units or in-duct units installed by an HVAC professional, are intended to clean the whole house ($450–$1,500). Central air cleaners can be more effective than room air cleaners (depending on how much they are operated), although two or more well-placed portable air cleaners can be equally effective, and their cost may still be less than a large central air cleaner.

Room air cleaner units should be sized to provide a filtered airflow at least two to three times the room volume per hour. Most portable units will state on the package the unit's airflow rate, the room size it is suitable for, its particle removal efficiency, and perhaps its Clean Air Delivery Rate (CADR). The CADR is a rating that combines efficiency and airflow.

The Association of Home Appliance Manufacturers (AHAM) maintains a certification program for air cleaners. The AHAM seal on the air cleaner's box lists separate CADR numbers for tobacco smoke, pollen, and dust. Higher numbers indicate faster filtration of the air. For wildfire smoke, choose a unit with a tobacco smoke CADR at least 2/3 of the room's area. For example, a 10' x 12' room (120 square feet) would require an air cleaner with a tobacco smoke

CADR of at least 80. If the ceiling is higher than 8', an air cleaner rated for a larger room will be needed.

Choose an air cleaner that effectively removes particles without producing ozone

The two common mechanisms for particle removal include:

- Mechanical air cleaners that contain a fiber or fabric filter. The filters need to fit tightly in their holders and be cleaned or replaced regularly. HEPA filters (and Ultra-Low Penetration Air [ULPA] filters, which are not generally available for residential use) are most efficient at removing particles.
- Electronic air cleaners, such as electrostatic precipitators (ESPs) and ionizers. ESPs use a small electrical charge to collect particles from air pulled through the device. Electronic air cleaners usually produce small amounts of ozone (a respiratory irritant) and some, especially those that are combined with other technologies, may produce substantial levels of ozone (see next section on Ozone Generators). Only ESPs that have been independently tested and documented to produce little or no ozone should be used. Ionizers, or negative ion generators, cause particles to stick to materials (such as carpet and walls) near the device and are also often a source of ozone. Ionized particles deposited on room surfaces can cause soiling and, if disturbed, can be resuspended into the indoor air.

Only portable (room) air cleaners that do not produce ozone above 0.050 ppm should be used (see below). The California Air Resources Board (CARB) certifies air cleaners that produce little or no ozone and only CARB-certified air cleaners may be sold in California.

A list of CARB-certified air cleaners can be found at: https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm.

Place and operate the air cleaner to maximize particle removal

Room air cleaners will provide the most protection when placed where people spend the most time, such as a bedroom. A good portable air cleaner placed in a bedroom may be particularly helpful to a person with asthma or COPD. For retired or homebound individuals, the portable room air cleaner should be set up in whichever room is used the most. To maximize air cleaner effectiveness, operate it continuously, or as often as possible. Use the highest fan speed and make sure the air flow to the air cleaner is not obstructed. Keep outside doors and windows closed to prevent additional particles from entering the room.

Air cleaners can be used in combination with central air system filter upgrades described in the preceding section to maximize the reduction of indoor particles. Air cleaners alone can effectively reduce particle concentrations even in homes that do not have central air conditioning if windows and doors remain closed and excessive heat is not a concern. Under normal (non-smoky) conditions, portable air cleaners fitted high-efficiency filters can reduce indoor particle concentrations by as much as 90 percent (Singer et al. 2016). During a wildfire smoke event, portable air cleaners fitted with high-efficiency filters may reduce indoor particle concentrations by as much as 45% (Fisk and Chan 2017).

Air cleaners for gases and odors

Most air cleaners are not effective at removing gases and odors, although some specialized models that perform this task well are available. Devices that remove gases and odors can cost more than particle air filters, both to purchase and maintain. They force air through materials such as activated charcoal or alumina coated with potassium permanganate. However, with smaller-sized air cleaners, the filtering medium can become quickly overloaded and may need to be replaced often. Large gas-removing devices may be useful for individuals that encompass an at-risk lifestage or population and may require less-frequent replacement of the filtering medium. New models that combine particle and gas removal are available in both portable and in-duct models.

Do-it-yourself box fan air cleaners

Some organizations provide instructions to assemble a do-it-yourself (DIY) box fan air cleaner by attaching a high-efficiency filter to a box fan. There is currently some limited evidence to support the filtration efficacy of these DIY devices. However, concerns have been raised that the box fan motor may overheat when operated with a filter attached. We expect there will be more research conducted on the safety and efficacy of DIY air cleaners in the coming years. In the meantime, though there is not enough evidence for us to endorse their use, we acknowledge that during a wildfire smoke event some people may choose to assemble a DIY air cleaner to reduce their exposure to wildfire smoke. Those who make this choice should be advised to use the device with caution and not to operate it unattended or when sleeping, to avoid any potential fire or electrical hazard.

For more information about residential air cleaners:

https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home

https://www.arb.ca.gov/research/indoor/aircleaners/consumers.htm

http://ahamverifide.org

Avoid ozone generators

Some devices, known as ozone generators, personal air purifiers, "super-oxygen" air purifiers, and "pure air" generators, are sold as air cleaners, but the position of public health agencies, including the California Air Resources Board and U.S. Environmental Protection Agency, is that they do more harm than good. These devices are designed to intentionally produce large amounts of ozone gas. Ozone generator manufacturers claim that ozone can remove mold and bacteria from the air, but this occurs only when ozone is released at levels many times higher than those that are known to harm human health.

Relatively low levels of ozone can irritate the airways, causing coughing, chest pain and tightness, and shortness of breath. Low levels of ozone can also worsen chronic respiratory diseases such as asthma and compromise the body's ability to fight respiratory infections. As a result, using an ozone generator during a smoke event may actually increase the adverse effects from the smoke. In addition, ozone gas does not remove particles from the air and can lead to particle formation; ozone reacts with certain chemicals commonly found indoors to produce particles and formaldehyde. California now prohibits the sale of air cleaners that emit potentially harmful amounts of ozone. A list of air cleaners that California has certified to emit little or no ozone is available at:

https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm

For more information about ozone generators marketed as air cleaners:

https://www.epa.gov/indoor-air-quality-iaq/ozone-generators-are-sold-air-cleaners

https://www.arb.ca.gov/research/indoor/ozone.htm

Humidifiers

Humidifiers are not air cleaners and will not significantly reduce the number of particles in the air during a smoke event. Nor will they remove gases like carbon monoxide. However, humidifiers and dehumidifiers (depending on the environment) may slightly reduce pollutants through condensation, absorption, and other mechanisms. In an arid environment, one possible benefit of running a humidifier during a smoke event might be to help the mucous membranes remain comfortably moist, which may reduce eye and airway irritation. However, if not properly cleaned and maintained, some humidifiers can circulate mold spores and other biological contaminants. The usefulness of humidification during a smoke event has not been studied.

Create a clean room at home

Creating an in-home "clean room" is a good exposure reduction strategy for people who live in areas regularly affected by wildfire smoke—especially those with pre-existing conditions that increase the risk of air pollution-related health effects. It is also a good strategy for those who must work outside so that they can breathe cleaner air while indoors at home after work. A good choice for a clean room is an interior room with few windows and doors, such as a bedroom. Anyone who cannot create an adequate clean room in their own home should be encouraged to seek out cleaner air shelters or cleaner air spaces located in their communities for periods of respite from the smoke (see discussion below).

Some suggestions for creating and maintaining a clean room:

- Keep windows and doors closed.
- Set up a properly sized room air cleaner (see above) to help remove particles from the air while emitting little or no ozone.
- Run an air conditioner or central air conditioning system. If the air conditioner provides a fresh air option, keep the fresh-air intake closed to prevent smoke from getting inside. Make sure that the filter is clean enough to allow good airflow indoors.
- Do not vacuum anywhere in the house, unless using a HEPA-filter equipped vacuum.
- Do not smoke or burn anything, including candles or incense, anywhere in the house.
- Keep the room clean by damp mopping or dusting with a damp cloth.
- Long-term smoke events usually have periods when the air is better. When air quality improves, even temporarily, air out your home to reduce indoor air pollution.
- People in homes that are too warm to stay inside with the windows closed or who are at-risk of smoke-related health effects should seek shelter elsewhere. Keep in mind that many particles will enter the home even if all of these steps are taken.
- For additional information, see the EPA website Create a Clean Room to Protect Indoor Air Quality During a Wildfire.

Cleaner air shelters and cleaner air spaces

Public health officials in areas at risk from wildfire smoke episodes should identify and evaluate public spaces where people can seek relief from wildfire smoke. For the purposes of this guide, these public spaces are defined as either cleaner air shelters or cleaner air spaces. People should be made aware that driving to and from a public shelter or cleaner air space for short-term relief and the stress of evacuating for an extended stay in a shelter can also have health consequences. Therefore, whether to create a clean room at home or leave for a public shelter or cleaner air space will depend on factors that the individual must assess.

Cleaner air shelters

Cleaner air shelters are public spaces for people who are displaced by wildfire or smoke. People who take refuge in these shelters may only need to stay overnight or may need the shelter for extended periods (days or even weeks). Some examples of cleaner air shelters are school gymnasiums, buildings at public fairgrounds, and civic auditoriums. A cleaner air shelter may also be considered an evacuation shelter but be aware that not all evacuation centers provide cleaner air for the occupants. Therefore, public health officials in areas at risk from wildfire smoke episodes should identify and evaluate public spaces where people can shelter from wildfire smoke well in advance of fire season. Guidance for identifying or setting up a cleaner air shelter is provided in Appendix B.

Cleaner air spaces

During severe smoke events, it is often impractical or impossible for people to set up a clean room in their homes. Individuals who cannot create an adequate clean room should be encouraged to seek out cleaner air spaces located in their communities for periods of respite from the smoke. People can find temporary relief from smoke, heat, or cold at public cleaner air spaces for several hours, or perhaps for the better part of a day; however, many of these commercial spaces and public facilities are unlikely to be open at night. Examples of cleaner air spaces could include libraries, museums, shopping malls, theaters, sports arenas, senior centers, and any indoor area with effective particle filtration and air conditioning.

Inside vehicles

Individuals can reduce the amount of smoke in their vehicles by keeping the windows and vents closed, and, if available, operating the air conditioning in "recirculate" mode. However, in hot weather, a car's interior can heat up very quickly to temperatures that far exceed that outdoors and heat stress or heat exhaustion can result. Children and pets should **never** be left unattended in a vehicle with the windows closed. The ventilation systems of older cars typically remove a small portion of the particles coming in from outside. Newer models may have better air filters that remove more particles from the air, but the vehicle owner should not assume that they will get the same level of protection they would get from a dedicated clean room or cleaner air space. Most vehicles can recirculate the inside air, which will help keep the particle levels lower.

Drivers should check the owner's manual and assure that the system is set correctly to minimize entry of outdoor smoke and particles. However, studies have shown that carbon dioxide levels can quickly accumulate to very high levels (possibly exceeding 2500 parts per million) in newer cars due to occupants' exhaled breath when vents and windows are closed and the recirculation setting is used (Fruin et al. 2011, Hudda and Fruin 2018, Lee and Zhu 2014). Therefore, if driving a recent model vehicle for more than a short period of time, it may be a good idea to briefly open windows or vents occasionally when smoke levels are low to avoid the build-up of carbon dioxide. Finally, vehicles should not be used as a shelter, but rather as a means of transportation to indoor locations with cleaner air.

Respiratory protection for wildfire smoke and ash

Respiratory protection (commonly referred to as "masks") can be useful for reducing personal inhalation of wildfire smoke or ash. Respirators are widely available and offer some protection for adults if selected and used properly, although the public should be advised to take more effective measures first to limit their exposures. Information provided in this section describes selection and proper use of tight-fitting particulate respirators certified by the National Institute for Occupational Safety and Health (NIOSH).

Drawbacks to recommending the use of respirators include the possibility that users will select the wrong type or use them incorrectly. A stand-alone factsheet, Protect Your Lungs from Wildfire Smoke or Ash, has been designed for the public and includes links to other resources. The use of respiratory protection without first ensuring that no medical conditions exist that would make use of respiratory protection a risk or first providing users with "fit tests" to ensure a reliable seal to the face is not ideal although inevitable in the case of public wildfire smoke exposure. A fit test is a procedure that quantitatively or qualitatively evaluates the fit of a specific model and size of respirator on an individual and is required in workplace settings. However, the respirators described in this section are available in multiple sizes and are likely to provide some protection to users who can achieve a reasonably close fit to the face, even without fit testing.

Respirators described in this section would also help to protect the public involved in cleaning up fire ash. There is additional guidance in this document on wildfire ash, and a factsheet for the public on cleaning up ash, Protect Yourself from Ash.

Respiratory protection use in workplace situations is beyond the scope of this section, see Chapter 5, Protecting Outdoor Workers. Employers who anticipate that their workers may need to wear respiratory protection are expected to put in place a full respiratory protection program prior to use.

In emergency situations, employers should consult the applicable Occupational Safety and Health Administration (OSHA) program for current guidance. Where respirator use is not required by OSHA regulations or by the employer, the employer may provide respirators at the request of employees or permit employees to use their own respirators, if the employer determines that such respirator use will not in itself create a hazard and provides some basic information about proper use and the limitations of respirators.

Children and respirator use

Respirators are not made to fit children and will not protect them from breathing wildfire smoke. Children are especially at risk from exposure to wildfire smoke because their lungs are still developing. Reduce children's exposure to wildfire smoke by checking air quality, keeping them indoors, creating a clean air room, and being ready to evacuate if necessary. See also the factsheet Protecting Children from Wildfire Smoke or Ash.

NIOSH does not currently certify respirators for children. As new research findings on efficacy become available, guidance by U.S. government agencies may be issued on the proper use of respirators by older children.

Who may need to wear a respirator

The most effective action the public can take to reduce the risk of health effects from inhalation of wildfire smoke or ash is to stay indoors or limit the time spent outdoors during wildfire smoke emergencies. People at higher risk of adverse effects, such as those with heart or lung disease and older adults, should check with their health care providers before using a respirator, since using a respirator can make it harder to breathe. If the smoke event is expected to be prolonged, these groups should consider temporary relocation out of the smoky area.

People who must be outdoors for extended periods of time in smoky air or in an ash-covered area may benefit from using tight-fitting, NIOSH-approved N95 or P100 respirators to reduce their exposures. People experiencing health effects from a smoky environment, even if indoors, may also benefit from using N95 or P100 respirators if they cannot move to locations with better air quality or take other steps to clean their indoor air.

For people who wish to wear respirators, learning how to select respirators and use them correctly is important for achieving the best protection possible.

Figure 4. Two types of N95 disposable particulate respirators. Note the presence and placement of the two straps above and below the ears. Photos courtesy of the California Department of Public Health

Choosing the correct respirator

Tight-fitting "particulate" respirators are designed to capture or filter out particles from contaminated air before the user can breathe them in. A "filtering facepiece" respirator, commonly called a disposable N95 or P100 respirator, has two straps and a facepiece made entirely of filtering material (Figure 4). Respirators must be certified by NIOSH, and the words "NIOSH" and either "N95" or "P100" will be printed on the facepiece by the manufacturer. The user should select a size and model that fits over the nose and under the chin and seals tightly to the face. Any leakage around the face seal causes unfiltered air to enter and be inhaled by the wearer, reducing or eliminating the ability of the respirator to provide protection. A good seal is not possible if the user has a beard or other excess facial hair where the respirator seals to the face.

The numbers "95" and "100" on a respirator facepiece indicate that the filter material captures 95% or 99.97%, respectively, of particles passing through it when tested using particles 0.3 micron in diameter that are the hardest to capture. However, when used by the public without individual user fit testing, there is likely little difference in effectiveness between N95 and P100 respirators, as leakage around the face seal will be a more significant factor determining effectiveness than filtration efficiency. "N" indicates filter material that is not resistant to degradation in the presence of oil mist; "P" identifies filters that are resistant. In environments where smoke or ash are present, N95 or P100 respirators can be used. Both types can be found in retail pharmacies, in hardware and home repair stores, or online. NIOSH-approved respirators with filters designated as N99, N100, R95, P95, and P99 are far less common, but would also be appropriate.

Other non-disposable NIOSH-certified respirators, such as elastomeric half-masks, can also be used for wildfire smoke or ash. They have a tight-fitting, flexible, re-useable half-mask facepiece and replaceable filters or cartridges; these provide similar protection from particles when they are used with N95 or P100 particulate filters. This type of respirator may also be purchased with a combination filter and organic vapor cartridge, which can reduce exposure to irritating gases in smoke, such as aldehydes. (Disposable N95 or P100 respirators remove only particles, not gases or vapors.)

How to use a tight-fitting respirator

To get a secure fit, a respirator user should put the facepiece over the nose and under the chin and position one strap at the back of the neck below the ears, and the other at the crown or top of the head, above the ears. Incorrect strap placement is a common problem with untrained respirator users and may compromise the face seal and reduce effectiveness.

Users must be clean-shaven where the respirator touches the skin. A good face seal is not possible with facial hair. Care should be taken so that hair, eyeglasses, or other objects do not interfere with the seal of the respirator to the face.

Some N95 or P100 respirators have a metal nose clip that should be pinched around the bridge of the nose to fit securely. The user should follow any instructions provided by the manufacturer for checking for a tight face seal.

Disposable respirators should be discarded when they become dirty, wet, deformed in shape, or when it gets harder to breathe through them.

Possible risks from wearing a respirator

Wearing a respirator can make it harder to breathe. Public health officials should encourage members of the public who have heart or lung problems to consult their health care provider before using a respirator.

Anyone who has difficulty breathing while wearing a respirator, feels dizzy, faint, or claustrophobic or has other symptoms, should remove it and go to a place with cleaner air.

Wearing a respirator, especially if a person is physically active or in a hot environment, may increase the risk of heat-related illness. Users should take periodic breaks from physical activity or, if possible, rest in a location with cleaner air where the

Figure 5. A one-strap paper mask is not a respirator and provides little or no protection from smoke particles. Photo courtesy of the California Department of Public Health

Figure 6. A surgical mask is designed to capture infectious particles generated by the wearer, is not a respirator, and provides little or no protection from smoke particles. Photo courtesy of the California Department of Public Health

respirator can be removed. Rest in a cooler area such as in shade and adequate hydration are important for heat illness prevention, as is gradually acclimating to physical activity in hot locations. Symptoms such as dizziness, nausea, or feeling faint should prompt the user to remove the respirator and seek medical attention or emergency care as appropriate.

Certain "masks" do not provide protection

The public should be cautioned that masks with one-strap nuisance dust masks (Figure 5) or surgical or procedure masks with two straps that loop around the ears (Figure 6) are not respirators. They are not designed to seal tightly to the face and will not provide protection from wildfire smoke or ash. Bandanas (damp or dry), handkerchiefs, and tissues held over the mouth and nose also should not be relied on for protection.

Handling respirator shortages

In a large-scale wildfire smoke emergency, local supplies of N95 and P100 respirators may become limited or exhausted. Local health officials might want to monitor respirator availability and consider ways to increase the supply if necessary. Extra respirators may be available from regional or state stockpiles of personal protective equipment, or directly from respirator manufacturers and distributors of safety equipment.

Respiratory protection resources

An excellent (but fairly technical) NIOSH article, Non-occupational Uses of Respiratory Protection – What Public Health Organizations and Users Need to Know, discusses common mistakes of untrained users as well as best practices and provides references to relevant studies.

NIOSH has a searchable website entitled Approved N95 Particulate Filtering Facepiece Respirators that lists NIOSH-approved N95s alphabetically by manufacturer.

Public health officials can find additional information on the NIOSH Respirator Trusted-Source Information website.

Avoiding smoky periods

Smoke levels from wildfires often change substantially over the course of the day, so there may be opportunities for the public to plan necessary trips outside at times of day that avoid the worst periods of smoke. Ground-level smoke impacts are often forecasted and posted on state smoke blogs in states that use these outreach tools. For example, officials in California, Idaho, Oregon, Washington, currently post forecasts to smoke blogs during fire season. Forecasts can also be found on the Inciweb site by specific named wildfire incidents and at the Wildland Fire Air Quality Response Program page (https://wildlandfiresmoke.net). For communities near active wildfires, smoke impacts often follow a pattern such as nighttime smoke draining downhill and settling into valleys before lifting out the next day. Communities farther downwind of a fire may see smoke arrive in the mid-to-late afternoon and occasionally linger overnight. Either way, it is sometimes possible for people to plan their days around the smokiest times in order to minimize exposure. Public health officials can recommend the use of NowCast AQI (current air quality in terms of the AQI) values from nearby or representative monitors to help people identify and avoid the smokiest times of day (see). Visual range-based estimation can be used if no monitoring is representative of the impact areas. Links to smoke forecasts can be disseminated to provide daily smoke impact patterns in your local Public Service Announcements (PSAs) (see Chapter 5). Chaper 5 describes the Wildland Fire Air Quality Response Program and provides an example of a smoke forecast from a large wildfire.

Closures

The decision to close schools, curtail business activities, or cancel public events is made at the local level and will depend upon predicted smoke levels and other local conditions. Check to see if your state or local air quality or public health agencies have developed guidance that local health officials can reference when trying to evaluate when or where closures should occur. Other factors to consider are whether pollutant levels inside schools and businesses are likely to be similar to or lower than those in homes. Children's physical activity may be better controlled in schools than in homes. On the other hand, smoky conditions may make travel to school hazardous. In many areas, it will not be practical to close businesses and schools, although partial closures may be beneficial. Closures and cancellations can target specific groups (e.g., the at-risk groups described earlier) or specific high-risk activities, such as outdoor sporting events and practices. Curtailing outside activities can reduce exposures, as can encouraging people to stay inside and restrict physical activity.

Evacuation

The most common reason for evacuation during a wildfire is the direct threat of engulfment by the fire, rather than exposure to smoke. Leaving an area of thick smoke may be a good protective measure for members of at-risk groups, but it is often difficult to predict the duration, intensity, and direction of smoke, making this an unattractive option to many people. There is stress associated with evacuation and most people do not want to leave their homes. Even if smoky conditions are expected to continue for weeks, it may not be feasible for a large percentage of the affected population to evacuate. Moreover, the process of evacuation can entail serious risks, particularly if poor visibility makes driving hazardous. In these situations, the risks posed by driving need to be weighed against the potential benefits of evacuation. Therefore, in areas where fires are likely to occur, public health officials are encouraged to develop plans to help at-risk groups shelter locally.

Where individuals are evacuated to a common center because of fire danger, public health officials need to pay particular attention to the potential for smoke to affect the evacuation center itself. It is not always possible to locate evacuation centers far away from smoky areas, or to expect that evacuees will be able to take the steps necessary to reduce their exposures in their new surroundings. Public health officials should consider informing incident commanders if this situation could arise and supplying evacuees with information and materials to further reduce exposures, including provision of a cleaner air shelter within the evacuation center, if possible, as well as other means of respiratory protection. (See "Respiratory Protection" above.) It is important to consider smoke levels when allowing those evacuated for fire safety reasons to return to their homes. Medical capability (from available transport to urgent care and hospital capacity) to address smoke induced medical situations should be assessed if smoke levels are predicted to be high. Additionally, the smoke from smoldering natural and (if structures are burned in fires) possibly manmade materials pose ongoing hazards that should be considered.

Summary of strategies to reduce smoke exposure

The public should be encouraged to prepare to minimize trips out of the home before fire season arrives by having food and medicine on hand to last several days. Foods stored for use during a smoke event should not require frying or broiling, since these activities can add particles to indoor air.

When smoky conditions are expected, people can pursue a number of strategies to reduce their exposure. Those with moderate to severe heart or lung disease might consider staying with relatives or friends who live away from the smoke impact area. If smoke is already present in substantial quantities, such individuals may want to evaluate whether their exposure during evacuation would be greater than staying at home and using other precautions described above. Depending on how sensitive they are to smoke, as smoke levels increase it may be appropriate for some people to stay in a clean room in the home, relocate temporarily to a cleaner air shelter, or to leave the area entirely if it is possible and safe to do so.

Everyone in a smoky area should avoid strenuous work or outdoor exercise to the greatest extent possible. They should avoid driving or if driving is necessary, run the air conditioner on recirculate mode to avoid drawing smoky air into the car. Smoke can also impair roadway visibility making driving hazardous. Guidance on protecting outdoor workers from wildfire smoke has been developed by the California Division of Occupational Safety and Health (Cal/OSHA). More information about the protection of outdoor workers can be found in Chapter 5.

Closing up a home by shutting windows and doors can give some protection from smoke. Most air conditioners are designed by default to recirculate indoor air. Systems that have both "outdoor air" and "recirculate" settings need to be set on "recirculate" during fire/smoke events to prevent smoke-laden air from being drawn into the building (note: this does not apply to HVAC systems in office and commercial buildings; see Appendix D). Additional protection in homes can be achieved by operating properly-sized air cleaners and upgrading the filtration efficiency of air filters in central air conditioning systems. High-efficiency filters (rated at MERV 13 or higher) should be installed when feasible. When filters have been upgraded, central air conditioning fans can be set to operate continuously during a wildfire event, and not cycle on and off, although this will increase energy use and costs.

Once people have closed up the building in which they live, they should avoid strenuous activity, which can make them breathe harder and faster. They should drink plenty of fluids to keep their respiratory membranes moist. Vacuuming (except with HEPA filter-equipped vacuums) should also be avoided, since most vacuum cleaners disperse very fine dust into the air.

Smoke levels can change substantially over the course of the day, so it may be possible to plan your day around the smokiest times to minimize exposure using tools and information in this Guide.

NIOSH-approved disposable particulate respirators (e.g., N95 or P100) available in hardware stores and online provide some level of protection from exposure to particles in smoke as long as a close-fitting model and size is selected, and they are used properly. One-strap paper masks, surgical masks, or other face coverings are not recommended since they provide little or no protection.

IV. COMMUNICATING AIR QUALITY CONDITIONS DURING SMOKE EVENTS

An important goal of air quality monitoring during a wildfire smoke event is to relay information to the public in a timely manner so people can make decisions about how to protect their health. Filter-based PM monitors take days to process, but continuous PM monitors give a near real-time reading of PM concentrations every hour. This is an estimate of the 24-hour average PM AQI using the NowCast algorithm discussed below. Areas without continuous PM monitors may be able to get temporary, portable monitors through their federal, state, tribal, or local air quality agencies or the U.S. Forest Service, especially when associated with a wildfire incident with an assigned Air Resource Advisor.

Air Quality Index

The Air Quality Index, or AQI, is a nationally uniform index promulgated by the EPA for reporting and forecasting daily air quality across the country. It is used to report information about the most common ambient air pollutants, including those most relevant to wildfire smoke: particulate matter ($PM_{2.5}$ or PM_{10}) and ozone. The AQI tells the public how clean or polluted the air is using standard descriptors (Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, Very Unhealthy, and Hazardous). The index converts ambient concentrations (µg/m^3 or ppb) to a number and category more easily understood by the public. The AQI uses a normalized scale from 0 to 500 and provides associated health-based descriptors for each category. An AQI value of 100 corresponds to the level of the short-term National Ambient Air Quality Standard for a given pollutant. An advantage of using the AQI value over the concentration (µg/m^3) for particulate matter is that the AQI value of 100 represents a clear demarcation between satisfactory and unhealthy air quality, at least with reference to the national standard, which is established at a level that will protect public health, including the health of at-risk groups. When AQI values exceed 100, air quality is considered to be unhealthy, at first for members of at-risk groups (in the Air Quality Index, the term "sensitive groups" is used), then for everyone as AQI values increase. Another advantage

Figure 7. Overall concept of the NowCast

is that the AQI provides actionable activity advice for at-risk groups, as well as the general public, to reduce smoke exposure.

AirNow

The AirNow website, at www.airnow.gov, is a multi-agency web site run by EPA that reports air quality using the AQI. The AirNow program accepts, stores, and displays data provided by state, local, and federal air quality agencies. Agencies submit continuous PM data to AirNow from over 1,200 $PM_{2.5}$ monitors and 500 PM_{10} monitors, plus temporary monitors, on an hourly basis. These data are available to the public via an interactive map on airnow.gov and through email notifications, widgets, and smart-phone apps. Media outlets and web developers can also access the data through AirNow's Application Program Interface (airnowapi.org). See Appendix C for a description of AirNow-Tech, a website that air quality organizations use for data analysis and management, including the Navigator tool for wildfire evaluation.

NowCast. The AQI for $PM_{2.5}$ and PM_{10} is a daily (midnight to midnight) 24-hour average, so hourly reporting requires a methodology called the NowCast to estimate the 24-hour AQI for each hour. The reported hourly value is what AirNow calls "current air quality."

The NowCast method for reporting each hour's current conditions is responsive to rapidly changing air quality such as occurs during a wildfire (Figure 7) The NowCast uses a weighted average of the previous 12 hours. When air quality is changing rapidly, the most recent hours are weighted more heavily. A longer average, approaching 12 hours,

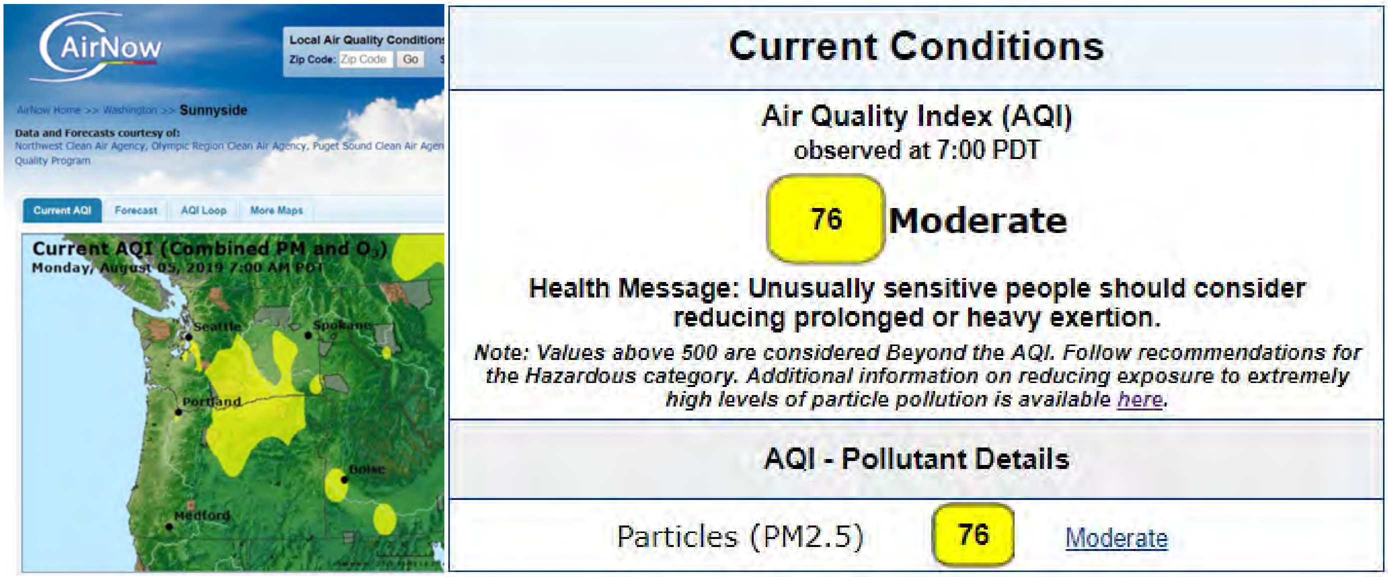


Figure 8. Sample AirNow current air quality data, map, and AQI values

is used when air quality is stable. The NowCast helps ensure that AQI maps and data on AirNow more closely match what people actually experience outdoors (Figure 8).

Fires: current conditions map. The wildfire map page on airnow.gov (https://airnow.gov/index.cfm?action=topics.smoke_wildfires) is a one-stop place where the public can assess current wildfire activity and air quality conditions across the country (Figure 9). The interactive map is a joint effort of the U.S. Forest Service, EPA, and state and local air quality agencies. The map displays several layers such as the current network of $PM_{2.5}$ monitors as well as any temporary $PM_{2.5}$ monitors deployed for a fire event. The monitors are shown in the color of their current AQI value. Other layers include active wildfires and smoke plumes. In addition, the page has important links to state advisories and smoke blogs, information about smoke and health, and a variety of external web resources pertaining to wildfires.

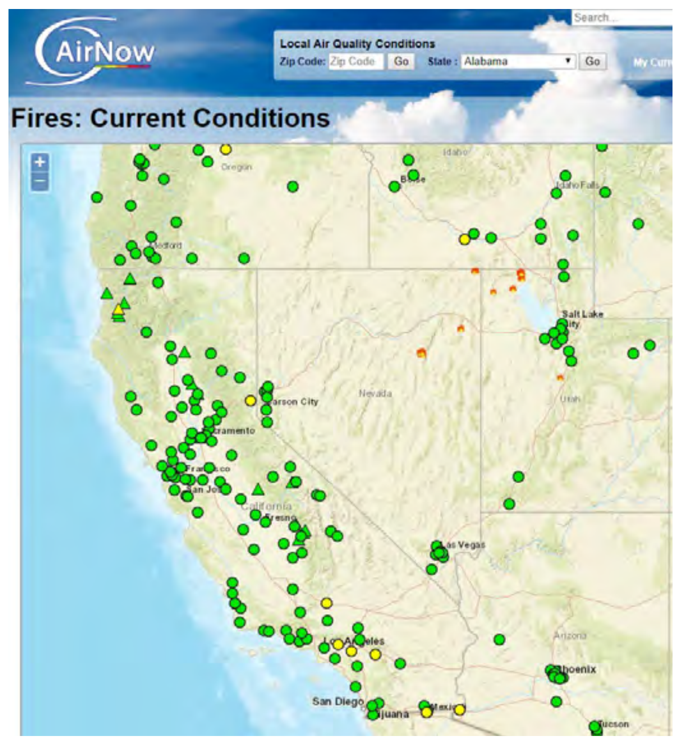


Figure 9. Sample AirNow Fires: Current Conditions map

Enviroflash. Offered in many areas around the country, EnviroFlash is a system that sends the daily air quality forecast by email to anyone who signs up. It can also be used by state and local agencies to send an email alert during an event such as a fire, including suggested safety measures which are included when air quality is unhealthy. This service is provided by the state or local environmental agency and EPA. Information about Enviroflash is available at http://www.enviroflash.info.

Outdoor activity guidance. The Air Quality and Outdoor Activity Guidance for Schools table, developed by the EPA and the Centers for Disease Control and Prevention (CDC), shows when and how to modify outdoor physical activity based on the AQI. This guidance can help protect the health of all children, including teenagers, who are more sensitive than adults to air pollution. The activity guidance can be found at: https://www3.epa.gov/airnow/flag/school-chart-2014.pdf. A similar guide for PM that includes activities for all ages can be found here: https://www3.epa.gov/airnow/air-quality-guide_pm_2015.pdf.

Air Quality Flag Program. The activity guidance can be used with the Air Quality Flag Program. The Air Quality Flag Program (https://airnow.gov/index.cfm?action=flag_program.index) is a visual way to alert schools and other organizations to the local air quality forecast. Seeing the flag alerts people about the local air quality so that they can take actions to protect their health.

Interagency Wildland Fire Air Quality Response Program and Air Resource Advisors

The Interagency Wildland Fire Air Quality Response Program (IWFAQRP, https://wildlandfiresmoke.net) is an interagency effort led by the U.S. Forest Service to provide enhanced information to wildfire incidents, agencies, and communities dealing with smoke issues. This need for predicting smoke impacts associated with wildfires and the role of the IWFAQRP was recognized and authorized by Congress in 2019. The IWFAQRP has several components including tools for enhanced monitoring and modeling of smoke; creating consistent smoke outlook forecasts in a simple format for sharing

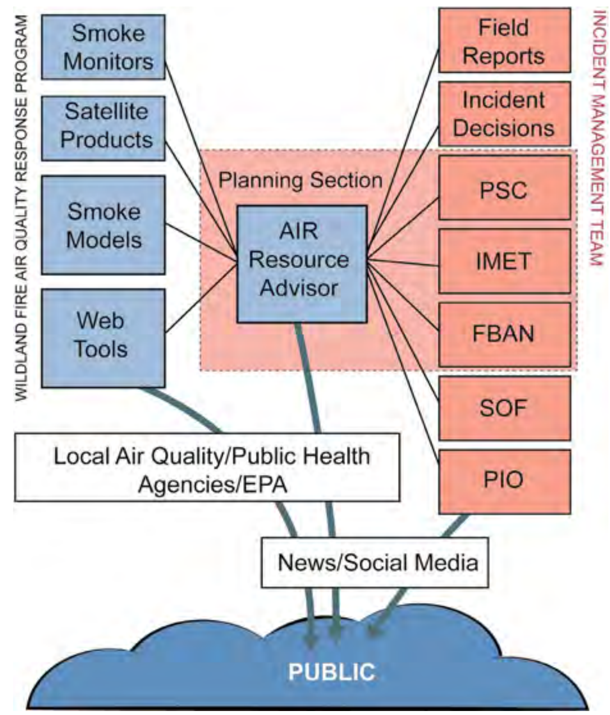
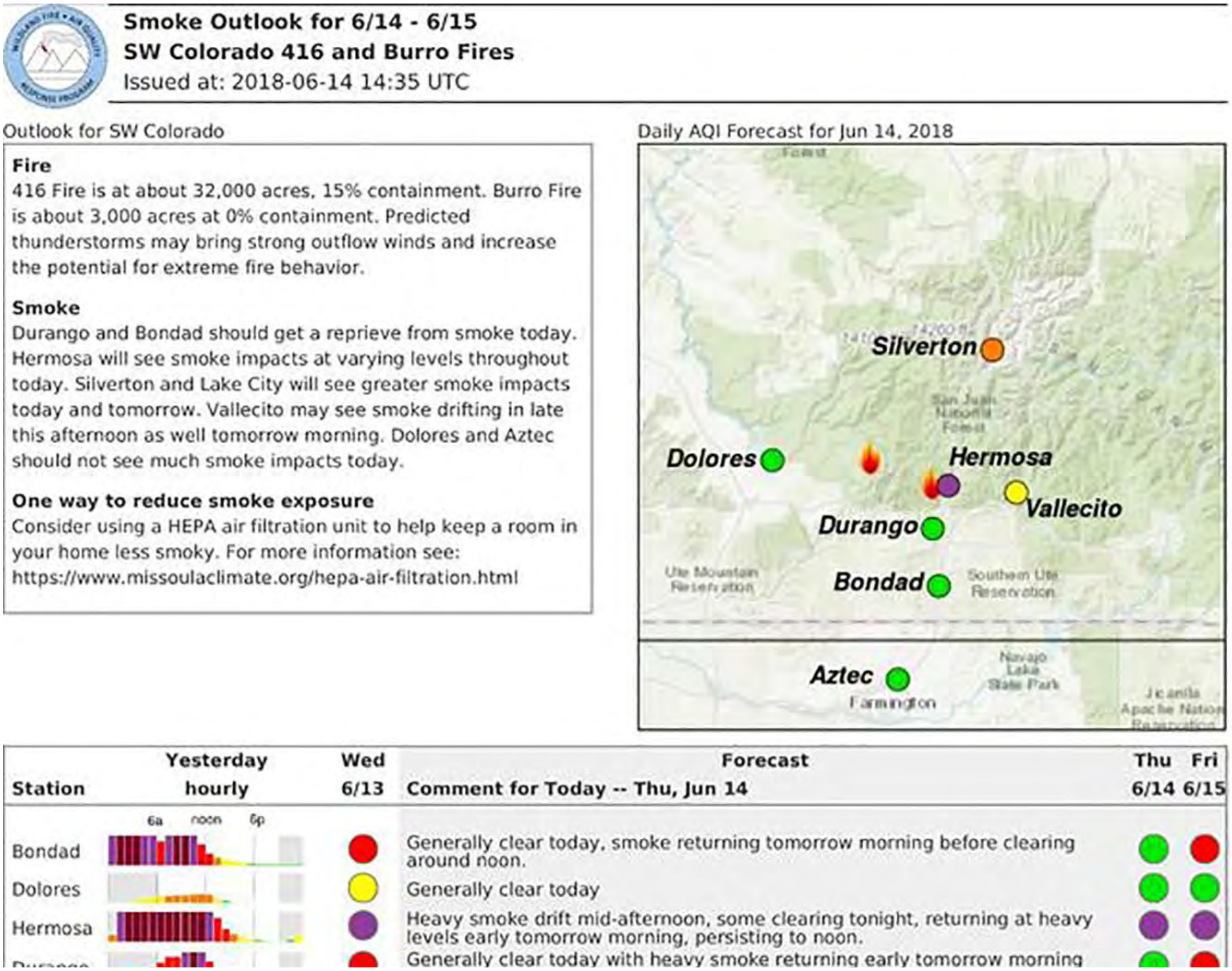


Figure 10. Elements of the Wildland Fire Air Quality Response Program supporting an Air Resource Advisor assigned to an Incident Management Team responding to a wildfire. Air Resource Advisors work under the Planning Section of an Incident Management Team with direct interaction with the Planning Section Chief (PSC), Incident Meteorologist (IMET), Fire Behavior Analyst (FBAN), Safety Officer (SOF), and Public Information Officer (PIO).

with the public; and messaging in conjunction with state, tribal, and local air quality agencies as well as health departments. Much of this work is done through the deployment of technical specialists called Air Resource Advisors (ARAs) working with either wildfire Incident Management Teams (IMT) or directly with land management agencies that request them as part of wildland fire management efforts. Deployed ARAs are a good resource for gaining insight into expected fire growth, emissions, and impacts. An ARA generally works in the planning section of the IMT and consults closely with experts in fire weather and fire behavior. ARAs are trained to use a variety of smoke dispersion models in conjunction with air quality monitoring to help build smoke forecasts and information products for the public.


Smoke Outlook for 6/14 - 6/15
SW Colorado 416 and Burro Fires
Issued at: 2018-06-14 14:35 UTC

Outlook for SW Colorado

Fire
416 Fire is at about 32,000 acres, 15% containment. Burro Fire is about 3,000 acres at 0% containment. Predicted thunderstorms may bring strong outflow winds and increase the potential for extreme fire behavior.

Smoke
Durango and Bondad should get a reprieve from smoke today. Hermosa will see smoke impacts at varying levels throughout today. Silverton and Lake City will see greater smoke impacts today and tomorrow. Vallecito may see smoke drifting in late this afternoon as well tomorrow morning. Dolores and Aztec should not see much smoke impacts today.

One way to reduce smoke exposure
Consider using a HEPA air filtration unit to help keep a room in your home less smoky. For more information see: https://www.missoulaclimate.org/hepa-air-filtration.html

Daily AQI Forecast for Jun 14, 2018

Station	Yesterday hourly	Wed 6/13	Forecast Comment for Today -- Thu, Jun 14	Thu 6/14	Fri 6/15
Bondad			Generally clear today, smoke returning tomorrow morning before clearing around noon.		
Dolores			Generally clear today		
Hermosa			Heavy smoke drift mid-afternoon, some clearing tonight, returning at heavy levels early tomorrow morning, persisting to noon.		
Durango			Generally clear today with heavy smoke returning early tomorrow morning		

Figure 11. Example smoke outlook (partially shown) produced by an Air Resource Advisor assigned to the 416 Fire. Current smoke outlooks are available at https://wildlandfiresmoke.net/outlooks.

Air Resource Advisors use a national cache of deployable smoke monitors (typically E-SAMPLERS and E-BAMS with real-time telemetry capability) during wildland fire incidents to provide ground information to communities lacking existing monitoring capabilities. Enhanced smoke modeling including high resolution grids over affected areas can be requested of the National Weather Service by an ARA. Air Resource Advisor deployments and contact information are available at https://wildlandfiresmoke.net. ARA-developed outlooks are available at https://wildlandfiresmoke.net/outlooks. A collection of IWFAQRP related tools developed by the U.S. Forest Service Pacific Northwest Research Station's AirFire Team are shown in Appendix C and are available at https://tools.airfire.org.

New monitoring and air quality estimation technologies – a caution

In recent years, technology development has expanded the variety of information available about air quality. These emerging technologies include miniaturized $PM_{2.5}$ sensors stationed in outdoor or indoor environments, mobile air quality monitoring systems, air quality models that can estimate concentrations in locations without nearby monitors, and data fusion products that blend together observational data and models. Still in a research phase, but likely to expand over time, are personal wearable devices or apps designed to estimate an individual's exposure to $PM_{2.5}$.

In many areas, these emerging technologies and their data are already part of the wildfire smoke dialogue. During a wildfire smoke event, communities lacking a centrally-located $PM_{2.5}$ monitor may rely on sensors as a primary source of air quality information. Citizens, especially those in at-risk groups, might make decisions based on localized estimates from emerging technologies to mitigate their smoke exposure.

Nevertheless, these data must still be regarded with caution. At this writing there are still many unknowns concerning the precision, accuracy, and reliability of readings from sensors, air quality models, and data fusion products, especially in extreme conditions like a wildfire smoke event. Although the technology is improving, it is important to recognize the limitation of using these as stand-alone devices and data products without a reference monitor nearby to evaluate the new technology's performance.

In cases where ARA-implemented monitors or official air quality network monitors exist and emerging technology is implemented, conflicts in air quality information may result. This does not mean that either information set is necessarily wrong, but reflects differences in the locations measured, how data are averaged, or how the AQI is computed. An additional cause for disagreement may be error in the measurement device or data fusion product.

Therefore, sensor data, models, and data fusion products should be considered as supplements to a larger package of information to make better informed decisions on smoke messaging. Comparing sensor data, models, or data fusion products with nearby reference monitors can help the public official understand how to consider this information in their assessment of smoke conditions and communications. These new sources of data may provide important information on the trends of $PM_{2.5}$, but they need to be put into context with the help of nearby regulatory monitors or short-term monitors implemented by an ARA, AQI estimates, satellite data, and from daily ARA Smoke Outlooks.

Using visual range to assess smoke levels in the interior western United States

Many communities do not have access to continuous PM monitoring and may need other ways to evaluate local air quality. Visual range (i.e., how far can be seen?), like other instantaneous monitoring approaches, can inform and help the public respond to smoky conditions. This is true even in areas that have continuous monitors, because smoke concentrations can vary widely within a couple of miles and can change rapidly.

Basic Approach:

To determine visual range, one **must:**

- use this method only during daylight hours, avoiding sunrise and sunset,
- use this method only if relative humidity is less than 65%,
- focus on the darkest object (e.g., black is better than green),
- determine the limit of visual range by looking for targets at known distances (miles), (the visible range is the point at which even high-contrast objects (e.g., a dark forested mountain viewed against the sky at noon) totally disappear, and
- after determining visual range in miles, use Table 3 to identify actions to take to reduce exposure.

Often, it is difficult to assess "the point at which even high-contrast objects (e.g., a dark forested mountain viewed against the sky at noon) totally disappear." Instead, it may be more useful to use known landmarks at a given distance away to assess possible visual ranges. For example, target A is 2 miles away and visible, but target B, which is 4 miles away, is not visible Therefore the visual range is somewhere

Table 3. Visual range and actions to take to reduce smoke exposure when wildfire smoke is in the air.**

Distance seen	Population Type		OR	Specific Illness
	A Healthy Adult, Teenager, or Older Child	Older adults (≥65 years), Pregnant, or A Young Child		Asthma, Respiratory Illness, Lung or Heart Disease
> 10 miles	Watch for changing conditions and moderate outdoor activities based on personal sensitivity	Watch for changing conditions and moderate outdoor activities based on personal sensitivity		
5–10 miles	Moderate outdoor activity	Minimize or avoid outdoor activity		
< 5 miles	Minimize or avoid outdoor activity	Stay inside or in a location with good air quality		

[1] Sensitivity to smoke can vary greatly from person to person and individuals can become more sensitive to smoke after extended periods of exposure. Individuals should pay attention to the advice of a medical professional or local health officials and adjust activity accordingly to their particular tolerance or sensitivity.

between 2 miles and 4 miles. Use Table 3 to identify the range of actions to consider to reduce smoke exposure.

Western United States: An important caveat is that the above visual range categories only apply in dry air conditions typically found in the interior west and inland of coastal areas. The combination of water and particulate matter in the atmosphere dramatically reduces visibility, therefore this method of estimation should not be used when relative humidity is greater than 65%.

Eastern United States and Higher Humidity Locations: Until this approach can be assessed for humid conditions, individuals may have to rely on common sense in estimating smoke conditions (e.g., mild, moderate, heavy smoke) and the kinds of protective actions that might be necessary to address personal response to the smoke.

Other Considerations: This method of estimating a visual range also contains much uncertainty (as discussed in Malm and Schichtel, 2013), further strengthening the need to use personal judgment when assessing smoke conditions. Smoke concentrations vary substantially from minute to minute. By comparison, continuous monitoring devices average their measurements over 1, 3, or even 24 hours, so what is seen at a particular moment may not be representative of the average reported at a nearby monitor. More uncertainty stems from sighting on non-black bodies (e.g., green forested landmarks, snow-covered peaks), difficulty at judging when an object is just barely visible, variations in the atmosphere and thickness of the smoke across the line of sight, and assuming the atmosphere remains constant after using an instantaneous "look" to assess conditions. Another commonly occurring problem with this method is that the concentration along the visual path is not constant, for example, when there is little smoke at the surface, but a thick layer of smoke aloft and the reference point being used is above that smoke layer such that the viewer is looking through it. In such cases these methods would be invalid. This method is also not effective in early morning or twilight hours when the sun is low on the horizon.

The bottom line is that, no matter how far one can see, it is always prudent to take measures such as those presented in this *Guide* to protect oneself if smoke exposure is a concern.

V. RECOMMENDATIONS FOR PUBLIC HEALTH ACTIONS

This chapter includes specific guidance to public health officials on actions to take to protect the public and to advise the public during a wildfire event, preparations to make before fires occur, and recommendations for cleaning up after a fire. Because there are many factors to consider during a wildfire event, these recommendations should be adapted for each specific situation.

Public advisories and protective measures

Areas with established air quality programs typically have a communication plan for alerting the public about air pollution events. A communication plan includes details on who should be given specific information, when that information should be delivered, and what communication channels to use to deliver the information. An effective communication plan anticipates what information will need to be communicated to specific audience segments, such as schools or nursing homes.

One approach is to refer the public to the AirNow website (www.airnow.gov), which is used by states and most communities across the country. Methods for sharing information include state smoke blogs, websites, hotlines, press releases, and social media, as well as emails and faxes to interested parties (such as sports team coaches and daycare providers). Some rural areas have used door-to-door dissemination of a visibility index (see Table 3) and the associated health effects.

Table 4 provides a general list of health effects and cautionary statements about altering behavior that can be used in public advisories. The advisories are based on the AQI, as well as on experience and evidence from fire situations. *If only PM_{10} measurements are available during smoky conditions, it can be assumed that the PM_{10} is composed primarily of fine particles ($PM_{2.5}$), and therefore the AQI and associated cautionary statements and advisories for $PM_{2.5}$ may be used.*

Table 5 provides guidance to public health officials about measures that can be taken to protect public health at different AQI categories and the corresponding ambient PM levels. This information is intended to help health officials, the media, and the general public make decisions about appropriate strategies to mitigate exposure to smoke. As noted earlier, the official AQI value for $PM_{2.5}$ for the previous day is a 24-hour average of $PM_{2.5}$ concentrations measured from midnight to midnight. The real-time AQI for $PM_{2.5}$ reported by the media and on AirNow is the hourly estimate of the 24-hour AQI based on the NowCast. Although Table 5 provides ambient $PM_{2.5}$ concentrations and the AQI values and descriptors associated with the categories (e.g., Good, Moderate), concurrent publication of both the AQI values and the ambient $PM_{2.5}$ concentrations (in $\mu g/m^3$) to describe air quality may lead to confusion among members of the public. To avoid such confusion, it may be preferable to publish just the AQI values.

Protecting children

Protecting children is always a high priority in smoke events. The factsheet Air Quality and Outdoor Physical Activity Guidance for Schools, developed jointly by EPA and CDC, provides guidelines about when and how to modify outdoor physical activity based on the AQI. If a smoke event is forecasted, local officials should prepare to implement the guidance, including assessing the availability of indoor spaces with good indoor air quality for children to be active.

As air quality worsens or is projected to worsen, additional protective measures may become necessary. These measures could range from allowing children with asthma or other medical conditions that place them at greater risk from smoke to stay home, to closing schools entirely. Several location- and event-specific factors should be considered in making these decisions. Some of these factors include the forecast duration of the event, the relative indoor air quality of the homes and schools in the area, and the ability to transport children safely to and from school. In some locations, indoor air quality may be better in schools than in local housing, making school closure less beneficial from a public health perspective. Indoor air quality in schools should be assessed before the start of the fire season to assist in planning and decision-making.

Protecting other at-risk groups

Protecting members of other at-risk groups, including older adults, people with heart or lung disease, pregnant women, and people of lower SES, is also a high priority for public health officials. Maintaining good indoor air quality, using the information provided above, is especially important in locations where these people are located, such as gyms, senior centers, hospitals, or residential facilities for older adults. To protect some at-risk groups, such as people of lower SES who may live in homes without air conditioning or in locations where the use of air conditioning may not be common, it is advisable to consider setting up cleaner air shelters. In addition, it is important to recognize that people of lower SES may experience social vulnerability due to socioeconomic and demographic factors (e.g., socioeconomic status, household composition and disability, minority status and language, and housing and transportation) that affect the resilience of communities (Flanagan et al., 2011). In disasters such as wildfires, the socially vulnerable are more likely to be adversely affected and less likely to recover.

In general, individuals in these groups should be advised to avoid or limit outdoor activities once air quality is characterized as "Unhealthy for Sensitive Groups" (orange on the AQI) and to remain indoors with windows closed if air quality is categorized as "Very Unhealthy" (purple on the AQI). Families should consider using an air cleaner with a HEPA filter that will help to reduce indoor air pollution, as well as to avoid adding particles by smoking tobacco, using wood-burning stoves or fireplaces, and candles, and only using a vacuum with a HEPA filter.

Protecting outdoor workers

Many workers have jobs that require them to work outdoors. Occasionally these workers may be exposed to wildfire smoke and other hazards due to wildfires. In addition to the workers who are directly involved with wildland fire management and suppression, there are also workers engaged in supporting fire response (e.g., at base camp or evacuation centers) or cleanup efforts (e.g., demolition crews) , and many others who continue to do their usual non-fire related outdoor jobs (e.g., agricultural workers, landscapers, park personnel) during an incident. Similar to the general public, outdoor workers may be at risk for adverse health impacts from smoke or ash exposure, particularly if they are in an at-risk group (described elsewhere in this Guide). However, some recommendations made to the public on how to reduce their exposures to wildfire hazards may not be relevant for outdoor workers who must continue to work. In addition, their employers may not have anticipated these hazards and may be ill equipped to implement effective protections. To better address these issues, employers and employees should prepare for and plan to implement procedures to protect outdoor workers.

The Occupational Safety and Health Administration (OSHA) is the regulatory entity for employee health and safety but, in about half of the states, a federal OSHA-approved state OSHA program regulates non-federal workplaces. There are currently no occupational standards specifically for wildfire smoke, except in California. On July 18, 2019, the California Safety and Health Standards Board adopted an emergency regulation for a Cal/OSHA standard to protect workers from hazards associated with wildfire smoke. This standard, Title 8 California Code of Regulations Section 5141.1, effective on July 29, 2019 and will be followed by a process to develop a permanent regulation (https://www.dir.ca.gov/dosh/doshreg/Protection-from-Wildfire-Smoke.

Although healthy adult workers may not be significantly affected by short-term exposure to smoke or ash while working outdoors, the risk of adverse health effects is dependent on the contaminant levels, type(s) of material burned, duration of exposure, level of physical activity, age of the worker, individual susceptibility (e.g., pre-existing heart or lung disease), as well as other factors (see Chapter 1). As a result, responses to exposures will vary.

Employers can take steps to protect healthy as well as more at-risk workers from the negative health impacts of unhealthy air quality. Some of the same recommendations listed in this document for the general public can apply when working outdoors in a smoky environment. Options for limiting workers' smoke exposure include postponing or shortening time spent outdoors; focusing on only performing high priority tasks; relocating workers or rescheduling work tasks to smoke-free or less smoky areas or times of the day; reducing outdoor workers' physical activity and exertion levels; encouraging and ensuring workers take frequent breaks inside cleaner air spaces such as enclosed structures or vehicles with recirculating air; and encouraging and using air cleaners with HEPA (or other protective) filters in indoor working areas to reduce overall smoke exposure.

In some cases, the use of particulate respirators should be considered to protect workers who cannot implement the exposure reduction recommendations listed above when performing outdoor work (see additional information below). Workers involved in post-fire cleanup activities clearly must be protected from exposure to ash and all other hazards (see sections pertaining to after-fire hazards) by using a range of control methods (e.g., dust suppression, personal protective equipment).

When other measures are not sufficient to control a respiratory hazard, OSHA requires employers to provide respirators that are appropriate for the hazard and work situation. An OSHA-compliant respirator program names a qualified person responsible for administering the program and describes procedures for respirator selection, medical evaluation for safe respirator use, fit testing for tight-fitting respirators, training on topics such as how to use and maintain respirators, and program evaluation.

Pre-planning and preparing for how to best implement these recommendations in the workplace are critical. This is especially true in areas where wildland fire smoke exposure is common, and workers are required to perform their work outdoors, even when the air quality is considered unhealthy, very unhealthy, or hazardous. Working together, employers and employees can take steps to reduce their exposures to the hazards associated with a wildland fire.

Prolonged smoke events

For smoke events that last for more than a few days or that occur repeatedly over the course of fire season, public health officials should consider all options in communicating the importance of reducing smoke exposure. Messages should include actions individuals can take to reduce smoke exposure and should highlight the benefits of creating cleaner air spaces in homes. The longer a smoke event continues, the more people will start to experience adverse health effects. Therefore, exposure reduction measures that are recommended for short-term exposures to smoke become even more important to take with prolonged exposures. Prolonged smoke events may require consideration of additional measures to protect the public, especially people in at-risk groups.

If they haven't already, public health officials should consider partnering with external businesses, agencies, and non-profits to provide spaces with cleaner air for the public to go during the day if it becomes necessary. These cleaner air spaces could include schools, senior centers, libraries, and shopping malls. Making spaces with cleaner air available during the day can provide an alternative for people unable to reduce smoke levels in their homes, or unwilling or unable to evacuate to a designated cleaner air shelter or out of the area to reduce their smoke exposure. Before advertising or advocating for these cleaner air spaces, public health officials should confirm that the locations have adequate filtration for particles. This clean air protection may be provided by a MERV 13 or higher filter in the HVAC system or a properly sized portable air cleaner with HEPA filtration. Building managers should continue to ensure that the building is adequately ventilated and that fresh air intakes have high-efficiency (MERV 13 or higher) filters to clean the air entering the building. Altering the building pressure balance by reducing or stopping air intake could actually create indoor air quality issues that could offset any benefit of reduced smoke exposure. For more information, refer to Appendix D. Cleaner air spaces should also have institutional controls to limit smoke infiltration, such as limited door and window use. Appendix B provides some guidelines for creating cleaner air in large spaces.

As smoke events continue, stress associated with increasing health concerns, loss of control over daily activities, reduction in physical activity, and isolation resulting from remaining at home indoors can cause mental health issues to arise. During a prolonged smoke event or repeated smoke events, make cleaner air spaces available where people can socialize. One beneficial strategy that has been reported consists of waiving fees for gym use, which allows people to get exercise and interact with others. Be aware of mental health issues in your jurisdiction and consider creating messages about mental health and available mental health services.

Protecting pets and livestock

Many people ask how wildfire smoke affects pets and livestock. As with humans, high levels of smoke may irritate animals' eyes and respiratory tract. Animals with heart or lung disease are especially at-risk and should be closely watched during periods of poor air quality. Strategies to reduce animals' exposure to smoke are like those for humans: reduce the time spent in smoky areas; if animals are indoors, keep indoor air clean; provide animals with plenty of water; limit physical activities that will increase the amount of smoke breathed into their lungs; and reduce exposure to dust or other air pollutants. If pets or livestock are coughing or having difficulty breathing, the owner should contact a veterinarian. Two factsheets, Protect Your Pets from Wildfire Smoke and Protect Your Large Animals and Livestock from Wildfire Smoke, are available for dissemination to the public.

Consider where pets and livestock could be housed if the evacuation of people from areas within your jurisdiction becomes necessary. For example, in some places, local shelters will house pets in carriers and it is not uncommon for temporary livestock shelters to be created in local fairgrounds or parking lots. Animals that are older or have a medical condition that increases sensitivity to smoke, may require sheltering facilities that can provide cleaner air or adequate medical attention. Animal accommodations are frequently set up with participation from local animal control, humane society or other animal rescue groups. For more information, check the American Veterinary Medical Association (AVMA) website: https://www.avma.org/public/EmergencyCare/Pages/Pets-and-Disasters.aspx.

Air quality cautionary statements and recommended public actions

Table 5 shows actions for public health officials to consider at the different AQI categories. Public health officials may want to recommend some or all of the recommended actions associated with these categories, based on an assessment of the local situation. Some factors that also should be considered include:

- **Predicted fluctuations in $PM_{2.5}$ levels.** Are the peaks of $PM_{2.5}$ predicted to occur relatively infrequently, interspersed with longer periods of good air quality, or to occur multiple times per day, superimposed on higher-than-usual $PM_{2.5}$ levels?
- **Predicted duration of high $PM_{2.5}$ levels.** For instance, if air quality is predicted to be in the "Unhealthy for Sensitive Groups" range or worse for multiple days to weeks, public health officials might consider opening cleaner air shelters or recommending evacuation plans for at-risk populations, including individuals with chronic lung or heart disease, who cannot take adequate personal protective actions to reduce exposures.
- **Potential indirect effects.** High $PM_{2.5}$ levels can impair visibility and increase the risk of traffic accidents. This may be reason enough to cancel an evening indoor event at a local high school, for example.

Table 4. Health effects and cautionary messages for at risk populations for each AQI category

AQI Category (AQI Values)	Health Effects	Cautionary Statements	Other Protection Messages
Good (0–50)	None expected	None	None
Moderate (51–100)	Possible aggravation of heart or lung disease	Unusually sensitive individuals should consider limiting prolonged or heavy exertion. People with heart or lung disease should pay attention to symptoms. Individuals with symptoms of lung or heart disease, including repeated coughing, shortness of breath or difficulty breathing, wheezing, chest tightness or pain, palpitations, nausea, unusual fatigue or lightheadedness, should contact a health care provider.	If symptomatic, reduce exposure to particles by following advice in box below.
Unhealthy for Sensitive Groups (101–150)	Increasing likelihood of respiratory or cardiac symptoms in sensitive individuals, aggravation of heart or lung disease, and premature mortality in people with heart or lung disease and older adults	Sensitive Groups: People with heart or lung disease, the elderly, children, and pregnant women should limit prolonged or heavy exertion. Limit time spent outdoors. Avoid physical exertion. People with asthma should follow their asthma management plan. Individuals with symptoms of lung or heart disease that may be related to excess smoke exposure, including repeated coughing, shortness of breath or difficulty breathing, wheezing, chest tightness or pain, heart palpitations, nausea, unusual fatigue or lightheadedness, should contact a health care provider.	Keep doors and windows closed, seal large gaps as much as possible. Avoid using exhaust fans (e.g., kitchen, bathroom, clothes dryer, and utility room exhaust fans). Keep the garage-to-home door closed. If cooling is needed, turn air conditioning to re- circulate mode in home and car, or use ceiling fans or portable fans (but do not use whole house fans that suck outdoor air into the home). If a home has a central heating and/or air conditioning system, install higher-efficiency filters (e.g., filters rated at MERV 13 or higher) if they can be accommodated by the system. Regardless of whether a filter upgrade has been performed, the system's circulating fan can be temporarily set to operate continuously to obtain maximum particle removal by the central air system's filter, although this will increase energy use and costs. Operate appropriately sized portable air cleaners to reduce indoor particle levels. Avoid indoor sources of pollutants, including tobacco smoke, heating with wood stoves and kerosene heaters, frying or broiling foods, burning candles or incense, vacuuming, and using paints, solvents, cleaning products, and adhesives. Keep at least a 5-day supply of medication available. Have a supply of non-perishable groceries that do not require cooking.

Table 4. Health effects and cautionary messages for at risk populations for each AQI category. (continued)

AQI Category (AQI Values)	Health Effects	Cautionary Statements	Other Protection Messages
Unhealthy (151–200)	Increased aggravation of heart or lung disease and premature mortality in persons with heart or lung disease and older adults; increased respiratory effects in general population.	Sensitive Groups: Should avoid prolonged or heavy exertion Everyone: Should limit prolonged or heavy exertion Limit time spent outdoors. Individuals with symptoms of lung or heart disease that may be related to excess smoke exposure, including repeated coughing, shortness of breath or difficulty breathing, wheezing, chest tightness or pain, palpitations, nausea or unusual fatigue or lightheadedness, should contact your health care provider.	Sensitive Groups: Stay in a "clean room" at home (where there are no indoor smoke or particle sources, and use a non-ozone producing air cleaner). Go to a "cleaner air" shelter (see Appendix D) or possibly out of area Everyone: Follow advice for sensitive groups in box above. Identify potential "cleaner air" shelters in the community (see Appendix D).
Very Unhealthy (201–300)	Significant aggravation of heart or lung disease, premature mortality in persons with heart or lung disease and older adults; significant increase in respiratory effects in general population.	Everyone: Should avoid prolonged or heavy exertion and stay indoors, preferably in a space with filtered air.	Everyone: If symptomatic, seek medical attention. If you are unable to create your own cleaner indoor air space to shelter in place, evacuate to a cleaner air shelter or leave the area, if it is safe to do so.
Hazardous (> 300)	Serious aggravation of heart or lung disease, premature mortality in persons with heart or lung disease and older adults; serious risk of respiratory effects in general population.	Everyone: Should avoid any outdoor activity, and stay indoors, preferably in a space with filtered air.	Everyone: If symptomatic, seek medical attention. If you are unable to create your own cleaner indoor air space to shelter in place, evacuate to a cleaner air shelter or leave the area, if it is safe to do so.

[1]Higher advisory levels automatically incorporate all of the guidance offered at lower levels.

Table 5. Recommended actions for consideration by public health officials

AQI Category (AQI Values)	$PM_{2.5}$[1] $\mu g/m^3$ 24-hr avg	Recommended Actions for Consideration
Good (0–50)	0–12	If smoke event forecast, implement communication plan.
Moderate (51–100)	12.1–35.4	Prepare for full implementation of School Activity Guidelines (https://www3.epa.gov/airnow/flag/school-chart-2014.pdf). Issue public service announcements (PSAs) advising public about health effects, symptoms, and ways to reduce exposure. Distribute information about exposure avoidance.
Unhealthy for Sensitive Groups (101–150)	35.5–55.4	Evaluate implementation of School Activity Guidelines If smoke event projected to be prolonged, evaluate and notify about possible sites for cleaner air shelters. If smoke event projected to be prolonged, prepare evacuation plans for at-risk populations.
Unhealthy (151–200)	55.5–150.4	Full implementation of School Activity Guidelines Consider canceling outdoor events (e.g., concerts and competitive sports), based on public health and travel considerations.
Very Unhealthy (201–300)	150.5–250.4	Move all school activities indoors or reschedule them to another day. Cancel school physical activities (e.g., physical education, athletic practice) unless the school is able to provide cleaner indoor air for the students. Consider closing some or all schools Cancel outdoor events involving activity (e.g., competitive sports). Consider canceling outdoor events that do not involve activity (e.g. concerts).
Hazardous (> 300)	250.5>500	Consider closing schools[2]. Cancel outdoor events (e.g., concerts and competitive sports). Consider air quality in indoor workplaces and take measures to protect workers as needed[3] Consider curtailment of outdoor work activities unless the workers have a fully implemented respirator plan in place and clean air respite breaks. If PM levels are projected to remain high for a prolonged time, consider evacuation of at-risk populations.

[1] If only PM_{10} measurements are available during smoky conditions, assume that the PM_{10} is composed primarily of fine particles ($PM_{2.5}$), and that therefore the AQI and associated cautionary statements and advisories for $PM_{2.5}$ may be used.

[2] See school considerations in section on Protecting Children, above. Newer schools with a central air cleaning filter may be more protective than older, leakier schools. Also, being at school may mean children's activity levels can be better monitored. It is important to make schools a safe place for children.

[3] See Appendix C for guidance.

Public service announcements

This section discusses using public service announcements (PSAs) to deliver messages to the public in advance of wildfire season. Preparing for wildfire season includes planning what actions can be taken by individuals well in advance of a wildfire smoke event. In areas where fires are likely to occur, state and local public health agencies should consider running pre-season PSAs or news and social media announcements to advise the public on preparing for the fire season. The factsheet, Prepare for Fire Season, is available on the AirNow website. EPA's webpage Wildfires and Indoor Air Quality also provides general information on how to reduce exposure to wildfire smoke in residences. PSAs should be simple (e.g., "the season for wildfires is approaching; take action now to protect your health and prepare your home") and should list a contact phone number and website for further information.

PSAs are also useful during fire or smoke events to provide timely updates on the situation, along with advice on protective actions. Effective PSAs use simple, non-technical messages that people can remember, such as "stay indoors" or "limit outdoor activities." News and social media releases and website posts should be used to provide more detailed information, including information for the general public and for people with chronic diseases. When wildfire risk is high, the area federal, state, tribal, or local land manager is also likely initiating a public information campaign to prevent wildfires, providing a natural partner for messaging about smoke with these agencies.

Consider reaching out to weather forecasters and news reporters, who are a valuable resource for sharing information with the public. Their role as communicators on television, radio, print, and online outlets makes them an essential partner in any outreach strategy. When reaching out to news reporters and meteorologists to "pitch" your messages:

- Tell them who you are, what agency you represent, and that your campaign affects the health and safety of the community.
- Make sure they have your contact information, including e-mail address, and at least one telephone number.

General recommendations to the public

General recommendations to the public should include at least the following:

1. Prepare for wildfire season. Have a several-day supply of nonperishable groceries that do not require cooking, since cooking (especially frying and broiling) can add to indoor pollutant levels. Have extra medications, such as asthma medicine. For more information for the public about steps to be ready – use the Prepare for Fire Season factsheet.
2. If you develop symptoms suggesting lung or heart problems, consult a health care provider as soon as possible.
3. Be alert to local announcements, air quality forecasts, and changing smoke conditions.
4. Be aware that outdoor events, such as athletic games or competitions, may be postponed or canceled if smoke levels become elevated.
5. During a wildfire smoke event, you can take steps to limit smoke infiltration and clean the air indoors with either the right-sized portable air cleaner with true HEPA filtration or a HVAC filter with a MERV rating 13+. See the EPA webpage Wildfires and Indoor Air Quality.

Recommendations for people with chronic diseases

Recommendations for people with chronic diseases should include at least the following:

1. These recommendations are for people with chronic diseases, including heart or lung disease. Have an adequate supply of medication (more than 5 days).

2. People with asthma should have a written asthma action plan. Check the EPA website for resources on asthma action plans: https://www.epa.gov/asthma/asthma-action-plan

   i. People with heart or lung disease should check with their health care providers about precautions to take during smoke events. They should do this prior to the fire season if they live in an area that has the potential for wildfires.

   ii. Contact a health care provider if your condition worsens when you are exposed to smoke.

   iii. When using one or more portable air cleaners, buy air cleaners that are appropriately sized for the intended rooms, as specified by the manufacturer, before a smoke emergency occurs. Be sure they are certified by California as low-or-no ozone models by checking the California Air Resources Board website at https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm.

   iv. A news release could also include recommendations for preparing residences to keep smoke levels lower indoors, and on the appropriate use of respiratory protection, as discussed above. See factsheets on Indoor Air Filtration and Protect Your Lungs from Wildfire Smoke or Ash, the webpage Wildfires and Indoor Air Quality, and Appendices B and D.

Use social media to raise awareness

Social media outlets, such as Twitter, Facebook, and Instagram, are a good way to raise awareness about wildfire smoke health protection. Keep in mind that you have many different audiences, so you will need to use many different media to share messages about smoky conditions in your community.

For information on how to use social media for health messages, visit the Centers for Disease Control and Prevention Health Communicator's Social Media Toolkit: https://www.cdc.gov/socialmedia/tools/guidelines/socialmediatoolkit.html.

Social media can attract and direct the public to a central website or document for distribution. This central website will provide complete wildfire smoke information. For social media success, post simple messages that reflect the community's needs at the time. Post different messages but always copy and paste the same link to direct the public to your webpage with the most complete, up-to-date information. Repeating the link to a central website is a good way to reach out and make more people aware of the information.

Prior to wildfire smoke season, create a template with a simple graphic element that is repeated on the central webpage and use the same look for any other wildfire smoke announcements, such as paper flyers, email, and social media, so that when the public sees it they will immediately recognize the information. Make the template usable in both electronic and print media. This can be something as simple as the health department or local government logo and a heading such as WILDFIRE SMOKE ALERT.

Social media messages, like any messages, require advance planning. You will want to find the right contact in your office or agency who oversees social media, ask them about the process for approving and posting messages, propose messages they can send out in a timely fashion, and evaluate the effectiveness of messages delivered over social media.

In the off-season, you can share messages from other sites by retweeting or sharing the information previously posted on a reputable social media site such as the CDC or EPA. Messages can include topics such as brush cleanup around the perimeter of a home. You can look to the following resources to find messages to share:

https://twitter.com/AIRNow

https://www.facebook.com/airnow

https://twitter.com/CDCenvironment

https://twitter.com/CDCemergency

Preparedness

Preparation is key to effective response to wildfire smoke events. In the months leading up to fire season, the National Significant Wildland Fire Potential Outlooks (https://www.predictiveservices.nifc.gov/outlooks/outlooks.htm), developed by the National Interagency Fire Center (NIFC), can give an idea of the predicted severity of the coming months of the fire season. These assessments indicate which areas of the country are likely to see various levels of fire activity and are designed to inform decision makers for proactive wildland fire management. Outlooks are available for the current month, the month following and a seasonal look at the two months beyond that. However, long-range predictions can be uncertain. Also, even if the NIFC is predicting normal or below normal fire activity in your region, you may be downwind of an area that is likely to see heightened activity.

Before wildfire season arrives, public health officials should consider taking some or all of the following steps, especially if they are in an area predicted to be a higher risk of fire. This is a simple list, more detailed information about each of these steps can be found other places in the Guide.

Recommended steps for public health officials before fire season

Recommended steps for public health officials in areas likely to experience smoke to take before fires start include:

1. Check fire risk level in monthly outlooks at National Interagency Fire Center (NIFC) website and, especially if high, communicate risk to the public.
2. Consider how to implement the recommended actions in Table 5 above.
    - Identify locations that could serve as cleaner air shelters.
    - Identify locations that could serve as cleaner air spaces.
    - Check indoor air quality (IAQ) capabilities in places where at-risk populations congregate (e.g., schools, preschools and daycares; senior centers and nursing homes) and investigate approaches to improving IAQ, if necessary.
    - Have supply of NIOSH-approved respirators to disseminate to public; consider approaches to supplying portable air cleaners.
3. Prepare a communication plan.
    - Include approaches for quick dissemination of information to the public (e.g., social media).
    - Include approaches to reach members of at-risk populations.
    - Develop messages about mental health and available mental health services, since stress can cause mental health issues to arise.
    - Inform public about steps to be ready - use Prepare for Fire Season factsheet.
4. Form partnerships with important partners or stakeholders, for example: air quality agencies, local health providers, the media and others.
    - Help local health providers learn about the health effects of smoke and the populations at greatest risk using the EPA and CDC continuing education course about particulate matter, Particle Pollution and Your Patients' Health.

After the fire, the effectiveness of the response to a wildfire smoke event should be assessed so needed improvements can be identified. A season-ending discussion with partners and preparation of a "lessons learned" plan or report will help the partnership continue to grow and improve.

Build strong partnerships

Wildfires can start and spread rapidly, and a smoke event may descend on a community in a matter of hours. Ideally, relationships between health departments, air quality agencies, land management agencies, and other partners will be in place before a crisis begins. To reduce potential public confusion, partner agencies responding to a wildfire smoke episode need to begin working together right away to inform the public of smoke and health risks using consistent messages. A pre-existing partnership enables a rapid response to a serious smoke episode and allows everyone to quickly access and share vital information.

All agencies working on fire and smoke response should coordinate closely during the incident to ensure consistent communications and to leverage resources for developing and delivering information to the public. This can be achieved through steps such as cross-linking websites, and clearly directing public and media inquiries to the appropriate agency and subject matter experts. Some agencies may have the best experts for media interviews while another may have easy access to language translation services. One partner may be able to access communication material design experts while another contributes monitoring data analysis experts. Building a team that capitalizes on agency and individual strengths while breaking down agency boundaries is the most effective way to quickly serve the public in an air quality emergency.

Physicians and other health care providers often have a high degree of credibility with the public. Having a good working relationship with local health providers who are knowledgeable about the health effects of smoke can be very useful in getting health and exposure reduction information out to the public through the media. EPA has developed an on-line training course, Particle Pollution and Your Patients' Health (https://www.epa.gov/pmcourse), to educate health providers about the effects of particulate matter. The training includes a section on high-particulate matter events, such as wildfires, that is consistent with the information and recommendations in this guide. Physicians, nurses, and health educators can receive continuing education credits from CDC for taking this online training.

Remember that while working with local media and posting information online is important, it is not the only way to deliver information during an emergency. Other methods are effective such as posters, door hangers, fliers, or radio and television. Note that smoke and messaging needs frequently cross state and international boundaries so coordination needs to be developed beyond typical jurisdictions.

Putting together a wildfire smoke team

Responding to the needs of the public in case of a serious or prolonged wildfire smoke event will be far more effective if relevant state, local, and federal agencies and organizations are engaged and working together as a team. Some states have ad hoc wildfire smoke response teams that have already formed during wildfire smoke response efforts, other states or areas may need to start at the beginning to find and engage partners. Some states have prepared formal emergency smoke response plans that outline local points of contact, responsibilities of state agencies and other cooperators, and instructions for acquiring extra needed resources such as monitors or masks. In some states when wildfire smoke impacts are serious or prolonged, these agencies and other local cooperators hold daily or as-needed conference calls to share information and coordinate air quality messaging and public outreach efforts. Participating in these internal calls can be very valuable for public health agencies. Possible key partners in a public response effort include:

- **State and local clean air agencies –** State and local clean air agencies are expert at accessing and summarizing local air monitoring data and often have the ability to forecast upcoming meteorology and dispersion conditions that will affect smoke movement and accumulation. State air agencies often work with the National Weather Service to have air pollution advisories issued when needed.

- **Federal and state land management agencies** – Typically, federal or state land management agencies have the lead in wildfire suppression and response. Any ARAs working in the area are likely assigned either to a wildfire incident management team or to a Federal Agency Administrator. ARA's are a very valuable source of information for the public health community and can help spread public health messages through ongoing communications. ARA efforts are improved through consultation and coordination with state public health entities. To see if an ARA is working in an area check www.wildlandfiresmoke.net.
- Incident management teams assigned to large wildfires are expert at connecting with local communities and frequently host public meetings where smoke and appropriate public responses may be discussed. These meetings can be an excellent forum for ARAs and public health agencies to deliver messages about smoke and public health.
- **Tribes –** Many tribal communities run their own air quality programs and have local information about supplemental monitors and effective outreach to their communities. EPA regional offices assist with tribal air programs. Federal agencies can help provide information to tribes if a fire is on, or smoke is affecting, lands in Indian country. Federal agencies have a trust responsibility to tribes and have established contacts who can help deliver information on wildfire smoke and health.
- **State and local public health agencies –** State and local health agencies are expert at communicating health risks and protective actions in simple language the public can understand and are well linked to organizations,such as assisted living facilities, hospitals, and clinics, that serve at-risk groups. Public outreach needs of public health agencies often mean they have language translation expertise so important health messages can reach non-English speakers.
- **EPA regional offices** and the **Wildland Fire Air Quality Response Program** may have por-table air quality monitors that can be deployed to smoky areas that are not well represented by existing state networks. The Wildland Fire Air Quality Response Program website (www.wildlandfiresmoke.net) also provides tools to help summarize monitoring data from state monitoring networks and from emergency monitors deployed to wildfires.
- **School systems –** School administrators are frequently anxious for advice on how to best protect their students from smoke. Schools can be invaluable channels for accessing not only children but entire families, particularly in regions where children may be more literate in English than older family members. In addition, schools can sometimes serve as temporary shelters for evacuees.
- **Faith-based and community-based organizations –** Faith-based and community-based organizations can help disseminate awareness messages and can potentially serve as partners for sheltering evacuated residents.

Cleaning up after the fire

Even after the worst of the fire and smoke is over there remain health and safety hazards that homeowners should be aware of. Exposure to lingering smoke and ash from a wildfire can cause significant health effects in both healthy individuals and those in at-risk groups. People may experience symptoms including respiratory irritation, heat-related illness, and even emotional stress after a fire. Physical stress from cleanup activities, exposure to toxic chemicals, damaged power lines, and equipment such as portable generators can cause injuries during clean up. To learn more about the health and safety hazards that people might encounter after a wildfire, refer to Appendix E.

Even after the fire is out, smoke and ash residue can affect the air quality in affected structures. Depending on the severity of smoke intrusion into the building and the length of exposure, some people may notice a lingering odor when they return to their homes, schools, or places of work. Removal of smoke odor is difficult, but there are ways to diminish the odor, including beginning with a thorough airing of any structure. If conditions permit, windows and doors can be opened and fans can be placed in rooms to circulate the air. If it is too warm or cold to open the doors and windows, a large portable air cleaner that has a high-efficiency filter (HEPA) can be used to ventilate the rooms and promote air exchange to help remove the odors. Any air cleaner used should meet ozone emissions and electrical safety requirements. Approved air cleaners can be found here: https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm. Note that while HEPA filters will remove lingering fine particles in the air, they do not remove the gaseous chemicals that cause odors associated with wildfire smoke. These chemicals must be removed by using a portable air cleaner with an activated charcoal prefilter or a prefilter composed of alumina coated with potassium permanganate and replacing the prefilter frequently. Most prefilters on smaller portable air cleaners will saturate quickly and lose effectiveness in a smoky environment. Portable air cleaners with more robust odor removal are available but are frequently on the higher end of the price spectrum.

In addition to ventilation, it is also important to thoroughly clean the affected space. Every surface of the space that was exposed to smoke will need to be cleaned. If ash or other hazards are present, individuals performing cleanup work should wear protective clothing and equipment, such as a well-fitting N-95 respirator, leather gloves, safety glasses or goggles, long pants, a long-sleeved shirt, and shoes with rugged soles. Cleaning will include wiping down the walls, floors, windows, baseboards, doors, frames, cabinets, furniture, and other surfaces with a dilute solution of water and soap. Some people may choose to use additional cleaning products; however, it is important to note that some cleaners also impact indoor air quality. Those who choose to use additional cleaning products should be advised to read label instructions carefully and follow all instructions. Curtains, rugs, furniture covers, bedding, and anything that can be safely washed in a washing machine can be cleaned in this manner. Carpets will also need to be cleaned. This can be done professionally or by using a carpet cleaner rented from a local market or rental center. Often the building ductwork for the heating and cooling system will not be an issue because in many cases the power goes out during fire events and the AC systems do not circulate smoke- and ash-filled air through the ductwork for very long. In cases where ductwork does have smoke residue and is a source of odors, it is recommended to consult with a local smoke remediation company or HVAC contractor to see what options are available to clean it. EPA has a guide for consumers on duct cleaning: https://www.epa.gov/indoor-air-quality-iaq/should-you-have-air-ducts-your-home-cleaned.

The use of an ozone generator to remediate smoke odor is not recommended because ozone can create as many problems as it is intended to fix. Many of the chemicals that are broken up by ozone can produce byproducts that are also dangerous to health. Furthermore, ozone does not remove ash and other particles from the air and indoor surfaces. If an ozone generator is used to remove smoke odors it should be used only by a remediation professional. The space where the ozone generator is being used must be unoccupied during, and for a designated period after, its use to be sure that no one is exposed to the ozone. Finally, some companies claim to use "hydroxyl" generators for remediation. Hydroxyl radicals are highly reactive and can also create chemical byproducts. These devices should be used with the same caution as ozone generators.

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ADDITIONAL RESOURCES AND LINKS

Active Wildfire Information

AirNow Fires: Current Conditions. https://airnow.gov/index.cfm?action=topics.smoke_wildfires

CAL FIRE, California Department of Forestry and Fire Protection: http://www.fire.ca.gov

Geographic Area Coordination Center, National Interagency Fire Center: http://gacc.nifc.gov/links/links.htm

InciWeb - Incident Information System: http://inciweb.nwcg.gov provides updates on all national fires, often several times a day.

National Interagency Fire Center Wildland Fire Morning Report: http://www.fs.fed.us/news/fire

Satellite Images of Fires and Smoke

GeoMAC Wildland Fire Support, Geospatial Multi-Agency Coordination: https://geomac.usgs.gov

NASA Moderate Resolution Imaging Spectroradiometer (MODIS): http://modis.gsfc.nasa.gov

National Interagency Coordination Center National Significant Wildland Fire Potential Outlook: http://www.predictiveservices.nifc.gov/outlooks/outlooks.htm

NOAA Hazard Mapping System Fire and Smoke Product: http://www.ospo.noaa.gov/Products/land/hms.html

Wildland Fire/Air Quality Tools, Wildland Fire Air Quality Response Program: http://tools.airfire.org

Weather

National Weather Service Fire Weather: https://www.weather.gov/fire

National Weather Service Central Region: https://www.weather.gov/crh

National Weather Service Eastern Region: http://www.weather.gov/erh

National Weather Service Southern Region: https://www.weather.gov/srh

National Weather Service Western Region: http://www.wrh.noaa.gov

Information about Wildfire Smoke and Health Effects

Wildfire Guide post-publication updates: https://airnow.gov/wildfire-guide-post-publication-updates

Air Quality Index Guide to Air Quality and Your Health: https://www3.epa.gov/airnow/aqi_brochure_02_14.pdf

AirNow Fires and Your Health: https://www.airnow.gov/index.cfm?action=topics.smoke_events

AirNow Smoke Advisories and Forecasts by State: https://airnow.gov/index.cfm?action=airnow.news_item&newsitemid=93

AirNow: https://www.airnow.gov

EPA Wildfires and Indoor Air Quality: https://www.epa.gov/indoor-air-quality-iaq/wildfires-and-indoor-air-quality-iaq

APPENDIX A

Available Factsheets as of March 2019

Recognizing the need for credible information to disseminate to the public, authors of this Guide have developed factsheets on topics of high interest for use with the public. The factsheets will be updated as needed and more factsheets are planned. In addition, these factsheets will become available in other languages. So please check the current fires page of AirNow website, where you can find this document and all related factsheets.

- Prepare for Fire Season: https://www3.epa.gov/airnow/smoke_fires/prepare-for-fire-season-508.pdf
- Indoor Air Filtration: https://www3.epa.gov/airnow/smoke_fires/indoor-air-filtration-factsheet-508.pdf
- Reduce Your Smoke Exposure: https://www3.epa.gov/airnow/smoke_fires/reduce-your-smoke-exposure.pdf
- Protect Yourself from Ash: https://www3.epa.gov/airnow/smoke_fires/protect-yourself-from-ash-fact-sheet.pdf
- Protect Your Lungs from Wildfire Smoke or Ash: https://www3.epa.gov/airnow/smoke_fires/respiratory-protection-508.pdf
- Protecting Children from Wildfire Smoke and Ash: https://www3.epa.gov/airnow/smoke_fires/protecting-children-from-wildfire-smoke-and-ash.pdf
- Protect Your Pets from Wildfire Smoke: https://www3.epa.gov/airnow/smoke_fires/protect-your-pets-from-wildfire-smoke.pdf
- Protect Your Large Animals and Livestock from Wildfire Smoke: https://www3.epa.gov/airnow/smoke_fires/protect-your-large-animals-and-livestock-from-wildfire-smoke.pdf

APPENDIX B

Identification and Preparation of Cleaner Air Shelters for Protection of the Public from Wildfire Smoke

1. Identify one or more facilities with tight-sealing windows and doors and public access (for example, libraries, school gymnasiums, buildings at public fairgrounds or civic auditoriums). As a rule of thumb, newer buildings will generally be more desirable than older ones. Consider using institutional controls to limit smoke infiltration, such as limited door and window use.

2. At a minimum, a cleaner air shelter should have central air conditioning with filtration that is at least medium or high-efficiency, particularly at the fresh (outdoor) air intake(s). If needed, filters should be upgraded prior to the fire season after assuring that the system can handle the increased airflow resistance. Building managers should ensure that filters are properly fit and sealed to prevent air bypassing the filter media. Filters should be regularly maintained and/or replaced according to the manufacturer's recommendations. Even during smoke events, building managers should continue to ensure that the building is adequately ventilated and that fresh air intakes have high-efficiency (MERV 13 or higher[1]) filters to clean the air entering the building. Reducing or stopping fresh air intake could actually alter the building air-pressure balance and create indoor air quality issues that could offset any benefit of reduced smoke exposure (for more information, refer to Appendix D.

3. Install/inspect room air cleaners where appropriate, such as in cleaner air shelters with separate, smaller rooms (e.g. classrooms, meeting rooms). Choose room air cleaners with sufficient capacity, i.e., a tobacco smoke Clean Air Delivery Rate (CADR) that is at least 2/3 the room volume. Choose an air cleaner with a higher CADR for rooms with ceilings higher than 8ft. Ensure proper maintenance of air cleaners, keep spare filters on hand, and provide instructions on changing the filter to trained personnel.

4. Assure that the facility can handle the increased cooling load due to high occupancy.

5. Install a properly calibrated carbon monoxide alarm that has a digital display and battery backup function (available at most hardware stores).

6. Provide a radio for updates on fire status and access to a telephone in case of emergency.

7. Ensure adequate services such as restroom facilities and garbage disposal/collection.

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[1] Minimum Efficiency Reporting Value as determined by ASHRAE Standard 52.2: Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

APPENDIX C

Technical Wildfire and Smoke Resources

The tools in this Appendix may aid public health agencies, communities, and air quality professionals in their technical assessment of wildfires and wildfire smoke. For more information about these tools contact Peter Lahm, U.S. Forest Service, peter.lahm@usda.gov.

Accessing Information about Active Wildfires

It's often difficult to obtain information about brand new or emerging wildfires and good information may take a day or two (or longer) to become available. Until then, the best way to get a little news on a new wildfire may come from scanning social media posts from state fire management agencies, county sheriff departments, and county emergency management. Local news is often quickly onsite and can be another source of information. The National Interagency Fire Center hosts a map that shows various incidents around the US including satellite detected hot spots which may show the location and size estimate of a new wildfire. The map can be accessed here: https://maps.nwcg.gov.

Once a wildfire grows to the point that local fire response agencies can no longer manage it, an Incident Management Team will be ordered. Information on a wildfire is much easier to find once one of these teams has arrived. Detailed information about wildfires can be accessed at the Incident Information System (INCIWEB): https://inciweb.nwcg.gov. Geographic area coordination centers (GACC's) have more localized information about wildfires and are another good source of information. Access your local GACC here: https://gacc.nifc.gov/index.php.

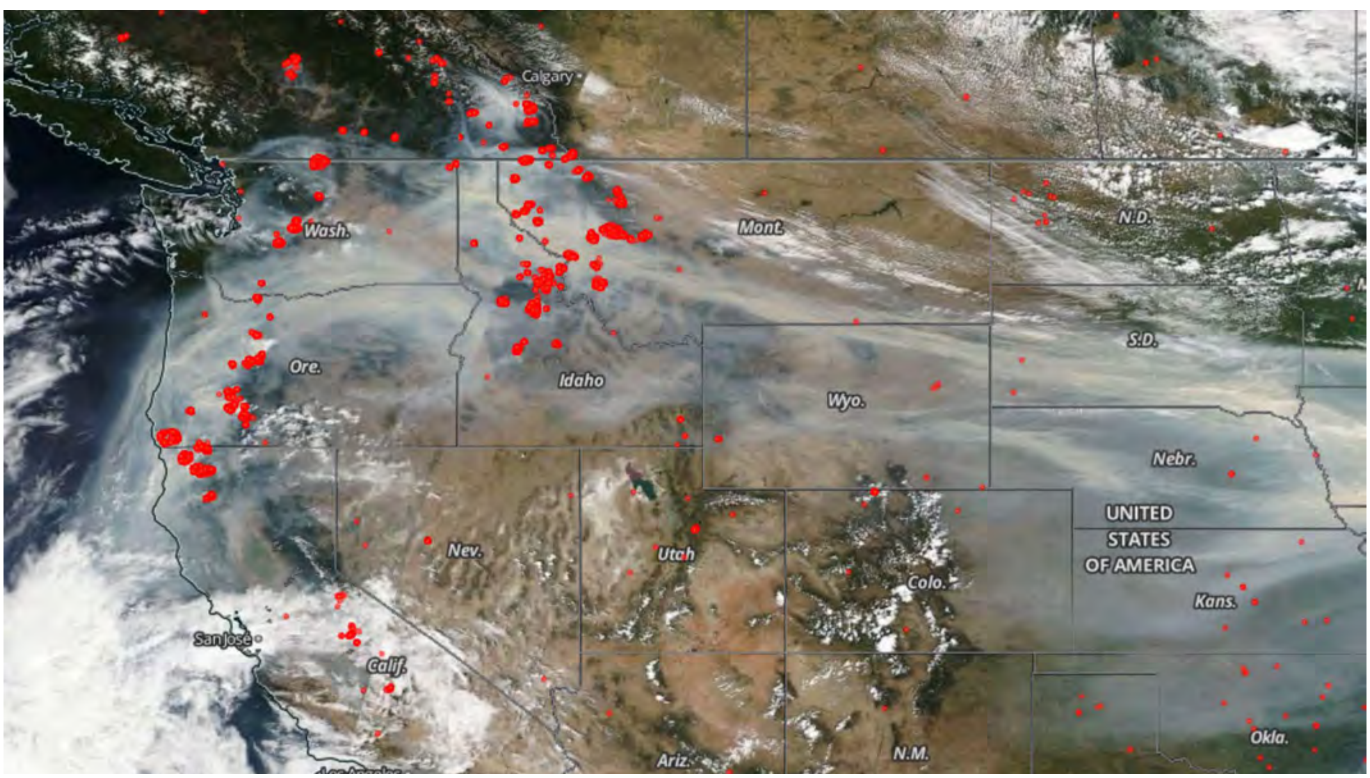

Figure C1. Smoke from many large fires creating haze across the western and central United States. Red dots are satellite fire hot spot detections (NASA WORLDVIEW, September 4, 2017). To learn more, see the NASA Worldview Tutorial by the NASA Health and Air Quality Applied Sciences Team (HAQAST) at https://haqast.org/nasa-tools.

Figure C2. Smoke plumes from NOAA Hazard Mapping System. See more about the NOAA HMS here: https://www.ospo.noaa.gov/Products/land/hms.html.

Seeing Smoke from Space

Satellites are continually viewing the planet and often see large wildfires and the smoke emanating from them. Satellite views can help determine where smoke is coming from. Is it from a near-by fire, or is it from Canada or even Siberia? It's important to note that the smoke seen from a satellite may be anywhere in the atmosphere, so it could be elevated and not affecting people at ground level. Clouds can generally be distinguished from smoke as they show up as bright white whereas smoke is off-white or beige with a brownish tinge. NASA WORLDVIEW provides access to satellite photos: https://worldview.earthdata.nasa.gov. An optional overlay layer of "fires and thermal anomalies" shows the locations of large fires as red spots (Figure C1)

Sometimes satellite pictures are difficult to interpret, such as when smoke mixes with clouds. Then a human analysis is useful, such as the NOAA Hazard Mapping System (HMS) smoke plume product. The analysis tells you where smoke is light (green), medium (yellow), or heavy (red). The Current Fires page on the AirNow website uses shades of gray to display the smoke plumes from the NOAA HMS (Figure C2).

AirNow-Tech

AirNow has a decision support tool called AirNow-Tech (airnowtech.org), which allows partner agencies to manage, quality control, query, and visualize not only their data but also a national dataset of air quality, meteorological and satellite information. One powerful AirNow-Tech tool for wildfire evaluation is Navigator GIS. Navigator allows the user to overlay meteorological, fire, and satellite data over air quality observations. In addition, users can run trajectories on any point of the display to see air parcel projections or for post wildfire event analysis (Figure C3).

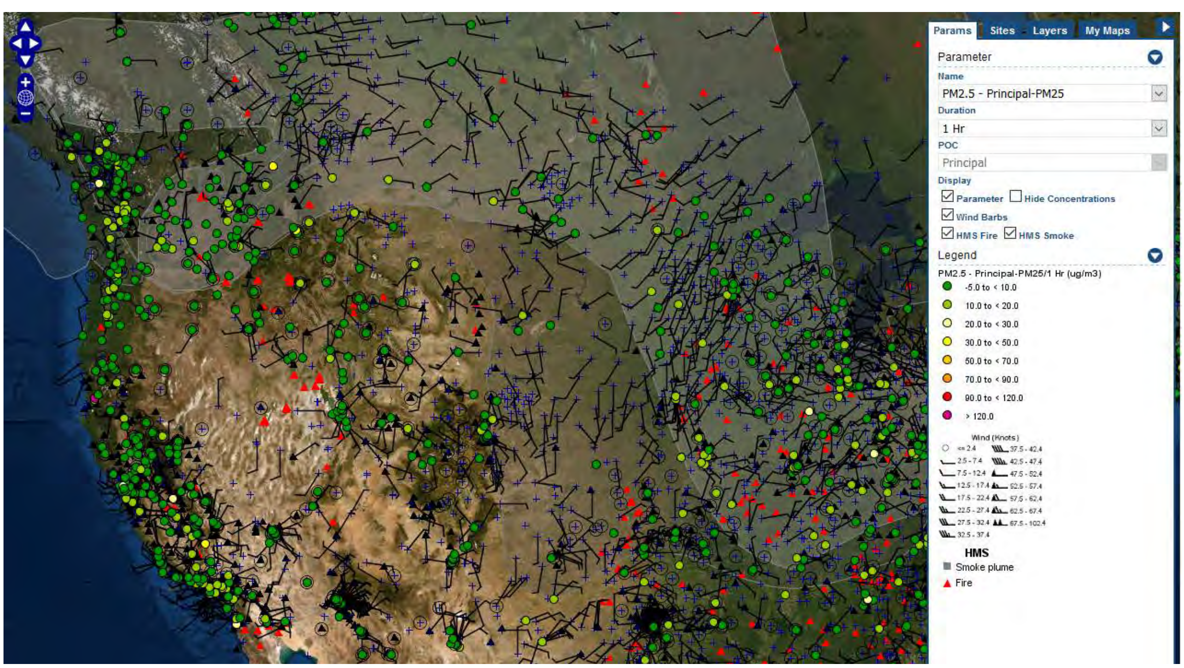

Figure C3. AirNow-Tech Navigator

U.S. Forest Service/Interagency Wildland Fire Air Quality Response Program Tools

The U.S. Forest Service Research AirFire Team and the Wildland Fire Air Quality Response Program have developed a number of tools and on-line resources to aid in summarizing monitoring data and making smoke dispersion predictions. These tools, plus others under development, are available here: https://wildlandfiresmoke.net/tools. These are some of the fundamental tools used by Air Resource Advisors assigned to wildfires.

Particulate ($PM_{2.5}$) Monitoring Website Tool

The Particulates Monitoring Website Tool (https://tools.airfire.org/monitoring) provides easy-to-use, rapid access to particulate air quality monitoring data from publicly available permanent monitoring sites across the United States and from temporary monitoring instruments set up during wildland fire incidents. Users

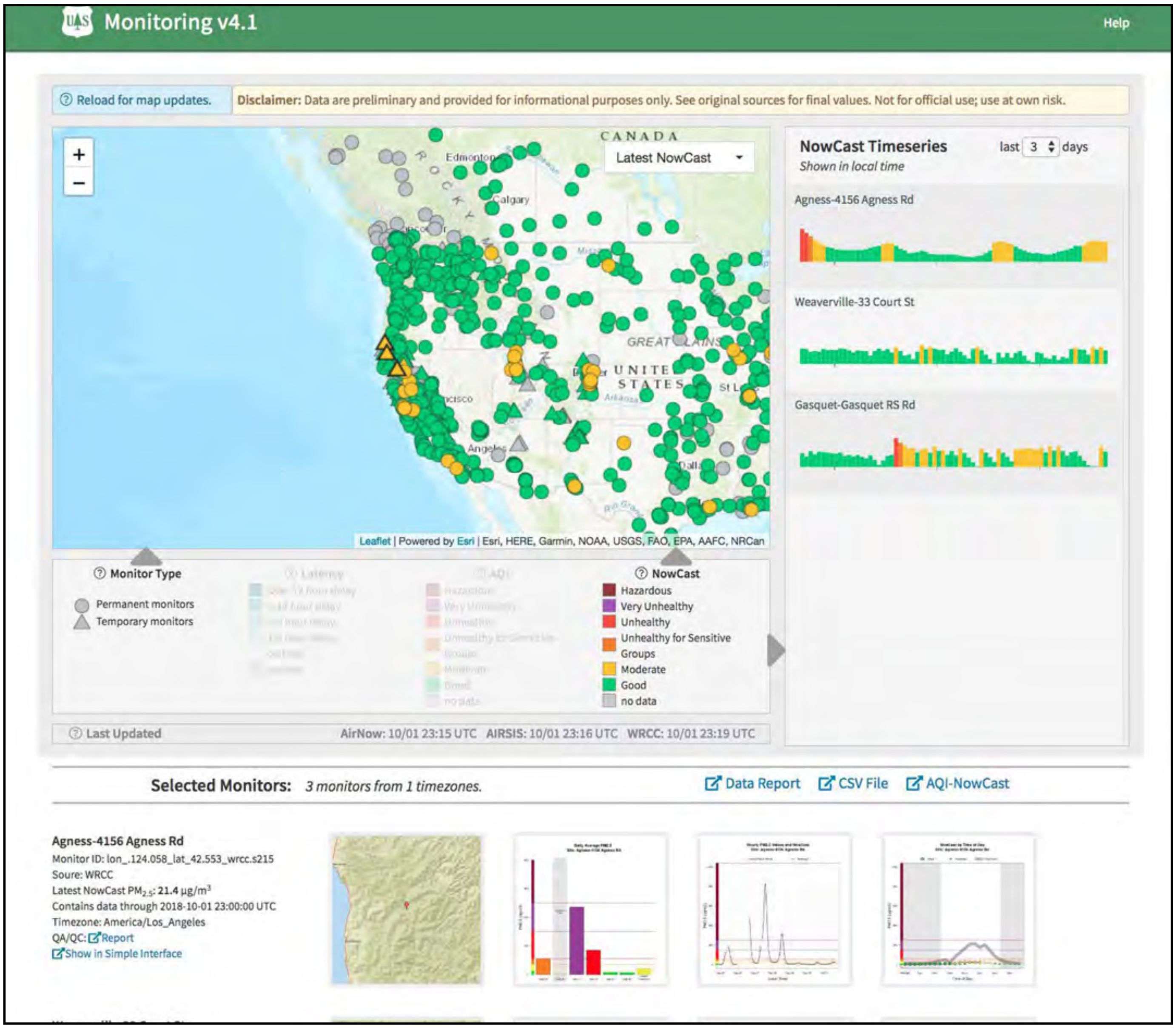

Figure C4. $PM_{2.5}$ monitoring web tool display example. Current fine particulate NowCast conditions are shown on the map. Selecting monitors of interest reveals a multi-day NowCast time series and other graphics. Access at https://tools.airfire.org/monitoring.

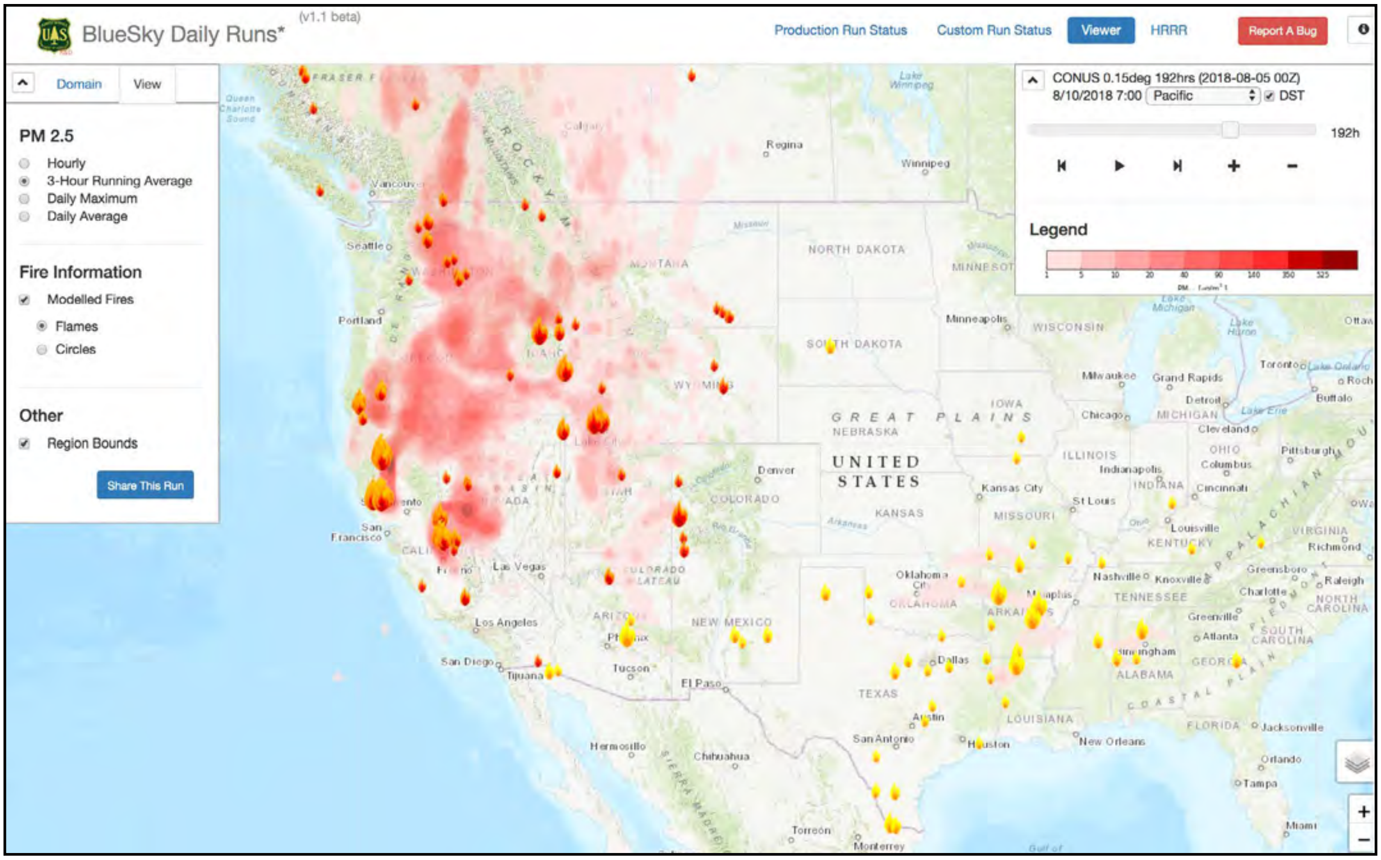

Figure C5. BlueSky daily smoke model run for the Continental United States (CONUS) shown in the web viewer version. KMZ and other output formats are also available at https://tools.airfire.org.

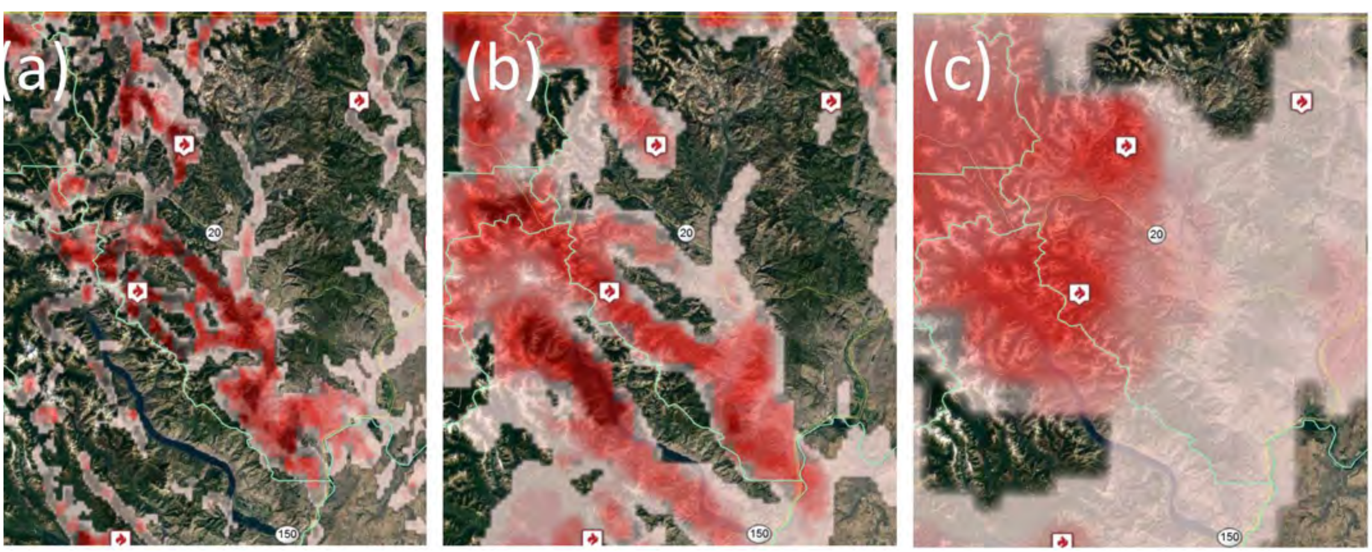

Figure C6. BlueSky hourly average surface smoke predictions at 1am on 8/19/2018 at 3 grid resolutions: (a) 1.33 km, (b) 4 km, and (c) 12 km in north central Washington. Higher resolution versions (a and b) allow the effect of complex terrain to be better reflected in smoke concentration estimates. KML/Google Earth version.

can select monitors from a map and view time-series data in a number of plots showing daily averages, hourly NowCast values, and diurnal smoke impact patterns. Multiple monitors of interest can be selected, and once selected bookmarking the site's URL allows users to share this list with others or to quickly return to this specific set of monitors and view updated air quality measurements.

Currently the tool displays fine particulate measurements ($PM_{2.5}$), but other pollutants may be added in the future. The tool uses public data made available from EPA's AirNow-Tech system (https://airnowtech.org), monitoring data from a national cache of temporary monitors that are deployed during wildfire incidents, plus any additional monitoring data made available by originating agencies as long as the source data has not been tagged as "private"[2] (Figure C4).

BlueSky Daily Smoke Model Runs

Predicting air quality impacts from active wildfires depends on linking together information and models to estimate fire size, fuel type, fuel consumption, smoke plume rise, weather, atmospheric dispersion, and ground-level smoke concentrations. One commonly used smoke tool developed by the Forest Service AirFire Research team is the BlueSky smoke modeling framework. Multiple versions of BlueSky run automatically each day with daily updates of fire and weather information. BlueSky combines basic fire information with available fuels maps (from the USFS Fire Characteristic Classification System [FCCS]) and current fuel moisture conditions (from the USFS Wildfire Information Management System [WIMS]), to compute fuel consumption (via the USFS CONSUME model) and emissions before computing plume rise and dispersion. Two different plume and dispersion models are used - a simple LaGrangian dispersion model with no chemistry (HYSPLIT), and the Community Multiscale Air Quality Modeling System (CMAQ). CMAQ is run in two modes; limited chemistry, or as a full photochemical model with all sources. Multiple geographic domains, weather models, weather model resolutions, and dispersion models combine to result in approximately 30 separate iterations for a user to choose from (Figure C5). All runs can be accessed at https://tools.airfire.org.

BlueSky relies on meteorological models with high resolution grids in order to better estimate local smoke effects. Currently the most fine-scale meteorological models used by BlueSky on a daily basis have a resolution of 1.33 km enabling predictions of smoke movement to reflect the effects of complex terrain (Figure C6). High resolution versions of BlueSky are available for the Pacific Northwest, California/Nevada, Arizona, and Alaska. National grids at 3-km resolution are available, as are combined Canada/CONUS grids. Movable, high-resolution meteorological grids (1.27 km) can be placed over areas of concern during the western wildfire season when made available by the National Weather Service. All model runs are viewable on a simple web map with options for 1-hour, 3-hour, and daily (24-hour) smoke estimates. Typical forecasts extend for 2–3 days into the future. KMZ files for use in Google Earth are available for download.

[2] Occasionally states set up special purpose monitoring studies where the data is not publicly available.

APPENDIX D

Guidance on Protecting Workers in Offices and Similar Indoor Workplaces from Wildfire Smoke (Adapted from Cal/OSHA)

Wildfire smoke can be a hazard for people who work in office and commercial buildings many miles from evacuation zones. Environmental and public health agencies have advised people to consider setting air conditioners in their homes to recirculation mode, if possible, in order to reduce the intake of pollutants. Subsequently, people have asked whether to apply this advice to limit the introduction of outdoor air applies to office and commercial buildings. Eliminating or substantially reducing the outdoor air supply in office buildings and other indoor workplaces as a first step to reduce exposure to smoke is generally not recommended.

The ventilation systems in office buildings and other commercial buildings are more complicated than home air-conditioning systems. Changing the outdoor air supply in public and commercial buildings can adversely affect other essential functions of the building. These buildings typically have heating, ventilating and air conditioning systems (HVAC systems) that bring outside air into the building through filters, blend it with building return air, and thermally condition the air before distributing it throughout the building. These buildings also have exhaust air systems for restrooms and kitchens, and may also have local exhaust systems for garages, laboratory fume hoods, or other operations. These exhaust systems require makeup air (outdoor air) in order to function properly. Also, without an adequate supply of outdoor air, these systems may create negative pressure in the building. Negative pressure will increase the movement of unfiltered air into the building through any openings, such as plumbing/sewer vents, doors, windows, junctions between building surfaces, or cracks. In general, buildings should be operated at slight positive pressure in order to keep contaminants out, and to help exhaust air systems function properly.

HVAC systems should be operated continuously while occupied in order to provide the minimum quantity of outdoor air for ventilation, as required by the standards or building codes to which the building was designed. For many office buildings, this is often in the range of 15–20 cubic feet per minute (cfm) per person, although it could be less in older buildings.[3]

Using the HVAC System(s) to Protect Building Occupants from Smoke

As a first step to protect building occupants from outdoor air pollution, including the hazardous conditions resulting from wildfire smoke, building managers and employers should ensure that the HVAC system's filters are not dirty, damaged, dislodged, or leaking around the edges. Before the wildfire season, or during smoke events if necessary, employers and building operators should ensure that a qualified technician inspects the HVAC systems, makes necessary repairs, and conducts appropriate maintenance. Filters should fit snugly in their frames, and should have gaskets or sealants on all perimeter edges to ensure that air does not leak around the filters.

Building operators should consider installation of the highest efficiency filters that do not exceed the static pressure limits of the HVAC systems, as specified by the manufacturer or system designer[4]. Pressure gauges

[3] Cal/OSHA regulations (8 CCR 5142) require that HVAC systems be operated continuously while occupied in order to provide the minimum quantity of outdoor air required by the state building code at the time the building permit was issued. These regulations are currently found in the California Code of Regulations, Title 24, Section 121. For most buildings, this quantity is 15 cubic feet per minute (cfm) per person.

[4] Many existing HVAC systems should be able to accommodate pleated, medium-efficiency filters with particle removal ratings of MERV 5 to 12, and some may be able to use high-efficiency filters with ratings of MERV 13 or higher. Consider a low-pressure HEPA filter (MERV 17 plus) if the building occupants have respiratory or heart

should be installed across the filter to indicate when the filter needs replacing, especially in very smoky or dusty areas. Indoor contaminants can be further reduced by using stand-alone high-efficiency particulate air (HEPA) filtering units. For more information on air cleaners, see the California Air Resources Board webpage at: https://www.arb.ca.gov/research/indoor/aircleaners/consumers.htm.

In some circumstances it may be helpful to reduce the amount of outdoor air in order to reduce smoke pollution inside the building, while still maintaining positive pressure in the building. Temporary reductions in outdoor air flow rates might be considered when all of the following conditions are met:

1. The local outdoor air quality for particulate matter meets the EPA Air Quality Index definition of Unhealthy, Very Unhealthy, or Hazardous due to wildfire smoke.
2. A qualified HVAC technician has inspected the HVAC systems and ensured that the filters are functioning properly, that the filter bank is in good repair, and that the highest feasible level of filtration has been provided. This should be documented in writing.
3. A qualified HVAC technician or engineer has assessed the building mechanical systems and determined, in writing, the amount of outside air necessary to prevent negative pressurization of the building, and to sufficiently ventilate any hazardous processes in the building (such as enclosed parking garages or laboratory operations).
4. The HVAC systems are operated continuously while the building is occupied to provide at least the minimum quantity of outdoor air needed, as determined by the HVAC technician or engineer in Item 3 above.

The employer or building operator ensures that the systems are restored to maintain the minimum quantity of outdoor air for ventilation, as required by the standards or building codes to which the building was designed, no later than 48 hours after the particulate matter levels fall below the levels designated by the EPA as Unhealthy.

Other Actions to Protect Employees from Wildfire Smoke

In addition to assessing and if necessary modifying the function of the HVAC system, employers are encouraged to take other reasonable steps to reduce employee exposure to smoke, including alternate work assignments or relocation and telecommuting. Some buildings rely on open windows, doors, and vents for outdoor air, and some may have mechanical ventilation systems that lack a functioning filtration system to remove airborne particles. In these cases, the employees may need to be relocated to a safer location. Employees with asthma, other respiratory diseases, or cardiovascular diseases, should be advised to consult their physician for appropriate measures to minimize health risks.

Respirators, such as N95s and other filtering facepiece respirators, may provide additional protection to some employees against environmental smoke. Employees whose work assignments require the use of respirators must be included in a respiratory protection program (including training, medical evaluations, and fit testing).

Additional Information

The Lawrence Berkeley National Laboratory has produced a multi-page summary on air cleaning and its effects on health and perceived air quality, which can be found at: https://iaqscience.lbl.gov/air-summary

disease conditions, or if the building experiences frequent wildfire episodes.

APPENDIX E

Hazards during Cleanup Work Following Wildfires from National Institute for Occupational Safety and Health (NIOSH)

The purpose of this section is to discuss some of the health and safety hazards that homeowners and workers may encounter after a wildland fire. This document is not designed to address health and safety for fire fighters or other emergency response workers during a wildfire or other emergency event.

After a wildfire has ended, cleanup and recovery activities are often needed. These activities may pose health and safety hazards that require necessary precautions. In most cases, it may be more appropriate for professional cleanup and disaster restoration companies, rather than homeowners or volunteers, to conduct this work. Although the types of hazards may be different for each wildland fire, some common hazards include:

1. Contact with fire.

   After a wildfire, trained fire fighters will make sure the fire is completely out. If there is any chance the wildfire could reignite, leave immediately and notify emergency personnel.

2. Burnt and unstable structures.

   Be aware of unstable and damaged houses and other structures after a wildfire. Do not assume that these areas are safe or stable because damage may not be noticeable and can create a risk for serious injuries from slips, falls, punctures, or being struck by collapsing materials.

   Safety Measures

   To prevent injuries from burnt and unstable structures:

   - Conduct a thorough inspection and identify and eliminate hazards before conducting any work. Avoid work around fire-damaged structures, including stairs, floors, and roofs, until an engineer or architect examines and certifies the structure is safe.
   - Wear personal protective equipment, including long sleeved shirts and pants, hard hats, safety glasses, leather gloves, and steel toe boots, to reduce the risk of injury.
   - Leave immediately if a structure shifts or makes an unusual noise that could signal a possible collapse.

3. Burnt and unstable trees. Another common hazard after a wildfire is unstable trees, known as 'snags' or 'hazard trees,' which can fall and injure homeowners and workers. It is important to assess the stability of all trees before working and driving around them.

   Safety Measures

   - Always contact a professional to evaluate a tree's stability and to safely remove any suspected hazardous trees from the property and along roadways before conducting cleanup work.
   - For more information about potential hazards from tree removal, see: Preventing Chain Saw Injuries During Tree Removal After a Disaster (https://www.cdc.gov/disasters/chainsaws.html).

4. Carbon monoxide.

   - Wildland fire cleanup activities may involve the use of gasoline or diesel powered pumps, generators, and pressure washers. This equipment releases carbon monoxide (CO), a deadly, colorless, odorless gas. It is important that homeowners and workers protect themselves from CO poisoning.

   Safety Measures

   To avoid the risk of CO poisoning:

   - Never bring gas or diesel powered machines indoors.
   - Only operate these machines in well-ventilated areas.
   - Do not work near exhaust gases (CO poisoning can occur even outdoors near exhaust from engines that generate high concentrations of CO).
   - Shut off the equipment immediately and seek medical attention if you experience symptoms of CO poisoning.
   - To learn more, visit NIOSH's webpages: Carbon Monoxide (https://www.cdc.gov/niosh/topics/co-comp/) or Carbon Monoxide Hazards from Small Gasoline Powered Engines (https://www.cdc.gov/niosh/topics/co/).

5. Confined spaces.

   A confined space is an area that has limited openings for entry or exit, has limited air flow and is not designed for human occupancy. Examples of confined spaces include septic tanks, storage tanks, utility vaults and wells. These spaces may contain toxic gases, may not have oxygen, or may be explosive. In many cases, these hazards are not easily recognized without proper training and equipment.

   Safety Measures

   - Never enter a confined space without proper training and equipment, not even to rescue a fellow worker. Contact the local fire department for help.
   - To learn more, visit NIOSH's webpage: Confined Spaces (https://www.cdc.gov/niosh/topics/confined-space/).

6. Fatigue and stress.

   A homeowner may experience emotional stress and mental and physical fatigue from cleanup and from loss of personal property or valuables. Fatigue and stress may increase the risk of injury and illness.

   Safety Measures

   After a fire, homeowners or other workers may need to:

   - Seek emotional support from family members, neighbors, and local mental health care workers to help prevent more serious stress-related problems.
   - Set priorities for cleanup tasks and pace work over days or weeks to avoid physical exhaustion.
   - Rest and take frequent breaks to avoid exhaustion.
   - Begin a normal sleep and eating schedule as quickly as possible.
   - Take advantage of disaster relief programs and services in the community.
   - Understand physical and mental limitations.

- To learn more, visit NIOSH's webpages: Traumatic Incident Stress: Information For Emergency Response Workers (https://www.cdc.gov/niosh/mining/works/coversheet643.html) and Stress at Work (https://www.cdc.gov/niosh/topics/stress/).

7. Electrical dangers.

   One common danger after a fire is a downed/damaged power pole with potentially energized power lines laying on the ground or hanging from the pole. Any type of work with power lines or other electrical sources must only be conducted by trained professionals, such as electricians and utility workers. If a potential electrical danger or a downed power line is identified, avoid all electrical hazards by stopping work and immediately notifying the local utility company.

Safety Measures

When working near power lines, it is important to follow these steps to prevent electrical injuries:

- Do not work or enter any area with any potential for electrocution from a power line or other electrical hazards.
- Treat all power lines and cables as energized until proven otherwise.
- When the power is off, never restore power until a professional inspects and ensures the integrity of the electrical system.
- Do not use electrical equipment that has been exposed to heat from a fire until checked by an electrician.
- Unless power is off, never enter flooded areas or touch electrical equipment if the ground is wet.
- Use extreme caution when equipment is moved near overhead power lines. For example, contact between metal ladders and overhead power lines can cause serious and often fatal injuries.
- Do not stand or work in areas with thick smoke. Smoke hides electrical lines and equipment.
- To learn more, visit NIOSH's Electrical Safety page: (https://www.cdc.gov/niosh/topics/electrical/).

8. Hazardous and other potentially dangerous materials.

   Many homes and other structures may contain or store hazardous materials and chemicals. Some common materials include asbestos, lead, pesticides, propane, and gasoline. These materials may cause health effects, may be explosive, or may react with other chemicals. Before beginning cleanup activities, contact a professional who is familiar with hazardous materials to determine the different types of hazards that are present and how to safely clean up and dispose of them in accordance with local and state laws.

Safety Measures

To reduce the chance of exposure to hazardous and other dangerous materials:

- Be cautious of chemicals, propane tanks, and other dangerous materials.
- Wear protective clothing and gear when handling hazardous materials.
- If exposed to hazardous materials, wash the affected area (e.g., skin, eyes) and contact your local poison control center or the American Association of Poison Control Centers at 1 (800) 222-1222. Seek medical care immediately if the exposure is severe or you experience symptoms.
- Homes built before 1980 may contain asbestos and lead. Contact your county health department to learn about local laws and regulations. Because disturbing lead and asbestos may result in serious health consequences, it is recommended that only trained professionals test for and clean up materials that contain lead or asbestos.

- Fires may also damage tanks, drums, pipes, or equipment that may contain hazardous materials, such as pesticides, gasoline, or propane. Before opening or removing containers that may contain hazardous materials, contact the local fire department or a hazardous materials team to help assess and remove hazardous waste.
- To learn more about chemical safety, visit NIOSH webpages: Pocket Guide to Chemical Hazards (https://www.cdc.gov/niosh/npg/) and Chemical Safety (https://www.cdc.gov/niosh/topics/chemical-safety/default.html).

9. Hot environments.

While working in hot weather, homeowners and cleanup workers could be at risk for heat-related illnesses, such as heat stress, heat rash, heat cramps, and heat stroke. It is important to be aware of the symptoms of heat related illness, how the illness can affect health and safety, and how it can be prevented.

Safety Measures

To reduce the potential for heat related illnesses, it is important to follow some basic work practices, such as:

- Wearing lightweight, light-colored, loose-fitting clothes,
- If possible, blocking out direct sun or other heat sources,
- Taking frequent breaks in cool, dry areas,
- Acclimatizing before working (getting used to weather conditions),
- Working during the cooler hours of the day when possible, and
- Maintaining hydration by drinking plenty of water and other fluids.
- If a homeowner or worker displays any signs of heat related illness, it is important to immediately go to a cool, shaded place, sit or lie down, and drink water. If possible, cool water may be poured over the homeowner's or worker's head and body. Seek medical attention immediately if the symptoms do not subside.
- To learn more, visit NIOSH's webpage: Heat Stress (https://www.cdc.gov/niosh/topics/heatstress/).

10. Musculoskeletal injuries.

Homeowners and workers who may be involved in cleanup activities are at risk for developing stress, strain, and potential musculoskeletal injuries, which are injuries or disorders of the muscles, nerves, tendons, joints, cartilage, or spinal discs. These common injuries can occur when moving debris and materials, using hand-held equipment (e.g., chainsaws) due to repetition, force, vibration, or awkward postures.

Safety Measures

Some useful tips to prevent these injuries:

- Use teams of two or more to move bulky objects.
- Take breaks when conducting repetitive work, especially if experiencing fatigue.
- Avoid working in unusual or constricting postures.
- Use correct tools and equipment for the job and use them properly.

- Do not lift material weighing 50 pounds or more and use automated lifting devices for heavier objects.
- Be sure the area is clear of slip, trip and fall hazards.
- To learn more, visit NIOSH's webpage: Ergonomics and Musculoskeletal Disorders (https://www.cdc.gov/niosh/topics/ergonomics/).

11. Wildfire smoke and ash

Smoke from a wildland fire can pose health risks. Older adults, young children or individuals with underlying heart or lung disease are the most likely to be affected by inhaling wildland fire smoke. Healthy individuals may also experience short-term respiratory irritation symptoms, such as burning eyes and runny nose. If there is smoke in the area, homeowners and cleanup workers who are at-risk of experiencing a smoke-related health effect should consider leaving the area until the smoke clears.

Ash from wildland fires can be deposited on indoor and outdoor surfaces in areas around the fire and can be irritating to the skin, nose and throat, and may cause coughing.

Safety Measures

To minimize the health effects that may occur due to exposure to smoke and ash:

- Always wear proper personal protective equipment (long sleeve shirts, pants, gloves and safety glasses) when working around ash. If you do get ash on your skin, wash it off as soon as possible.
- Do not use leaf blowers or take other actions (e.g., dry sweeping) that will put ash into the air. Shop vacuums and other common vacuum cleaners do not filter out small particles, but rather blow the particles out the exhaust into the air. To clean up ash, use vacuums equipped with High Efficiency Particulate Air (HEPA) filters.
- Do not consume any food, beverages, or medication that has been exposed to burn debris or ash.
- Well-fitting respirators may provide some protection during cleanup. Please visit NIOSH's Respirator Trusted-Source Information web site at: http://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/RespSource.html.
- If the presence of asbestos, lead, CO or other hazardous material is suspected, do not disturb the area. Dust masks or filtering facepiece respirators do not protect against asbestos or gases such as CO.
- Avoid burned items that may contain hazardous chemicals, such as cleaning products, paint and solvent containers.
- Avoid ash from wooden decks, fences, and retaining walls pressure treated with chromated copper arsenate (CCA) as it may contain lethal amounts of arsenic.

12. Working with and around heavy equipment.

Do not operate heavy equipment, such as bulldozers, backhoes, and tractors, unless you are properly trained. Serious and fatal injuries can occur when equipment is used improperly. To learn more about motor vehicle safety, visit NIOSH's webpages: Motor Vehicle Safety (https://www.cdc.gov/niosh/motor-vehicle/default.html) and Fatality Assessment Control and Evaluation (https://www.cdc.gov/niosh/face/default.html).

13. First aid

First aid, even for minor cuts and burns, is extremely important as workers are exposed to smoke and burned materials. For more information, please visit NIOSH's webpage: NIOSH's First Aid Procedures (https://www.cdc.gov/niosh/npg/firstaid.html).

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