

Health Effects of Wildfires

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Chiwaukum Creek Wildfire 2014
Okanogan-Wenatchee National Forest
Photo Credit: <https://ecology.wa.gov/>

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- Wildfire smoke and air quality
- Health effects & research needs
- Mitigating wildfire smoke exposure
- Information for public health officials, healthcare professionals, and the public



Source: Brianna Paciorka, Knoxville News Sentinel

Complex mixture

- Particulate matter
- Carbon dioxide
- Carbon monoxide
- Hydrocarbons
- Organic chemicals
- Oxides of nitrogen
- Trace minerals
- Water vapor



Lands End San Francisco, CA
Camp Fire November 2018
Picture by Wayne Cascio

What is Particulate Matter?

- Mixture of solid and liquid droplets
 - Primary particles emitted directly from a source (e.g., smokestacks, fires, construction sites)
 - Secondary particles produced through complex atmospheric reactions of chemicals (e.g., NO_2 , SO_2) emitted by sources such as power plants, automobiles, etc.
- Particles defined by aerodynamic diameter
 - Fine particles ($\text{PM}_{2.5}$), aerodynamic diameter $\leq 2.5 \mu\text{m}$
 - Coarse particles ($\text{PM}_{10-2.5}$), aerodynamic diameter $> 2.5 \mu\text{m}$ and $\leq 10 \mu\text{m}$
 - Ultrafine particles (UFPs), aerodynamic diameter $\leq 0.1 \mu\text{m}$

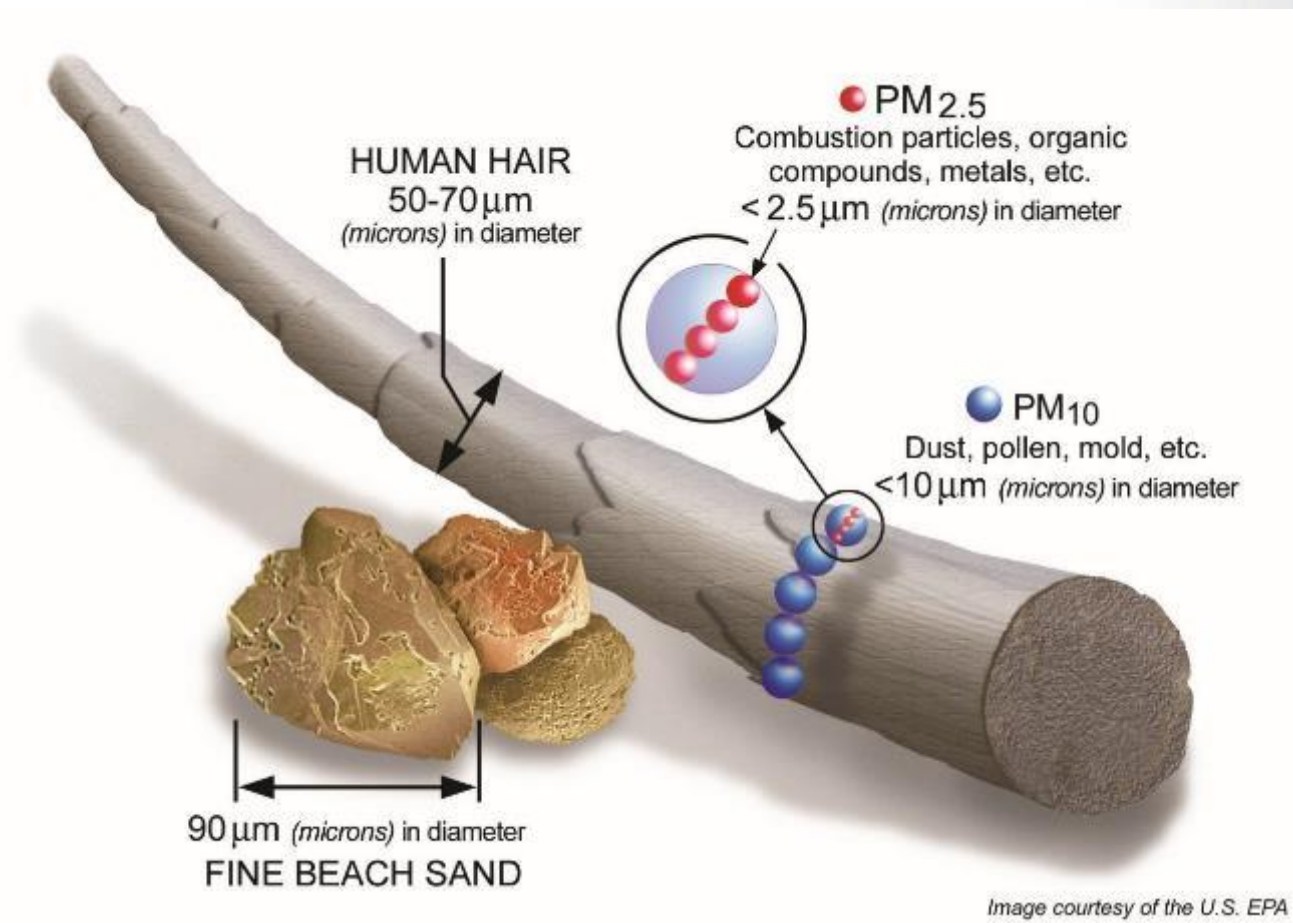


Image courtesy of the U.S. EPA

Source: <https://www.epa.gov/pm-pollution>

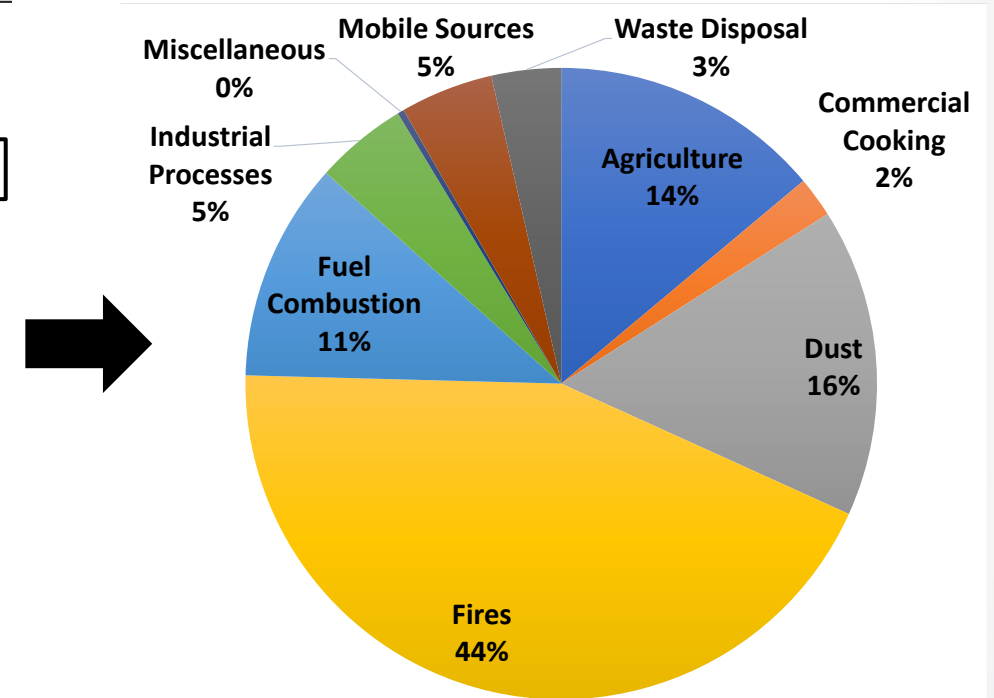
Pollutants in Wildfire Smoke

| Pollutant name | Category | Acronym or formula | Molecular weight | <i>n</i> | Mean EF |
|---------------------------|----------|--|------------------|----------|---------|
| Acetic acid | | C ₂ H ₄ O ₂ | 60.052 | 153 | 2.13 |
| Acetylene | | C ₂ H ₂ | 26.038 | 291 | 0.83 |
| Ammonia | CAP, TOX | NH ₃ | 17.031 | 216 | 1.55 |
| Black carbon | | BC | | 115 | 0.96 |
| Carbon dioxide | GHG | CO ₂ | 44.009 | 597 | 1549.98 |
| Carbon monoxide | CAP | CO | 28.010 | 640 | 103.51 |
| Ethene | TOX | C ₂ H ₄ | 28.054 | 261 | 1.10 |
| Formaldehyde | HAP, TOX | H ₂ CO | 30.026 | 204 | 1.59 |
| Formic acid | TOX | HCOOH | 46.025 | 192 | 0.33 |
| Furan | TOX | C ₂ H ₄ O | 68.075 | 179 | 0.34 |
| Hydrogen cyanide | HAP, TOX | HCN | 27.026 | 188 | 0.46 |
| Methane | GHG | CH ₄ | 16.043 | 451 | 5.53 |
| Methanol | HAP, TOX | CH ₃ OH | 32.042 | 219 | 1.44 |
| Nitric oxide | CAP | NO | 30.006 | 193 | 2.29 |
| Nitrogen dioxide | CAP | NO ₂ | 46.005 | 160 | 1.26 |
| Nitrogen oxides | CAP | NO _x | | 117 | 3.36 |
| Nitrous acid | | HNO ₂ | 47.013 | 164 | 0.49 |
| Non-methane hydrocarbons | | NMHC | | 112 | 5.87 |
| Particulate matter 2.5 μm | CAP | PM _{2.5} | | 337 | 27.87 |
| Phenol | HAP, TOX | C ₆ H ₆ O | 94.113 | 137 | 0.71 |
| Propene | TOX | C ₃ H ₆ | 42.081 | 295 | 0.68 |
| Sulfur dioxide | CAP | SO ₂ | 64.058 | 127 | 1.11 |
| Total particulate matter | | PM | | 289 | 23.57 |

n = # observations; EF = emissions factor

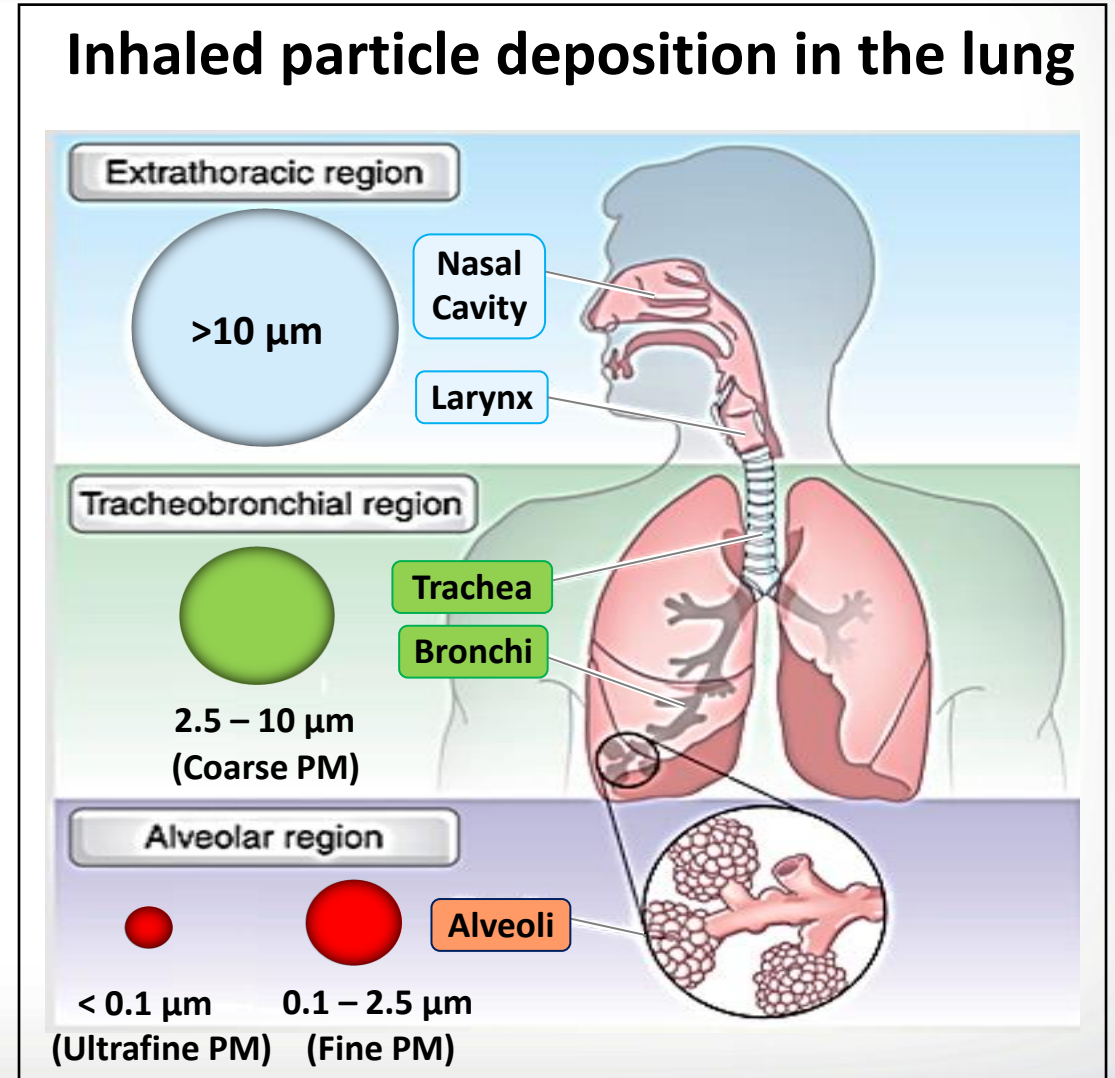
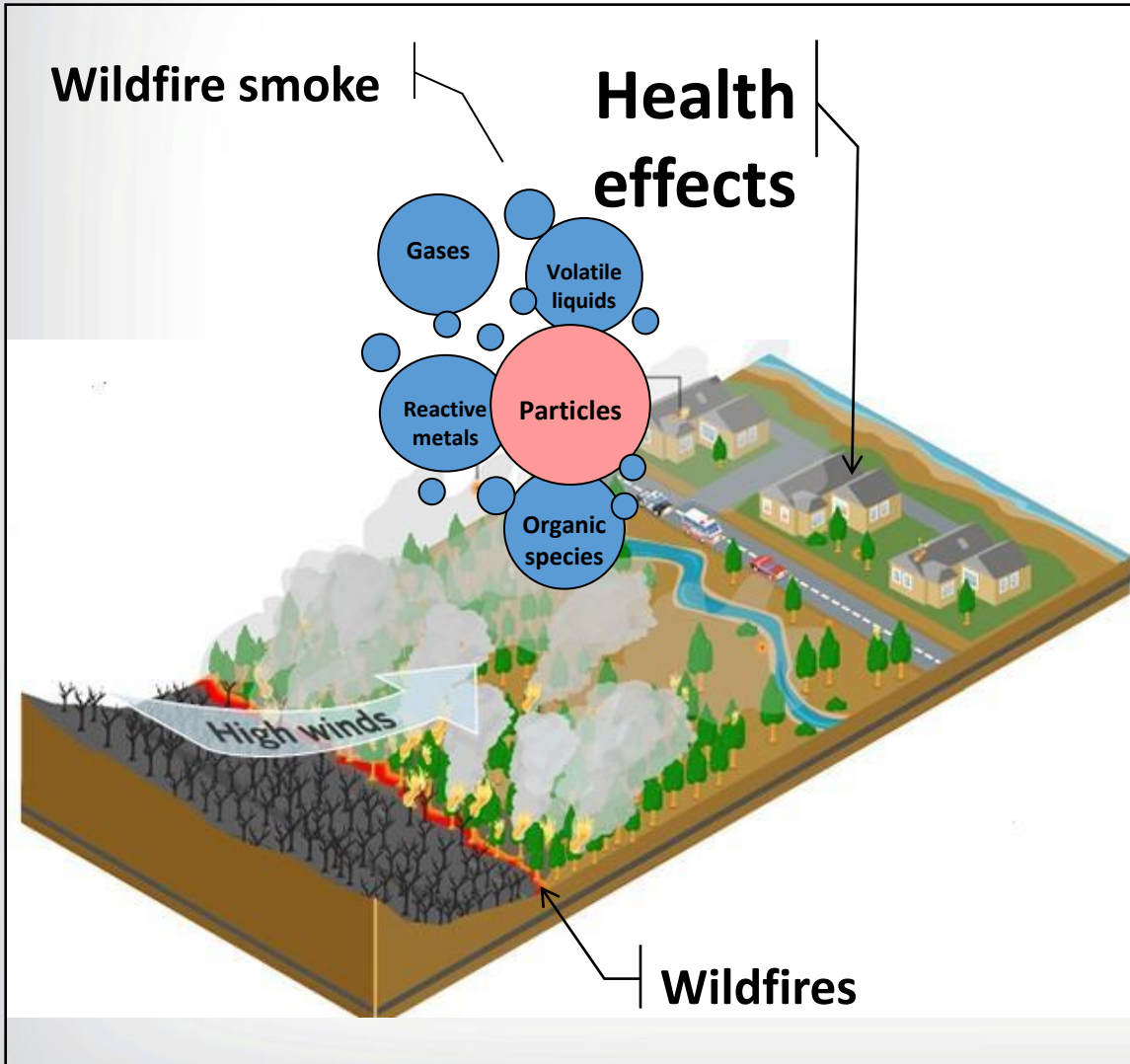
Source: Prichard et al. (2020). Int. J. Wildland Fire, 29, 132-147. Table 3.

Total PM_{2.5} Emissions in 2017 NEI (5.7 million tons)



Source: <https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data>

Where There is Smoke There is Illness

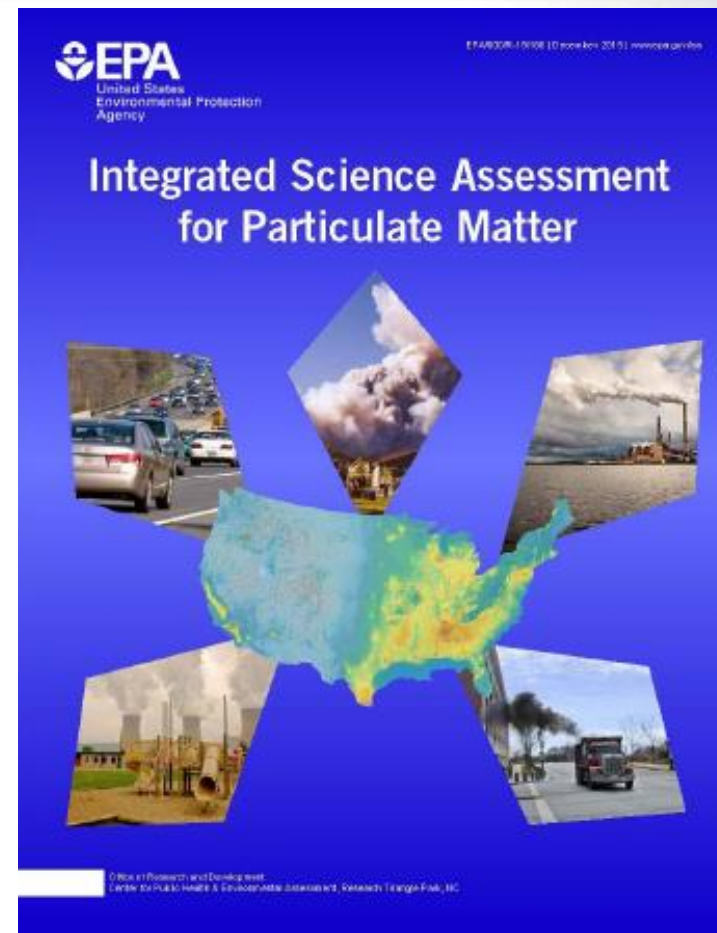




Health Effects of Wildfire Smoke

Decades of research on the health effects of ambient PM_{2.5} exposures

- Studies provide extensive scientific evidence demonstrating a range of health effects due to both short-term (i.e., 1-hour to a month) and long-term (i.e., 1 month to years) exposures



<https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter>

| HUMAN HEALTH EFFECTS | | | | | | |
|------------------------|----------------|--|--------------------|----------------------|-----|---|
| | | ISA | Final PM ISA | | | |
| | | Indicator | PM _{2.5} | PM _{10-2.5} | UFP | |
| Health Effect Category | Respiratory | Short-term exposure | ■ | ■ | ■ | |
| | | Long-term exposure | ■ | ■ | ■ | |
| | Cardiovascular | Short-term exposure | ■ | ■ | ■ | |
| | | Long-term exposure | ■ | ▲ | ■ | |
| | Metabolic | Short-term exposure | * | * | * | |
| | | Long-term exposure | * | * | * | |
| | Nervous System | Short-term exposure | ▲ | ■ | ▲ | |
| | | Long-term exposure | * | * | * | |
| | Reproductive | Male/Female Reproduction and Fertility | Long-term exposure | ■ | ■ | ■ |
| | | Pregnancy and Birth Outcomes | | ■ | ■ | ■ |
| | Cancer | Long-term exposure | ▲ | ▲ | ■ | |
| | Mortality | Short-term exposure | ■ | ■ | ■ | |
| | | Long-term exposure | ■ | ▲ | ■ | |

■ Causal ■ Likely causal ■ Suggestive □ Inadequate

Health Effects Associated with Wildland Fire Smoke

- All-cause mortality
- Asthma & chronic obstructive pulmonary disease (COPD) exacerbations
- Bronchitis & pneumonia
- Childhood respiratory disease
- Cardiovascular outcomes
- Adverse birth outcomes
- Symptoms such as eye irritation, sore throat, wheeze and cough

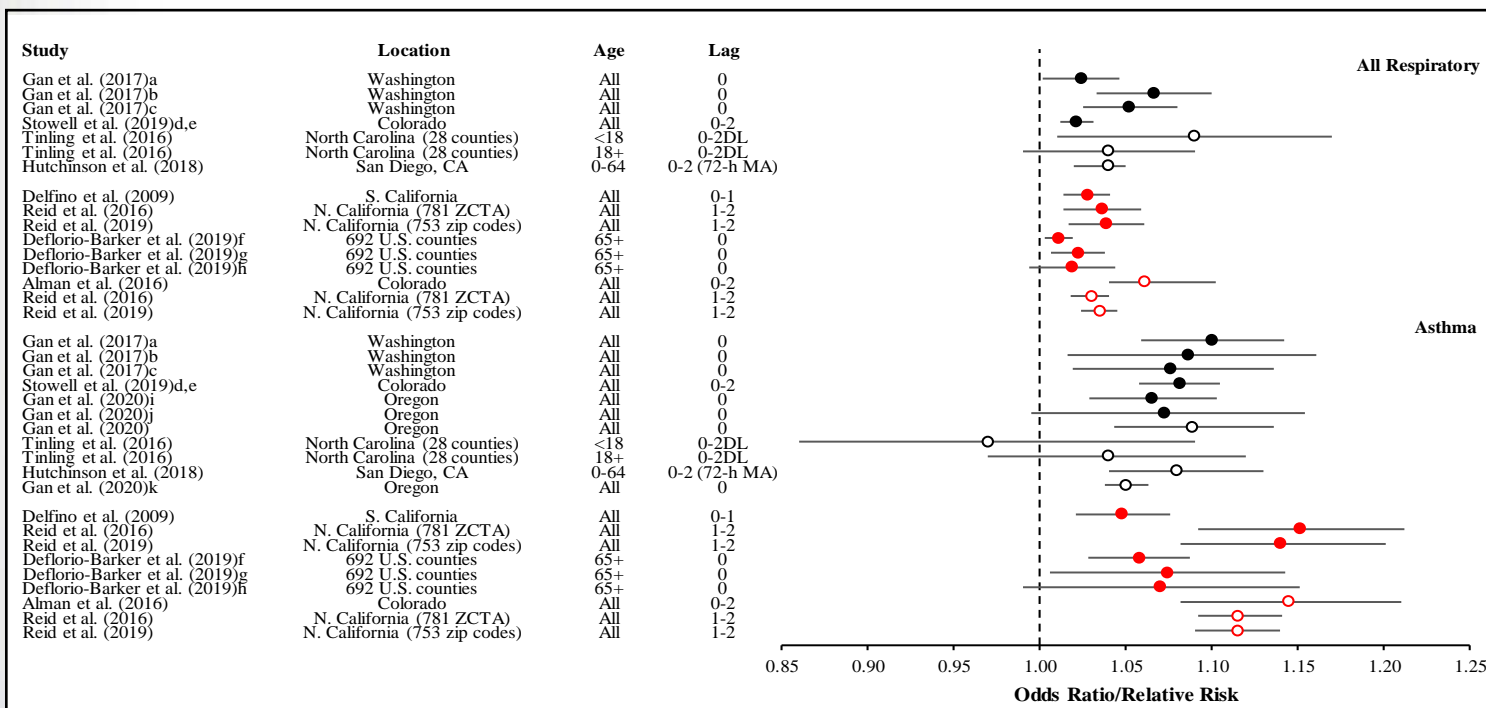


Source: Liu et al 2015; Reid et al. 2016; Cascio 2018



Health Effects of Wildfire Smoke: Epidemiologic Evidence

- **Exposure Assessment:** Different exposure indicators used across studies (e.g., wildfire-specific PM_{2.5}, smoke plume density)
 - Associations generally consistent across studies regardless of exposure indicator
 - Most studies focus on daily (24-h avg) exposures
- **Consistent, positive associations** across studies examining respiratory-related and asthma hospital admissions and ED visits
- **Fewer studies examining cardiovascular outcomes and mortality**



Legend:

- = studies that used smoke/wildfire PM_{2.5} as the exposure indicator
- = studies that used ambient PM_{2.5} measurements as the exposure indicator
- Solid circles = hospital admissions
- Open circles = ED visits

Note: All risk estimates are for a 10 µg/m³ increase in PM_{2.5} concentrations, except for Stowell et al. (2019), which are for a 1 µg/m³ increase.

U.S.-based Epidemiologic Studies Examining the Relationship Between Short-term Wildfire Smoke Exposure and Combinations of Respiratory-Related Diseases and Asthma Hospital Admissions and Emergency Department Visits

Source: U.S. EPA (2021) – CAIF Report, <https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=352824>



Who's At-Risk from Wildland Fire Smoke?

At-risk populations include:

- Older adults (i.e., > 65 years of age)
- Children
- People with respiratory disease
- People with cardiovascular disease
- Pregnant women and fetuses
- People of low socioeconomic status
- Outdoor workers

Source: U.S. EPA (2019), Wildfire Smoke: A Guide for Public Health Professionals

More recent evidence:

- Minority populations
- Populations with chronic inflammatory diseases (e.g., diabetes, obesity)

Source: U.S. EPA (2020), Integrated Science Assessment for Particulate Matter (PM ISA)

A large blue oval with a black border, containing white text.

**~30% of the
U.S.
population
is at-risk**



Health Effects of Wildfire Smoke: Uncertainties

Exposures < 24-hour average

- Potentially important from the standpoint of public health messaging
- Limited number of studies examining ambient PM_{2.5}, with most consisting of panel studies and controlled human exposure studies
 - Primarily examining subclinical effects (e.g., markers of inflammation), changes in heart and lung function
- Recent wildfire study focusing on emergency ambulance dispatches reports an association with 1-h PM_{2.5} exposure and respiratory and cardiovascular outcomes (Yao et al. 2020. Environ Health Perspect 128,6)

Exposures > 1 week

- Examined in firefighters (Adetona et al. 2016, Inhalation Tox 28:3, 95-139)
 - Focus on respiratory-related health effects
 - Some evidence that cumulative exposures (> 1 week) can lead to changes in lung function
- Increased risk of mortality in hemodialysis patients as cumulative exposures increase up to 30 days (Xi et al. 2020, JASN 31)



Health Effects of Wildfire Smoke: Uncertainties

Repeated high exposures over a few days

Long-term health consequences of high exposure

- Initial evidence of a relationship between high wildfire smoke exposure:
 - Reductions in lung function in subsequent years (Orr et al. *Toxics*, 2020, 8, 53)
 - Increased risk of influenza during the following winter influenza season (Landguth et al. 2020, *Environ Int.* 139:105668)
 - COVID-19 cases and deaths (Zhou et al. 2021, *Sci Adv.* Aug 13;7(33))

Exposures over multiple fire seasons

- Particularly in communities that experience wildfire smoke exposure on a recurring basis

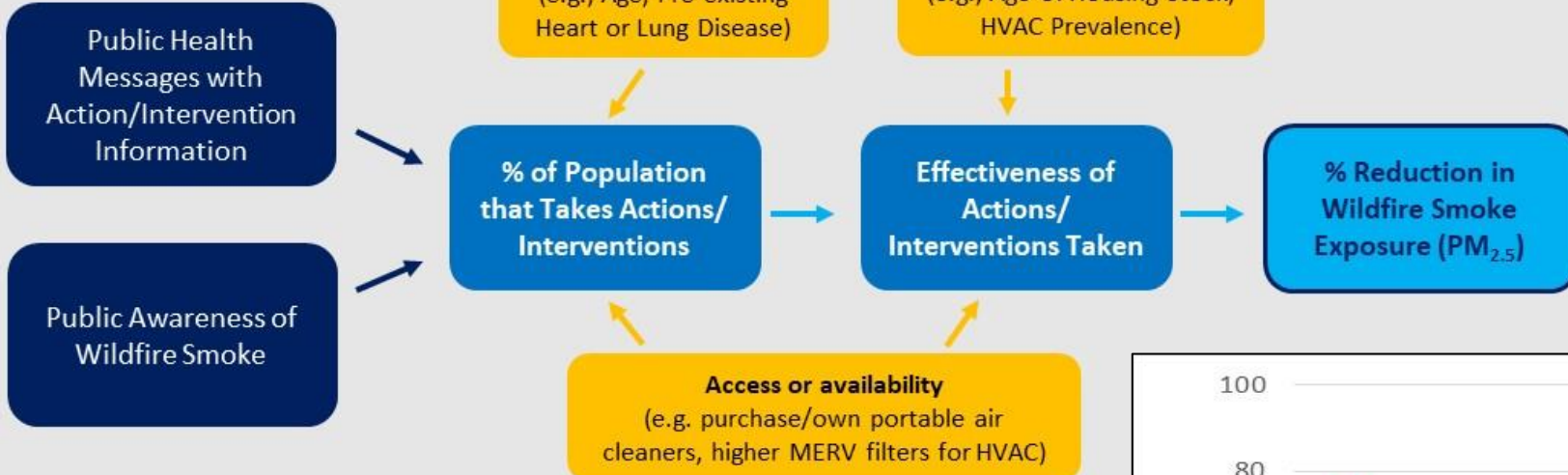
Changing wildfire smoke mixture and exposures

- Wildland-urban interface (WUI)

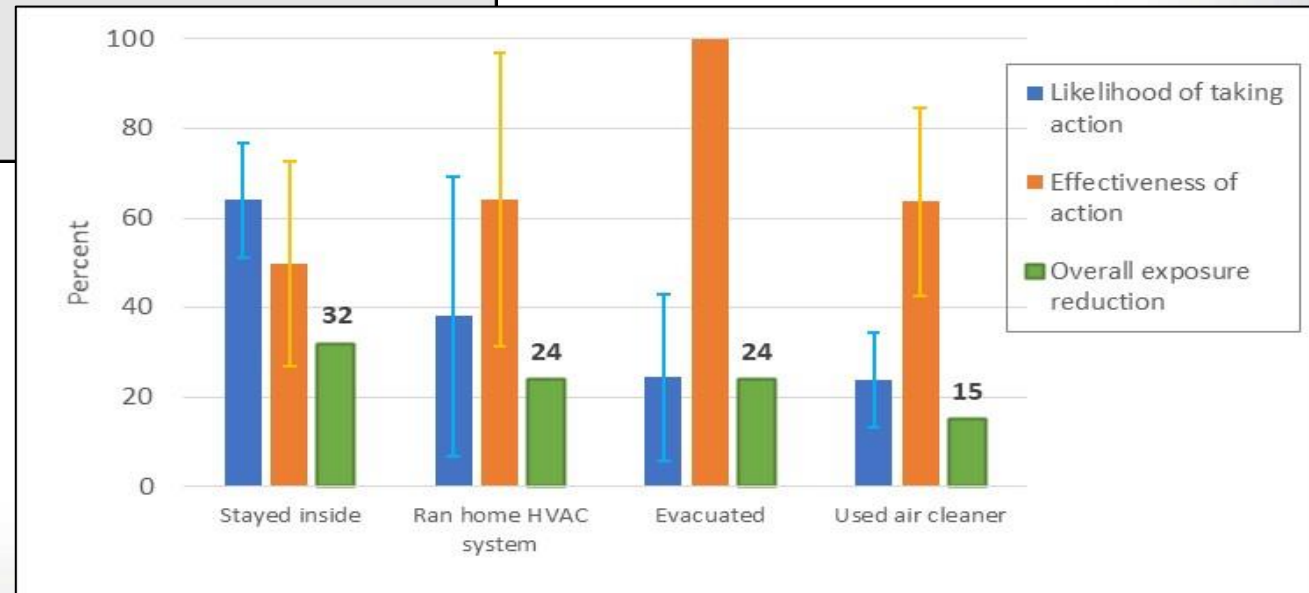


Mitigation of Wildfire Smoke Exposure

Drivers for Actions



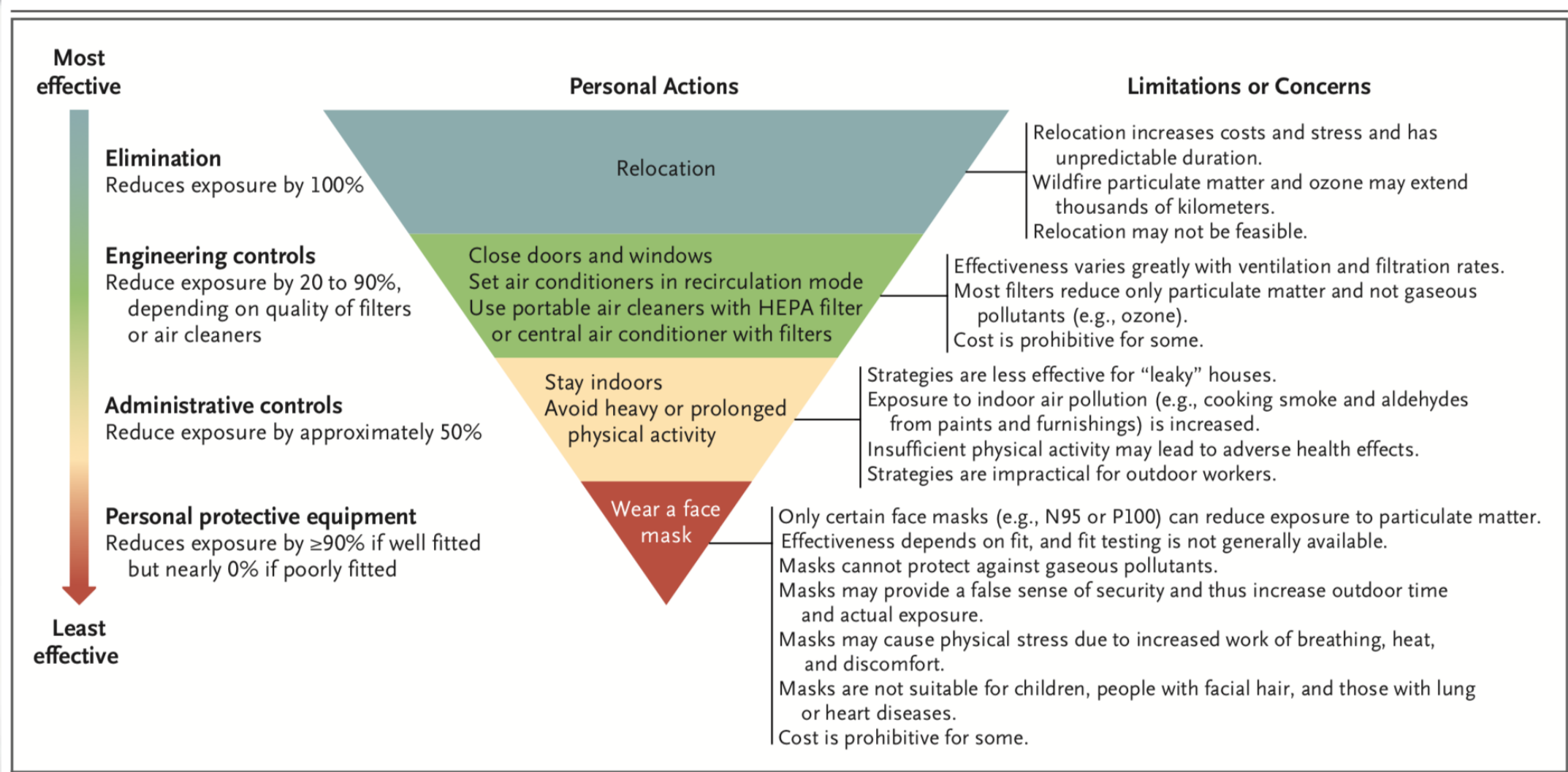
- In studies examining wildfire smoke exposure there is high variability between studies, and within studies (between homes/filters) on the effectiveness of different actions
 - Studies examined whether people took actions to reduce exposures, not if health responses changed



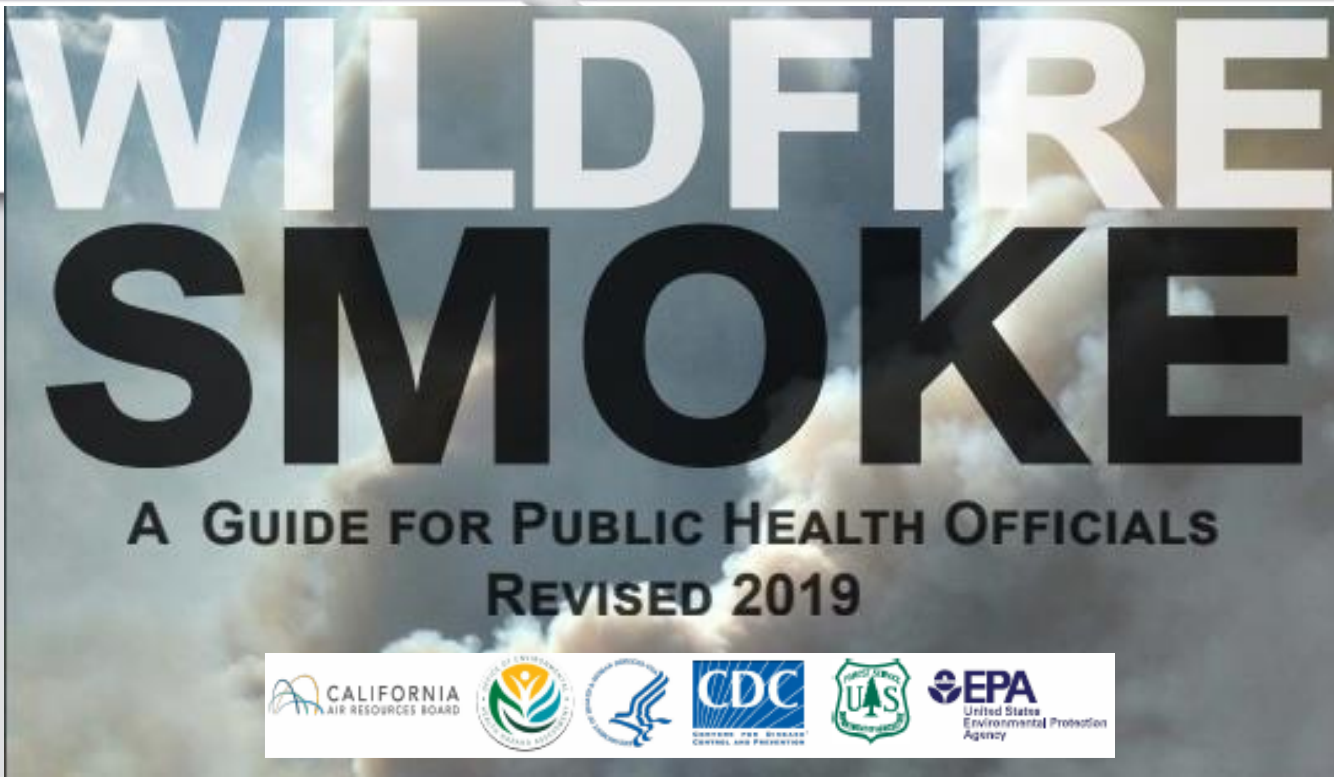
Source: U.S. EPA (2021) – CAIF Report
(<https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=352824>)



Main Actions that Individual People can Take to Reduce Wildfire Smoke Exposure

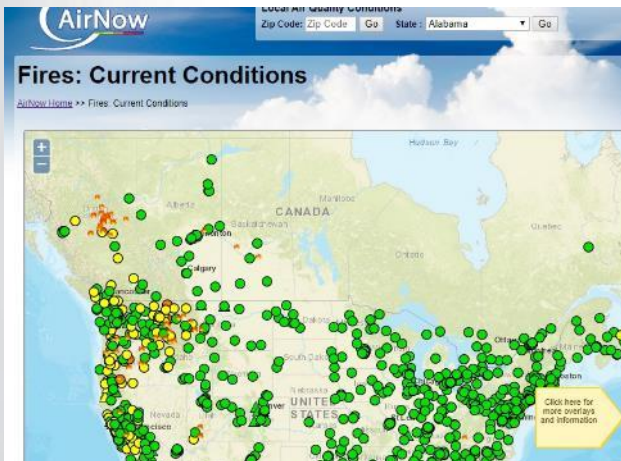


Source: Xu et al. (2020). N Engl J Med 2020; 383:2173-2181



EPA Plays a Supportive Role

- **Public health outreach:** helping the public understand how fires impact their health, including providing real-time information during fire events.
 - [AirNow](#)
 - [Wildfire Smoke: A Guide for Public Health Officials](#)
 - [Smoke Sense App](#)
- **Preparedness resources**
 - [Clean Air Spaces](#)
 - [Respirator Use](#)
- **Information Clearinghouse:** [Smoke Ready Toolbox](#)
- **Continuing Medical Education (CME) Courses**
 - [Particle Pollution and Your Patients' Health](#)
 - [Wildfire Smoke and Your Patients' Health](#)
- **Research**
 - How to improve community capacity and resiliency around smoke events
 - [Community Health Vulnerability Index](#)
 - How fires impact air quality
 - Monitoring Needs





Summary

- Extensive scientific evidence demonstrating the health effects of PM_{2.5}
 - While uncertainties remain with respect to the health effects of wildfire smoke for some exposure durations, clear evidence that PM_{2.5} can lead to adverse health effects
- Actions and interventions can be instituted to reduce wildfire smoke exposure with proper health messaging and/or availability
- AQI, and other similar indices, can provide information to inform the public on wildfire smoke

Thank you

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