

# Wildfire Health Threats: Risk Factors for Outdoor Workers

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**ENVIRONMENTAL & OCCUPATIONAL HEALTH SCIENCES**

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# Outline

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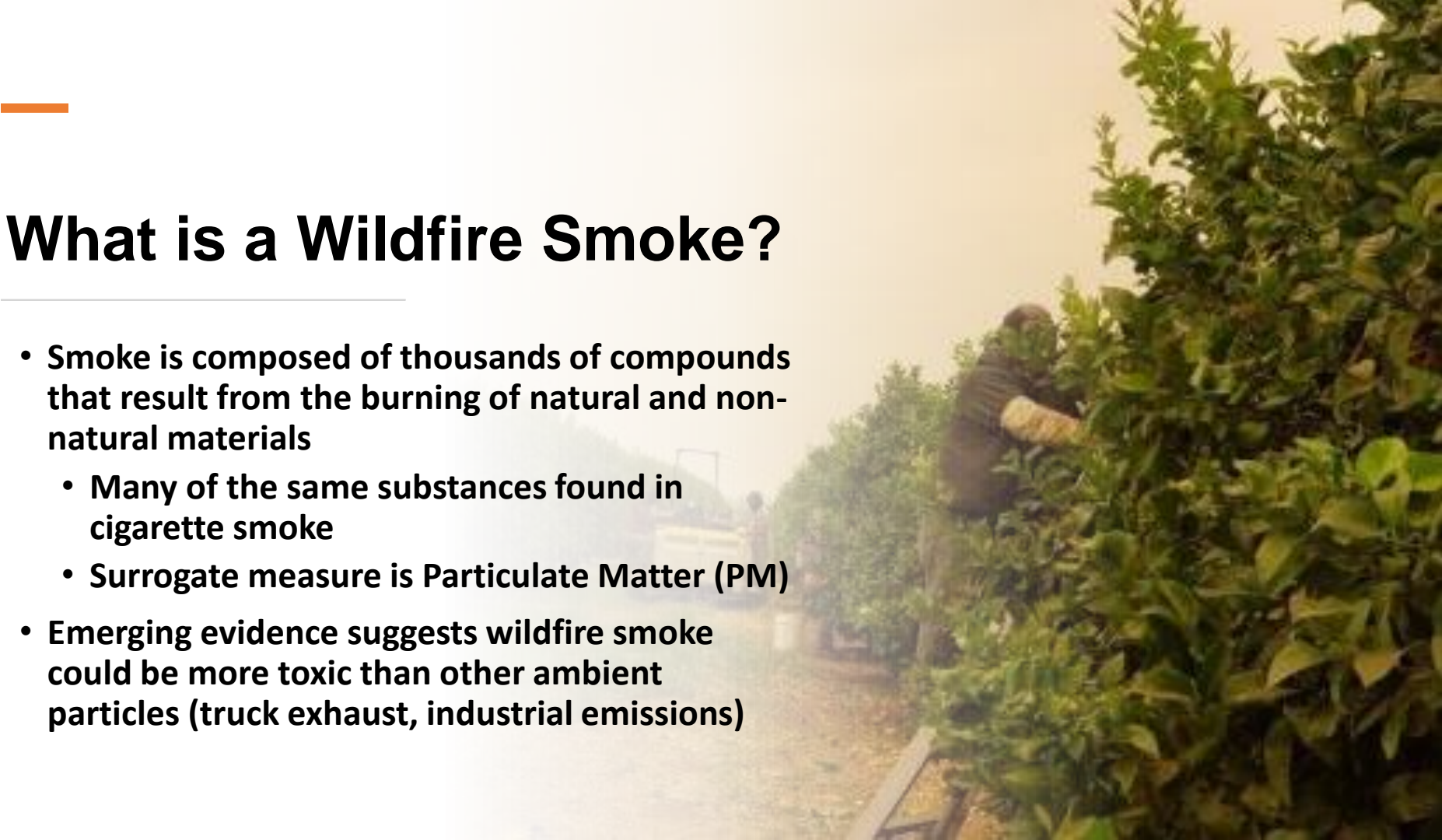
1. Wildfire Smoke Characteristics
2. Acute and chronic health effects
3. Wildfire smoke data sources
4. Trends wildfire events and intensity
5. Workplace consideration



# What is a Wildfire Smoke?

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- Smoke is composed of thousands of compounds that result from the burning of natural and non-natural materials
  - Many of the same substances found in cigarette smoke
  - Surrogate measure is Particulate Matter (PM)
- Emerging evidence suggests wildfire smoke could be more toxic than other ambient particles (truck exhaust, industrial emissions)



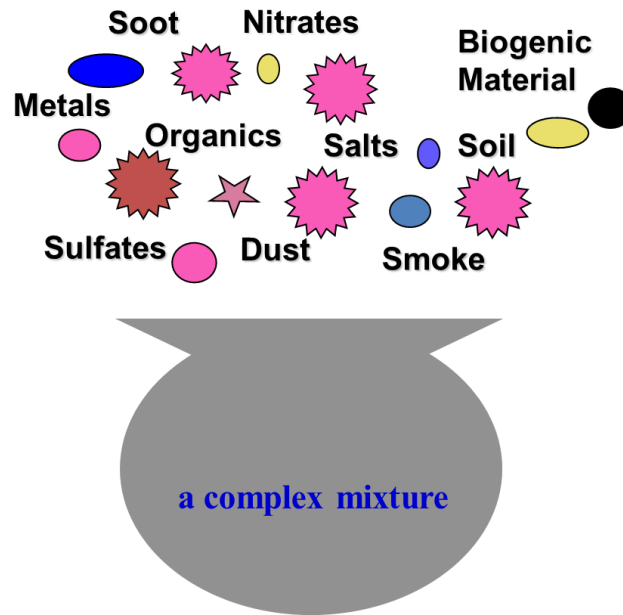
# Review

## Ambient Air Pollution

Ambient concentrations of “Criteria Air Pollutants” are regulated on a national level because:

- Widespread, cannot be controlled at a single source
- Known to be harmful to health
- May be harmful to the environment and can cause damage to property (welfare impacts)
- May be a gas or a particle

## Particulate Matter



# THE RELATIVE SIZE OF PARTICLES

From the COVID-19 pandemic to the U.S. West Coast wildfires, some of the biggest threats now are also the most microscopic.

A particle needs to be 10 microns ( $\mu\text{m}$ ) or less before it can be inhaled into your respiratory tract. But just how small are these specks?

Here's a look at the relative sizes of some familiar particles »

HUMAN HAIR 50-180 $\mu\text{m}$  »  
FOR SCALE

FINE BEACH SAND 90 $\mu\text{m}$  »

GRAIN OF SALT 60 $\mu\text{m}$  »

WHITE BLOOD CELL 25 $\mu\text{m}$  »

GRAIN OF POLLEN 15 $\mu\text{m}$  »

DUST PARTICLE (PM<sub>10</sub>) <10 $\mu\text{m}$  »

RED BLOOD CELL 7-8 $\mu\text{m}$  »

RESPIRATORY DROPLETS 5-10 $\mu\text{m}$  »

DUST PARTICLE (PM<sub>2.5</sub>) 2.5 $\mu\text{m}$  »

BACTERIUM 1-3 $\mu\text{m}$  »

WILDFIRE SMOKE 0.4-0.7 $\mu\text{m}$  »

CORONAVIRUS 0.1-0.5 $\mu\text{m}$  »

T4 BACTERIOPHAGE 0.225 $\mu\text{m}$  »

ZIKA VIRUS 0.045 $\mu\text{m}$  »



Pollen can trigger allergic reactions and hay fever—which 1 in 5 Americans experience every year.

Source: Harvard Health

The visibility limits for what the naked eye can see hovers around 10-40 $\mu\text{m}$ .



Respiratory droplets have the potential to carry smaller particles within them, such as dust or coronavirus.



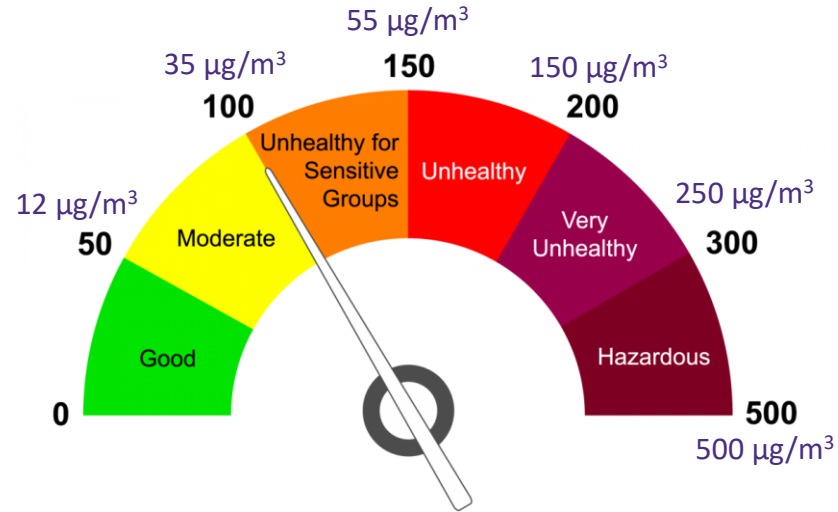
Wildfire smoke can persist in the air for several days, and even months.

# National Ambient Air Quality Standards (EPA)

Pollutant	Averaging	Concentration Limit
PM <sub>2.5</sub>	1 year	12.0 µg/m <sup>3</sup> OR 50 AQI
	24 hours	35 µg/m <sup>3</sup> OR 100 AQI
PM <sub>10</sub>	24 hours	150 µg/m <sup>3</sup>

# Understanding Air Quality Data

- > **PM<sub>2.5</sub>** is used as a proxy for wildfire smoke.
- > **PM<sub>2.5</sub>** measures mass of particles per volume of air ( $\mu\text{g}/\text{m}^3$ )
- > **The EPA produces an index that translates concentration into AQI value**
  - **Nowcast AQI** : Approximates current air quality conditions
  - **Forecast AQI**: Predicted 24-hour AQI tomorrow
  - **Daily AQI**: Represents an average of the previous 24 hours



# HEALTH IMPACTS OF PM<sub>2.5</sub>

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## SHORT-TERM EXPOSURES

- > Increased hospital admissions for cardiovascular disease, including heart attacks and strokes
- > Increased hospital admissions and emergency department visits for COPD
- > Increased death

## LONG-TERM EXPOSURES

- > Worsening of COPD in adults
- > Slowed lung function growth in children and teenagers
- > Increased risk of death from cardiovascular disease
- > Increased risk of heart attacks and strokes
- > Cancer
- > Increased death



# Health Impacts of Wildfire Smoke

- > Immediate symptoms of smoke inhalation
  - Irritation: Coughing, trouble breathing, stinging, scratchy throat, runny nose, irritated sinuses, headache
  - Worsening of existing disease: Asthma, COPD, Heart Disease
- > Very limited info on cumulative/long-term effects
  - Some evidence of decreased lung function during burn seasons in wildland firefighters
  - Increased risk of influenza infection months later



<https://www.cbha.org/about-us/cbha-blog/2018/august/holy-smokes/>

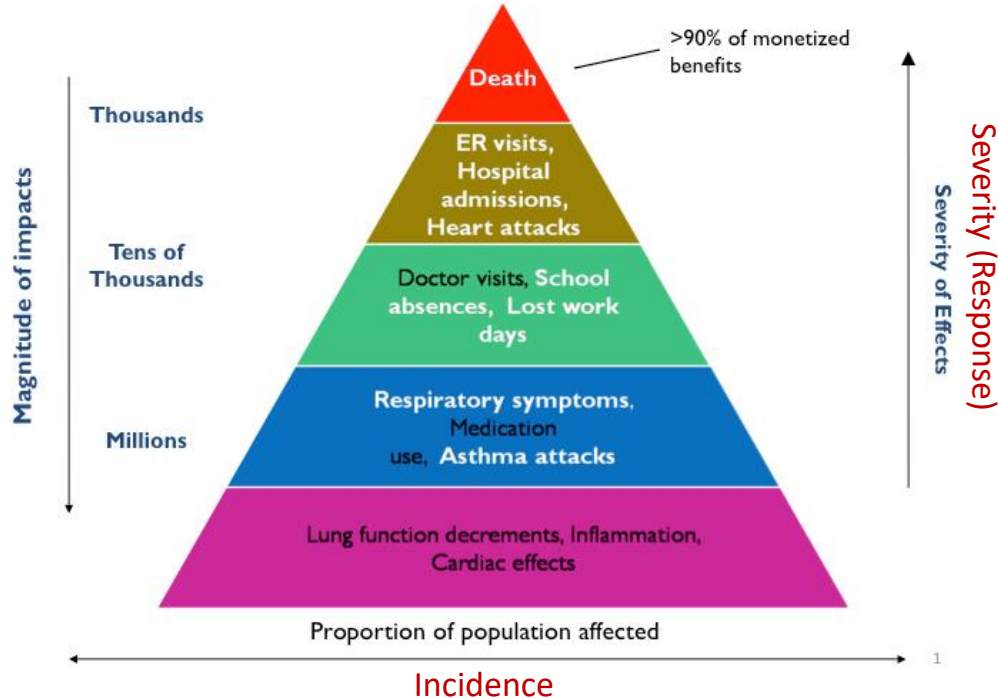
# Controlled human exposures to wood smoke

- 22 publications from 12 human controlled wood smoke exposure studies (Schwartz et al., 2020 review)
  - Large heterogeneity in outcome measures between studies, but significant effects reported in a few studies for increased airway inflammation (FeNO) and cardiovascular effects (decreased HRV, increased arterial stiffness)
  - Still more work to develop a dose-response relationship
    - Wildfire smoke varies in composition, and so too does the composition of smoke explored in controlled exposure studies – however, the composition of smoke in controlled exposure studies is typically well-characterized

# Health Impacts

## Particulate Matter

### A “Pyramid of Effects” from Air Pollution



# Safe Exposure Levels

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## Occupational Limit

8-hr averaging time

~PM4.0 "Respirable Fraction" >

5 mg/m<sup>3</sup> for general dust

## General Population Limit

24-hr averaging time

PM2.5 AQI of 100

0.035 mg/m<sup>3</sup>

35 µg/m<sup>3</sup>



# Workplace Exposures to Wildfire Smoke

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- > Historically there has been no guidance for employer responses to wildfire
- > Some States are developing Emergency Wildfire Rules to protect employee health
  - California (implemented): Cal/OSHA 5141.1
  - Oregon (proposed): OR OSHA
  - Washington (proposed): WA L&I



# EXPOSURE RECOMMENDATION BY AQI

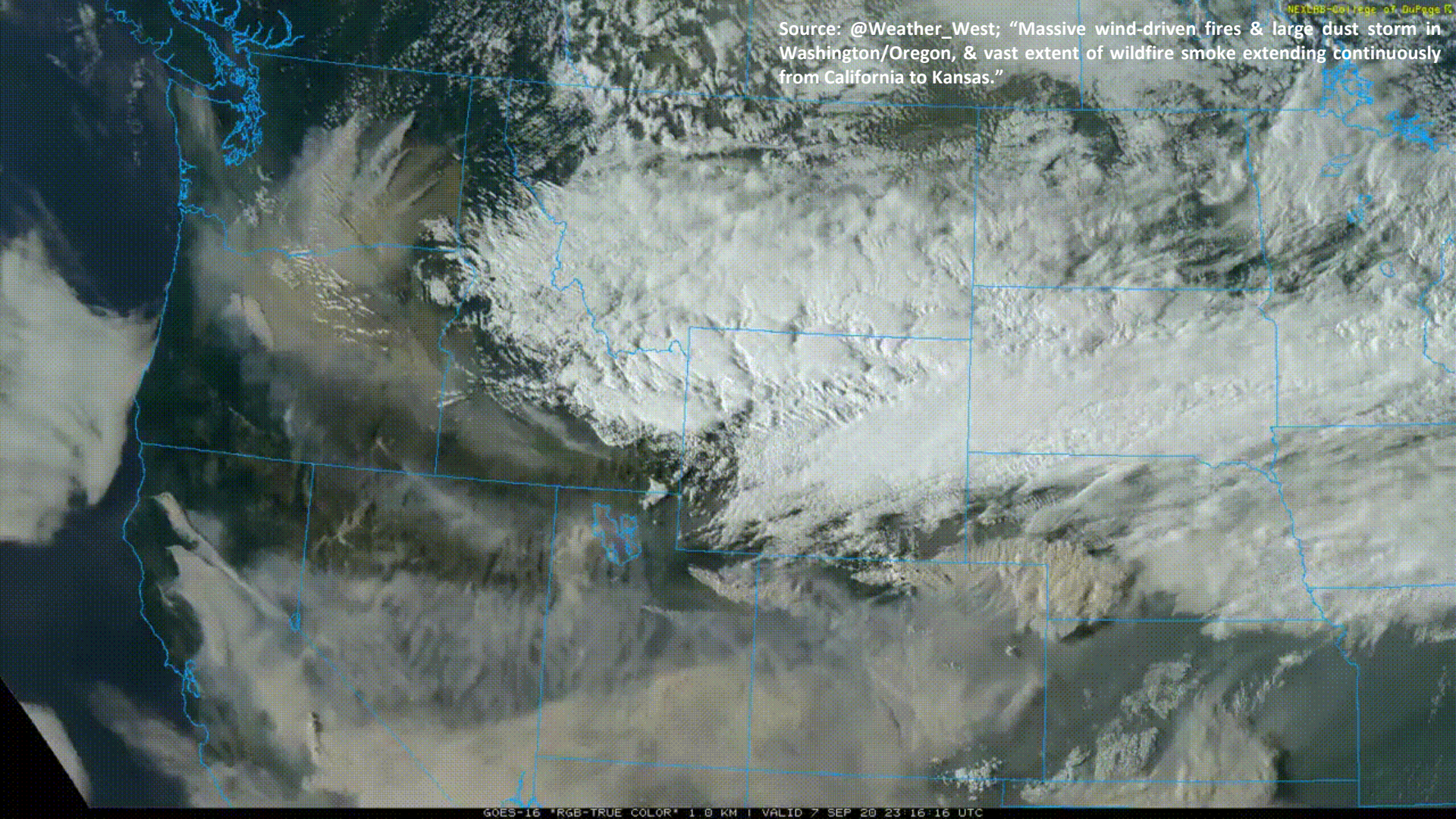
Color Code	AQI Value	Actions to Protect Your Health
Green	Good (0-50)	None.
Yellow	Moderate (51-100)	Unusually sensitive people should reduce prolonged or heavy exertion outdoors.
Orange	Unhealthy for Sensitive Groups (101-150)	Sensitive groups should reduce prolonged or heavy exertion outdoors: People with heart and lung disease Children and older adults People that are active outdoors
Red	Unhealthy (151-200)	Sensitive groups should avoid prolonged or heavy exertion outdoors.  Everyone should reduce prolonged or heavy exertion outdoors.
Purple	Very Unhealthy (201-300)	Sensitive groups should avoid all physical activity outdoors.  Everyone should avoid prolonged or heavy exertion outdoors.

Washington Emergency Rule (WAC 296-62-085): At AQI 69 employer is encouraged to provide mechanisms to reduce exposure. At AQI 151 for 1 hour or more, employers are **required** to reduce exposure through administrative, engineering or PPE use.

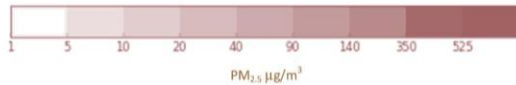
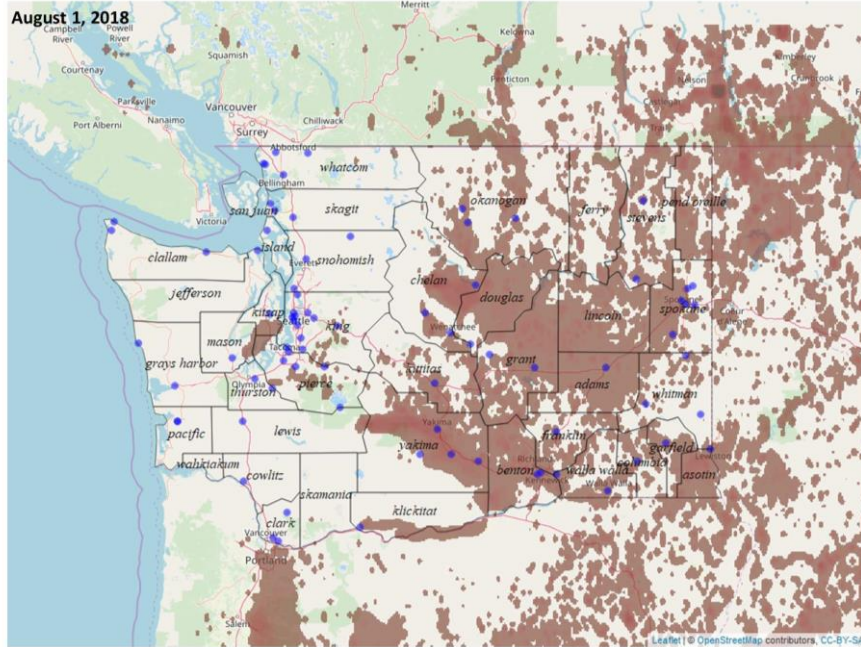




Source: @Weather\_West; "Massive wind-driven fires & large dust storm in Washington/Oregon, & vast extent of wildfire smoke extending continuously from California to Kansas."

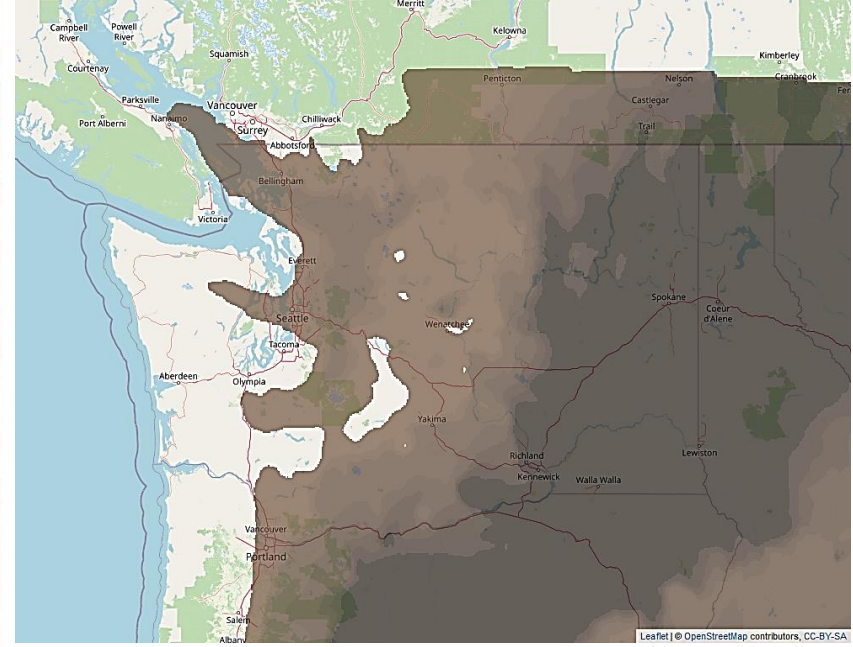


## Smoke Distribution in WA (Aug 1, 2018)



● Location of air quality monitors

## Smoke Distribution in WA (Sept 15, 2020)





# PM2.5 Data sources

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- > **Local air quality agency (directly responsible for air quality monitoring in your area)**
- > **State air quality agency**
  - Department of Ecology
- > **Federal EPA**
- > **Air quality sensor**
  - Operated by others in your area
  - Operated by an employer
  - Considerations: Appropriate instrument, trained user, regular maintenance



# Low-Cost Sensors

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- > Produce data on the 5-minute scale
- > Usually directly measure concentrations
- > Less reliable than regulatory (EPA) instruments, different instruments have different error.

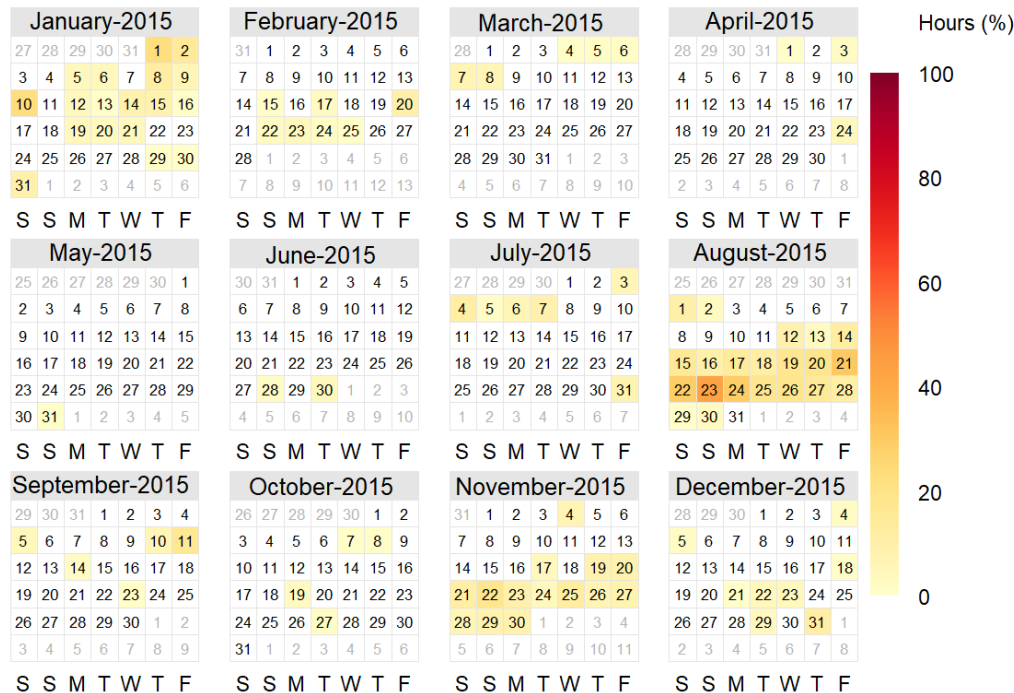
# Trends in wildfire smoke intensity and duration

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- > Hourly data from the ~30 PM<sub>2.5</sub> monitoring sites in Washington State
- > Concentrations across the State vary hour by hour
- > When is PM<sub>2.5</sub> higher than AQI = 151?
- > Do all the sites agree?

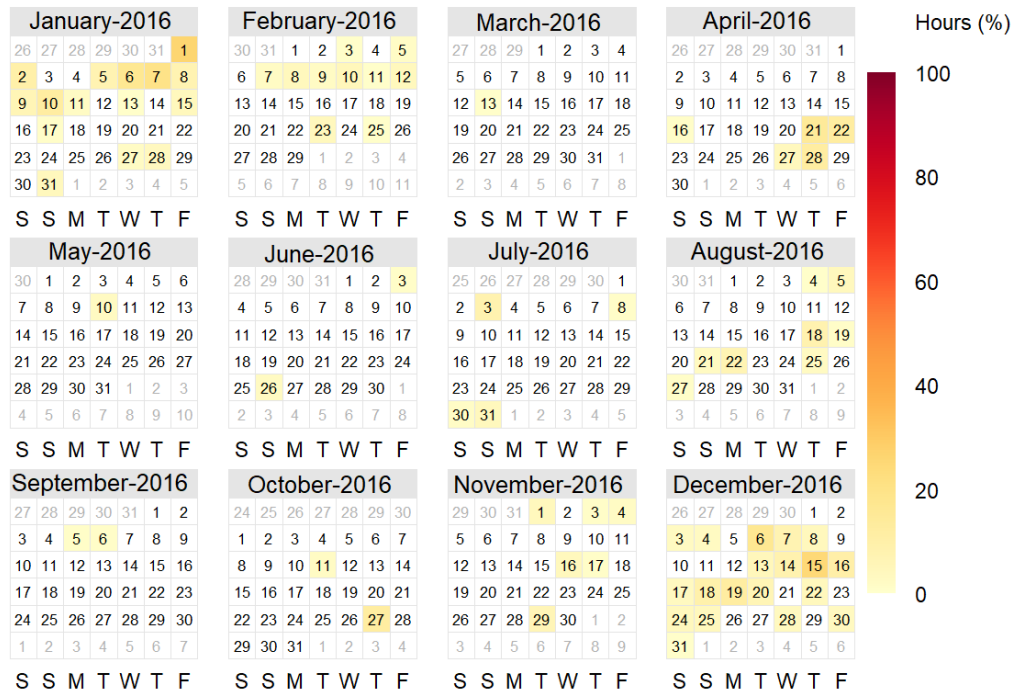
# ACROSS WASHINGTON STATE IN 2015

## AQI GREATER THAN 150



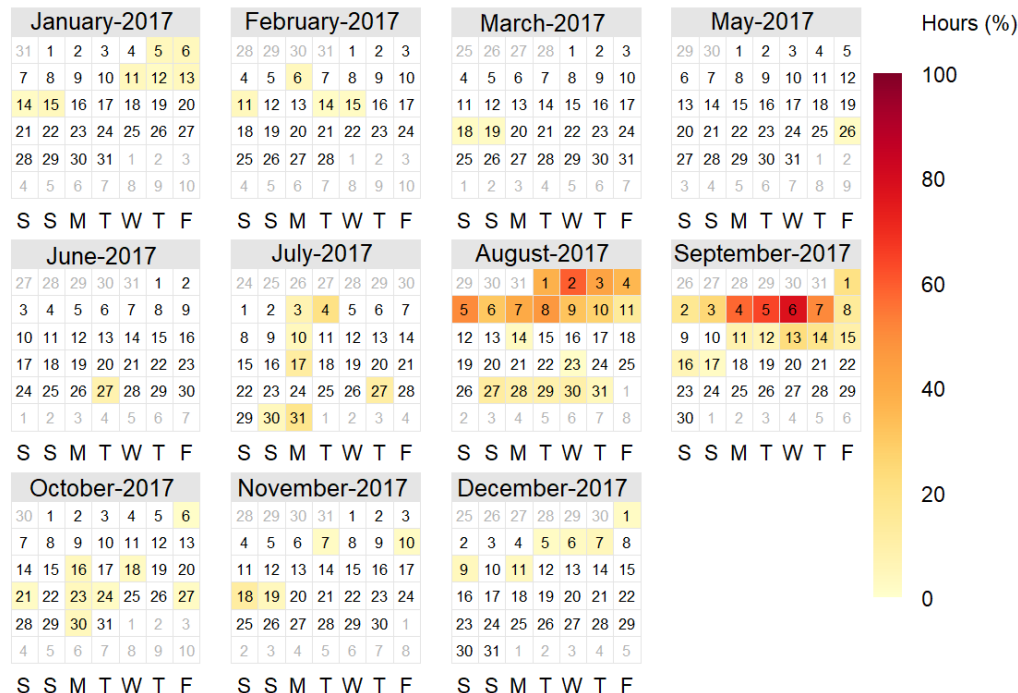
# ACROSS WASHINGTON STATE IN 2016

## AQI GREATER THAN 150



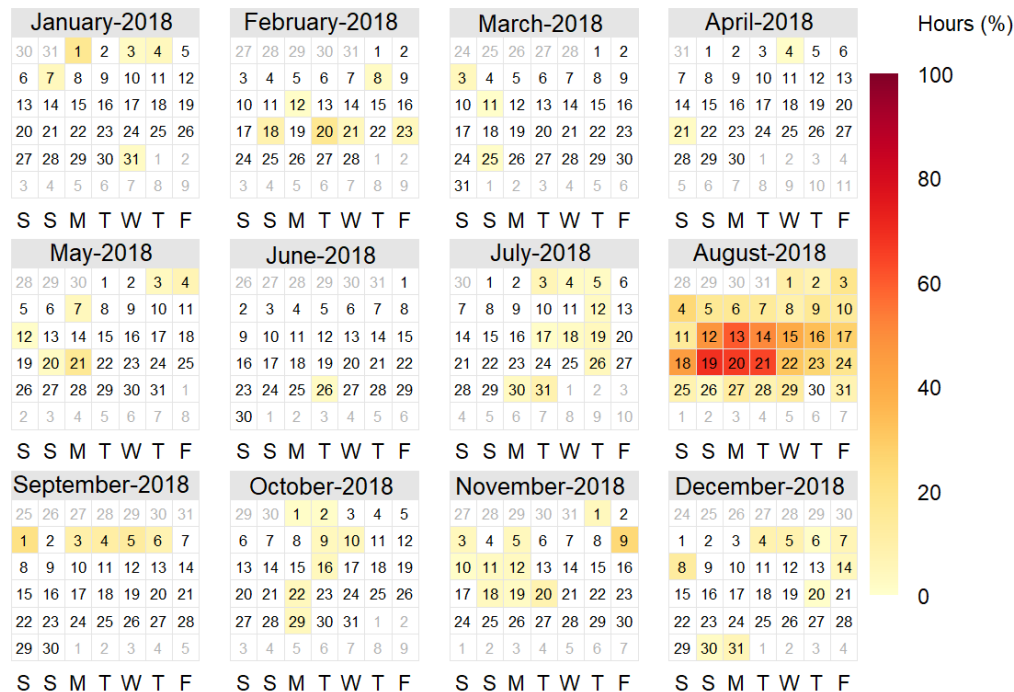
# ACROSS WASHINGTON STATE IN 2017

## AQI GREATER THAN 150



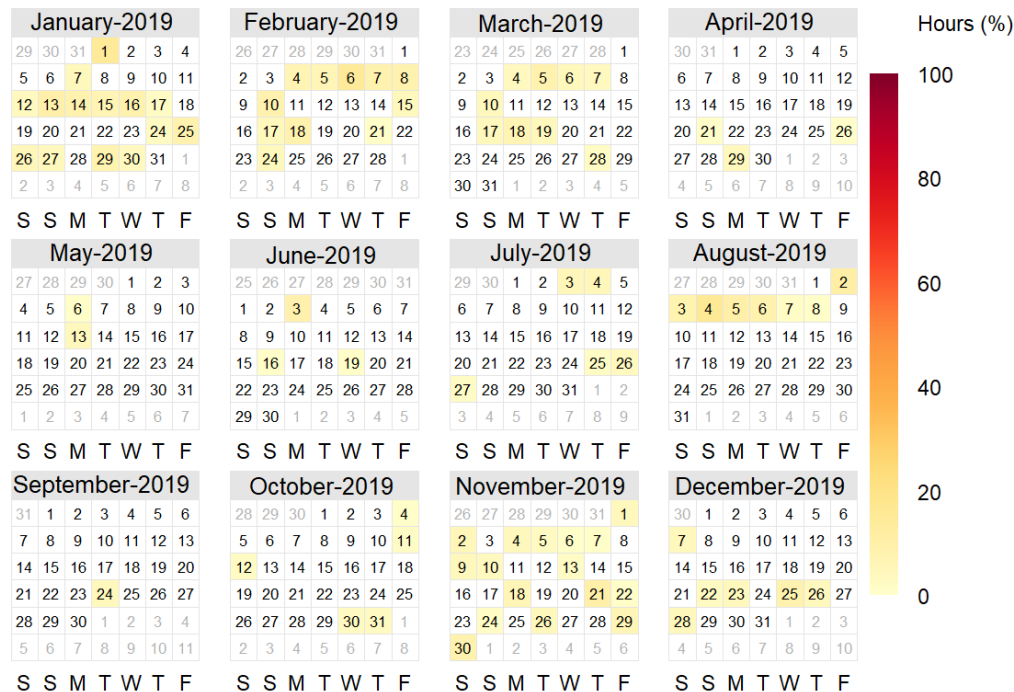
# ACROSS WASHINGTON STATE IN 2018

## AQI GREATER THAN 150



# ACROSS WASHINGTON STATE IN 2019

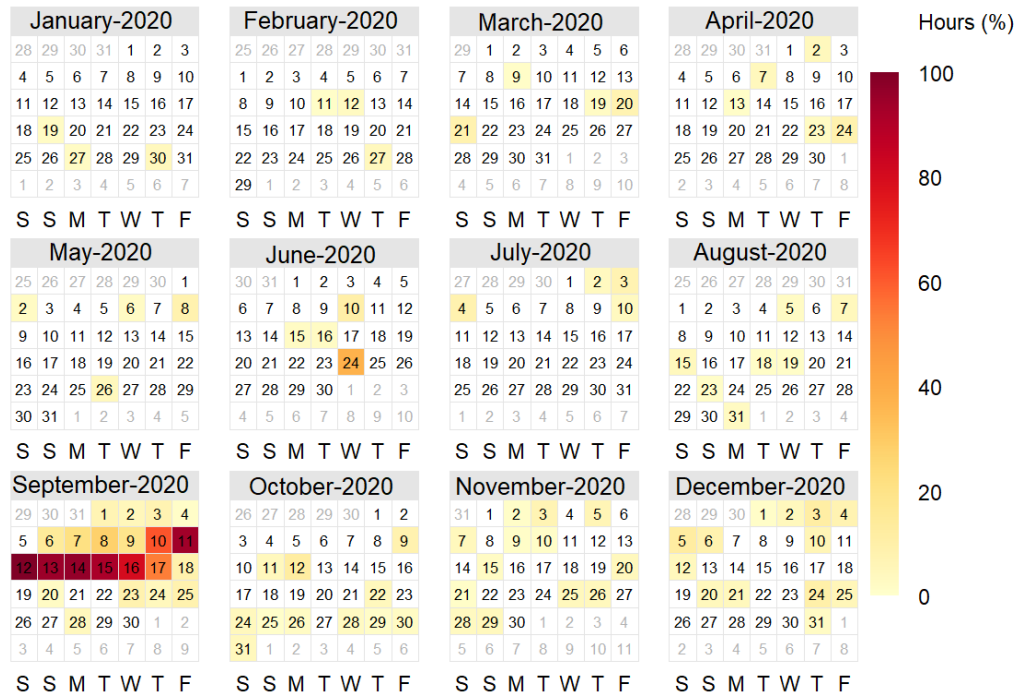
## AQI GREATER THAN 150





# ACROSS WASHINGTON STATE IN 2020

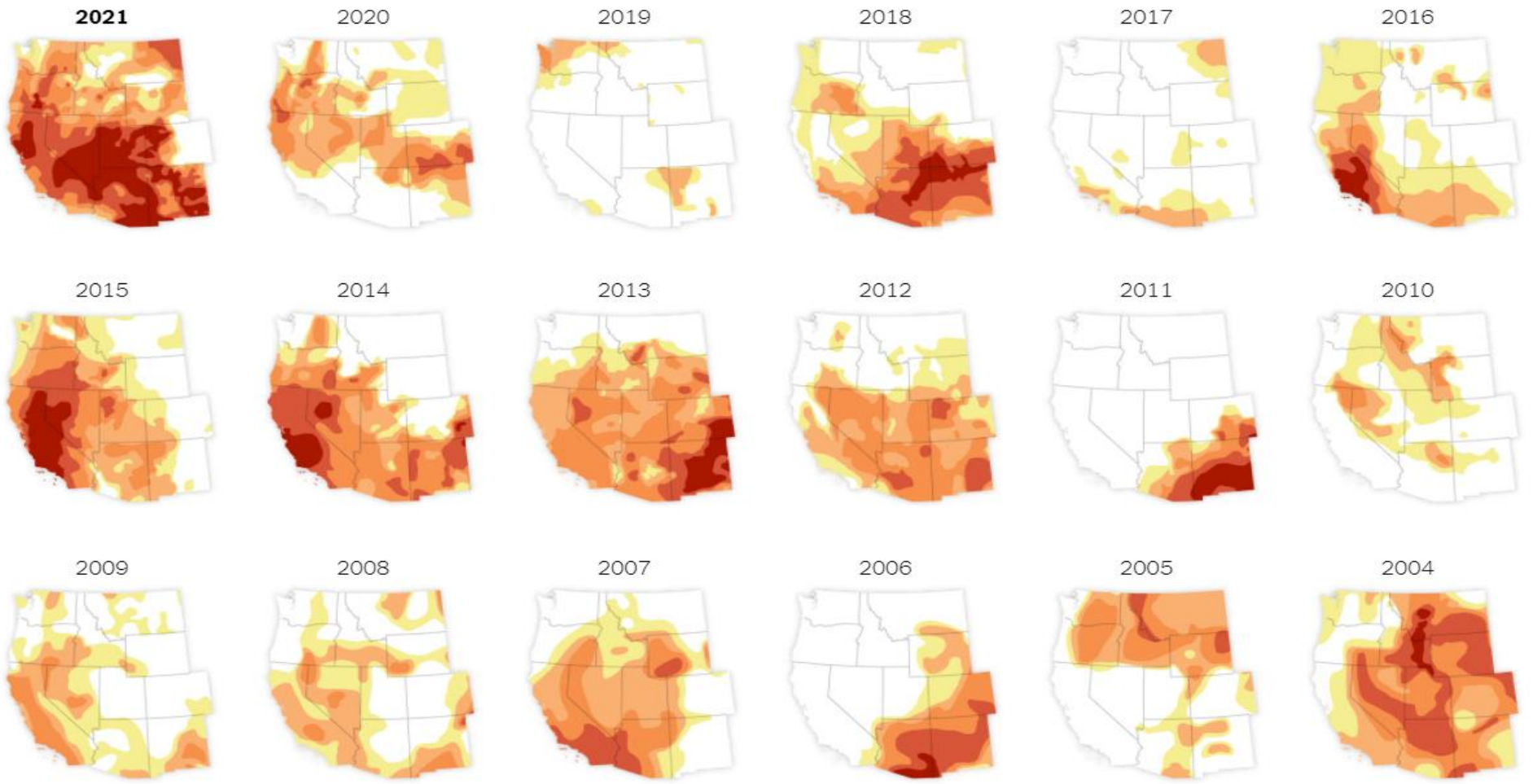
## AQI GREATER THAN 150



Early June Drought Conditions in the West

Source: U.S. Drought Monitor, Conditions during the first week of June.

EXCEPTIONAL DROUGHT   EXTREME   SEVERE   MODERATE   ABNORMALLY DRY



# Using PPE in workplace settings for wildfire smoke exposure

- > The emergency rule in WA proposed employers provide PPE under voluntary use guidelines
- > **Masks**
  - Tight-fitting N95 and P100 respirators provide some protection from wildfire smoke (in some cases KN95)
  - One-strap paper masks, surgical masks and other face coverings offer little protection because they do not capture most small particles in smoke



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



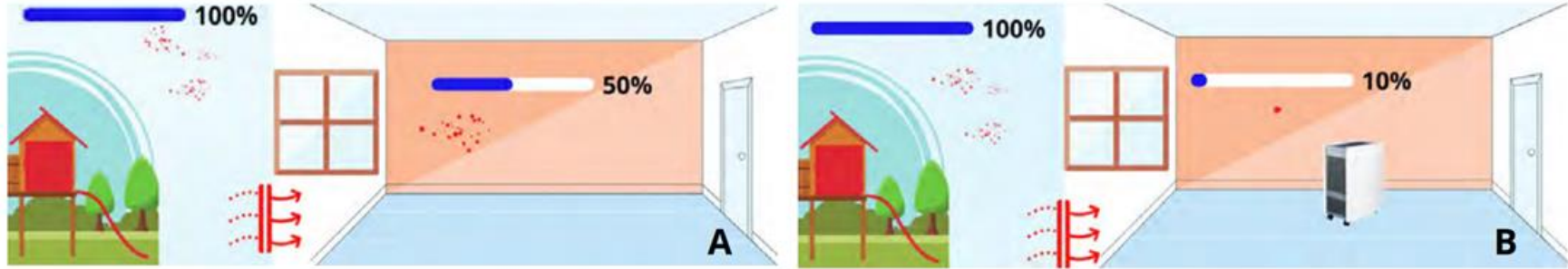
Figure 6. A surgical mask is designed to capture infectious particles generated by the wearer, is not a respirator, and provides little or no protection from smoke particles. Photo courtesy of the California Department of Public Health



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

Source: US EPA 2019. Wildfire Smoke Guide

# Indoor Air Quality during Wildfire Smoke



- Approximately 50% of outdoor particles enter into public buildings
- HEPA filter interventions reduce the indoor penetration to 10%

# Worker Exposure Scenarios

- Exposure concentrations will vary based on whether the worker is indoor or outdoors, or whether PPE is used.
- Inhalation rates will vary based on activity, with outdoor occupations such as agriculture and construction involving moderate intensity activity with higher inhalation rates.

outdoor conc = 100						
Hour	work hour	METS	Activity level	Inhalation Rate (m3/min)	concentration (ug/m3)	dose (ug)
1	0	0.95	Sleep or Nap	4.30E-03	50	12.9
2	0	0.95	Sleep or Nap	4.30E-03	50	12.9
3	0	0.95	Sleep or Nap	4.30E-03	50	12.9
4	0	0.95	Sleep or Nap	4.30E-03	50	12.9
5	0	0.95	Sleep or Nap	4.30E-03	50	12.9
6	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
7	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
8	1	1.3	Sedentary/Passive	4.20E-03	50	12.6
9	1	1.3	Sedentary/Passive	4.20E-03	50	12.6
10	1	1.3	Sedentary/Passive	4.20E-03	50	12.6
11	1	1.3	Sedentary/Passive	4.20E-03	50	12.6
12	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
13	1	1.3	Sedentary/Passive	4.20E-03	50	12.6
14	1	1.3	Sedentary/Passive	4.20E-03	50	12.6
15	1	1.3	Sedentary/Passive	4.20E-03	50	12.6
16	1	1.3	Sedentary/Passive	4.20E-03	50	12.6
17	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
18	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
19	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
20	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
21	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
22	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
23	0	0.95	Sleep or Nap	4.30E-03	50	12.9
24	0	0.95	Sleep or Nap	4.30E-03	50	12.9
total		8				
average						12.7

outdoor conc = 100						
Hour	work hour	METS	Activity level	Inhalation Rate (m3/min)	concentration (ug/m3)	dose (ug)
1	0	0.95	Sleep or Nap	4.30E-03	50	12.9
2	0	0.95	Sleep or Nap	4.30E-03	50	12.9
3	0	0.95	Sleep or Nap	4.30E-03	50	12.9
4	0	0.95	Sleep or Nap	4.30E-03	50	12.9
5	0	0.95	Sleep or Nap	4.30E-03	50	12.9
6	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
7	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
8	1	4	Moderate Intensity	2.60E-02	100	156.0
9	1	4	Moderate Intensity	2.60E-02	100	156.0
10	1	4	Moderate Intensity	2.60E-02	100	156.0
11	1	4	Moderate Intensity	2.60E-02	100	156.0
12	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
13	1	4	Moderate Intensity	2.60E-02	100	156.0
14	1	4	Moderate Intensity	2.60E-02	100	156.0
15	1	4	Moderate Intensity	2.60E-02	100	156.0
16	1	4	Moderate Intensity	2.60E-02	100	156.0
17	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
18	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
19	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
20	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
21	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
22	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
23	0	0.95	Sleep or Nap	4.30E-03	50	12.9
24	0	0.95	Sleep or Nap	4.30E-03	50	12.9
total		8				
average						60.5

outdoor conc = 100						
Hour	work hour	METS	Activity level	Inhalation Rate (m3/min)	concentration (ug/m3)	dose (ug)
1	0	0.95	Sleep or Nap	4.30E-03	50	12.9
2	0	0.95	Sleep or Nap	4.30E-03	50	12.9
3	0	0.95	Sleep or Nap	4.30E-03	50	12.9
4	0	0.95	Sleep or Nap	4.30E-03	50	12.9
5	0	0.95	Sleep or Nap	4.30E-03	50	12.9
6	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
7	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
8	1	4	Moderate Intensity	2.60E-02	5	7.8
9	1	4	Moderate Intensity	2.60E-02	5	7.8
10	1	4	Moderate Intensity	2.60E-02	5	7.8
11	1	4	Moderate Intensity	2.60E-02	5	7.8
12	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
13	1	4	Moderate Intensity	2.60E-02	5	7.8
14	1	4	Moderate Intensity	2.60E-02	5	7.8
15	1	4	Moderate Intensity	2.60E-02	5	7.8
16	1	4	Moderate Intensity	2.60E-02	5	7.8
17	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
18	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
19	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
20	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
21	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
22	0	1.3	Sedentary/Passive	4.20E-03	50	12.6
23	0	0.95	Sleep or Nap	4.30E-03	50	12.9
24	0	0.95	Sleep or Nap	4.30E-03	50	12.9
total		8				
average						11.1

## Wildfire Smoke Resources for Agriculture

High Plains Intermountain Center for Agricultural Health and Safety

<https://vetmedbiosci.colostate.edu/hicahs/resources/>

Western Center for Agricultural Health and Safety

<https://aghealth.ucdavis.edu/wildfires>

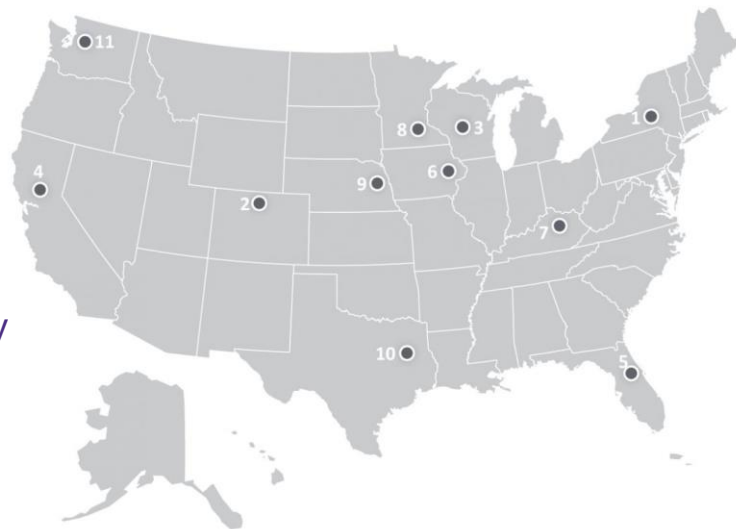
Pacific Northwest Agricultural Safety and Health Center

<https://deohs.washington.edu/pnash/wildfiresmoke>

Metabolic Equivalent Inhalation Rates Calculator

<https://edmundseto.shinyapps.io/METIH/>

NIOSH Centers for Agricultural Safety and Health



<https://www.cdc.gov/niosh/oep/agctrhom.html>



# Questions & Discussion