Health Effects of Wildfires

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Chiwaukum Creek Wildfire 2014
Okanogan-Wenatchee National Forest
Photo Credit: https://ecology.wa.gov/
The views expressed during this presentation are those of the author and do not necessarily reflect the views or policies of the U.S. EPA.
• 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
Wildland Fire Smoke

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., NO₂, SO₂) emitted by sources such as power plants, automobiles, etc.
- Particles defined by aerodynamic diameter
  - Fine particles (PM₂.₅), aerodynamic diameter ≤ 2.5 µm
  - Coarse particles (PM₁₀₋₂.₅), aerodynamic diameter > 2.5 µm and ≤ 2.5 µm
  - Ultrafine particles (UFPs), aerodynamic diameter ≤ 0.1 µm

Source: [https://www.epa.gov/pm-pollution](https://www.epa.gov/pm-pollution)
Wildfire Smoke Emissions and PM$_{2.5}$

Pollutants in Wildfire Smoke

<table>
<thead>
<tr>
<th>Pollutant name</th>
<th>Category</th>
<th>Acronym or formula</th>
<th>Molecular weight</th>
<th>$n$</th>
<th>Mean EF</th>
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</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td></td>
<td>C$_3$H$_4$O$_2$</td>
<td>60.052</td>
<td>153</td>
<td>2.13</td>
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<tr>
<td>Acetylene</td>
<td></td>
<td>C$_2$H$_2$</td>
<td>26.038</td>
<td>291</td>
<td>0.83</td>
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<tr>
<td>Ammonia</td>
<td>CAP, TOX</td>
<td>NH$_3$</td>
<td>17.031</td>
<td>216</td>
<td>1.55</td>
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<tr>
<td>Black carbon</td>
<td></td>
<td>BC</td>
<td>115</td>
<td></td>
<td>0.96</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>GHG</td>
<td>CO$_2$</td>
<td>44.009</td>
<td>597</td>
<td>1549.98</td>
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<tr>
<td>Carbon monoxide</td>
<td>CAP</td>
<td>CO</td>
<td>28.010</td>
<td>640</td>
<td>103.51</td>
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<tr>
<td>Ethene</td>
<td>TOX</td>
<td>C$_2$H$_4$</td>
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<td>261</td>
<td>1.10</td>
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<tr>
<td>Formaldehyde</td>
<td>HAP, TOX</td>
<td>H$_2$CO</td>
<td>30.026</td>
<td>204</td>
<td>1.59</td>
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<tr>
<td>Formic acid</td>
<td>TOX</td>
<td>HCOOH</td>
<td>46.025</td>
<td>192</td>
<td>0.33</td>
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<td>Furane</td>
<td>TOX</td>
<td>C$_2$H$_2$O</td>
<td>68.075</td>
<td>179</td>
<td>0.34</td>
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<tr>
<td>Hydrogen cyanide</td>
<td>HAP, TOX</td>
<td>HCN</td>
<td>27.026</td>
<td>188</td>
<td>0.46</td>
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<tr>
<td>Methane</td>
<td>GHG</td>
<td>CH$_4$</td>
<td>16.043</td>
<td>451</td>
<td>5.53</td>
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<tr>
<td>Methanol</td>
<td>HAP, TOX</td>
<td>CH$_3$OH</td>
<td>32.042</td>
<td>219</td>
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<tr>
<td>Nitric oxide</td>
<td>CAP</td>
<td>NO</td>
<td>30.006</td>
<td>193</td>
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<tr>
<td>Nitrogen dioxide</td>
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<td>NO$_2$</td>
<td>46.005</td>
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<td>1.26</td>
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<tr>
<td>Nitrogen oxides</td>
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<td>117</td>
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<td>Nitrous acid</td>
<td>CAP</td>
<td>HNO$_2$</td>
<td>47.013</td>
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<td>Non-methane hydrocarbons</td>
<td>CAP</td>
<td>NMHC</td>
<td>112</td>
<td>5.87</td>
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<tr>
<td>Particulate matter 2.5 μm</td>
<td>CAP</td>
<td>PM$_{2.5}$</td>
<td>337</td>
<td>27.87</td>
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<td>Phenol</td>
<td>HAP, TOX</td>
<td>C$_6$H$_5$O</td>
<td>94.113</td>
<td>137</td>
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<td>Propene</td>
<td>TOX</td>
<td>C$_3$H$_6$</td>
<td>42.081</td>
<td>295</td>
<td>0.68</td>
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<tr>
<td>Sulfur dioxide</td>
<td>CAP</td>
<td>SO$_2$</td>
<td>64.058</td>
<td>127</td>
<td>1.11</td>
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<tr>
<td>Total particulate matter</td>
<td></td>
<td></td>
<td>289</td>
<td>23.57</td>
<td></td>
</tr>
</tbody>
</table>

$n$ = # observations; EF = emissions factor

Where There is Smoke There is Illness

Wildfire smoke

Health effects

Wildfires

Inhaled particle deposition in the lung

Extrathoracic region

>10 µm

Nasal Cavity
Larynx

Tracheobronchial region

2.5 – 10 µm
(Coarse PM)

Trachea
Bronchi

Alveolar region

< 0.1 µm
(Ultrafine PM)

0.1 – 2.5 µm
(Fine PM)

Alveoli

Wildfire smoke components:
- Gases
- Volatile liquids
- Reactive metals
- Organic species
- Particles

Health effects:
- Inhaled particle deposition in the lung:
  - >10 µm
  - 2.5 – 10 µm (Coarse PM)
  - 0.1 – 2.5 µm (Fine PM)
  - < 0.1 µm (Ultrafine PM)
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

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

### 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

#### Study Location Age Lag

- **Gan et al. (2017)a** Washington All 0
- **Gan et al. (2017)b** Washington All 0
- **Gan et al. (2017)c** Colorado All 0
- **Stowell et al. (2019)d,e** North Carolina (28 counties) 0-2
- **Tinling et al. (2016)** North Carolina (28 counties) 18+ 0,2DL
- **Hutchinson et al. (2018)** San Diego, CA 0,64 0.2 (72h MA)
- **DeFlorio-Barker et al. (2019)f** California All 0
- **DeFlorio-Barker et al. (2019)g** California All 0
- **DeFlorio-Barker et al. (2019)h** California All 0
- **Alman et al. (2016)** North Carolina (28 counties) 65+ 0
- **Reid et al. (2016)** Oregon 0
- **Gan et al. (2017)a** Washington All 0
- **Gan et al. (2017)b** Washington All 0
- **Gan et al. (2017)c** Colorado All 0
- **Gan et al. (2019)** Oregon All 0
- **Gan et al. (2020)** Oregon All 0
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### Odds Ratio/Relative Risk

- **Asthma**

#### 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/m$^3$ increase in PM$_{2.5}$ concentrations, except for Stowell et al. (2019), which are for a 1 µg/m$^3$ increase.

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

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


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)
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)
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)

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)
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.
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
• 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
• 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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