Wildfire Smoke

Considerations for California's Public Health Officials

August 2022

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Introduction

The ten largest wildfires in California's recorded history have occurred since 2000—with five of these wildfires occurring in a single year (2020). The 2020 August Complex wildfire was the first California wildfire to burn over 1,000,000 acres.[1] Instead of primarily late summer and early fall, wildfires now occur throughout the year—the 2022 Big Sur wildfire started in January and the 2017 Thomas wildfire started in December. Scientists predict that climate change will result in "longer, hotter, and drier fire seasons" that increase the risk of severe wildfires and exposure to wildfire smoke.[2]

This new reality creates challenges for California's public health officials on many fronts. Wildfires pose immediate risk to human life in addition to the public health consequences beyond the immediate impacts to people, animals, and the environment. Wildfire smoke can be especially concerning for marginalized communities, where people have fewer resources for avoiding smoke and less access to adequate health care. The COVID-19 pandemic has added to the challenges of planning for and responding to wildfire smoke incidents.

The wildfire smoke incidents experienced in many areas of the state during 2017-2018 prompted the California Department of Public Health (CDPH) to publish *Wildfire Smoke: Considerations for California's Public Health Officials* in 2019. This document has been updated in 2022 to add new information relevant to managing the public health impacts of wildfire smoke.

Once a Seasonal Threat, Large Wildfires in California Are Now Occurring Year Round

Traditionally, wildfire season in California occurs in late summer and fall, before seasonal rains come later in the year. However, recent years have shown that fire 'season' is extending, bringing large fires in December and January. As drought conditions have worsened in California, drying terrain and lowering water levels, many in the state are shifting their thinking from a "fire season" to a "fire year."

This document contains information about wildfire smoke and its health effects, sensitive populations, strategies to reduce exposure, and other public health considerations to support community response. Additional resources and information, including links, are provided throughout the document and in appendices to support the public health response to wildfire smoke.

1 Top 20 California Wildfires

2 Robinne FN, Burns J, Kant P, Flannigan M, Kleine M, de Groot B, Wotton DM. Global fire challenges in a warming world. 2018, IUFRO.

The primary audience for this document includes California's public health officials and emergency management professionals, although it may be of interest to anyone involved in the management of wildfire smoke and its impacts.

A successful community response requires collaboration among multiple entities, including local health departments, environmental health departments, air districts, emergency management agencies, school districts, tribal entities, healthcare providers, local EMS agencies, and state and federal agencies. Local health officials are vital participants in planning to prevent and reduce the health impacts of climate change through providing health and equity input to climate action plans, general plans, local hazard mitigation plans, transportation plans, and other planning processes.

Highlighted Tools & Resources

This document contains a variety of templates, references, and links to additional information. For ease of visual navigation, select resources are highlighted with screenshots, graphics, or a toolbox icon (see left).

Any mention of trade names, products, or services is for informational purposes only and is neither an endorsement nor recommendation for use.

Wildfire Smoke

Wildfires produce large amounts of particles and gases, including fine and coarse particles, greenhouse gases (carbon dioxide, methane, nitrous oxide), photochemically reactive compounds (e.g., carbon monoxide), non-methane hydrocarbon, and nitrogen oxides. Wildfires contribute to air pollution through the emission of primary pollutants and the production of secondary pollutants, e.g., ozone, during photochemical processing.

The impact of wildfires on air quality depends on weather patterns (including temperature, humidity, and wind speed), fire plume dynamics, amount and chemical composition of the emissions, and atmosphere into which the emissions are dispersed. Geography also plays a role; mountains and other features may contribute to inversion layers that can keep smoke contained in certain areas (or keep smoke out).

Wildfire smoke can impact large areas that span multiple health jurisdictions and air districts. Response partners include but are not limited to:

- Local health departments
- Local environmental health departments
- Local/regional air districts
- Local EMS agencies
- Local emergency management agencies
- School districts
- Tribal entities
- Mass care and shelter organizations
- California Air Resources Board (CARB)
- California Department of Public Health (CDPH)
- California Governor's Office of Emergency Services (Cal OES)
- Other local, state, and federal agencies that support local jurisdictions impacted by wildfire smoke

Particulate Matter

Particulate matter (PM) is currently the principal known pollutant of concern from wildfire smoke for relatively short-term exposures (hours to days).[3] PM refers to small particles suspended in air that are typically a mixture of solid particles and liquid droplets.

There are many sources of PM, although they are generally divided between human (anthropogenic) activities such as industrial processes, agricultural operations, combustion of wood and fossil fuels, and natural (biogenic) activities such as windblown dust and wildfires. Other contributors to PM include tobacco smoke, gas stoves, wood dust, and cleaning products.

Particles are characterized according to their size. Particles that have an aerodynamic diameter of 10 µm or less are inhalable and include both coarse and fine particles.

Coarse particles have a diameter less than or equal to 10 µm and while they may irritate the eyes, nose, and throat, larger particles generally do not penetrate deeper into the lungs. **Fine** particles have a diameter of 2.5 µm or less; and **ultrafine** particles have a diameter of less than 0.1 µm. Fine particles constitute the main component of wildfire smoke that impacts public health due to their ability to penetrate deeper into the lungs and enter the bloodstream, affecting vital organs throughout the body. See Table 1.

Table 1. Categories of Particulate Matter

Particulate Matter (PM)		
Name	**Diameter**	**Symbol**
Coarse	≤10 µm	PM_{10}
Fine	≤2.5 µm	$PM_{2.5}$
Ultrafine	≤0.1 µm	$PM_{0.1}$

3 Protecting Yourself From Wildfire Smoke (CARB)

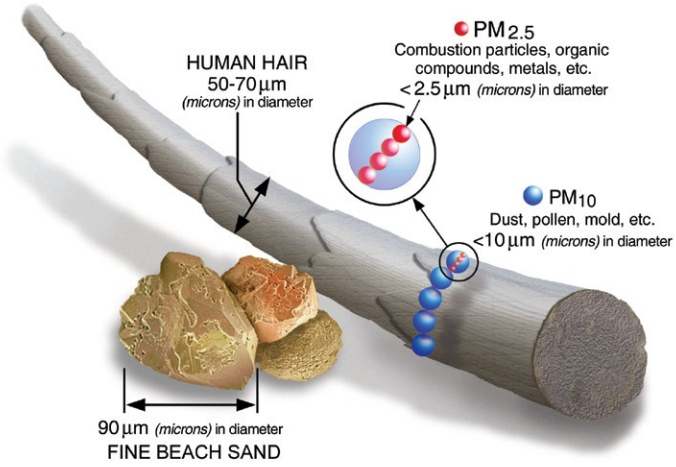


Figure 1. *Relative Size Comparison for $PM_{2.5}$ and PM_{10} (courtesy of the United States Environmental Protection Agency (U.S. EPA)*[4]

Air quality standards have been established for both $PM_{2.5}$ and PM_{10}. Air quality standards for PM do not distinguish between chemical composition or the source of emissions, i.e., the standards do not differentiate between PM due to anthropogenic activities such as traffic emissions and industrial processes versus PM associated with wildfire smoke. Preliminary studies suggest the possibility that wildfire-associated $PM_{2.5}$ may have a greater impact on human health than equal doses of non-wildfire associated $PM_{2.5}$, although further research is needed to fully understand its impact.[5]

Other Pollutants in Wildfire Smoke

Wildfire smoke composition varies due to several factors, including the composition of fuel being burned, combustion temperature and type (flaming versus smoldering), photochemical aging, and other factors. In addition to PM, wildfire smoke contains a variety of pollutants, including chemicals listed as Hazardous Air Pollutants (HAPs) by U.S. EPA and Toxic Air Contaminants (TACs) by the Office of Environmental Health Hazard Assessment (OEHHA), California Environmental Protection Agency (CalEPA). Certain chemicals differentially affect children.[6]

4 Particulate Matter (PM) Basics - U.S. EPA

5 Aguilera R, Corringham T, Gershunov A, Benmarhnia T. Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California. Nat Commun. 2021;12(1):1493.

6 Document Available: Prioritization of Toxic Air Contaminants - Children's Environmental Health Protection Act - Final Report - OEHHA

The major components of wildfire emissions are PM and gases, including carbon dioxide, carbon monoxide, nitrogen oxides, and volatile organic compounds (VOCs, such as formaldehyde and benzene). If fires reach the wildland-urban interface, other toxic chemicals are likely to be released from the burning of household or industrial materials, such as plastics, pesticides, and other hazardous waste.

The California Air Resources Board (CARB) compared air quality data from the 2018 Camp Fire that destroyed nearly 19,000 buildings with three other large wildfires that burned mostly vegetation.[7] CARB's analysis showed that elevated levels of lead, zinc, iron, and manganese were located as far as 150 miles away.

Smoke and flames from the Airport Fire in Owens Valley CA, February 2022. (Ross Stone/Unsplash)

7 California Air Resources Board, Camp Fire Air Quality Data Analysis

Regulatory Air Monitoring

The federal Clean Air Act requires the U.S. EPA to establish air quality standards for major pollutants: **primary standards** to protect public health and **secondary standards** to protect the public against environmental effects, including adverse impacts to soil, water, and crops. Primary standards must protect public health, including sensitive populations, with an adequate margin of safety. Regulatory air monitoring is used to assure these standards are met throughout the U.S. and identifies attainment and nonattainment areas.[8]

To this end, the U.S. EPA establishes National Ambient Air Quality Standards[9] (NAAQS) for six major air pollutants (also called "criteria air pollutants"), including particulate matter (PM), ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. California law establishes California Ambient Air Quality Standards (CAAQS) that may be more stringent than national standards and include additional pollutants as determined by the California Air Resources Board (CARB), including sulfates, hydrogen sulfide, vinyl chloride, and visibility-reducing particles.[10]

There are two primary standards for $PM_{2.5}$: a **24-hour standard** and an **annual standard**. The 24-hour standard is designed to protect the public from *short-term exposure* and the annual standard is designed to protect the public from *long-term exposure* (see Table 2).

Table 2. *Federal regulatory standards for $PM_{2.5}$*

$PM_{2.5}$ Primary Standards	Purpose	Limit	Computational Method
24-hour	Protect short-term health	35 µg/m^3	An area meets the 24-hour standard ("attainment") if the 98th percentile of the 24-hour daily $PM_{2.5}$ concentrations, averaged over three years, is less than or equal to 35 µg/m^3.
Annual	Protect long-term health	12 µg/m^3	An area meets the annual average standard if the three-year average of its annual average $PM_{2.5}$ concentration is less than or equal to 12 µg/m^3.

8 U.S. EPA Nonattainment Areas and Designations
9 National Ambient Air Quality Standards (NAAQS) Table - EPA
10 Ambient Air Quality Standards (California and National)

Air Quality Regulation in California

Implementing air quality standards is the joint responsibility of U.S. EPA and states. States are responsible for developing enforceable state implementation plans to achieve and maintain air quality that meets national standards. State and local agencies are responsible for air monitoring.

The state agency responsible for air quality standards in California is the California Air Resources Board (CARB). Thirty-five local air districts are responsible for regional air quality planning, monitoring, and stationary source and facility permitting. These air districts are called Air Quality Management Districts (AQMDs) or Air Pollution Control Districts (APCDs); see Appendix E for a map of California's air districts.[11]

The primary purpose of California's *State and Local Monitoring Network*[12] is to monitor criteria air pollutants and determine if areas are in attainment of established standards. Regulatory air monitoring stations must comply with federal and state requirements and involve significant resources to acquire, site, operate, and maintain (see Figure 2). There are approximately 250+ regulatory air monitors in California, the nation's most populous state.

Wildfire smoke patterns can be highly variable due to several factors and smoke-impacted areas may not have a fixed-site regulatory air monitor nearby. During severe smoke events, portable monitors may be deployed to fill critical gaps in spatial coverage (see Figure 3).[13]

Figure 2. *Regulatory air quality monitoring station (fixed location)*

Figure 3. *Beta Attenuation Monitor (portable)*

11 California Air Districts

12 California Ambient Air Monitoring Network

13 Schweizer, D.; Cisneros, R.; Shaw, G. A comparative analysis of temporary and permanent beta attenuation monitors: The importance of understanding data and equipment limitations when creating $PM_{2.5}$ air quality health advisories. Atmos. Pollut. Res. 2016, 7, 865–875.

Local, state, and federal agencies deploy portable air monitoring equipment from existing caches. CARB maintains a cache of field-deployable portable monitors that can augment existing monitoring capacity during smoke events; see CARB Emergency Air Monitoring Support Services.

The U.S. Forest Service's Wildland Fire Air Quality Response Program also maintains smoke monitoring equipment that may be deployed during wildfire smoke events based on requests received from firefighting agencies or Air Resource Advisors (see Appendix G).

Wildfire smoke in San Francisco, CA, September 2020. (Thom Milkovic/Unsplash)

Air Quality Index (AQI)

The Air Quality Index (AQI) communicates information about air quality, including health impacts, to the public.[14] The AQI is a standardized, color-coded system that is applied to major air pollutants, including particle pollution ($PM_{2.5}$ and PM_{10}) and ozone. The averaging period for the AQI is 24 hours for PM and 8 hours for ozone.

The AQI can be thought of as a yardstick that runs from 0 to 500; lower numbers are better than higher numbers. For each pollutant, an AQI value of 100 corresponds to the 24-hour primary health standard. The AQI is most often displayed for two pollutants, $PM_{2.5}$ and ozone, depending on which is highest. An AQI value of 100 for $PM_{2.5}$ corresponds to a $PM_{2.5}$ value of 35 µg/m^3, while an AQI value of 100 for ground level ozone corresponds to a value of 70 parts per billion. See Table 3 for the AQI scale for $PM_{2.5}$:

Table 3. Air Quality Index (AQI) for $PM_{2.5}$

Category	AQI	$PM_{2.5}$ (µg/m^3)
Good	0-50	0.0–12.0
Moderate	51-100	12.1–35.4
Unhealthy for Sensitive Groups	101-150	35.5–55.4
Unhealthy	151-200	55.5–150.4
Very Unhealthy	201-300	150.5–250.4
Hazardous	301-500	250.5–500.4

For $PM_{2.5}$, an AQI of 100 corresponds to a value of 35.4 µg/m^3. Higher AQI values indicate higher $PM_{2.5}$ levels.

The AQI is divided into six color-coded categories (Green, Yellow, Orange, Red, Purple and Maroon), each of which corresponds to a different level of health concern. The use of color-coded categories makes it easier for people to quickly determine air quality in their community. AQI values at or below 100 (Green and Yellow categories) are generally thought of as satisfactory. When AQI values are above 100, beginning with the Orange category, air quality is venturing into the unhealthy range—at first, for sensitive groups of people, then for everyone as AQI values increase. In some extraordinary circumstances, pollutant concentrations can be so high that they are "off the AQI scale", i.e., beyond the value of 500. (Note that a modified version of the AQI scale has been developed by the South Coast Air Quality Management District (SCAQMD) to improve accessibility for people with color vision deficiencies. See Appendix K.)

14 AQI Basics

Information on air quality, including the AQI, can be found on AirNow (see Figure 4), a partnership of the U.S. EPA; National Oceanic and Atmospheric Administration (NOAA); National Park Service; National Aeronautics and Space Administration (NASA); U.S. Centers for Disease Control and Prevention (CDC); and tribal, state, and local air quality agencies. Agencies across the country send monitoring data to AirNow for inclusion in the data maps. The AQI is used by local air districts and others seeking to communicate information on air quality. In addition to providing a yardstick on air quality, the AirNow website also provides information on potential health impacts and steps people can take to reduce their risk.

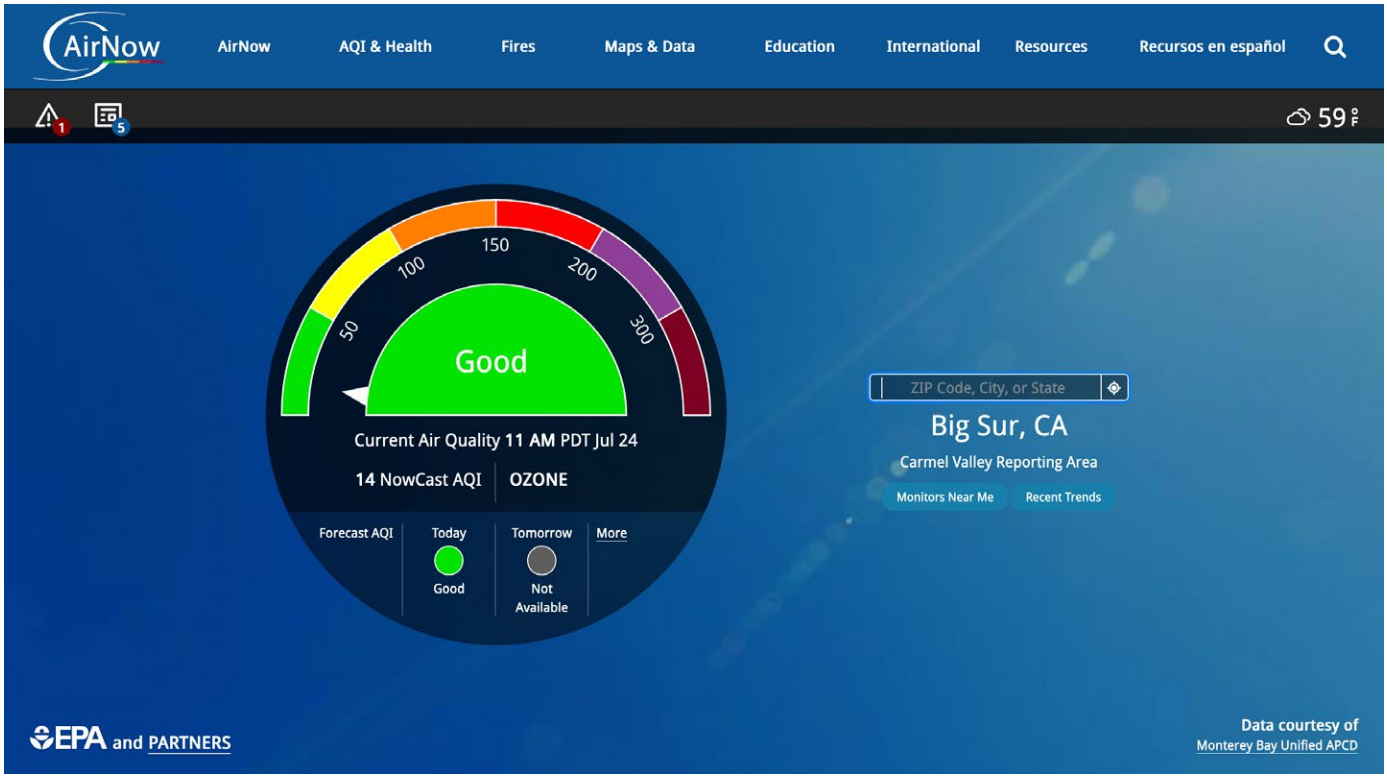


Figure 4. *The AirNow website provides information about air quality, potential impacts, and steps people can take to reduce their risk (airnow.gov)*

Because the AQI standard for $PM_{2.5}$ is based on a 24-hour average measured from midnight to midnight, it may not be sufficiently responsive to indicate rapidly changing conditions associated with a wildfire smoke event. Shorter averaging periods are desirable for taking actions to mitigate smoke exposure. The following sections describe how agencies have modified the AQI to reflect the need for actionable information during a wildfire smoke event.

Current (NowCast) AQI

Officials determine compliance with air quality standards by collecting data over extended periods of time. For $PM_{2.5}$, regulatory compliance is based on averaging 24-hour measurement periods. However, wildfire smoke conditions may change rapidly based on factors like weather conditions, terrain, and time of day.

In 2013, the U.S. EPA updated its method of reporting air quality information to be more responsive to rapidly changing conditions. NowCast, the updated method to reflect Current Conditions, provides up-to-date information to the public so that they can take action to reduce their exposure to air pollutants.

In brief, the NowCast method looks at data collected over the most recent 12 hours for $PM_{2.5}$. If conditions are stable, the NowCast AQI is averaged across the 12 hours. If the $PM_{2.5}$ values are changing rapidly (either increasing or decreasing), the data from the last three hours are more heavily weighted in the computation of the NowCast AQI. This provides information to the public that is closer to real-time information during an event where conditions are rapidly changing. See Figure 5.

Figure 5. *NowCast AQI for $PM_{2.5}$ ("Current Conditions" on AirNow)*

However, even the NowCast AQI may lag during rapidly-changing wildfire smoke conditions and some California air districts have begun reporting local hourly AQI and forecast air quality to enable the public to make effective decisions during periods of poor air quality.

Table 4. *Sampling Periods for Standard AQI vs. Current (NowCast) AQI*

$PM_{2.5}$	Period
AQI	24 hours (midnight-to-midnight)
Current (NowCast) AQI	12 hours (emphasizes last 3 hours if conditions are rapidly changing)

Forecast AQI

The South Coast Air Quality Management District (SCAQMD) launched hourly air quality forecasts to help residents better plan their outdoor activities during times when air quality is predicted to be the cleanest. The forecast has the ability to predict hourly levels of fine particulate matter ($PM_{2.5}$) and ozone (smog). This information can be helpful to those who wish to plan their day to minimize exposure, e.g., exercise during better air quality periods. SCAQMD has also developed an app for iPhone and Android that allows consumers to directly access this information.

Hourly AQI

Air quality can change quite rapidly. During wildfire smoke events, the Current (NowCast) AQI uses a shorter data collection period and emphasizes the final three hours if conditions are rapidly changing. While the Current AQI is more useful than the 24-hr average AQI when it comes to decision-making during wildfire smoke events, some individuals may benefit from more granular information when conditions are rapidly changing (e.g., is this a good time to exercise outdoors?). The Real-Time Air Advisory Network hosted by the San Joaquin Valley Air Pollution Control District provides air quality data that is updated hourly.

See Appendix L for how one can determine hourly reported information from a nearby air monitor.

Wildfire smoke in San Francisco, CA, September 2020. (Thom Milkovic/Unsplash)

Sources of Air Quality Information

Information on air quality may be provided by government agencies and commercial sources. In general, information gathered from governmental air monitoring stations is the most accurate and reliable, although useful information may be provided by other sources. It's important to be aware that variations in air quality readings can be due to many factors, including the technology used, longer versus shorter data reporting periods, and other factors.

AirNOW

The AirNow website provides comprehensive information on air quality. AirNow includes information on current and forecast air quality; fire conditions and smoke plumes, and air quality-related health information for the public, healthcare professionals, and teachers and students. AirNow is a partnership of the U.S. EPA, National Oceanic and Atmospheric Administration (NOAA), National Park Service, NASA, CDC, and tribal, state, and local air quality agencies. See Figure 4.

The Fire and Smoke Map available on the AirNow website (located under "Fires" tab) incorporates data from three sources during wildfires—permanent regulatory monitors (designated as circles), temporary monitors deployed for smoke events (designated by triangles), and low-cost sensors (currently manufactured by PurpleAir and designated by boxes). See Figure 6. Low-cost sensor data incorporated into the Fire and Smoke Map undergo quality assurance screening, are averaged to hourly values, corrected for bias, and have the U.S. EPA NowCast algorithm applied. Note that low-cost sensor data are used for informational purposes only and not for regulatory purposes.

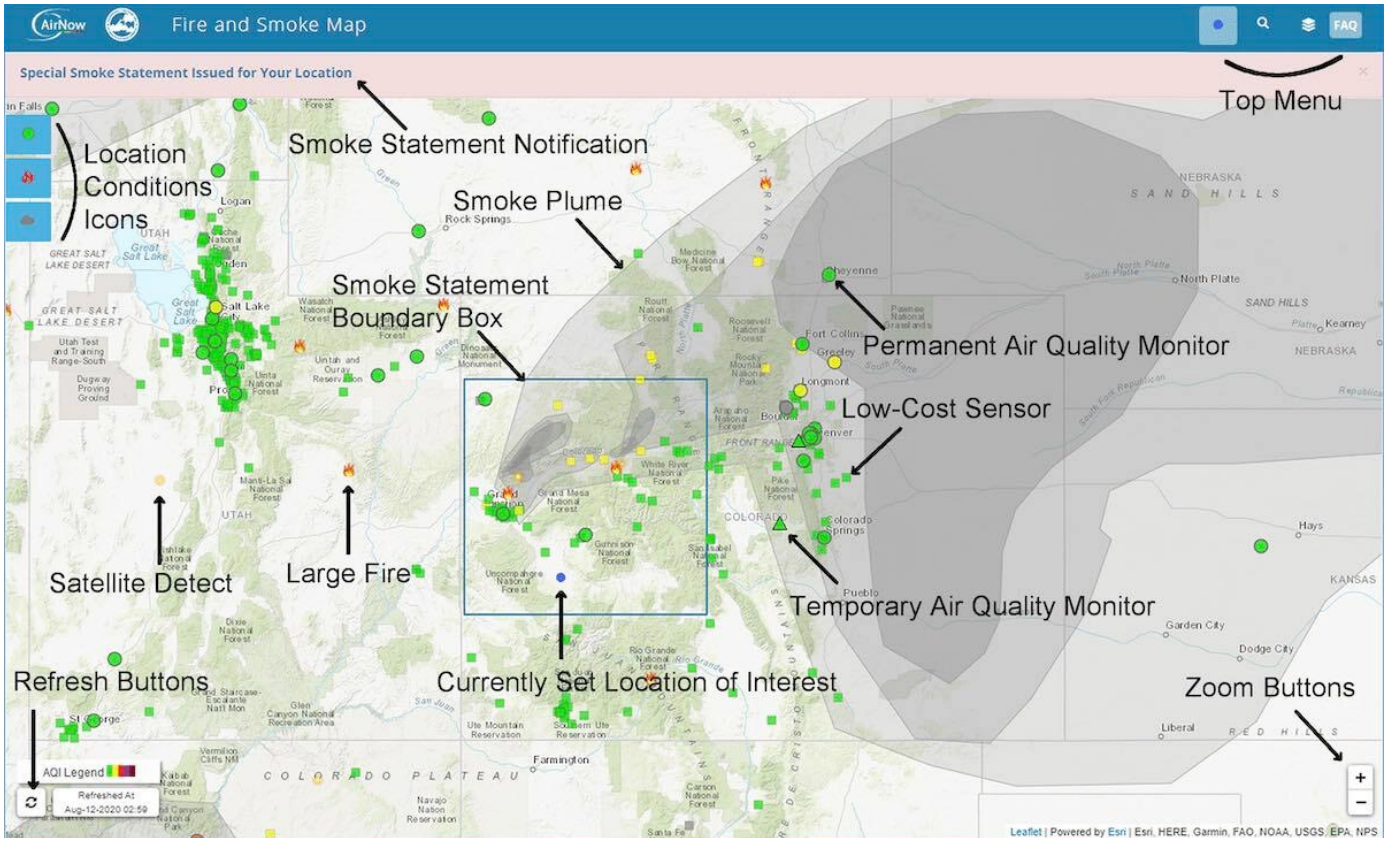


Figure 6. *AirNow Fire and Smoke Map*

During larger fires, the Fire and Smoke Map may also provide Smoke Forecast Outlooks developed by Air Resource Advisors; see Figure 7. The Smoke Forecast Outlook is found on the Fire and Smoke Map (select top tab on left of screen, then select “Smoke Statements”).

Smoke Outlook

Lake Tahoe Basin - Dixie Fire

8/18 - 8/19

Issued: 2021-08-18 08:47 (PDT)
By: Lou Ballard, ARA, lou_ballard@fws.gov

Fire

The Dixie Fire is now 635,728 acres, an increase of 31,217 acres with 33% Contained. With winds shifting from southwest to a northerly component, the fire pushed south on both the West and East Zones. This created several areas of fire growth and smoke production.
inciweb.nwcg.gov/incident/7690/

Smoke

Northeast winds will begin to push some of the smoke out of the Reno/Tahoe Basin area. Lingering smoke will persist throughout the day and better air quality should be realized later this evening into the overnight hours. Grass Valley and Auburn will see decreased air quality as they are in line with smoke blowing in from the Dixie Fire.

Health and Safety

Take it easier during smoky times to reduce how much smoke you inhale. If it looks or smells smoky outside, avoid strenuous activities such as mowing the lawn or going for a run.
https://www.airnow.gov/sites/default/files/2021-07/reduce-your-smoke-exposure.pdf

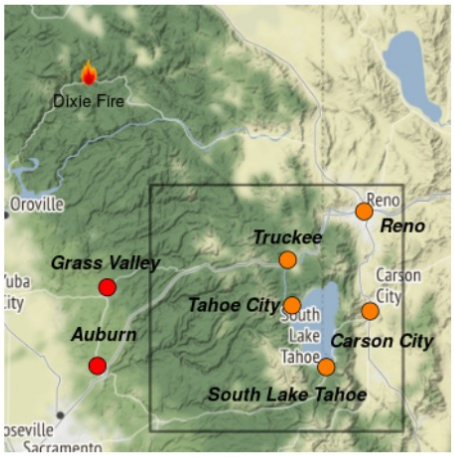


Figure 7. *Smoke Forest Outlook*

California Air Districts

California has 35 air districts that have the primary responsibility for monitoring air quality and report data on their district websites. California's air districts range from small, single-county districts to multi-county, regional agencies. See California Air Districts | California Air Resources Board.

Low-Cost Sensors

There has been a large increase in the number of low-cost air quality sensors produced by private companies, academic institutions, private-public partnerships, and others. In general, low-cost sensors do not match the accuracy of government monitoring systems. However, low-cost sensors can provide certain advantages, e.g., greater localization and access to real-time readings. Low-cost sensors can also provide insight into indoor air quality, allowing occupants to understand how certain activities can improve indoor air quality (e.g., upgrading filters, adding portable air cleaners, etc.) or worsen air quality (e.g., frying foods without exhaust ventilation, burning candles).

Commercial air quality sensors are not currently regulated; however, SCAQMD has established a program to evaluate such sensors and provide the resulting information to the public. SCAQMD created the Air Quality Sensor Performance Evaluation Center (AQ-SPEC)

to independently evaluate the performance of low-cost sensors. The AQ-SPEC program evaluates sensors in both controlled laboratory conditions and in the field. In the field, sensors are tested alongside one or more of SCAQMD's existing air monitoring stations using traditional federal reference/equivalent method instruments to gauge overall performance. Sensors demonstrating acceptable performance in the field are brought to the AQ-SPEC laboratory for more detailed testing in an environmental chamber under controlled conditions alongside traditional federal reference/equivalent method and/or best available technology instruments. AQ-SPEC has posted test results for more than 65 low-cost sensors for PM; see AQ-SPEC PM Sensor Evaluations for the updated list of tested sensors. It is not known how well low-cost sensors perform over time.

One example of a low-cost sensor evaluated by AQ-SPEC is the PurpleAir PA-II. The sensor must be connected to a power source and a wi-fi network that allows data to be shared on the PurpleAir website (see PurpleAir Map). The PurpleAir website allows the user to apply various conversion algorithms to their sensor data, including the U.S. EPA conversion algorithm that was developed for use on the AirNow Fire and Smoke Map.

Community Science Applications

Low-cost sensors may be used in community science applications. The creation of a local air monitoring network can bring data awareness to a community, educating students and the general public. A local air monitoring network may include low-cost sensors and reference-grade monitoring equipment to form a hybrid network. Such networks can both educate and empower residents.

CARB maintains a list of known community air monitoring networks at Community Air Monitoring Systems in California. These community air monitoring systems use a variety of technologies and approaches to address community-specific air quality concerns. Air monitoring within communities is often a collaborative process and can be led by community members, community groups, and/or state and local air quality districts.

Low-cost sensors:

- Do not replace traditional regulatory monitors
- May complement the existing regulatory monitoring network
- May be used to identify locations requiring additional monitoring focus
- Can collect indoor and outdoor measurements, depending on placement
- Can provide backup information when network monitors are unavailable
- Can be used for monitoring at schools and:
  - Use existing infrastructure if available (power/wi-fi/security)
  - Serve as an informational tool for administrators to help reduce student exposures
  - Serve as an educational resource for students – encouraging interest in air quality, technology, measurement, and health

Monitoring Can Inform Exposure Reduction Strategies

Individuals may benefit from using accurate low-cost sensors to assess the effectiveness of exposure reduction strategies, provided they are accurate, installed correctly, and not influenced by nearby or unintended sources or air pollution such as a wood burning, barbeque, cigarette smoke, idling vehicles, generators, and other sources of particle pollution. For additional information on the proper siting of low-cost sensors, U.S. EPA provides a Guide to Siting and Installing Air Sensors.

For example, a low-cost sensor can be used to determine how specific actions improve air quality in the home, such as closing windows and doors; upgrading to a high-efficiency air filter if the home has a forced air system; using a portable air purifier; and avoiding indoor activities that worsen air quality, such as frying or broiling at high heat, burning candles or incense, or vacuuming without a high efficiency particulate air (HEPA) filter.

Low-cost sensors can be placed either outdoors or indoors—the example below (Figure 8) shows how an indoor sensor can be used to assess improvements to indoor conditions.

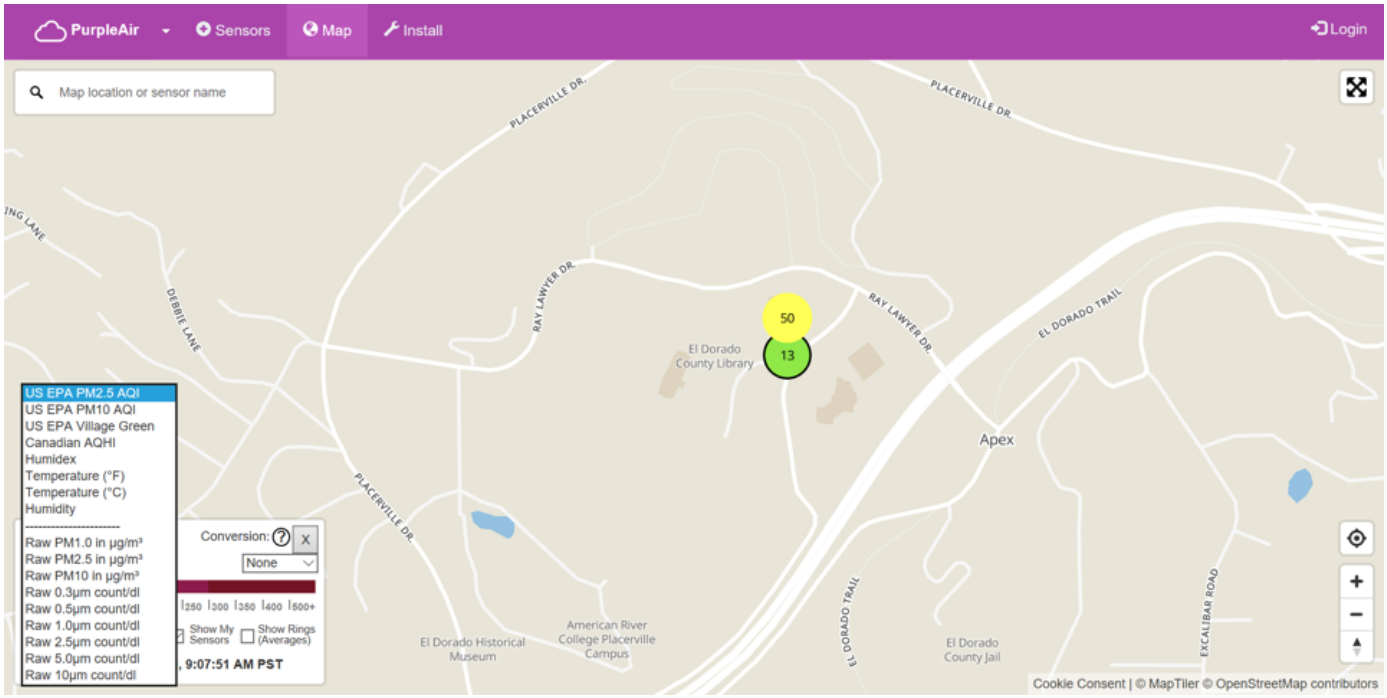


Figure 8. PurpleAir map displaying an outdoor sensor and indoor sensor, allowing comparison of indoor air quality to outdoor air quality

Wildfire Smoke and Health

Until recently, most of the research on the detrimental health effects of air pollution were not wildfire-specific. Increased fire activity has led to an uptick in published research on a broad range of health outcomes associated with exposure to wildfire smoke. Wildfire smoke measurement and epidemiology are active areas of research with new approaches uncovering associations that were previously undetectable. In addition, wildfire smoke episodes have led to greater public interest in air quality, advances in low-cost sensor technology, and community-led projects that provide expanded access to information.

A growing body of scientific evidence links wildfire smoke exposure to various adverse health effects. Although it is often assumed that most healthy people will recover from short-term exposure to wildfire smoke, others may experience more severe symptoms due to biological factors (e.g., life stage or pre-existing medical condition) and extrinsic, non-biologic factors (e.g., socioeconomic status, lack of access to adequate housing, lack of access to healthcare, etc.).

The risk of health effects due to wildfire smoke exposure appears to vary throughout a lifetime, being generally higher in childhood, lower in young adults, and increasing in middle age through older age as the prevalence of heart, lung, and metabolic disease increases. Pregnancy is also a period of unique vulnerability for both the pregnant person and developing fetus.

Public health authorities should pay heightened attention to reducing exposure to wildfire smoke among at-risk groups, including focusing educational efforts on how vulnerable groups can access smoke information, air filtration, and other mitigation measures.

Exposure to PM is currently the most well-described public health threat from wildfire smoke. Fine particles from smoke and coarse particles from ash are respiratory irritants that can cause coughing, wheezing, and difficulty breathing. PM may also affect the body's physiological mechanisms that remove inhaled foreign materials from the lungs, such as pollen and bacteria, and may cause systemic inflammation that can affect multiple organs. Studies of ambient air pollution have found that exposure to fine and coarse particles is linked with increased risk of premature mortality and aggravation of pre-existing respiratory and cardiovascular disease.

Recent reviews conclude that a strong association exists between exposure to wildfire smoke or wildfire-$PM_{2.5}$ and all-cause mortality and respiratory morbidity.[15] Strong positive associations have been found between wildfire smoke exposure and exacerbations of the following common respiratory ailments:[16]

- Asthma
- COPD
- Bronchitis
- Pneumonia

Studies have linked fine PM to increased risks of heart attacks and sudden death from cardiac arrhythmia, heart failure, or stroke.[16] The epidemiological data specifically linking wildfire smoke exposure to cardiovascular morbidity and mortality have been mixed, although several recent studies identified elevated risks of specific health outcomes, including emergency department visits for:

- Ischemic heart disease
- Dysrhythmia
- Heart failure
- Pulmonary embolism
- Stroke[17]

The following sections provide additional information on population groups that appear to be more sensitive to wildfire smoke.

15 Youssouf H, Liousse C, Roblou L, et al. Non-accidental health impacts of wildfire smoke. Int J Environ Res Public Health. 2014;11(11):11772-804.

Liu JC, Pereira G, Uhl SA, Bravo MA, Bell ML. A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. Environ Res. 2015;136:120-32.

Reid CE, Brauer M, Johnston FH, Jerrett M, Balmes JR, Elliott CT. Critical Review of Health Impacts of Wildfire Smoke Exposure. Environ Health Perspect. 2016;124(9):1334-43.

16 U.S. Environmental Protection Agency. (2009) Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2009). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009.

17 Wettstein ZS, Hoshiko S, Fahimi J, Harrison RJ, Cascio WE, Rappold AG. Cardiovascular and Cerebrovascular Emergency Department Visits Associated with Wildfire Smoke Exposure in California in 2015. J Am Heart Assoc. 2018;7(8).

DeFlorio-Barker S, Crooks J, Reyes J, Rappold AG. Cardiopulmonary Effects of Fine Particulate Matter Exposure among Older Adults, during Wildfire and Non-Wildfire Periods, in the United States 2008-2010. Environ Health Perspect. 2019;127(3):37006.

At-Risk Populations

Infants and Children

All children are considered sensitive to the health effects of air pollution, including wildfire smoke, because their lungs and immune systems are still developing. Several factors lead to increased exposure in children compared with adults—children inhale more air (and therefore more pollutant) per pound of body weight; tend to spend more time outside; and engage in more vigorous activity—all of which can contribute to adverse effects on developing lungs.[18]

One study examined the healthcare utilization of Medi-Cal beneficiaries during the 2007 San Diego wildfires to provide insight on the effects of wildfire smoke among a vulnerable population.[19] They found that young children appear at highest risk for respiratory problems during a wildfire. Children aged 0-4 years had a 136% increase in emergency department visits for asthma, while very young children aged 0-1 years experienced a 243% increase.

Another study examined the association between wildfire-specific $PM_{2.5}$ and respiratory health in children in San Diego County from 2011 to 2017.[20] This study noted that wildfire-specific $PM_{2.5}$ was more harmful to children's respiratory health than $PM_{2.5}$ from other sources and that younger children aged 0–5 years were more affected by $PM_{2.5}$ in wildfire smoke than older children. More research is needed to understand the toxicity of wildfire $PM_{2.5}$ in comparison to nonsmoke sources of $PM_{2.5}$, e.g., traffic emissions.

Holm, Miller, and Balmes[21] published a comprehensive review of the health effects of wildfire smoke in children along with three different tools that may be helpful to minimize exposures:

- Using low-cost sensor data for decision-making
- Considering respirator or mask use by children
- Minimizing exposures at schools

18 Sacks JD, Stanek LW, Luben TJ, et al. Particulate matter-induced health effects: who is susceptible? Environ Health Perspect. 2011;119(4):446-54.

19 Hutchinson JA, Vargo J, Milet M, et al. The San Diego 2007 wildfires and Medi-Cal emergency department presentations, inpatient hospitalizations, and outpatient visits: An observational study of smoke exposure periods and a bidirectional case-crossover analysis. PLoS Med. 2018;15(7):e1002601.

20 Aguilera R, Corringham T, Gershunov A, Leibel S, Benmarhnia T. Fine particles in wildfire smoke and pediatric respiratory health in california. Pediatrics. 2021;147(4):e2020027128.

21 Holm SM, Miller MD, Balmes JR. Health effects of wildfire smoke in children and public health tools: a narrative review. J Expo Sci Environ Epidemiol. 2021;31(1):1-20.

Low Cost Sensors: They found that low-cost sensors can play an important role in providing enhanced spatial and temporal resolution. Continuing improvements in technology and linking to nearby government regulatory monitors will likely lead to improvements in the quality of information available.

Respirators: For adults, respirators (e.g, NIOSH-approved N95) are often recommended for protection from wildfire smoke when avoidance is not possible, but the question of respirator use by older children has been evolving.

The authors note that NIOSH-approved N95s are not available in the U.S. in child sizes, but small-sized N95s could fit some older/larger children. During the COVID-19 pandemic, internationally certified respirators such as KN95s and KF94s became widely available; they have ear loops rather than head straps and are available in smaller sizes including ones suitable for children. Children over 2 years of age have worn surgical masks or cloth masks for protection from virus particles. Among these options, well-fitting N95, KN95, or KF94 respirators would be preferred for filtering either virus or wildfire smoke particles, because they are designed to fit close to the face and have met a certification standard for filtration. Smoke particles and virus particles are filtered out in the same manner; see Masks for Kids: Tips and Resources (ca.gov).

Given the growing body of evidence that children are particularly sensitive to the effects of wildfire smoke, all mitigation measures should be considered, particularly when smoke cannot be avoided. Two possible concerns have been raised: 1) could respirator use by children provide a false sense of security, possibly leading to increased exposures; and 2) could respirator use by children lead to adverse physiologic effects?

The increasing occurrence of wildfire smoke events affecting California, along with a better understanding of the impact to children's health, has led some clinical pediatric groups to recommend the use of respirators by children under specified conditions.

The Western States Pediatric Environmental Health Specialty Units (WSPEHSU), a network of experts in reproductive and children's environmental health, provide their recommendations on respirator use by children here: Wildfires and Mask Use - PEHSU. WSPEHSU has created a series of infographics specific to the topic of children and wildfire smoke here: Wildfires and Children's Health.

The authors noted that there is nothing about pediatric physiology that would make one concerned that children are at higher risk than adults for adverse cardiopulmonary effects, although this has not been evaluated.

Minimizing Exposure at School: A limited number of studies in North American schools suggest that indoor air levels of $PM_{2.5}$ are roughly 90% of outdoor levels. This observation emphasizes the importance of adequate filtration (either central air filtration or portable air cleaners) in school and childcare settings. Interest in indoor air quality has been heightened by more frequent wildfire smoke incidents and the COVID-19 pandemic.

See Summary Recommendations from a 2021 Workshop on Children's Health and Wildfire Smoke.

Pregnant People

Physiologic changes occur during pregnancy (e.g., higher respiratory rates and increased blood and plasma volumes) that may influence a person's vulnerability to environmental exposures. Holstius et al. examined the impact of wildfire smoke on pregnancy outcomes in Southern California.[22] Researchers found that exposure to wildfire smoke during pregnancy was associated with slightly reduced average birth weights among infants exposed *in utero* (9.7 g lower when exposure occurred during the second trimester and 7 g lower when exposure occurred during the third trimester). It is not known how the psychological stress that may result from wildfires affects the health of pregnant people and their fetuses.

Older Adults

Older adults are considered more sensitive to the adverse health effects of wildfire smoke due to a gradual decline in physiological processes and the higher prevalence of lung and heart diseases found in this age range compared to younger groups.

Liu et al. studied associations between wildfire-specific fine particles and the amount of hospital admissions for respiratory causes among those older than 65 years in the western U.S.[23] They found that the increased risk of respiratory admission was higher for women than for men (10.4% vs. 3.7%) and for Black persons compared to White persons (21.7% vs. 6.9%).

22 Holstius DM, Reid CE, Jesdale BM, Morello-Frosch R. Birth weight following pregnancy during the 2003 Southern California wildfires. Environ Health Perspect. 2012;120(9):1340-5.

23 Liu JC, Wilson A, Mickley LJ, et al. Who Among the Elderly Is Most Vulnerable to Exposure to and Health Risks of Fine Particulate Matter From Wildfire Smoke? Am J Epidemiol. 2017;186(6):730-735.

Wettstein et al. examined cardiovascular and cerebrovascular emergency department visits and wildfire smoke exposure among adults in eight California air basins in 2015.[24] They found:

- Wildfire smoke exposure was associated with increased rates of emergency department visits for numerous cardiovascular disease outcomes, including ischemic heart disease, dysrhythmia, heart failure, pulmonary embolism, and stroke.
- The observed risk was greatest among adults > 65 years of age.

People with Lung Conditions

Persons with asthma, chronic obstructive pulmonary disease (COPD), or other chronic lung diseases may experience breathing difficulties during smoke events. Asthma is characterized by chronic inflammation of the bronchi and smaller airways with intermittent airway constriction that may lead to coughing, wheezing, and shortness of breath. Individuals with COPD, encompassing emphysema and chronic bronchitis, may also experience worsening of symptoms due to exposure to wildfire smoke. Patients with COPD often have an asthmatic component to their condition that may result in their experiencing asthma-like symptoms. However, because their lung capacity is typically reduced, additional airway constriction may result in symptoms requiring medical attention.

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.[25] In a review, Reid et al. found consistent evidence of associations between wildfire smoke exposure and respiratory morbidity in general, and specifically for exacerbations of asthma and COPD.[26]

Acute lung disease, such as COVID-19, may also increase susceptibility to the respiratory effects produced by wildfire smoke.

24 Wettstein ZS, Hoshiko S, Fahimi J, Harrison RJ, Cascio WE, Rappold AG. Cardiovascular and Cerebrovascular Emergency Department Visits Associated with Wildfire Smoke Exposure in California in 2015. J Am Heart Assoc. 2018;7(8).

25 U.S. Environmental Protection Agency. (2009) Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2009). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009.

26 Reid CE, Brauer M, Johnston FH, Jerrett M, Balmes JR, Elliott CT. Critical Review of Health Impacts of Wildfire Smoke Exposure. Environ Health Perspect. 2016;124(9):1334-43.

People with Heart Conditions

Cardiovascular disease is the leading cause of mortality in the U.S. and includes high blood pressure, heart failure, and vascular diseases such as coronary artery or cerebrovascular disease. Air pollution studies have linked PM to increased risk of heart attacks, heart failure, cardiac arrhythmias, and other adverse effects in those with existing cardiovascular disease.[27] Chemical messengers released into the blood due to lung inflammation may increase the risk of blood clot formation, angina episodes, heart attacks, and strokes. Despite this evidence regarding cardiovascular effects, wildfire-related cardiovascular studies have been inconsistent, although several recent investigations have identified elevated risks of specific health outcomes, including increased rates of emergency department visits for ischemic heart disease, dysrhythmia, heart failure, pulmonary embolism, and stroke.[28]

Wettstein et al. found a positive association between wildfire smoke density and emergency department visits attributable to cardiovascular, cerebrovascular, and respiratory disease.[29] Impacts were greatest on medium and dense smoke days and among adults aged ≥65 years.

People with Social Vulnerabilities

Certain groups have increased sensitivity to wildfire smoke based on life stage (e.g., youth and older adults) or the presence of one or more medical conditions (e.g., lung and heart conditions). Other groups may be more vulnerable to the health impacts of wildfire smoke due to other reasons, including but not limited to socioeconomic status, housing, access to health care, race/ethnicity, access and functional needs, and language barriers. People of color and low-income families bear a disproportionate burden of asthma and other respiratory diseases.[30] Some groups experience greater exposure to wildfire smoke due to living conditions (e.g., people experiencing homelessness or living in inadequate housing) or the need to work outdoors (e.g., farm workers, day laborers, utility workers).

27 U.S. Environmental Protection Agency. (2009) Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2009). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009.

28 Wettstein ZS, Hoshiko S, Fahimi J, Harrison RJ, Cascio WE, Rappold AG. Cardiovascular and Cerebrovascular Emergency Department Visits Associated with Wildfire Smoke Exposure in California in 2015. J Am Heart Assoc. 2018;7(8).

DeFlorio-Barker S, Crooks J, Reyes J, Rappold AG. Cardiopulmonary Effects of Fine Particulate Matter Exposure among Older Adults, during Wildfire and Non-Wildfire Periods, in the United States 2008-2010. Environ Health Perspect. 2019;127(3):37006.

29 Wettstein ZS, Hoshiko S, Fahimi J, Harrison RJ, Cascio WE, Rappold AG. Cardiovascular and Cerebrovascular Emergency Department Visits Associated with Wildfire Smoke Exposure in California in 2015. J Am Heart Assoc. 2018;7(8).

30 Brim SN, Rudd RA, Funk RH, Callahan DB. Asthma prevalence among U.S. children in underrepresented minority populations: American Indian/Alaska Native, Chinese, Filipino, and Asian Indian. Pediatrics. 2008;122(1):e217-22.

Resource constraints directly impact the ability of certain groups to avoid high-smoke environments. Examples of effective mitigation options that may not be available to those with resource constraints include temporarily leaving the area during high-smoke periods, modifying the home environment to provide cleaner air, e.g., if the home has a central AC system, consider upgrading to a better filter (MERV 13 or higher, if appropriate to the installed system); reducing outside air intrusion into the home (close windows and doors) without allowing the interior home temperature to rise to uncomfortable/unsafe levels; and using a safe and appropriately sized portable air cleaner. Outreach activities and support may be required to reduce the exposure of people with social vulnerabilities to wildfire smoke.

Table 5 summarizes the main groups that are currently recognized as sensitive to wildfire smoke (note that some people are members of multiple groups).

Table 5. *Summary of population groups that may be more sensitive to wildfire smoke*

Group	Potential Health Effects from Wildfire Smoke
Children	All children: possible coughing, wheezing, difficulty breathing, chest tightness, decreased lung function. Children with asthma: possible worsening of asthma symptoms, heightened risk of asthma attacks.
Older adults	Possible exacerbation of heart and lung disease leading to the need for medical care, emergency department visits, or hospital admissions.
People with lung disease	Possible breathing difficulties (e.g., coughing, wheezing, and chest tightness) and exacerbations of chronic lung diseases (e.g., asthma and COPD) that may lead to increased medication usage, emergency department visits, or hospital admissions.
People with heart disease	Possible triggering of ischemic events, such as angina, heart attack, or stroke; abnormal heart rhythms that could lead to emergency department visits or hospital admissions; worsening of heart failure.
Pregnant people	Limited evidence shows air pollution-related effects on pregnant individuals and the developing fetus.
People with social vulnerabilities	Greater exposure to wildfire smoke due to less adequate housing and reduced access to mitigation options, along with a higher likelihood of untreated or inadequately treated health conditions such as lung, heart, or metabolic disease. Unhoused individuals are particularly vulnerable to wildfire smoke.

Group	Potential Health Effects from Wildfire Smoke
Outdoor workers	Those who must work outdoors may experience greater exposures due to environmental working conditions. Low wage and migrant workers are especially vulnerable.
People who are immunocompromised	CDC states that people who are immunocompromised or taking drugs that suppress the immune system are likely to be at greater risk of health effects due to wildfire smoke.
People who have had COVID-19	CDC states that people who currently have or who are recovering from COVID-19 may be at increased risk of health effects from exposure to wildfire smoke due to compromised heart and/or lung function related to COVID-19.

COVID-19 and Wildfire Smoke

The occurrence of wildfire smoke during the COVID-19 pandemic poses special challenges to public health officials and others working to reduce the impacts of both types of emergencies. Evidence exists that air pollution, including wildfire smoke, can drive increased vulnerability to infectious diseases such as COVID-19.[31] A study of California counties affected by the 2020 wildfire season found a significant relationship between the resulting air pollution and confirmed cases of COVID-19; short term-exposure to increased concentrations of $PM_{2.5}$, CO, and higher AQI values are associated with an increased risk of COVID-19.[32] Additional studies suggest that wildfire smoke may have a role on COVID-19 case counts and deaths, although more research is needed to better understand this interaction.

"Evidence exists that air pollution, including wildfire smoke, can drive increased vulnerability to infectious diseases such as COVID-19."

Given the additional risk posed by the pandemic, taking steps to avoid or reduce wildfire smoke exposure are warranted. Most people spend the majority of their time indoors, emphasizing the importance of cleaner indoor air to reduce exposure to both wildfire smoke and SARS-CoV-2. Access to alternate control strategies such as portable air cleaners and operating HVAC system filtration in 100% recirculation mode are important mitigation measures, along with the ability to access cleaner air spaces if necessary. It is critical that

31 Schwarz L, Dimitrova A, Aguilera R, Basu R, Gershunov A, Benmarhnia T. Smoke and COVID-19 case fatality ratios during California wildfires. Environ Res Lett. 2022;17(1).

32 Ademu LO, Gao J, Thompson OP, Ademu LA. Impact of short-term air pollution on respiratory infections: a time-series analysis of COVID-19 cases in California during the 2020 wildfire season. Int J Environ Res Public Health. 2022;19(9):5057.

efforts focus on equity; see COVID-19, Climate Change, and Health Equity and CDPH's Interim Guidance for Ventilation, Filtration, and Air Quality in Indoor Environments.

The occurrence of wildfire smoke during the COVID-19 pandemic has created challenges around respirator/mask recommendations. Properly worn respirators (NIOSH-approved N95s) protect against the PM in wildfire smoke (vs. significantly less protection from surgical or cloth masks). It's important to note that respirators with exhalation valves are often more comfortable to wear, especially in warmer conditions or if physically active. A NIOSH-approved N95 respirator with an exhalation valve offers the same protection to the wearer as one that does not have a valve. Relative to source control, NIOSH research indicates that N95 respirators with exhalation valves provide the same or better source control than surgical masks, procedure masks, cloth masks, or fabric coverings. For the general public, internationally certified respirators such as KN95s or KF94s, which typically have ear loops rather than head straps, are another option for either COVID-19 or wildfire smoke protection; they are designed to fit closely to the face and have met a certification standard for filtration.

Smoke rises over Santa Monica. (Matia Rengel/Unsplash)

Strategies to Reduce Exposure to Wildfire Smoke

Basics

Prior to discussing options to reduce exposure, it may be helpful to consider the primary factors that determine exposure to the harmful pollutants in wildfire smoke. Understanding the relationship between these variables can assist public health officials, healthcare providers, and risk communication professionals in recommending exposure reduction strategies. These factors include:

1. Concentration of pollutant (e.g., $PM_{2.5}$) near the breathing zone
2. Rate at which the pollutant is inhaled into the lungs (pulmonary ventilation)
3. Time spent in smoky conditions (duration of exposure)

Already familiar with how wildfire smoke can affect you?

Check out our recmmendations in the next subsections:

- Basics
- Stay Indoors
- Avoid Smoky Conditions
- Consider Temporary Relocation
- Reduce Physical Activity in Smoke
- Manage Indoor Air Quality
- Use an Approved Respirator if Necessary and Safe
- Protect Pets From Wildfire Smoke

Pulmonary ventilation is the product of a person's *respiratory rate* and the volume of air contained in each breath called *tidal volume*. Table 6 illustrates the increase in pulmonary ventilation as a person progresses from rest to moderate activity to vigorous activity:

Table 6. *Breathing parameters at rest, moderate activity, and vigorous activity (estimate for adult male).*

Breathing at Rest, Moderate Activity, and Vigorous Activity

	Respiratory Rate (breaths/minute)	Tidal Volume (liters/breath)	Pulmonary Ventilation (liters/minute)
Rest	12	0.5	6
Moderate Activity	30	2.5	75
Vigorous Activity	50	3.0	150

Pulmonary ventilation at rest averages about 6 liters/minute but can increase to 150 liters/minute with vigorous activity – a 25-fold increase. This illustrates the value of reducing personal exposure through risk management, e.g., avoiding strenuous exertion in smoky conditions to the extent possible. A number of local air districts identify anticipated periods of improved air quality so people can schedule outdoor activities at better times.

Stay Indoors

While staying inside is a common advisory issued during wildfire smoke events, public officials are encouraged to consider the following:

1. To provide protection, indoor air quality should be significantly better than outdoor air quality
2. The risk of overheating in indoor environments should be avoided

The value of staying indoors to avoid wildfire smoke exposure depends on how well the home or commercial building prevents infiltration of outdoor smoke coupled with the ability to maintain acceptable temperature and air quality (e.g., enhanced filtration, portable air cleaners). In general, newer homes have a tighter building envelope and are more effective at keeping smoke out when windows and doors are closed. In leaky homes and buildings, outdoor PM can more easily infiltrate indoors, in which case guidance to stay inside provides less protection. Another important factor to keep in mind is the avoidance of indoor pollution sources, e.g., smoke from tobacco or other sources; burning candles; failure to use exhaust fan while cooking; etc.

When windows are open, the indoor concentration of PM can approach outdoor levels; when windows are closed, indoor concentrations of PM can be 50% or less of outdoor concentrations for large particles, although smaller particles may infiltrate through cracks.[33]

Activity surveys indicate that people typically spend about 85% of their time indoors, 5% of their time in a vehicle, and 10% of their time outdoors.[34] Because people spend such a large percentage of their time indoors, a significant portion of total personal exposure to PM occurs in indoor environments.

One major drawback of advising people to stay inside and close windows and doors without air conditioning during smoke events is the increased risk of heat stress. Extreme heat conditions pose a substantial health risk, especially for vulnerable populations including young children, elderly individuals, people with chronic diseases or disabilities, outdoor workers, and pregnant people.

33 Allen RW, Adar SD, Avol E, et al. Modeling the residential infiltration of outdoor PM(2.5) in the Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air). Environ Health Perspect. 2012;120(6):824-30.

Chen C, Zhao B. Review of relationship between indoor and outdoor particles: I/O ratio, infiltration factor and penetration factor. Atmos Environ. 2011;45(2):275–288.

34 Klepeis NE, Nelson WC, Ott WR, et al. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J Expo Anal Environ Epidemiol. 2001;11(3):231-52.

If temperatures are high during a smoke event, individuals who do not have access to cleaner, cool air at home may benefit from visiting family members, neighbors, or public buildings with air conditioning and enhanced air filtration. The same suggestion applies to people who live in older, leaky homes who don't have forced air systems that can accommodate better filters. Examples of potentially suitable locations include:

- Libraries
- Indoor shopping malls
- Cooling centers

Some public buildings may have older air conditioning systems that use low efficiency filters, in which case they may be less adequate at providing cleaner air. Ideally, public health officials should work with local emergency managers to obtain information about the filtration and cooling capabilities of buildings prior to recommending specific shelters. This information should be part of the development of a pre-event mitigation plan.

COVID-19 has introduced additional challenges to managing wildfire smoke incidents, and general guidance and information can be found at COVID-19, Climate Change, and Health Equity. Specific information on Cooling Centers can be found at Cooling Center COVID-19 Guidance.

ASHRAE recently published a guidance document that provides a framework for protecting building occupants from smoke exposure that also addresses the transmission of SARS-CoV-2; see Protecting Building Occupants from Smoke During Wildfire and Prescribed Burn Events.

Long-term smoke events usually have periods when the air quality is better. When air quality improves, even temporarily, homes should be aired out to reduce indoor air pollutants.

Avoid Smoky Conditions

Smoke levels may change substantially throughout the day and night, creating opportunities to plan around the worst periods of smoke. In outreach to the public, it can be helpful to point out that wildfire smoke often follows a pattern, e.g., nighttime smoke travels downhill and settles into valleys before lifting out the next day. Communities farther downwind from a fire may see smoke arrive in the mid-to-late afternoon and occasionally remain overnight. Prior to engaging in outdoor activities, community members can check current conditions and avoid or delay exposure until conditions improve.

The Fire and Smoke Map on the AirNow website provides high quality information about air quality during smoke events. The Fire and Smoke Map displays information from air quality monitors in addition to providing information on fires and smoke plume locations. The Fire and Smoke Map incorporates information from permanent regulatory monitors, temporary

monitors, and government-adjusted data from low-cost sensors. This site may include Smoke Forecast Outlooks by Air Resource Advisors during larger wildfires.

Specific wildfire smoke impacts may be forecast and posted on state smoke blogs, including the California Smoke Blog. More detail may also be found on the InciWeb site. Additionally, local air districts are most familiar with their area and may provide wildfire smoke forecasts at their respective California Air District.

Consider Temporary Relocation

Temporarily leaving an area impacted by dense smoke may the best protective measure for people who are particularly sensitive to wildfire smoke. Another option may be to temporarily re-locate to a more protective house within the area (e.g., stay with family or friends). Unfortunately, temporary relocation is not a viable option for many due to work commitments, children in school, financial considerations, etc.

Reduce Physical Activity in Smoke

Reducing or eliminating physical exertion is an effective strategy to lower the dose of inhaled air pollutants during a smoke event. As described in the "Basics" section, people can increase their air intake by as much as 10 to 25 times their resting level through physical exertion. Increased breathing rates and deeper breathing patterns bring more pollutants into the gas exchange areas of the lungs.

At rest, most people breathe primarily through their nose. During exercise, people breathe more through the mouth, bypassing the natural filtering ability of the nasal passages. They also tend to breathe more deeply, modifying the usual patterns of PM deposition in the lungs.

Compared to adults, children tend to rely more on oral breathing at rest and during exercise, further highlighting the need for children to avoid exercising in smoky conditions.

During smoky periods, options for exercise should take into account:

- Avoiding or reducing physical exertion in smoky conditions
- Identifying an indoor environment with acceptable air quality
- Planning exercise for a forecast period of improved outdoor air quality

Manage Indoor Air Quality

The degree to which wildfire smoke exposure is reduced within any building, including homes, depends on two factors:

1. How well the building is sealed (which slows the rate of smoke entry)
2. How quickly and effectively any available air cleaning equipment removes smoke from the indoor air

By slowing the rate that smoke enters, there is more time for air cleaning equipment and natural removal processes to reduce the concentration of smoke inside the building. The mitigation measures discussed here can help to reduce indoor air concentration of SARS-CoV-2 particles along with wildfire smoke particles, which can help prevent infection, especially when used in conjunction with appropriate face coverings or masks, frequent hand washing, and other practices.

Reducing the entry of smoke starts with closing all windows and doors and turning off any fans that operate routinely to provide ventilation, i.e., the entry of outdoor air. Starting in 2008, California statewide building standards require that all newly constructed or extensively renovated homes must have ventilation fans to ensure that there is always enough outdoor air coming into the home. Normally, this helps to maintain indoor air quality. These ventilation fans should be turned off during outdoor air pollution events—including wildfire smoke—and turned on again when wildfire smoke (or other pollution) clears. The most common system is an exhaust fan that is designed to operate continuously at low speed or intermittently at higher speed, e.g., for 20-30 minutes every hour. These fans may be in the laundry room or a bathroom. In some homes, ventilation is provided by a ducted connection between the central forced air heating and cooling system and outdoors. These may be called a “fresh vent” or “outdoor air supply vent” and the airflow through them may be controlled by the thermostat or by a separate controller. California building standards require labeling of switches that control ventilation fans although labels are sometimes unclear or missing. If you live in a newer home or think you may have a ventilation fan, it is helpful to determine in advance how to control the system.

There are two main ways that pollutants, including wildfire smoke particles, can be removed from air in homes:

1. By operating a forced air system with suitable filters
2. By operating standalone or portable air cleaners

Many California homes have a central forced air system that draws air from the living space, heats or cools the air as needed, then pushes air back into the home through registers on the walls or ceilings. Air is pulled from the house through one or more large return grilles that are usually located near the center of the house with at least one per floor.

Every forced air system should have slots for filter(s) either behind the return grilles or at the location where the return ductwork is connected to the heating or cooling system. Originally, filters were designed to protect only the heating and cooling equipment, but today there are many filters available for under $20 that can remove a substantial fraction of PM from smoke and other sources of air pollution. If there are no filters behind the return grille(s), they may be located with the heating and cooling system in the attic, garage, crawlspace, or a utility closet.

Modern forced air systems can be set to circulate air – from the return grille, through the filter, and back out to the supply registers – even when no heating or cooling is needed. This type of operation can be controlled using the thermostat and typically involves setting the fan to "on" or "circulate" mode. During wildfire smoke events, setting the HVAC system to "circulate" or "on" will increase filtration and provide a significant improvement in indoor air quality over running it intermittently.

If a home has a forced air system, it is generally recommended to use the highest performance filter(s) the system can accommodate to improve indoor air quality, especially during wildfire smoke incidents. However, higher performance filters will generally cause increased airflow resistance, which not all central air systems can accommodate. To avoid damage to the HVAC system, homeowners should consult with an HVAC technician or their central air system manufacturer to confirm performance requirements for high-efficiency filters to work with their specific system.

Filtration performance is a function of the *fractional removal efficiency* of a filter and *airflow*. Filters can remove particles only when the system fan is on and passing air through the filter. A filter's performance rating is based on an industry standard called the *Minimum Efficiency Reporting Value* (MERV) that can range from MERV 1 to MERV 16, or proprietary test metrics developed by certain manufacturers including the *Microparticle Performance Rating* (MPR) and *Filter Performance Rating* (FPR). In general, the higher the filter rating, the higher the filter's removal efficiency (see Table 7).

Table 7. *Filter Rating Systems*

Rating System	Best	Very Good	Good	Special Use
MERV (general industry standard)	MERV 13 or better	MERV 9-12	MERV 7-8	MERV 16 or HEPA
FPR (Honeywell)	FPR 8-10	FPR 7	FPR 5	
MPR (3M Filtrete)	MPR 2200 or better	MPR 1000-1900	MPR 600	

Because high-efficiency filters (and portable air cleaners) may be difficult to find during a wildfire smoke event, it is **strongly recommended that such products be obtained in advance,** particularly if the household includes people who may be sensitive to wildfire smoke (children, pregnant people, older adults, those with heart or lung conditions, or anyone who is sensitive to wildfire smoke).

Filters should be replaced on a regular basis according to manufacturer's recommendations and **always** after a wildfire smoke event.

To summarize, the following actions can help reduce exposure during wildfire smoke events.

Checklist of activities to manage indoor air quality during wildfire smoke:

- Keep windows and doors closed if elevated temperature is not an issue
- Close fireplace dampers
- If applicable to your system, turn off continuous ventilation fans that pull in outside air
- Upgrade to higher efficiency filters
- Operate central fan on "circulate"
- Use HEPA filter-equipped vacuum cleaner

Reduce Indoor Sources of Air Pollutants

Given that wildfire smoke introduces additional pollutants to the air, some of which cannot be avoided, one way to lower risk in general is to reduce other pollutants in the home. There are numerous sources of indoor air pollutants that should be reduced to the extent possible during a wildfire smoke event.

Indoor sources of PM may include:

- Smoking/vaping
- Using gas, propane, and wood-burning stoves and furnaces that are not vented to the outside
- Frying or broiling foods
- Burning candles or incense
- Using cleaning methods that promote the re-suspension of particles (e.g., dusting or using a vacuum cleaner without HEPA filtration)

To illustrate the impact of indoor air pollutants, it takes about 10 minutes for the smoke of a single cigarette in a standard room (125 square feet) to generate hazardous indoor levels of $PM_{2.5}$ (160 µg/m3). This corresponds to an AQI in the "Very Unhealthy" range.

Combustion processes that are not properly vented to the outdoors can be another source of indoor air pollutants. "Room-vented" or "vent-free" appliances such as unvented gas

or propane fireplaces, decorative logs, and portable heaters can contribute substantial quantities of pollutants to indoor air.

Frying or broiling at high heat generally produces high levels of PM. These sources can also increase the levels of polycyclic aromatic hydrocarbons, carbon monoxide, acrolein, and nitrogen oxides, all of which are potentially harmful to health.

Lastly, certain cleaning practices can affect indoor air quality. People who wish to clean their residences during or after smoke events should use cleaning practices that reduce re-suspension of particles that have settled. Preferred cleaning activities include using a HEPA filter-equipped vacuum cleaner, damp-mopping, and dusting with a damp cloth. Hosing off window screens in addition to cleaning window coverings may also be helpful. Because chemical cleaning products should be used in a well-ventilated environment, it may be better to clean after the smoke has cleared and outdoor air quality is acceptable, allowing ventilation of the home's interior during the use of cleaning products.

Use California-Approved Air Cleaners

Portable air cleaners can be very helpful for improving indoor air quality during a smoke incident. CARB certifies air cleaners for use in California that produce little or no ozone, which is a respiratory irritant. See CARB's list of certified air cleaners.

Particularly for homes that have smoke-sensitive occupants, the decision to purchase an air cleaner is best made before a smoke event occurs. Smoke events can lead to a high demand for air cleaners and commercial suppliers may not be able to meet that demand.

Air cleaners will provide the most protection when placed where people spend most of their time, such as a bedroom when sleeping. Air cleaners generally work better in smaller rooms rather than large spaces, however multiple small air cleaners can also be used together in a larger room. To save on cost, people can purchase smaller air cleaners for bedrooms and relocate them to the larger living room during the day.

Air cleaners have different air-cleaning capacities. It is important to match the air cleaner's specifications to the size of the space to be cleaned. The Association of Home Appliance Manufacturers (AHAM) maintains a certification program for air cleaners. The *Clean Air Delivery Rate* (CADR) is a rating that combines efficiency and airflow; the higher the CADR, the faster the unit filters particles in air. CADR numbers are reported based on the highest fan speed.

The AHAM seal on the air cleaner's box lists three CADR numbers – one for smoke, one for pollen, and one for dust. The CADR for smoke is most relevant to wildfire smoke.

As a general rule of thumb, choose a unit with a CADR for smoke that is 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 CADR for smoke of at least 80 (higher numbers are even better). If the ceiling is higher than 8', an air cleaner rated for a larger room is needed. **For areas that are heavily impacted by wildfire smoke, AHAM recommends that the CADR matches the room size.** For example, an air cleaner with a smoke CADR of 200 would be appropriate for a 200 square-foot room in an area affected by smoke. See Using an Air Cleaner to Manage Wildfire Smoke.

To maximize effectiveness, operate the portable air cleaner continuously or as often as possible on the highest fan speed. Ensure that airflow to the air cleaner is not obstructed. Keep doors and windows closed to prevent additional PM from entering the room.

Generally, air cleaners with higher CADRs cost more than smaller capacity units and also tend to be noisier due to larger fans. If occupants are sensitive to noise and have the resources, an option would be to purchase multiple, smaller units that operate on lower, quieter speeds.

Devices that remove gases and odors in addition to PM typically cost more 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 sensitive individuals and may require less frequent replacement of the filtering medium. Products that combine particle and gas removal are available in both portable and in-duct models.

Portable air cleaners may be used in combination with central forced air system filter upgrades (as described in the preceding section) to maximize the reduction of indoor particles. One strategy—if resources allow—is to use the central forced air system for air cleaning when household members are moving about the house and use a portable air cleaner in each occupied bedroom overnight. Portable air cleaners 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.

A recent study investigated the projected health benefits if residential indoor particle filtration interventions had been implemented in the homes of six Southern California counties during a wildfire.[35] The six interventions involved various combinations of forced air system operation (intermittent, continuous, or none); the use of low versus high efficiency filters; and the use of a continuously operating portable air cleaner. The authors found that the interventions could reduce projected $PM_{2.5}$ levels in the home by 11% to 62%.

35 Fisk WJ, Chan WR. Health benefits and costs of filtration interventions that reduce indoor exposure to $PM_{2.5}$ during wildfires. Indoor Air. 2017;27(1):191-204.

The smaller reductions came from operating the home's forced air system on an intermittent basis and upgrading to a high-efficiency filter. Larger reductions were produced by operating the home's forced air system on a continuous basis, upgrading to a high-efficiency filter, and continuously operating a portable air cleaner. If a home does not have a forced air system, continuously operating a portable air cleaner decreased estimated $PM_{2.5}$ by 45% (see Table 8).

Table 8. *Comparison of different filtration interventions in various combinations with a goal of reducing $PM_{2.5}$ concentration.*

Forced Air System Operation	Efficiency of Filter in Forced Air System	Continuously Operating Portable Air Cleaner	Decrease in Predicted $PM_{2.5}$ Concentration
Intermittent	Upgraded to high	No	11%
Continuous	Typical low	No	24%
No forced air	N/A	Yes	45%
Continuous	Upgraded to high	No	47%
Continuous	Typical low	Yes	51%
Continuous	Upgraded to high	Yes	62%

Do-It-Yourself (DIY) Portable Air Cleaners

Portable air cleaners are commercially available but the acquisition cost of such devices may be prohibitive for some. This has led many to suggest Do-It-Yourself (DIY) portable air cleaners that typically involve attaching one or more air filters to a box fan, such as the Comparetto cube. See What is a DIY air cleaner and can it help protect homes from COVID-19? | U.S. EPA. It's important to note that DIY portable air cleaners are not tested for compliance with electrical safety standards for appliances and great care must be taken to keep fingers and clothing away from moving blades when building or using a DIY air cleaner. Some commercial manufacturers are creating less costly portable air purifiers using simple designs similar to DIY approaches, e.g., Lasko™ Air Purifier and Room Fan.

Create a Clean Space at Home

People who live in areas where the risk of wildfire smoke risk is high, particularly those who are more sensitive, may wish to prepare a "clean room" in their home before the next smoke event. A good choice is an interior room, with as few windows and doors as possible, where people can spend most of their time. It is easier to clean air in a smaller room in comparison to a larger room. See Create a Clean Room to Protect Indoor Air Quality During a Wildfire.

Some suggestions for preparing and maintaining a clean room include:

- Turn off any automatic ventilation systems that bring outside air in.
- Upgrade to a higher-efficiency filter in a forced air system (check recommendations for your particular system); recognize that you may have to change the filter more often due to smoke (it's a good idea to obtain higher efficiency filters before a wildfire smoke incident when supplies become less available).
- Keep windows and doors closed unless this leads to a dangerous heat situation.
- Set up a properly-sized portable air cleaner to help remove PM from indoor air while emitting no or minimal levels of ozone (i.e., a CARB-certified portable air cleaner).
- Run the air conditioning system if you have one. 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.
- Do not smoke or burn anything in the house, including candles or incense.
- Smoke events usually have periods when the air quality is better. When air quality improves, even temporarily, air out your home to reduce indoor air pollutants.
- If it is too warm to stay inside with the windows closed, or if you are especially sensitive to smoke, consider temporary relocation, i.e., seek shelter elsewhere. Some PM will enter a home even if efficient filtration and air cleaners are employed.
- If necessary, use cleaning activities that do not re-suspend particles:
    - Use a HEPA-filter equipped vacuum cleaner
    - Clean hard surfaces by damp-mopping or damp-dusting
    - Ideally, wait until the smoke clears to use household cleaners, since chemical cleaning products should be used in a well-ventilated environment

Use an Approved Respirator if Necessary and Safe

This section provides basic information on respirators and includes considerations for their use in a wildfire smoke context.

The most effective action the public can take to reduce the risk of health effects from the inhalation of wildfire smoke is to stay indoors in cleaner air and minimize the amount of time spent outdoors in smoky conditions.[36] However, for those who must be outdoors during smoke events, N95 respirators offer enhanced protection if selected and used properly.

The N95 respirator is a common type of particulate filtering facepiece respirator.[37] N95 respirators must be certified by the U.S. National Institute of Occupational Safety and Health (NIOSH) to filter at least 95% of airborne particles 0.3 microns in size. N95 respirators filter particles; they do not reduce exposure to other potentially harmful constituents of wildfire smoke such as toxic gases or vapors. An N95 respirator is also effective in reducing transmission of SARS-CoV-2. People with pre-existing medical conditions should check with their healthcare provider before using a respirator.

If N95 respirators are not available or do not fit well, properly selected KN95 and KF94 respirators also provide filtration of PM. For respirators that use ear loops, they are not likely to fit as well as a 2-headstrap NIOSH-approved N95. Both good fit and good filtration are needed for effective protection. NIOSH-approved N95 respirators are an excellent choice to protect the wearer against wildfire smoke.

During the COVID-19 pandemic, episodic shortages of NIOSH-approved N95 respirators led to the temporary Emergency Use Authorization (EUA) of other respirator/mask types. KN95 and KF94 respirators are manufactured to standards established by other countries and are not approved by NIOSH. During the pandemic, strong consumer demand led to some misbranded or counterfeit products entering the U.S. Due to an improved supply of N95 respirators, the FDA has revoked the EUAs for non-NIOSH-approved respirators effective July 6, 2021, and as of that date they are no longer authorized and can no longer be imported for health care personnel use.

36 The advice to "stay indoors" assumes the indoor environment does not present heat risk. Heat risk should be avoided.

37 An N95 respirator may also be called an air-purifying respirator or filtering facepiece respirator. N95 respirators are sometimes referred to as "masks". The "N" indicates the filtering material is not resistant to oil.

In California, the Division of Occupational Safety and Health (Cal/OSHA) is responsible for enforcing California laws and regulations pertaining to worker safety and health.[38] For more information on new regulations to protect workers during wildfire smoke, see the section on "Protect Outdoor Workers".

Additional resources:

- NIOSH-approved N95 respirators.
- International respirator assessments to support COVID-19 response
- Information on counterfeit or misbranded respirators

Protect Pets From Wildfire Smoke

Animals are also sensitive to wildfire smoke and steps should be taken to avoid unnecessary exposure to wildfire smoke. Additional resources are provided in Appendix B.

A dog gets some extra care in South Lake Tahoe, CA. (Eric Ward/Unsplash)

38 Cal/OSHA

Considerations and Tools For Public Health Planning and Response

This section focuses on key factors to consider in planning for wildfire smoke:

Pre-Incident

- ☐ Build relationships among response partners, including:
  - Local Health Department/Local Environmental Health Department
  - Local Air District
  - Local School District
  - Local Emergency Management Agency
  - Local EMS Agency
  - Tribal Representatives
  - Medical Reserve Corps
  - Community Emergency Response Team
  - Listos California
  - Faith-Based and Community Based Organizations
  - Healthcare Providers
  - Media
- ☐ Identify clean air shelter locations and share information with communities
- ☐ Acquire stock of respiratory protection equipment and supplies (e.g., respirators, portable air cleaners)
- ☐ Develop plans for coordinated public alerts and messaging, including sensitive/vulnerable populations
- ☐ Develop and implement risk mitigation checklists for schools, group facilities, special events
- ☐ Outreach to employers and independent outdoor workers to ensure they are aware of regulations related to protecting workers from wildfire smoke and that they have protective equipment available in advance
- ☐ Encourage improved ventilation systems that effectively mitigate wildfire smoke intrusion into buildings

During Incident

- ☐ Provide coordinated risk communication messaging to the public, including at-risk populations
- ☐ Open clean air shelters if needed
- ☐ Distribute available respiratory protection equipment and supplies as needed
- ☐ Share situational information with response partners

Post-Incident

- ☐ Provide coordinated risk communication messaging on post-wildfire activities, e.g., re-entry, debris cleanup
- ☐ Update mitigation, response, and recovery plans

Build Strong Partnerships in Advance

Key government agencies and community organizations should establish strong working relationships prior to a wildfire smoke event (see list on preceding page). Building relationships and collaborative pre-planning are critical to effective response during smoke events.

California has total of 61 local health departments that include 58 county and 3 city health departments. Environmental health may be part of the local health department or its own department, depending on the jurisdiction's organization. California has 35 air districts that have primary responsibility for monitoring air quality, many of which are single-county, although regional air districts may span multiple counties. There are 33 local EMS agencies within California that may experience increased 9-1-1 calls due to wildfire smoke impacts. Local emergency management agencies include those at the county or city level. Numerous community-based groups integrated into the planning framework can effectively support community response to acute or extended wildfire smoke incidents.

Wildfire smoke incidents are likely to affect multiple jurisdictions in an area. It may be wise for officials to engage in pre-planning according to air basin geography rather than jurisdictional boundaries. See California Air Basins.

Ideally, jurisdictions will identify agreed-upon roles and responsibilities of response partners during a wildfire smoke event.

Develop Effective Public Messaging

Consistent public messaging about current air quality, forecast air quality, and recommended protective actions is helpful to the public who may be concerned and anxious during smoke events. Messaging should strive to be multilingual and accessible to people of different abilities (e.g., low literacy levels, vision impaired) and circumstances (e.g., lack of internet access).

Communication is more effective if the affected local/regional agencies collaborate on issuing joint advisories, or at a minimum, communicate the same information to their respective audiences. Under stress, the public seeks trustworthy information and can become frustrated when information is not consistent among sources.

Typically, the lead agency for providing information on air quality, including air quality alerts, is the local air district. It is routine business for California's 35 air districts to issue air quality alerts, including "Spare the Air" announcements or advisories.

During a smoke event, local public health officials may also issue advisories on recommended actions to protect the public from the harmful effects of wildfire smoke. During recent wildfires, LHDs and air districts provided joint advisories and social media updates. Local health departments may also disseminate these messages to trusted messengers, including community-based organizations, healthcare providers, schools, in addition to other involved agencies such as their local emergency management agency, Cal FIRE, and the U.S. Forest Service.

The Bay Area Regional Air Quality Messaging Steering Committee (comprised of the Bay Area Joint Information System, Association of Bay Area Health Officials, Bay Area Air Quality Management District, and regional officials) has developed an air quality messaging toolkit to provide unified messaging throughout the Bay Area region. The toolkit provides core guidance for air quality messaging, messaging templates by AQI-level, risk communication product templates, and guidance for communicating with vulnerable populations. For more information: http://www.bayareauasi.org/aqi.

Plan Ahead for Impacts to Schools and Outdoor Events

Schools and Childcare Facilities

Schools and childcare facilities are important sites for wildfire smoke preparedness activities. Before a smoke event, schools and childcare facilities can evaluate their ventilation systems; acquire access to portable air cleaners; identify students and staff that may be particularly sensitive (e.g., those with asthma); and confirm that such students have an Asthma Action Plan.[39]

Decision-making is complex when it comes to how to optimally respond to wildfire smoke that affects schools and childcare facilities. Many factors may be involved, e.g., the age of the building, quality of school ventilation, availability of portable air cleaners, risk reduction trade-offs, and the perspective of parents/guardians. School administrators should consider in advance what changes they will make to the school agenda during smoke events.

Some communities impacted by wildfire smoke focus on doing what they can to safely keep students in school. Closing schools can leave some students without a safe place to go. In addition, some California schools and residential childcare institutions provide meals to students who qualify. When school is cancelled due to wildfire smoke, these students may not have access to this important source of nutrition. Closing schools may also cause a hardship for working parents who may not be able to arrange supervision for children not in school.

The California Department of Education partnered with the California Air Resources Board, California Air Pollution Control Officers Association, California County Superintendents Educational Services Association, Association of California School Administrators, and California School Boards Association to develop guidance that local education leaders can use in conversation with local air districts and public health officials to determine how school activities will be affected when air quality is poor. See School Air Quality Activity Recommendations (CA Dept of Education) and Air Quality - CDE.

This guidance identifies factors that should be considered when making a school closure decision:

39 CDC Asthma Action Plan

Asthma rates for California children differ by region, averaging 15% for all school-age children. County estimates vary. See Estimated percentage of California children ages 1-17 who have ever been diagnosed with asthma.

Health and Safety:

- **Indoor air quality.** Filtration systems at schools may offer a higher level of protection than residential systems.
- **Supervision.** The school environment provides appropriate student supervision by trained adults who can ensure students remain indoors.
- **Student support services.** School may be the primary place where students receive needed health and counseling services.
- **Nutrition services.** Schools serve healthy meals to a significant proportion of students. If school is closed, it can be a challenge for local educational agencies to feed students.

Equity:

- **Childcare availability.** Socioeconomically disadvantaged families may not have options for alternate childcare.
- **Impact on working families.** Working parents and guardians are disproportionately affected by school closure and could suffer significant professional or economic consequences as a result.
- **Food access.** Students receiving free or reduced-price meals may not have a reliable alternate source of healthy food.
- **Access to services.** Students with Individualized Education Programs (IEPs) may not have access to needed services during school closure.
- **Safety.** Schools provide safe and supportive environments for their students; our most vulnerable students rely on them most.

Low-cost technology advances are likely to benefit schools. For example, low-cost sensor technology is used in a project involving Southern California schools[40] whose goals are to:

- Educate youth about air quality issues
- Inspire student interest in science
- Increase awareness of air quality health impacts among parents
- Convert awareness into action
- Inspire and train the next generation of air quality advocates

Natural disasters can be especially traumatic for children and youth. The National Association of School Psychologists has issued guidance for parents and teachers to help children after wildfires. The guidelines include possible reactions to wildfires and symptoms by age groups, tips for teachers and parents on how to assist children in their coping skills and resiliency, and information for schools on mental health support and resources. See Helping Children After a Wildfire: Tips for Parents and Teachers.

40 CLEAR in Schools STEM Program

For more information on schools and indoor air quality, see the U.S. EPA websites on Creating Healthy Indoor Air Quality in Schools and Indoor Air Quality Tools for Schools Action Kit. Also see Improving Indoor Air Quality in California Schools.

Also see Protecting Commercial Building Occupants From Smoke During Wildfire and Prescribed Burn Events.

Outdoor Events

In general, the decision to cancel an outdoor event is made by the event sponsor, school, or professional league, preferably in consultation with local public health and air district officials.

For outdoor athletic competitions, wildfire smoke can adversely impact both participating athletes and spectators. For athletes, higher ventilation rates during competition substantially increase personal exposure to smoke pollutants. For spectators, travel to and from the athletic event and fan activities (e.g., tailgating) can contribute to increased exposure.

NCAA Guidance for Member Institutions

In September 2018, the National Collegiate Athletic Association (NCAA) Committee on Competitive Safeguards and Medical Aspects of Sports updated its guidance for member institutions on practice and competition activities during periods of poor air quality.[41] The NCAA guidance on air quality includes:

- Attentive monitoring of local AQI and associated air quality alerts, especially during times of extreme environmental conditions, is recommended. This monitoring is best performed by the primary athletics healthcare providers trained to monitor environmental impacts on student-athlete health and safety. However, schools may choose to delegate this responsibility to another staff member with knowledge and training about environmental monitoring.
- Member schools should consider shortening or canceling outdoor athletic events (practices and competitions) in accordance with AQI guidance. Exposure should be managed more conservatively for student-athletes with pre-existing pulmonary or cardiac conditions, which may exacerbate the complications of these conditions and lead to an acute medical emergency. Specifically, at an AQI of 100 or higher, schools should consider removing sensitive athletes from outdoor practice or competition venues and should closely monitor all athletes for respiratory difficulty. Reduce heavy or prolonged exertion in sensitive individuals.

41 https://www.ncaa.org/sport-science-institute/air-quality

- At AQIs of over 150, outdoor activities should be shortened, and exertion should be minimized by decreasing the intensity of activity. Sensitive athletes should be moved indoors.
- At AQIs of 200 or above, serious consideration should be given to rescheduling the activity or moving it indoors. Prolonged exposure and heavy exertion should be avoided. Avoid all outdoor physical activity for sensitive individuals.
- At AQIs of 300 or above, outdoor activities should be moved indoors or canceled if indoor activity is not an option. School emergency action plans should guide the emergency care response in these circumstances, and staff should rehearse the plan at a minimum of once a year.

Note that this guidance is applicable only to NCAA member institutions and may be subject to change.

Assess Community Vulnerabilities

Specific communities and groups within communities face heightened vulnerability to wildfire smoke. These communities are diverse in population demographics and vary widely across California's landscape from urban areas to rural frontier mountain counties. Identifying groups and communities, including indigenous communities, that are most vulnerable to adverse health outcomes due to wildfire smoke exposure can increase community resilience by focusing on effective pre-incident planning and mitigation activities.

Environmental Justice

Environmental Justice (EJ) communities are commonly identified as those where residents are predominantly low-income or people of color; subject to a disproportionate impact from one or more environmental hazards; excluded from environmental policy setting or decision-making processes; and experience disparate implementation of environmental regulations, requirements, practices, and activities in their communities. Health equity and EJ efforts attempt to address the inequities in distribution of social and economic resources that lead to disproportionate vulnerability in these communities.

Planning activities should consider the health equity and EJ status of communities, as people living in such communities may experience higher exposures due to reduced access to mitigation options before and during wildfire smoke events (e.g., access to air-conditioned spaces, ability to leave the area, ability to reduce time spent laboring outdoors, etc.). SB 1000 requires that cities and counties with EJ communities adopt an EJ element, or integrate EJ-related policies, objectives, and goals throughout other elements of their

General Plan. An SB 1000 Toolkit by the California Environmental Justice Alliance helps jurisdictions meet this requirement in a way that advances health and equity.

Community Vulnerability Assessment

Vulnerability assessment can assist jurisdictions in preparing hazard mitigation and emergency response plans. California counties should have explicit wildfire and wildfire smoke plans as part of their emergency services plan and general plan appendices. This is important for applying for and receiving funds from Cal OES and FEMA to address activities for preparation, response, and recovery. Inclusion of wildfire smoke as part of the wildfire plan may allow access to funding for wildfire smoke pre-response and post-interventions.

It's important to position wildfire smoke in a larger context within the structural mechanisms that empower counties to apply for and obtain resources to address wildfire smoke. This points to a population level response led by public health, not just individual, household, or neighborhood remedies and solutions. Without county engagement in planning and pre-mitigation, it is difficult to acquire resources for community level interventions.

Resources for Community Planning

California Building Resilience Against Climate Effects (CalBRACE) Project

The CDPH Climate Change and Health Equity Section (CCHES) provides data, tools, and technical assistance to prevent, reduce, and prepare for major climate effects facing California—increasing temperature/extreme heat, drought, wildfire, and sea level rise (including flooding), and their direct and indirect health impacts. CCHES developed the Climate Change and Health Visualization (CCHVIz) interactive data visualization platform for the Climate Change & Health Vulnerability Indicators for California (CCHVIs). The CCHVIs include indicators of environmental exposure, population sensitivity, and adaptive capacity to the impacts of climate change, down to the census tract or county level. The CCHVIs allows the user to develop a county snapshot, look at a single indicator or a combination of vulnerabilities, and to query the data.

Within CCHES, the California Building Resilience Against Climate Effects (CalBRACE) Project uses the Building Resilience Against Climate Effects (BRACE) framework developed by the U.S. Centers for Disease Control and Prevention to help California health departments identify likely climate impacts in communities, potential health effects associated with these impacts, and their most at-risk populations and locations. Climate Change and Health Profile Reports provide projections for county and regional climate impacts, the climate-related health risks, and local populations that could be vulnerable to climate effects. Indicators in the county-level reports include heat-related emergency department visits, adults living

with multiple chronic conditions, population living in poverty, race/ethnicity, outdoor workers, air conditioning ownership, tree canopy, and public transit access. The CalBRACE Adaptation Toolkit helps local health departments and communities understand and develop a plan to address health risks from climate change.

National Environmental Public Health Tracking Network

The CDC National Environmental Health Public Health Tracking Network provides a database of environmental and non-infectious disease data from national, state, and city sources that public health officials can use to make information-based decisions. The Tracking System provides visualization of wildfire data overlayed with health data via interactive maps, tables, and charts.

The Tracking System provides a County Level Snapshot of environmental health issues such as air quality, asthma, and extreme heat. The Tracking System's Data Explorer allows the user to search data such as wildfires and air quality and overlay them with social vulnerability indicators to visualize county-specific data.

Social Vulnerability Index

The CDC/ATSDR Social Vulnerability Index (SVI) data included on the Tracking Network come from the Agency for Toxic Substances and Disease Registry (ATSDR). The SVI shows relative vulnerability of every U.S. Census tract on 14 social factors including poverty, lack of vehicle access, and crowded housing. These data can be used by public health officials and local planners to better prepare communities to respond to emergency events like severe weather and wildfires. See SVI Interactive Map.

Recent State Legislation

Community Air Protection Program (AB 617)

In response to AB 617, CARB established the Community Air Protection Program (CAPP). The Program's focus is to reduce exposure in communities most impacted by air pollution. Communities around the state are working together to develop and implement new strategies to measure air pollution and reduce health impacts. More information can be found here: Community Air Protection.

Community Air Quality (AB 619)

AB 619 specifies that CDPH will develop a plan with recommendations and guidelines for counties to use in the case of a significant air quality event caused by wildfires or other sources. AB 619 requires a county, in advance of its next emergency plan update, to use the air quality plan developed by CDPH and develop a county-specific plan that addresses the recommendations and guidelines identified in CDPH's air quality plan.

Wildfire Smoke Clean Air Centers for Vulnerable Populations Incentive Pilot Program (AB 835)

In October 2019, the California Governor signed Assembly Bill 835 into law which established until January 1, 2025, the Wildfire Smoke Clean Air Centers for Vulnerable Populations Incentive Pilot Program. This program, administered by CARB, provides funding through a grant program to retrofit ventilation systems and create a network of clean air centers to mitigate the adverse public health impacts from wildfires and smoke events. Qualified applicants include, but are not limited to, schools, community centers, senior centers, sports centers, and libraries.

Wildfire smoke obscuring Half Dome, in Yosemite National Park, July 2020. (Sterling Lanier/Unsplash)

Establish Community Clean Air Shelters and Spaces

In some communities or living spaces, indoor air quality may not be significantly better than outdoor air quality due to the age of the homes, lack of air conditioning systems, or lack of indoor air filtration. Specific populations, such as people experiencing homelessness or those who live in inadequate housing, may not have access to acceptable indoor air spaces or the ability to access acceptable alternatives.

Local jurisdictions should evaluate sites that could be used as community clean air shelters and spaces prior to fire season. See Creating Clean Air Spaces During Wildland Fire Smoke Episodes: Web Summit Summary for a recent summary of useful information.

Additional information on the basic requirements of a community clean air shelter is provided in Appendix I.

Newer commercial buildings are likely to have better indoor air quality in comparison to the outdoor environment or older, leaky buildings. However, even modern commercial buildings may have worsened air quality if many people are entering and exiting, allowing more outside air into the building.

In October 2019, the California Governor signed Assembly Bill 835 into law which established until January 1, 2025, the Wildfire Smoke Clean Air Centers for Vulnerable Populations Incentive Pilot Program. This program, to be administered by the California Air Resources Board, provides funding through a grant program to retrofit ventilation systems and create a network of clean air centers to mitigate the adverse public health impacts from wildfires and smoke events. Qualified applicants include, but are not limited to, schools, community centers, senior centers, sports centers, and libraries.

Protect Workers

Wildfire smoke can travel great distances and become a hazard to employees in both indoor and outdoor workplaces, oftentimes far from the actual wildfire. Cal/OSHA enforces California laws and regulations pertaining to workplace safety and health and provides assistance, outreach, and education to employers and workers. Comprehensive information on the protection of workers can be found on Cal/OSHA's website.

In work settings, a well-established "hierarchy of controls" is typically applied to protect the health and safety of workers from occupational hazards.[42] In general, this approach is effective for reducing the risk associated with hazards, including wildfire smoke. This hierarchy of controls progresses from "most effective" to "least effective" options. See Figure 9.

42 NIOSH Hierarchy of Controls

If the hazard cannot be eliminated or replaced, the next most effective option is to isolate people from the hazard (Engineering Controls). If that is not an option, then making changes to the way people deal with the hazard is the next most effective approach (Administrative Controls). The least effective approach is to protect the worker with Personal Protective Equipment, which may include N95 respirators. In other words, if avoiding smoke is not possible, then properly wearing a well-fitting N95 respirator can offer valuable protection.

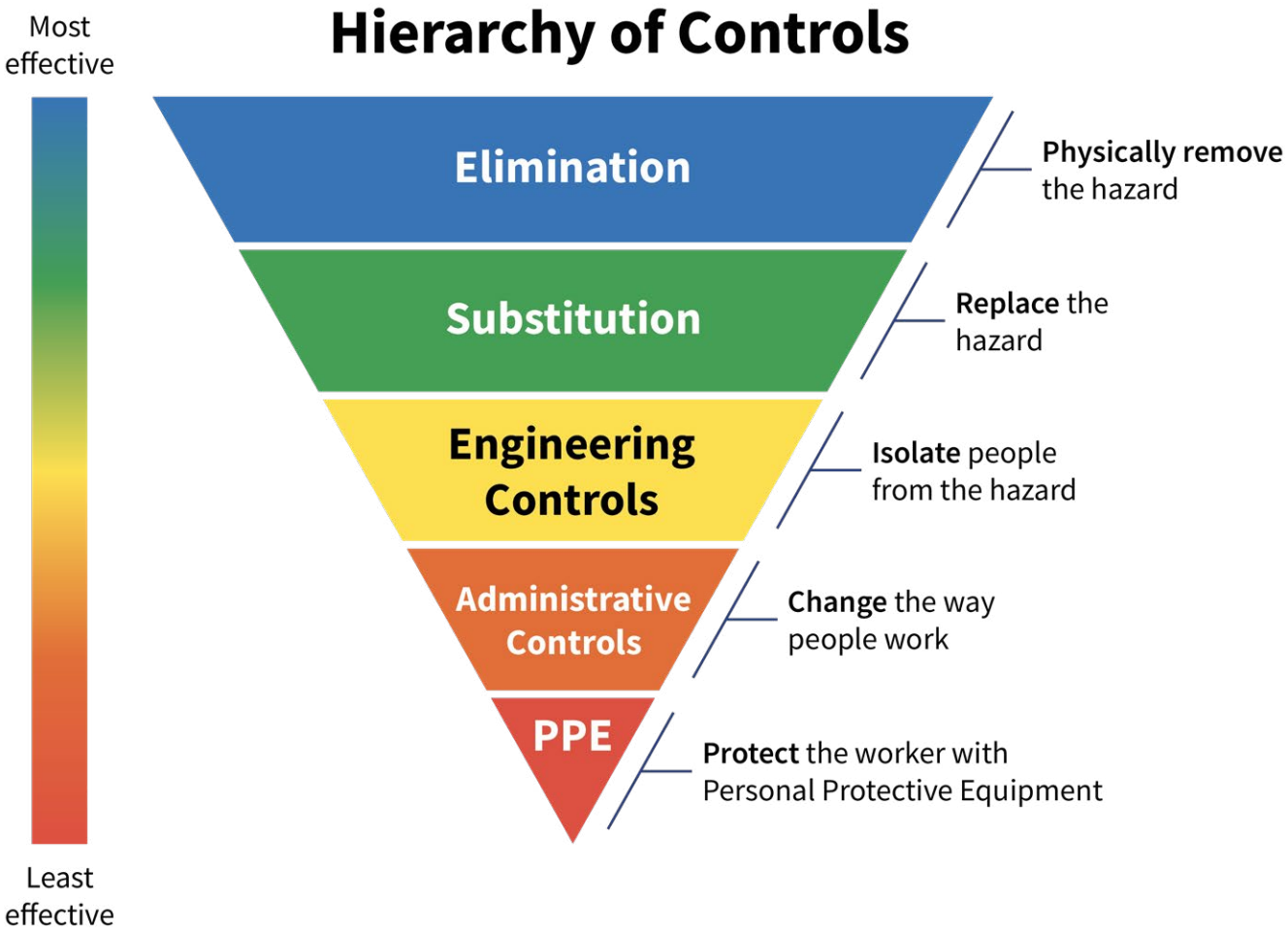


Figure 9. *Hierarchy of Controls*

Table 9 summarizes a recent publication on personal interventions to reduce exposure to wildfire smoke:

Table 9. Summary of personal actions for reducing exposure to PM from wildfire smoke, in order of priority according to hierarchy of controls.

Tier in Hierarchy of Controls	Exposure Control Action	Estimated Exposure Reduction	Considerations
1. Elimination	Relocate	100%	• Stress of relocation may be harmful, especially for vulnerable populations • Exposure to air pollution and other unsafe conditions while in transit • May not have feasible places to go
2. Engineering	Reduce indoor infiltration by closing doors and windows Filter air with portable air filters, central air filters, or air conditioners in recirculation mode	20-80%	• Effectiveness varies greatly with ventilation and filtration rates. • Portable HEPA filters generally more effective, if properly sized and used • Central forced-air filtration is generally less effective due to lower-efficiency filters and shorter run times. • Upfront costs, but may provide year-round benefit by reducing indoor PM from other sources
3. Administrative	Stay indoors Avoid heavy or prolonged physical activity	~50% on average, but varies widely Lowers inhaled dose of pollutants	• Without added filtration, the building envelope limits infiltration to a widely variable extent depending on tightness • Especially important for outdoor activity • Pulmonary ventilation rates may increase 10- to 20-fold during heavy exertion • If temporary, little risk of harmful reducation in beneficial physical activity
4. Personal Protective Equipment	Wear a NIOSH-approved N95 or P100 filtering facepiece respirator	90% or greater, depending on quality of fit. Near 0% if poorly fitted.	• Should be used only when outdoor activity cannot be avoided • Performance depends on fit • Fit testing and medical clearance are not generally available • Physiological stress due to increased work of breathing, heat, discomfort • Populations vulnerable to wildfire PM may also be more vulnerable to adverse effects of wearing a respirator

Definition of abbreviations: HEPA = high-efficiency particulate air; NIOSH = National Institute for Occupational Safety and Health; PM = particulate matter.

For indoor workers, employers should assess their HVAC systems, and consider other methods of protection such as respirators, telecommuting, alternate work sites, and reducing the overall exposure to smoke. Guidelines for protecting indoor workplaces from wildfire smoke with building ventilation system and other methods can be found on Cal/OSHA's website.

The California Code of Regulations, Title 8, Section 5141.1 applies to most outdoor workplaces where the current Air Quality Index (current AQI) for airborne particulate matter 2.5 micrometers or smaller ($PM_{2.5}$) is 151 or greater, and where employers should reasonably anticipate that employees could be exposed to wildfire smoke. The regulation includes:

1. **Identification of Harmful Exposures (subsection c)—**For worksites covered by the regulation, employers (with certain exceptions) must determine employee exposure to $PM_{2.5}$ at the start of each shift and periodically thereafter, as needed.
2. **Communication (subsection d)—**Employers must implement a system for communicating wildfire smoke hazards in a language and manner readily understandable by employees.
3. **Training and instruction information (subsection e and Appendix B)—**For worksites covered by the regulation, employers must provide effective training that includes at least the information contained in Appendix B of the regulation.
4. **Control of harmful exposures to employees (subsection f)—**With certain exceptions, employers must reduce workers' exposure to wildfire smoke in the following ways:
    - If feasible, by providing an enclosed location with filtered air so that employee exposure to $PM_{2.5}$ is less than a current AQI of 151, or to the extent feasible.
    - If that is not feasible or adequate, by relocating to another outdoor location where the current AQI for $PM_{2.5}$ is lower, changing work schedules, reducing work intensity, or providing more rest periods.
    - With respiratory protective equipment if employers cannot reduce workers' exposure to $PM_{2.5}$ to a current AQI of less than 151.
        - Where the current AQI for $PM_{2.5}$ is from 151 to 500, employers must provide a sufficient number of NIOSH-approved particulate respirators, such as N95 masks, to all employees for voluntary use, and training on the regulation, the health effects of wildfire smoke, and the safe use and maintenance of respirators.
        - Where the current AQI for $PM_{2.5}$ is higher than 500, the employer must provide and require employees to use NIOSH-approved particulate respirators that will reduce employee exposure to $PM_{2.5}$ to an equivalent of an AQI less than 151. Such respirator use must be within the context of a comprehensive respiratory protection program (including medical clearance, fit testing, training, etc.) per Section 5144.

Cal/OSHA provides further information here: Worker Protection from Wildfire Smoke.

Understand the Public Health Benefits of Prescribed Fire

The health risks associated with high intensity wildfires have led to renewed interest in the use of lower intensity prescribed fire to reduce population health impacts.[43] Prescribed burns decrease the build-up of flammable vegetation and subsequent fuel for wildfires, mitigating both the spread and intensity of wildfires. In addition to reducing wildfire hazards, prescribed fire serves other important purposes, including controlling plant diseases, improving rangeland and wildlife habitats, and restoring natural ecosystems. The State of California along with federal agencies have entered into a joint agreement to increase the use of prescribed fire, potentially as much as 500,000 acres annually by 2025.

Unlike wildfires, since prescribed fires are planned, they provide an opportunity to prepare for smoke impacts. Also, smoke from prescribed burns is typically less intense and more short-lived than smoke from wildfires.

Local agencies coordinate to ensure that conditions are optimal to keep smoke impacts to a minimum, with the goal of directing any smoke away from populated areas as much as possible. As the planned burn day approaches, officials notify the public and monitor conditions to ensure a safe burn and minimize air quality impacts. These conditions include humidity and wind, as well as the vegetation moisture levels. If conditions do not appear favorable for a successful burn with minimal smoke, the burn may be rescheduled to a better time. Local air districts provide final approval for each burn on the day it is scheduled to be conducted. Often, agencies will set up portable air quality monitors to keep track of how the burn may be affecting air quality.

Before a prescribed burn, public health officials can communicate with the agency responsible for prescribed fires in their area to find out when the burn is expected to start and end, and where any smoke impacts may occur. Public health messaging can parallel recommendations for wildfire smoke protections, e.g., in addition to informing the nearby residents of the planned burn, recommendations can be made to suggest that before a prescribed fire begins, residents can open windows and doors to let in fresh air, get any outdoor activities done and know to stay indoors during the burn, replace filters in air cleaners or HVAC systems, or purchase an air cleaner if they lack filtration in their home. Persons who are especially sensitive to smoke can consider making plans to leave the area.

Residents can also be made aware of and encouraged to sign up for notifications for prescribed fire, e.g., from sources such as Cal FIRE or Nixle. Persons who live in areas that have been impacted by wildfires may experience stress when smelling any smoke, and it will

43 Prunicki M, Kelsey R, Lee J, *et al.* The impact of prescribed fire versus wildfire on the immune and cardiovascular systems of children. Allergy. 2019;74(10):1989-1991.

be especially important for such individuals to have resources to promptly determine if the source is wildfire or prescribed fire smoke.

The California Air Resources Board has created the California Smoke Spotter app. The app provides members of the public with access to a comprehensive overview of the latest information on prescribed fires, projected smoke impacts, current air quality and educational material. The app is designed to help the public plan their day's activities, and also determine if smoke is from a local prescribed fire. Key features of the app include:

- Location, size, and burn status
- 24-hour statewide smoke forecasts
- Personalized alerts that notify users when a prescribed fire will be burning nearby (notifications can be set for multiple locations)
- Current Air Quality Index (AQI) data to help users make health-based decisions
- Additional information on prescribed fire, its benefits, and how users can protect themselves from smoke

CARB provides additional information on Agricultural and Prescribed Burning.

As Californians deal with the consequences of drought and climate change, prescribed fires during appropriate fuel and weather conditions may help to reduce the likelihood of severe damage caused by uncontrolled wildfires. Researchers are interested in this topic from a public health perspective.

Wildfire smoke sets in over the Central Valley, October 2021. (Simon Hurry/Unsplash)

The Time To Prepare Is Now

Fire has always been a part of California's ecosystem and factors like drought and climate change are increasing the risk of wildfire smoke incidents. Public health officials can play a vital role in preparing communities and individuals to more sustainably adapt to this new reality.

Wildfire smoke rises above King's Canyon National Park, October 2015. (Dominik Lange/Unsplash)

Appendix A. Acronyms

Acronym	Definition
AHAM	Association of Home Appliance Manufacturers
AQ-SPEC	Air Quality Sensor Performance Evaluation Center
AQI	Air Quality Index
AQMD	Air Quality Management District
APCD	Air Pollution Control District
ARA	Air Resource Advisor
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CAAQS	California Ambient Air Quality Standards
CADR	Clean Air Delivery Rate
CalEPA	California Environmental Protection Agency
Cal FIRE	California Department of Forestry and Fire Protection
Cal OES	California Governor's Office of Emergency Services
Cal/OSHA	California Division of Occupational Safety and Health
CAPCOA	California Air Pollution Control Officers Association
CARB	California Air Resources Board
CCHES	CDPH Climate Change and Health Equity Section
CCHIVI	Climate Change and Health Vulnerability Indicators for California
CCHIVIz	Climate Change and Health Vulnerability Indicators Visualization
CCLHO	California Conference of Local Health Officers
CDC	U.S. Centers for Disease Control and Prevention
CDPH	California Department of Public Health
COPD	Chronic Obstructive Pulmonary Disease

Acronym	Definition
BAM	Beta Attenuation Monitor
EJ	Environmental Justice
FEM	Federal Equivalent Method
FPR	Filter Performance Rating
FRM	Federal Reference Method
HEPA	High Efficiency Particulate Air
HCAI	Health Care Access and Information
ISA	Integrated Science Assessment
LHO	Local Health Officer
MERV	Minimum Efficiency Reporting Value
MPR	Microparticle Performance Rating
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
OEHHA	Office of Environmental Health Hazard Assessment
PM	Particulate Matter
SCAQMD	South Coast Air Quality Management District
SVI	Social Vulnerability Index
U.S. EPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service

Appendix B. Resources and Links[44]

This document has included a number of tools and resources to enable further learning and action on the information provided here. The following section includes links to additional content based on common topics of interest:

Wildfire Smoke — General Information

Website	Source	Notes
AirNow	U.S. EPA	Government website that displays the Air Quality Index (AQI) that may range from Green ("Good") to Purple ("Hazardous") and educational information on air quality.
Fire and Smoke Map (airnow.gov)	U.S. Forest Service (Interagency Wildland Fire Air Quality Response Program) and U.S. EPA	Government website that displays fine particle pollution ($PM_{2.5}$) from permanent monitors (designated by circles); temporary monitors deployed by agencies for smoke events (designated by boxes); and low-cost sensors (designated by triangles and not used for regulatory purposes). Low-cost sensor information is averaged to hourly values and subjected to the EPA NowCast algorithm on the Fire and Smoke Map.
California Smoke Information	Multi-Agency	California-based website that aggregates information for California communities affected by wildfire smoke.
California Smoke Spotter app	CARB	Mobile app provides a comprehensive overview of the latest information on prescribed fires, projected smoke impacts, current air quality and educational material.

44 These resources and links are current as of July 2022 and are subject to change.

Smoke Mapping and Forecasting Tools		
Website	**Source**	**Notes**
California Smoke Spotter app	CARB	The California Smoke Spotter app provides a comprehensive overview of the latest information on prescribed fires, projected smoke impacts, current air quality and educational material. This will help them plan their day's activities, and also determine if smoke is from a local prescribed fire.
Smoke Forecast Outlooks	USFS Wildland Fire Air Quality Response Program	Smoke forecast outlooks issued by Air Resource Advisors (ARAs) when deployed for major smoke events.
WebSky v1 (airfire.org)	USFS	This experimental tool provides a visualization of results from a wide array of daily smoke model prediction runs, particularly the BlueSky based smoke model runs by USFS-AirFire. Additional runs by NOAA (the High Resolution Rapid Refresh model, HRRR-Smoke) and Environment and Climate Change Canada (FIREWORK) are also available through this viewer courtesy of these organizations.
Smoke COVID Dashboard (airfire.org)	USFS-led Interagency Wildland Fire Air Quality Response Program	Experimental site that displays data related to smoke and COVID-19.
Wildland Fire Air Quality Tools	USFS	This page provides links to the most recent versions of tools produced by the USFS Pacific Northwest Research Station's Pacific Wildland Fire Sciences Laboratory in support of wildland fire operations.
InciWeb: Incident Information System	Interagency (National Wildfire Coordinating Group)	InciWeb is an interagency all-risk incident information management system.

Wildfire Smoke and Health		
Website	**Source**	**Notes**
Protecting Yourself from Wildfire Smoke	CARB	CARB's California Smoke Ready information, including key steps the public can take to protect health. Includes infographics.
Wildfire Smoke	CDC	Health effects of wildfire smoke.
Protect Yourself from Wildfire Smoke	CDC	Tips to decrease risk from wildfire smoke.
Wildfire Smoke and COVID-19	CDC	Tips to decrease risk from wildfire smoke during the COVID-19 pandemic.
Public Health Strategies to Reduce Exposure to Wildfire Smoke during the COVID-19 Pandemic	CDC	Provides information about wildfire preparedness and response during the COVID-19 pandemic. It is intended for use by public health, environmental health, and air quality personnel in federal, state, territorial, local, and tribal jurisdictions.
Wildfire Smoke: A Guide for Public Health Officials	U.S. EPA	Document describing health effects due to wildfire smoke, mitigation strategies, communication, and recommended public health actions.
Smoke Sense Study and App Resources	U.S. EPA	Smoke Sense is a citizen science research project developed by U.S. EPA focused on increasing public awareness and engagement related to health risks associated with wildfire smoke.
AirNow: Fires and Your Health	U.S. EPA	Compilation of resources and publications related to wildfire smoke and health.
Wildland Fire Publications, Fact Sheets, and Other Resources	U.S. EPA	Compilation of resources and publications related to wildfire smoke and health.
Air Quality Guide for Particle Pollution	U.S. EPA	Guide on protecting health when particle pollution reaches unhealthy levels.
Reducing Your Exposure to Particle Pollution	CARB	General guidance on reducing exposure to particle pollution outdoors, indoors, or while traveling in vehicles.

Community Vulnerability		
Website	**Source**	**Notes**
Climate Change and Health Vulnerability Indicators for California	CDPH	Interactive data visualization platform that reflects Climate Change & Health Vulnerability Indicators for California produced by the CDPH's Climate Change and Health Equity Section.
California Building Resilience Against Climate Effects (CalBRACE) Project	CDPH	The CDPH Climate Change and Health Equity Section and its CalBRACE Project provide data, tools, and technical assistance to state and local health departments, tribes, and other agencies to prevent and reduce the health impacts of climate change and enhance resilience at the local and regional levels.
County Climate Change and Health Profile Reports	CDPH	The Climate Change and Health Profile Reports are designed to help California counties plan to address health impacts related to climate change through adaptation planning. The reports present projections for county and regional climate impacts, climate-related health risks, and local populations that could be vulnerable to climate effects.
County Climate and Health Profile Reports	CDPH	The Climate Change and Health Profile Reports are designed to help California counties prepare for health impacts related to climate change through adaptation planning. The reports present projections for county and regional climate impacts, climate-related health risks, and local populations that could be vulnerable to climate effects.
Tracking California: Informing Action for Healthier Communities	Public Health Institute	Compilation, visualization, and analysis of environmental health data and information for community groups, government agencies, researchers, and health advocates.
National Environmental Health Tracking Network	CDC	Compilation of data and information on environments, hazards, health effects, and population health from national, state, and city sources.

Community Vulnerability		
Website	**Source**	**Notes**
California Healthy Places Index	Public Health Alliance of Southern California	Compilation of data on local factors that predict life expectancy such as housing, transportation, access to health care, and clean environment. Visualization tool comparing community conditions across the state.
CalEnviroScreen	California Office of Environmental Health Hazard Assessment	Mapping tool that uses environmental, health, and socioeconomic information to produce scores for every census tract in the state and identify California communities that are most affected by sources of pollution.
4 Types of Low-Cost Air Sensor Community Science Projects	New Jersey Dept of Environmental Protection	Includes description of 4 different types of community science projects using low-cost air sensors.

At-Risk Populations[45]		
Website	**Source**	**Notes**
Integrated Science Assessment (ISA) for Particulate Matter	U.S. EPA	The Integrated Science Assessment (ISA) for Particulate Matter contains detailed information on the impact of PM on health (independent of source).
Chronic Conditions and Wildfire Smoke	CDC	Precautions recommended for people with certain chronic conditions.
Heart Disease, Stroke, and Outdoor Air Pollution	U.S. EPA	Factsheet jointly developed by the U.S. EPA, American College of Cardiology, American Heart Association, and American Stroke Association.
Million Hearts: Particle Pollution and Your Health	CDC	Tools, data, and reports that raises awareness of heart disease and its link to air pollution and other environmental factors.

45 Certain people may be particularly sensitive to the pollutants in wildfire smoke due to life stage, pre-existing medical condition, or other social or economic factors which may contribute to enhanced sensitivity or the inability to effectively mitigate adverse health impacts.

At-Risk Populations[45]		
Website	**Source**	**Notes**
Healthy Heart Toolkit: Public Educational Materials	U.S. EPA	Public educational materials such as factsheets, infographics, and videos regarding association between air pollution, stroke, and heart disease.

Children and Pregnant People		
Website	**Source**	**Notes**
Wildfire Smoke and Pregnancy	CDC	Recommendations for pregnant people to protect themselves from wildfire smoke before, during, and after a wildfire smoke incident.
Wildfires and Children's Health	Western States Pediatric Environmental Health Specialty Unit (PEHSU)	Guidance and resources on the effects of wildfire smoke in the pediatric population.
How to Reduce Wildfire Smoke Exposure for Kids	PEHSU	Infographic for caregivers on steps to take to reduce wildfire smoke exposure for kids.
Reducing Wildfire Smoke Exposure for Children	PEHSU	Infographic for caregivers on steps to take to reduce wildfire smoke exposure for kids.
Masks to Protect Children and Pregnant People from Wildfire Smoke	PEHSU	Factsheet providing mask guidance for children and pregnant people.
Wildfire Smoke and Children	CDC	Recommendations for caregivers to protect children from wildfire smoke before, during, and after a wildfire smoke incident.

46 Certain people may be particularly sensitive to the pollutants in wildfire smoke due to life stage, pre-existing medical condition, or other social or economic factors which may contribute to enhanced sensitivity or the inability to effectively mitigate adverse health impacts.

Children and Pregnant People

Website	Source	Notes
Children and Disasters: Wildfires	American Academy of Pediatrics	Guidance and resources on the impact of wildfires and smoke on children.
Protecting Children from Wildfire Smoke and Ash	U.S. EPA	Factsheet providing recommendations for caregivers on how to protect children from wildfire smoke before, during, and after a wildfire smoke incident.
Wildfire Resources	National Child Traumatic Stress Network (NCTSN)	Mental health guidance and resources to support children, families, and communities to recover after wildfires.
Parent Guidelines for Helping Children Impacted by Wildfires	NCTSN	Factsheet for parents on how to talk to children about wildfires.
Age-Related Reactions to Traumatic Events	NCTSN	Factsheet for parents on how to talk to children about traumatic events.

Protecting Workers from Smoke

Website	Source	Notes
Workers Exposed to Wildfire Smoke - for Workers	Cal/ OSHA	Fact sheet for workers (English).
Workers Exposed to Wildfire Smoke - for Employers	Cal/ OSHA	Fact sheet for employers (English).
Workers Exposed to Wildfire Smoke - for Workers - Spanish	Cal/ OSHA	Fact sheet for workers (Spanish).
Workers Exposed to Wildfire Smoke - for Employers - Spanish	Cal/ OSHA	Fact sheet for employers (Spanish).

Protecting Workers from Smoke		
Website	**Source**	**Notes**
Requirements to Protect Workers Exposed to Wildfire Smoke Video	Cal/ OSHA	Training Video: Protection of workers from wildfire smoke (English).
Requirements to Protect Workers Exposed to Wildfire Smoke Video - Spanish	Cal/ OSHA	Training Video: Protection of workers from wildfire smoke (Spanish).
Protecting Indoor Workplaces from Wildfire Smoke with Building Ventilation Systems and Other Methods	Cal/ OSHA	How to protect indoor workspaces from smoke using building ventilation systems and other methods.

Schools		
Website	**Source**	**Notes**
Clear Guidelines for Schools and Wildfire Smoke	California Department of Education	Information provided by the California Department of Education and other agencies/organizations regarding schools and wildfire smoke.
Protecting Building Occupants From Smoke During Wildfire and Prescribed Burn Events	American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	Provides guidance on building and HVAC measures to minimize occupant exposures and health impacts from smoke due to wildfires or prescribed burn events.
Tips for Improving Air Quality at School	CDPH	Strategies that can be used to limit exposure to COVID-19, harmful chemicals, and wildfire smoke in schools and classrooms.

Schools		
Website	**Source**	**Notes**
Ventilation and Filtration to Reduce Long-Range Airborne Transmission of COVID-19 and Other Respiratory Infections: Considerations for Reopened Schools (2021)	CDPH	Guidance that supplements the state interim ventilation guidance and provides a road map on the practical steps that schools can take to assess and improve classroom ventilation and air filtration.
Protecting Kids from Wildfire Smoke: Actions for California Schools	Stanford University	Actions that can be taken by California schools prior to wildfire season, including COVID-19 considerations.
Improving Indoor Air Quality in California Schools	UC Davis Western Cooling Efficiency Center	Information and videos on improving filtration and ventilation in schools.
Guidance for Re-Opening Schools	ASHRAE	Guidance on the re-opening of schools to minimize COVID transmission.
Air Quality	California Department of Education	List of air quality resources and guidance for schools.
Air Quality Flag Program: Factsheet	U.S. EPA	The Flag Program uses brightly colored flags based on the U.S. EPA's Air Quality Index (AQI) to notify people and their communities about outdoor air quality conditions. Organizations raise a flag each day that corresponds to their local air quality forecast.
Air Quality and Outdoor Activity Guidance for Schools	U.S. EPA	Factsheet providing outdoor activity guidance for schools according to AQI and visualized by colored flags.
Oregon Public Health Guidance: School Outdoor Activities During Wildfire Events (English)	Oregon Health Authority	Factsheet providing outdoor activity guidance for Oregon schools according to AQI. (English)

Schools		
Website	**Source**	**Notes**
Oregon Health Guidance: School Outdoor Activities During Wildfire Events (Spanish)	Oregon Health Authority	Factsheet providing outdoor activity guidance for Oregon schools according to AQI. (Spanish)
Washington Air Quality Guide for School & Child Care Activities	Washington State Department of Health	Note that Washington State uses a modification of the U.S. EPA's AQI called the Washington Air Quality Advisory (WAQA) to advise residents about air quality levels. The WAQA bases its advice on lower levels of fine particles relative to the EPA's national AQI.
Improving Ventilation and Indoor Air Quality during Wildfire Smoke Events	Washington State Department of Health	Recommendations for schools and buildings with mechanical ventilation. (Note that Washington State uses a modification of the U.S. EPA AQI; see above comment.)
Indoor Air Quality in Schools	Lawrence Berkeley National Lab	Overview of indoor air quality (IAQ) in schools and its influence on the health, performance, and absence of occupants of schools. The review is based on papers published in peer reviewed journals.
Helping Children After a Wildfire: Tips for Parents and Teachers	National Association of School Psychologists	Factsheet providing guidance to parents and teachers on how to help children and youth cope in the aftermath of a wildfire.
Key Resources to Help You Stay Safe While Evacuated from Wildfires	Oregon Health Authority	Factsheet providing guidance and tips on how to protect oneself while evacuating from wildfires during a pandemic.
A Story of Health: Sofia's Story (E-book)	ATSDR, OEHHA, WSPEHSU	Follow Sofia and her family as they learn how to protect themselves from the immediate and longer-term health dangers of a wildfire, with a focus on children's health and prevention strategies.

Indoor Air Quality, Ventilation, and COVID-19		
Website	**Source**	**Notes**
Interim Guidance for Ventilation, Filtration, and Air Quality in Indoor Environments	CDPH, Cal/OSHA, HCAI	Guidance recommending practical steps building operators can take to promote better ventilation, filtration, and air quality in indoor environments for the purpose of reducing the spread of COVID-19.
Protecting Building Occupants From Smoke During Wildfire and Prescribed Burn Events	American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	Provides guidance on building and HVAC measures to minimize occupant exposures and health impacts from smoke due to wildfires or prescribed burn events.
Core Recommendations for Reducing Airborne Infectious Aerosol Exposure	American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	Factsheet providing recommendations for HVAC operators on how to reduce airborne infectious aerosol exposure.
Guidance for COVID-19 Risk Reduction in Residential Buildings	ASHRAE	Factsheet providing indoor air guidance to reduce spread of SARS-Cov-2 in residential buildings.
Guidance for the Re-Opening of Schools	ASHRAE	Factsheet providing recommendations related to HVAC and water systems in schools to minimize spread of SARS-Cov-2.
Indoor Air and Coronavirus (COVID-19)	U.S. EPA	Guidance and resources to reduce airborne transmission of COVID-19.
Air Quality Tips and Resources During a Wildfire	LBNL (Indoor Environment Group)	Excellent source of information on indoor air quality, including air quality tips and resources during a wildfire.
Ventilation in Buildings	CDC	Information to reduce the spread of disease and reduce the risk of exposure through ventilation and other means.

Indoor Air Quality, Ventilation, and COVID-19		
Website	**Source**	**Notes**
ASHRAE Information for Schools and Universities	ASHRAE	Information provided by ASHRAE Task Force to mitigate the potential for transmission of the SARS-CoV-2 virus through HVAC systems and to reduce concentrations of infectious aerosols present in occupied spaces to the extent possible.

N95 Respirators		
Website	**Source**	**Notes**
Non-Occupational Uses of Respiratory Protection	NIOSH/CDC	NIOSH and CDC recommendations and lessons learned regarding the use of respirators in a work setting and by the public.
N95 Respirators, Surgical Masks, Face Masks, and Barrier Face Coverings	FDA	Information on the different types of respirators, masks, and face coverings.
How to Properly Put On and Take Off a Disposable Respirator	NIOSH/CDC	Factsheet for how to don/doff a disposable respirator.
Facial Hairstyles and Filtering Facepiece Respirators	NIOSH/CDC	Infographic on which facial hairstyles are compatible with filtering facepiece respirators.
Using Disposable Respirators (N95 through P100)	Cal/OSHA	Factsheet and infographic on the correct use of disposable respirators (English and Spanish).
Respiratory Protection in the Workplace – A Guide for Employers	Cal/OSHA	Respiratory protection in the workplace – a guide for employers.

Clean Air Shelters

Website	Source	Notes
Create a Clean Room to Protect Indoor Air Quality During a Wildfire	U.S. EPA	Guidance provided by the U.S. EPA on creating a clean room to protect indoor air quality during a wildfire.
Identification of Cleaner Air Shelters/Spaces for Protection from Wildfire Smoke	Oregon Health Authority	Guidance for identification of cleaner air shelters/ spaces.
Home and Community Clean Air Shelters to Protect Public Health during Wildfire Smoke Events	Provincial Health Services, British Columbia, Canada	Scientific research review of home and community clean air shelters.

Air Quality Sensors

Website	Source	Notes
Air Quality Sensor Performance Evaluation Center (AQ-SPEC)	South Coast Air Quality Management District (SCAQMD)	Air Quality Sensor Performance Evaluation Center (AQ-SPEC) evaluates the performance of commercially available low-cost air quality sensors in both field and laboratory settings. Provides guidance and clarity for new sensor technology and data interpretation.
Sensor Performance (Summary Table)	SCAQMD	Summary reports of evaluation of low-cost air monitoring sensors.

Filters and Portable Air Cleaners

Website	Source	Notes
California Certified Air Cleaning Devices	California Air Resources Board (CARB)	Air cleaning devices certified by CARB to meet ozone and electrical safety standards for California.
Air Filters and Air Cleaners in the Home	U.S. EPA	General information on air filters and air cleaners.

Filters and Portable Air Cleaners

Website	Source	Notes
Residential Air Cleaners	U.S. EPA	Technical summary of air cleaners for residential use.
In-Room Air Cleaner Guidance for Reducing Covid-19 In Air In Your Space/Room	American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	Guidance on how to select an in-room, portable, stand-alone air cleaner to reduce exposure to viruses and other microorganisms.
AHAM Certified Room Air Cleaners	Association of Home Appliance Manufacturers (AHAM)	Searchable database of air cleaners that meet standards established by the Association of Home Appliance Manufacturers.
Indoor Air Quality Scientific Findings Resource Bank	Lawrence Berkeley National Lab	General information and FAQs on how to select a portable air cleaner for the home.

Air Cleaners/Scrubbers (Industrial) — Rental

Website	Source	Notes
Air Scrubbers from HERC Rentals	HERC	Equipment rental retail website.
Air Scrubbers from Home Depot	Home Depot	Equipment rental retail website.
Air Scrubbers from United Rentals	United Rentals	Equipment rental retail website.
Air Scrubbers from Dryco	DRYCO	Equipment rental retail website.

Protect Pets and Animals

Website	Source	Notes
Protect Your Pets from Wildfire Smoke	U.S. EPA	Factsheet for public on how to protect pets from wildfire smoke.

Protect Pets and Animals

Website	Source	Notes
Protect Your Pets in an Emergency	CDC	Compilation of resources for pet safety and pet shelters in an emergency.
Wildfire Smoke and Animals	American Veterinary Medical Association	Information to protect animals from wildfire smoke.
Pet Safety in Emergencies	CDC	General information on protecting pets during emergencies.
Protect Your Large Animals and Livestock from Wildfire Smoke	U.S. EPA	Information to protect large animals and livestock from wildfire smoke.
Interim Guidelines for Animal Health and Control of Disease Transmission in Pet Shelters	CDC	Guidance for the care of animals entering shelters and for persons working with or handling the animals in response to natural disasters.

Infographics

Website	Source	Notes
Reduce Health Risks in Areas With Wildfire Smoke	U.S. EPA	Infographic for the public with recommendations how to reduce health risks from wildfire smoke.
How to Use a Respirator	U.S. EPA	Infographic for the public on the proper respirator and fit for wildfire smoke.
Wildfire Smoke and Health	Santa Barbara County APCD	Infographic for the public on how to reduce health effects from wildfire smoke.
Air Monitoring Facts	Bay Area AQMD	Infographic for the public regarding air monitors (type, function, benefits, and limitations).
Know the Difference Between Symptoms of Smoke Exposure and COVID-19	Oregon Health Authority	Infographic for the public on how to distinguish between symptoms of COVID-19 and smoke exposure.

Information for Healthcare Providers

Website	Source	Notes
Climate Change and Health Training Modules for Clinicians	San Francisco Department of Public Health	Training on global climate change and local health impacts, clinician climate health best practices, and sustainability.
Air Quality Resources for Clinicians	San Francisco Department of Public Health	Document created by SFDPH with links to local programs, services, and resources regarding air quality for clinicians.
Particle Pollution and Your Patients' Health	U.S. EPA	This course is designed for family medicine physicians, internists, pediatricians, occupational and rehabilitation physicians, nurse practitioners, nurses, asthma educators, pulmonary specialists, cardiologists, and other medical professionals.
Healthy Heart ToolKit and Research	U.S. EPA	This toolkit from the U.S. EPA has resources for both clinicians and patients that explain how air pollution can trigger heart attacks and strokes and worsen heart conditions in people with known heart disease.
Particle Pollution and Heart Disease	CDC and Centers for Medicare and Medicaid Services (CMS)	Website that provides resources and publications regarding heart disease and its link to air pollution and other environmental factors. Million Hearts webpage, a national initiative to prevent heart attacks and strokes.
What Healthcare Providers Should Know about Particle Pollution and Cardiovascular Risk	U.S. EPA	Infographic about particle pollution and cardiovascular risk.

Public Education Resources

Website	Source	Notes
Reduce Your Smoke Exposure	U.S. EPA	Multi-agency sponsored factsheet providing tips on how to reduce smoke exposure during wildfire.

Public Education Resources		
Website	**Source**	**Notes**
Smoke Ready Social Media Resources	Interagency Wildland Fire Air Quality Response Program	Compilation of social media graphics and videos regarding wildfire smoke and clean air shelters which can be modified and rebranded.
Wildfire Smoke FAQs	CDPH	Guidance to the public regarding wildfire smoke.
Protect Your Lungs From Wildfire Smoke or Ash	U.S. EPA	Multi-agency sponsored factsheet on how to use a respirator during a wildfire smoke event.
Indoor Air Filtration	U.S. EPA	Multi-agency sponsored factsheet on how to reduce sources of indoor air pollution.
Asthma and Outdoor Air Pollution	U.S. EPA, CDC	Factsheet on how to minimize asthma symptoms due to air pollution.
Bay Area Regional Air Quality Messaging Kit	Bay Area Urban Area Security Initiative	Messaging toolkit for public information officers (PIOs) to prepare for and respond during air quality incidents. Provides messaging guidance, templates, and resources.
Clean Air at Home	Oregon Health Authority	Factsheet on how to improve residential indoor air quality.
Wildfire Smoke and Healthcare Recommendations	Montana Department of Public Health and Health Services	Factsheet providing tips on how to reduce exposure to wildfire smoke and frequently asked questions (FAQs) regarding wildfire smoke and health considerations.
Wildfire Smoke and COVID-19 Fact Sheet	USDA	Provides Air Resource Advisors and other environmental health professionals with key messages about wildfire smoke and COVID-19. It also provides resources that can be given to communities affected by wildfire smoke during community spread of SARS-CoV-2.
Wildfire Smoke and Your Health	Alameda County Public Health Department	Factsheet for public regarding guidance for wildfire smoke and unhealthy air quality during the COVID-19 pandemic.

Appendix C. Roles and Responsibilities

The following table outlines major roles and responsibilities during a wildfire smoke incident.

Agency/Organization	Activities/Expertise
Local	
Local Health Department, Local Environmental Health Dept	Coordinate with the local/regional air district and other local/state/federal response agencies. The jurisdiction's health officer may issue advisories notifying the public and media of health risks from smoke in addition to recommended protective actions. Coordinate public messaging with the local/regional air district during wildlife smoke incidents. If additional smoke monitoring support is needed, coordinate with local air district officials to request support from the California Air Resources Board (CARB) Incident Air Monitoring Support (IAMS) section.
Air Quality Management District, Air Pollution Control District	Coordinate with impacted local health jurisdictions and local/state/federal response agencies including the California Air Resources Board Incident Air Monitoring Section. Track local air quality monitoring data for health implications. The Air Pollution Control Officer issues air quality advisories to the public. During wildfire smoke incidents, coordinate public messaging with the local health jurisdiction.
Local EMS Agency	Coordinate with local health jurisdiction and air district to anticipate and prepare for impact to 9-1-1 system and pre-hospital care.
School District	With assistance from supporting agencies, determine student health risk and make decisions on event cancellations and school closures. Collaborate with the public health officer and local air district for information to support decision-making.
Local Emergency Management Agency	Coordinate with the local health jurisdiction and air district to mitigate health impacts.
Tribal	
Tribal Governments	Request assistance as needed; coordinate with response agencies.

Agency/Organization	Activities/Expertise
State	
California Air Resources Board Incident Air Monitoring Section	Deploy air monitoring personnel to set up and operate portable particulate monitoring and meteorological instruments that can provide data for forecasting, identify areas at risk, support public/media outreach, and coordinate with air districts, local health departments, federal land managers, and others.
California Department of Public Health	Actively monitor the situation from a public health perspective and collaborate with local health jurisdictions as needed. Assess potential health effects and recommend protective measures. Provide subject matter expertise in environmental science, occupational health, and disaster epidemiology. Work closely with healthcare facilities in the affected areas. Prepare guidance materials and disseminate information to the public and media.
California Office of Environmental Health Hazard Assessment	Assist responders, public health, environmental health, and air district officials to review air monitoring data and compare to health guidance values. Research health effects and characterize risk to public health and the environment from wildfire smoke. Review burn debris and ash data to provide cleanup recommendations protective of public health and the environment. Provide guidance for handling ash during cleanup. Provide health information and guidance to local, state, federal, and tribal officials.
California Department of Industrial Relations, Division of Occupational Safety and Health (DOSH), also known as Cal/OSHA	Protect and improve the health and safety of workers in California by setting and enforcing standards; and providing outreach, education, and assistance. Cal/OSHA has a regulation (section 5141.1) to protect employees exposed to wildfire smoke.

Agency/Organization	Activities/Expertise
Federal or National	
Federal Emergency Management Agency (FEMA)	Federal response agency for natural disasters.
Federal Land Managers (U.S. Forest Service, National Park Service, Bureau of Land Management, Fish and Wildlife Service)	Wildfire suppression and containment, smoke management and air quality expertise, request and staff incident management teams, provide wildfire status updates, deploy air monitoring personnel and equipment, and support public outreach and communication.
U.S. EPA Region 9	Coordinate with state and local air districts, tribes, and other response partners. May respond to inquiries from the public. Conduct Clean Air Act regulatory process after the fact.
Air Resource Advisor, Wildland Fire Air Quality Response Program	Technical specialist (THSP-ARA) with expertise in air quality monitoring and modeling for public health, transportation safety, and firefighter safety. Provide detailed smoke forecasts. Advise IC/UC and analyzes, summarizes, and communicates smoke impacts to the incident teams, air quality regulators, and the public.

Appendix D. Local Air Districts

California has 23 Air Pollution Control Districts (APCDs) and 12 Air Quality Management Districts (AQMDs). These agencies are county or regional governing authorities that have primary responsibility for controlling air pollution from stationary sources. The air districts range from small, single-county districts to multi-county, regional agencies such as the Bay Area and South Coast AQMDs. Air districts provide local expertise and experience particular to their air basins and weather patterns. The California Association of Air Pollution Control Officers (CAPCOA) represents all 35 local air quality agencies throughout California.

Each air district is governed by a Board of Directors consisting primarily of elected officials, and are staffed by engineers, planners, attorneys, inspectors, meteorologists, chemists, and technicians. In general, local air districts are responsible for control of stationary sources of emissions. While mobile source emissions are mostly controlled by state and federal regulations, local districts have authority to implement control measures which affect transportation sources, including automobiles. Local district activities are overseen by both the state and federal agencies. The primary activities of air districts include:

- **EMISSIONS CONTROL:** Districts adopt cost-effective rules to limit harmful emissions from commercial and industrial facilities.
- **MONITORING:** Many air districts operate a sophisticated and extensive network of monitors to measure daily ambient concentrations of pollutants in a local area and track compliance with state and federal air quality standards.
- **COMPLIANCE:** Tens of thousands of sources of air pollution are inspected on a regular basis statewide to assure compliance with local, state and federal regulations. Assistance programs are set up to help business comply.
- **PERMITTING:** Facilities that emit air pollutants must obtain an operating permit to ensure the sources operate according to the rules and regulations of their respective districts. Operating conditions and emissions data are reviewed to ensure that regulations are implemented in a timely and environmentally sound manner.
- **COMPLAINTS:** Citizen complaints are promptly and thoroughly investigated by air district personnel to make sure the public health is being adequately protected.
- **PLANNING & RESEARCH:** Districts must look ahead to identify future needs to meet state and federal mandates. Research projects are conducted to find new technologies, such as alternative fuels, which support our efforts.
- **OUTREACH:** Districts have established outreach programs, including business assistance programs designed to help the business community understand and more easily comply

with applicable regulations, and to provide businesses with technical, financial, and administrative assistance. Many air districts have school and community outreach programs to educate students and adults about air quality and what we can do to keep our air clean.

Appendix E. Map of California Air Districts

California Air Districts

Appendix F. State Air Monitoring Support

Requesting CARB Emergency Air Monitoring Support Services

Note: If additional air monitoring support is needed, it is preferred that local agencies coordinate with local air district officials to request support from the California Air Resources Board (CARB) Incident Air Monitoring Support (IAMS) section.

This procedure applies to any emergency involving release of a hazardous airborne contaminant for which a local agency has exhausted its resources to protect public health or the environment. Requesting agencies typically include local air districts, public or environmental health departments, and county or city fire departments. The process for requesting State support is established by the Emergency Services Act (Government Code § 8550-8692 et seq.) and the State Emergency Management System, or SEMS.

The California Air Resources Board's (CARB) Incident Air Monitoring Section (IAMS) can provide State-level support for air contaminant monitoring, sampling, analysis, and dispersion modeling. IAMS also coordinates with numerous partner agencies to provide emergency toxicological assessments, health advisory recommendations, indoor air quality assessments, air monitoring for recovery operations, and assessment of air quality for re-entry.

Steps to Obtain IAMS Support:

1. **Contact IAMS**
   a. Contact an IAMS team member from the Contact Table below at the earliest indication of the need for air monitoring and/or assessment support. If IAMS cannot be reached, call the State Warning Center directly at (916) 845-8911 to initiate a support request.
   b. Describe in as much detail as possible the release situation and the specific services needed. This enables us to assess your needs and determine how we can provide timely assistance.
   c. Follow up the request with an e-mail, including your name, position, agency, contact information and name of the incident if known.

d. IAMS will review your request, assess the situation and resources available and respond as quickly as possible with initial recommendations. This will be documented in e-mail.

2. **Obtain a State Support "Mission Task"**
   a. Contact your Operational Area or County Emergency Operations Center (EOC), the organization designated to coordinate assistance from the State.
   b. Ask the Operational Area to assist you in submitting a "Mission Request" for air monitoring support. This is the official process for counties or special districts to request state assistance. You will need to provide the same information as noted in Step 1b and 1c above.

3. **If your agency (e.g., air district) covers more than one county jurisdiction, it will be most expedient to submit a Mission Request via the most impacted county.**

4. **Mission Request Approval**
   a. The Operational Area will forward a Mission Request to the Regional Emergency Operations Center (REOC). The REOC will approve the mission or forward it to the State Office of Emergency Services Operations Center (SOC) for approval.
   b. Once approved, a "Mission Task" is issued authorizing IAMS to support the incident and expend available resources as necessary.
   c. The REOC or SOC will notify IAMS and the Operational Area duty officer of the approval and the Mission Task number.

5. **Deployment**
   a. IAMS will contact the requesting agency directly to coordinate monitoring logistics and data disposition. IAMS will work with you to complete a Monitoring and Sampling Plan for the incident.
   b. IAMS will contact Incident Command or Unified Command and monitoring partners of our activities.
   c. IAMS will follow-up with the requesting agency on data access, equipment performance, potential equipment repositioning, short-term monitoring needs, and demobilization plans as dictated by the incident.

SERVICE NOTE: CARB does not have an on-call system. IAMS makes every effort to maximize their availability for during emergency events, but is not a 24/7 operation.

Appendix G. Air Resource Advisors

Air Resource Advisors (ARAs) are technical specialists who are expert in air quality and smoke dispersion science in order to assess wildland fire smoke risks and impacts. They work with meteorological data and smoke models to produce a smoke forecast for areas being impacted by wildfire smoke. Currently, most large federal Incident Management Teams (IMTs) will request an ARA when needed.

ARA expertise includes: monitoring, modeling interpretation, data analysis, and regulatory compliance and computer simulation modeling. During wildfire events when smoke is a concern, the ARA's objective is to provide timely smoke impact and forecast information and messaging that are based on best available science. An ARA works with multiple agencies to address public health concerns, smoke risk to transportation safety, and firefighter exposure.

Duties

- Addresses specific wildland smoke needs at incidents or at various levels within the Geographic Area Coordination Center jurisdiction.
- Monitors air quality to determine effects on public and firefighter health and safety. Working as a technical specialist (THSP) for the Incident Management Team (IMT) either solely or supervising other ARAs – THSP (Task Group) carries out air quality monitoring and reporting on incidents.
- At times works directly with State Air Regulators or Health Departments in determining impacts from smoke and associated air pollutants. An ARA's work activities necessitate interactions with many different IMT members.
- Works directly with Liaison, Public Information and Safety Officers in developing smoke mitigation plans to address firefighter exposure, downwind impacts to smoke sensitive areas and transportation corridor safety. Transportation corridor assessments can include briefings for State and Local law enforcement, Department of Transportation and Emergency Management agencies on predictions of nighttime smoke impacts.
- Develops a schedule based on incident management objectives in order to provide timely and accurate smoke intelligence that addresses risk and supports decisions.
- Establishes, coordinates and maintains appropriate contact within IMT whereby Command and General Staff and other key IMT positions are supported.
- Develops a network and routinely collect and exchange smoke information within IMT (e.g., Operations personnel, Meteorologist, Fire Behavior Analyst, Safety Officer, Liaison Officer, Public Information, Field Observer, Fire Effects and other specialists pertinent to the incident) and partnering agencies to assure accurate information is disseminated (e.g., public meetings, Inciweb, smoke blogs, etc).

- Produces products and provides support for decision making and planning for time specified periods (e.g., input for: Incident Action Plan [IAP], wildland fire decision support—WFDSS documentation, burnout operations, addressing optimum smoke dispersion, etc).
- Interprets weather forecasts, fire behavior predictions, and smoke dispersion prediction models, in the development of decision support products to evaluate smoke management impacts, Incident Site Specific—smoke drift maps, transportation, EBAM/ESAMPLER station observations, corridor, visibility statements, NWS NOAA radio statements and special weather statements (FPS), smoke mitigation plan or appropriate product, cumulative wildfire effects, air quality index projections, plum projection maps or appropriate products; obtain and/or provide smoke dispersion predictions concerning road visibility, super-fog events, downwind smoke sensitive areas or population centers.
- Recognizes and notifies incident personnel of special conditions that promote extreme smoke conditions for firefighter personnel, transportation corridors and downwind smoke sensitive areas.
- Monitors smoke emissions for health, safety, and transportation visibility impairment as required by the incident. Monitors smoke column and dispersion. Recognizes emission problems and recommend applicable mitigation measures. Deployment of fire cache ESAMPLERS, EBAMS, CO dosimeters (communities, base, and spike camp).
- Maintains communications (e.g., air quality regulators, National Weather Service, weather observers, lookouts). Coordinate Special Weather Statements, Dense Fog Advisory, NOAA Radio Broadcast, and AQI maps for AQ agencies.
- Participates in public meetings to address current and project air quality impacts.
- Provides public safety, law enforcement, emergency management and state transportation departments with projected smoke impacts to alert and warn motorists of smoke and unsafe driving conditions.

Appendix H. Sample Air Quality Warning Template

[Agency(ies) logo]

FOR IMMEDIATE RELEASE [DATE]

Public Health Contact: [NAME], Public Information Officer, [DIRECT LINE AND/OR CELL]

Air Pollution Control District Contact: [NAME, TITLE, PHONE NUMBER]

Air Quality Warning Issued for [LOCATION]

Smoke from [NAME] Fire near [LOCATION]

[CITY/COUNTY], Calif. — The [NAME] Public Health Department and the [NAME] Air Pollution Control District today issued an Air Quality Warning for [LOCATION] areas [DIRECTION; EAST/WEST/NORTH/ SOUTH]. Air quality is impacted due to smoke from due to smoke from the [NAME] fire [SPECIFIC AREAS DESIGNATED BY ROAD BOUNDARIES OR GEOGRAPHIC DESIGNATIONS].

If you see or smell smoke in the air, be cautious and use common sense to protect yourself and your family's health. Everyone, especially people with heart or lung disease (including asthma), children, and older adults should limit the amount of time spent outdoors to reduce exposure to smoke pollutants. Everyone should avoid outdoor exercise when smoke is in the area. If you develop mild symptoms such as eye irritation or coughing, contact your healthcare provider. Call 9-1-1 or go to an emergency department if more serious symptoms develop, e.g., chest tightness or pain.

The level of smoke may vary during the day/night and will depend on fire and weather conditions. This Air Quality Warning will be updated [FREQUENCY TBD].

For more information [WEBSITE OR OTHER LINKS]. For recorded advisory updates, call [PHONE NUMBER].

Appendix I. Clean Air Shelters

This section provides information to consider in selecting a site to be used as a community clean air shelter. Also see the references included in Appendix B under Clean Air Shelters. Desirable facility characteristics include:

- Public accessibility (e.g., community centers or libraries)
- Newer construction (newer buildings have tighter building envelopes, reducing smoke infiltration)
- Central air conditioning with enhanced system filtration capability (e.g., high efficiency in-duct MERV 13 or higher filters)
- If necessary, access to portable air cleaners/scrubbers (may be purchased or leased)

Building managers or facility maintenance staff are important sources of information for assessing the suitability of a particular building as a community clean air shelter since they are familiar with the building's design and HVAC system. Steps that can be taken to reduce wildfire smoke intrusion into a building:

- Reduce the amount of outdoor air introduced into the building while still maintaining the minimum amount required per the State Building Standards Code (refer to California Code of Regulations, title 8, section 5142).
- If the building has dual door vestibules, have the outer entry doors close before proceeding through the inner doors so that both sets of doors are not open at the same time.
- Temporarily route access into and out of the building through a single entry. For example, close all other doors and seal with painter's tape or have staff present to redirect traffic and open the doors in the event of an emergency.
- Provide sticky mats at entries to reduce the amount of smoke particulate from entering the space via foot traffic.
- Inspect the Air Handling Unit (AHU) filters for the building to determine if the filters are seated correctly and if the filters are becoming overloaded with particulate matter. Change the filters when they have become overloaded.
- Place carbon filters over the AHU's intakes for odor reduction and additional gas and particulate filtration.
- Temporarily install portable air filtration devices to assist in filtering the air continuously. Devices should be equipped with high efficiency particulate air (HEPA) filters.

Reference: Medina, Enrique (Editor), *Technical Guide for Wildfire Impact Assessments for the OEHS Professional*, AIHA, 2018.

Appendix J. Integrated Science Assessment for PM

The Clean Air Act requires review of the National Ambient Air Quality Standards (NAAQS) periodically to incorporate the latest evidence of both short-term and long-term health impacts. The last published Integrated Science Assessment (ISA) on Particulate Matter (PM) was issued in 2009; an updated draft ISA on PM was released for public comment in October 2018.[51]

An array of outcomes are evaluated as part of a broad health effect category: physiological measures (e.g., airway responsiveness), clinical outcomes (e.g., hospital admissions), and cause-specific mortality. The draft 2018 ISA remains in draft form and *"does not represent and should not be construed to represent any Agency determination or policy".* The research referenced in the draft 2018 ISA is publicly available.

The table below is adapted from the 2009 ISA and draft 2018 ISA on PM (Table ES-1) regarding health effects from $PM_{2.5}$.

Table 10. *Integrated Science Assessment for PM*

$PM_{2.5}$		
Health Effects and Exposure Duration	**2009 PM ISA**	**Current Draft PM ISA (2018)**
Respiratory Effects—Short-term exposure	Likely to be a causal relationship	Likely to be a causal relationship
Respiratory Effects—Long-term exposure	Likely to be a causal relationship	Likely to be a causal relationship
Cardiovascular Effects— Short-term exposure	Causal relationship	Causal relationship
Cardiovascular Effects—Long-term exposure	Causal relationship	Causal relationship
Nervous System Effects—Long-term exposure	Not evaluated	Likely to be a causal relationship
Cancer—Long-term exposure	Suggestive of, but not sufficient to infer, a causal relationship	Likely to be a causal relationship

51 Integrated Science Assessment (ISA) for Particulate Matter

$PM_{2.5}$		
Health Effects and Exposure Duration	**2009 PM ISA**	**Current Draft PM ISA (2018)**
Total mortality—Short-term exposure	Causal relationship	Causal relationship
Total mortality—Long-term exposure	Causal relationship	Causal relationship

Appendix K. Modified AQI Scale Colors

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

PRESS RELEASE

South Coast AQMD

www.aqmd.gov @SouthCoastAQMD

FOR IMMEDIATE RELEASE: May 2, 2022
MEDIA CONTACT:
Nahal Mogharabi, (909) 396-3773, Cell: (909) 837-2431
Kim White, (909) 396-3456, Cell: (909) 323-9479
press@aqmd.gov

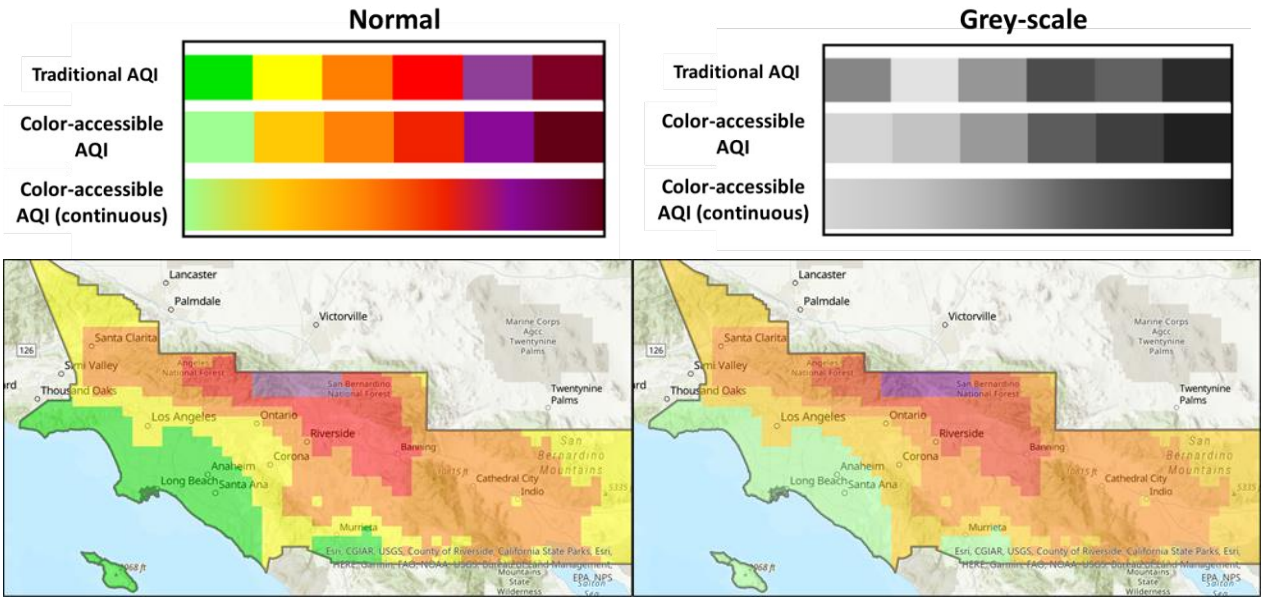
South Coast AQMD Develops Modified Air Quality Index, Improving Accessibility for People with Color Vision Deficiencies

DIAMOND BAR – The South Coast Air Quality Management District (South Coast AQMD) has led the development of a modified version of the Air Quality Index (AQI) that will provide better accessibility for those with color vision deficiencies. The changes were primarily made to the hues, keeping the essential colors associated with each AQI category and health impacts (green, yellow, orange, red, purple, maroon). The original color scale can be difficult to discern for those individuals who have challenges distinguishing certain colors, especially red and green.

"This is an important step to make our air quality measurements and recommendations accessible to even more residents," said Wayne Nastri, South Coast AQMD's Executive Officer. "Since the AQI is associated with important health recommendations, it is our goal to make all the information that we provide to the public as accessible and easy to use."

Colors on the AQI are associated with important recommendations to help the public minimize their exposure to poor air quality. The modified color scale will accommodate individuals with color vision deficiencies, while still being similar enough to the traditional AQI color scale that has been used for decades. The modified scale was tested against eight common types of color impairments using a simulator to ensure the categories would be distinguishable. Another key feature is that the new scale moves from the lightest color (green) to the darkest color (maroon) so that it can be interpreted when converted to grayscale.

The new color scale also works as a continuous gradient, which will improve AQI animations and visualizations from air pollution events such as smoke from a wildfire. Currently the modified AQI is being piloted on several applications including the U.S. Environmental Protection Agency's (U.S. EPA) Fire and Smoke map at https://fire.airnow.gov/ as well as South Coast AQMD's real-time air quality map available at www.aqmd.gov.



Current/Traditional AQI color-scale (left) and color vision deficiency accessible AQI color-scale (right): South Coast Air Basin

South Coast AQMD is the regulatory agency responsible for improving air quality for large areas of Los Angeles, Orange, Riverside and San Bernardino counties, including the Coachella Valley. For news, air quality alerts, event updates and more, please visit us at www.aqmd.gov, download our award-winning app, or follow us on Facebook, Twitter and Instagram.

# # #

Appendix L. Near Real-Time Air Quality Calculation

1. Go to the Fire and Smoke Map for your area.
2. Select a monitor near you, noting that 3 different types of monitors may be available (circle for permanent regulatory monitor, triangle for temporary monitor, square for low-cost sensor). If a permanent regulatory monitor is near your location, select that monitor; otherwise, select the closest temporary monitor.
3. Once you have selected the desired monitor, click "History" as shown in Figure 10.
4. The NowCast AQI is displayed as a series of bars that correspond to values that are updated on an hourly basis (keep in mind the NowCast AQI algorithm emphasizes more recent data under rapidly changing conditions). See Figure 11.
5. Select the "Hourly Concentration" tab, hover the mouse over the last recorded value, and write that concentration down. See Figure 12.
6. Go to the AQI Calculator at AQI Calculator | AirNow.gov, select "Concentration to AQI" option, and select $PM_{2.5}$ as the Pollutant. The unit value of µg/m3 will automatically be selected.
7. Under "Enter the Concentration", enter the most recent concentration value obtained from the selected monitor. Select "Calculate". This will provide an AQI value based on the most recent $PM_{2.5}$ hourly concentration reading available from that monitor.

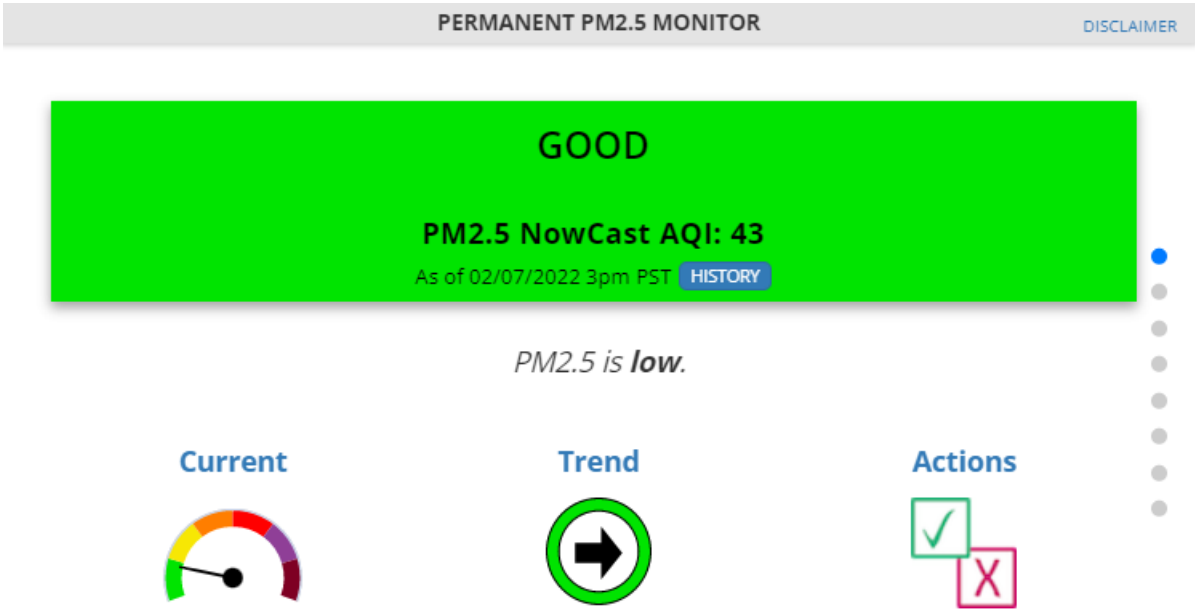


Figure 10. *Monitor selected; select history to see 7-day trend.*

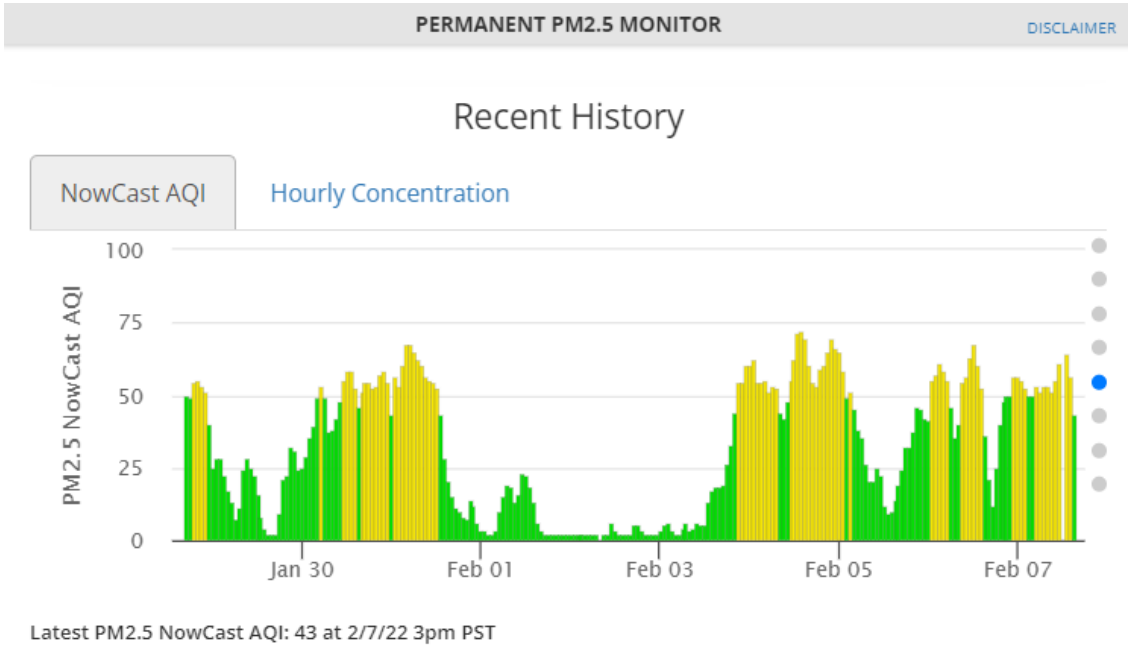


Figure 11. *History of selected monitor (note tabs for "NowCast AQI" or "Hourly Concentration").*

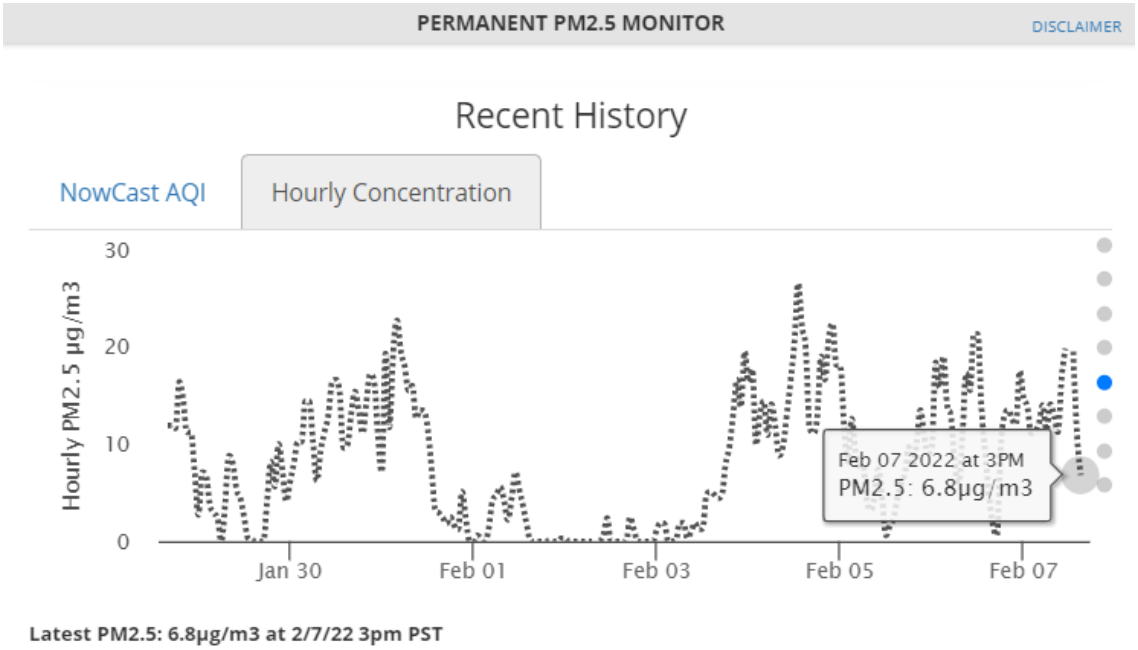


Figure 12. *Select "Hourly Concentration" and position mouse over dotted line to obtain most recent $PM_{2.5}$ concentration.*

Specific wildfire smoke impacts may be forecast and posted on state smoke blogs, including the California Smoke Blog. Information may also be found on the InciWeb site. Additionally, local air districts are most familiar with their area and may provide wildfire smoke forecasts.