Wildfire Smoke and Public Health
- Why is the EPA Concerned?

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Protection of Public Health
Assisting the States Address Environmental Challenges

• The Clean Air Act 1970 Title 1; Part A – protection of “public health” is noted 64 times – founded on the principle of endangerment

• In §7403 (Research) – “human health” is noted 9 times; “welfare” or “environment” 12 times; “training” 14 times; “multiple” pollutants and stressors” twice

• Protection of sensitive subpopulations
How does Wildland Fire Smoke Factor In?

• Wildland fires are a national challenge impacting public health and environmental quality through complex multi-media pathways

• Uncontrolled wildfires and the use of prescribed fire are raising questions related to benefits and harms to:
  
  o Ambient air quality
  o Water quality
  o Land management
  o Ecosystem services
  o Public health
  o Local economic health
Present Concerns

- Increasing acreage burned
- Increasing impact on urban areas
  - 10% of all land with housing is situated in the wildland-urban interface
- Increased vulnerability of populations
  - Expanding WUI
  - Aging US population
  - Increasing chronic disease

Adapted from https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html
U.S. Air Quality Improves 1988-2016
Except in Wildfire-Prone Areas

McClure CD and Jaffe DA. PNAS 115 (31): 7901-7906, 2018
**Health Impacts Can Extend Hundreds of Miles**

- Forest fires in Quebec, Canada, during July 2002 (red circles)
- Baltimore, Maryland, a city nearly a thousand miles downwind
- 30-fold increase in airborne fine particle concentrations

Source: Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on the Terra satellite, Land Rapid Response Team, NASA/GSFC
Health Effects of Wildfire Smoke
Systematic Reviews are Now Available

**Environ Res.**
2015;136:120-32

**Environ Health Perspect.**
2016; 124:1334–1343

**Environ Toxicol Pharmacol.**
2017;55:186-195

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**Review**
A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke
Jia C. Liu 3#, Gergely Tóth 3, Hannah J. Moore 3, and Rafael E. Brumfield 3*

**Critical Review of Health Impacts of Wildfire Smoke Exposure**
Colleen E. Reid,1,2 Michael Brauer,3 Fay H. Johnston,4,5 Michael Jerrett,1,6 John R. Balmes,1,7 and Catherine T. Elliott3,8
1Stanford University, Stanford, California, USA; 2University of California, Berkeley, Berkeley, California, USA; 3Harvard School of Public Health, Cambridge, Massachusetts, USA; 4School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania, USA; 5School of Human Ecology, University of Wisconsin-Madison, Madison, Wisconsin, USA; 6Saskatchewan Centre for Health Policy, University of Saskatchewan, Saskatoon, Saskatchewan, Canada; 7Health Canada, Ottawa, Ontario, Canada; 8University of British Columbia, Vancouver, British Columbia, Canada

**Meta-Analysis of Heterogeneity in the Effects of Wildfire Smoke Exposure on Respiratory Health in North America**
Michelle C. Kondo 1,*, Annedale J. De Roos 2, Lauren S. White 2, Warren E. Heilman 3,*, Miranda H. Mockin 4, Carol Ann Cross-Davis 4, and Igor Busutyn 4*

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Health Effects Known or Suspected to be Caused by Wildland Fire Smoke

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

At-risk populations include –
- Pregnant women and fetuses
- Children
- Older populations
- Populations with pre-existing respiratory disease
- Populations with pre-existing cardiovascular disease

Populations suspected to be at greater risk –
- Populations with chronic inflammatory diseases (e.g., diabetes, obesity)
- Women, African-Americans and populations with lower socio-economic status*


27% of U.S. population is at-risk
Cardiopulmonary hospitalizations among adults ≥65 years

- Exposure to PM$_{2.5}$, on all days and locations, was associated with increased hospitalizations on smoke and non-smoke days.
- Estimated effects persisted across multiple exposure days.
- CV outcomes increased by 0.61% on smoke days and 0.69% on non-smoke days.
- No apparent difference between wildfire and non-wildfire PM$_{2.5}$

DeFlorio-Barker Environmental Health Perspectives 2019
EPA:

“Epidemiologic evidence is sufficient to conclude that a causal relationship exists between: short-term and long-term exposure to PM$_{2.5}$ and cardiovascular mortality.”

Integrated Science Assessment (ISA) for Particulate Matter 2009
Air Quality Impacts of Wildland Fires

Annual average daily fire-PM$_{2.5}$ footprint for US counties

Health protective standards
Annual: 12 μg/m$^3$ daily avg.
Daily: 35 μg/m$^3$

How much does smoke contribute to air quality and how often does it lead to exceeding daily standard?

# of days with fire-PM$_{2.5}$ above 35 μg/m$^3$ by counties of continental US

California 2015 Wildfire Study

Epidemiology study designed to examine respiratory, cardiovascular, & cerebrovascular health effects of wildfire smoke

- Associated wildfire-PM$_{2.5}$ exposure with emergency department visits for cardiovascular and respiratory diagnoses

Smoky days/county during the study: May through September 2015

California air basins included in the study are labeled and outlined in black

Wettstein Z, Hoshiko S, Cascio WE, Rappold AG et al. JAHA 2018
Wildfire-PM$_{2.5}$ Exposure Increases Heart Attack & Stroke

- **Wildfire-PM$_{2.5}$ associated with heart attacks and strokes for all adults, particularly for those over 65 years old**

- **Increase in risk the day after exposure:**
  - All cardiovascular, 12%
  - Heart attack, 42%
  - Heart failure, 16%
  - Stroke, 22%
  - All respiratory causes, 18%
  - Abnormal heart rhythm, 24% (on the same day as exposure)

*Wettstein Z, Hoshiko S, Cascio WE, Rappold AG et al. JAHA April 11, 2018*
Air-Quality Impacts
Urban Areas, at a Distance, High Exposures

2013 California Rim Fire

Affected Californian Counties

Aug. 30 – Sep. 10

Daily Mass Intake
µg PM_{2.5} per Person

- 0 – 486
- 487 – 1,459
- 1,460 – 2,919
- 2,920 – 18,141

Exposure up to 35 times greater than the 24 hr PM_{2.5} standard

Daily mass intake breathing PM at the EPA 24 hr PM_{2.5} standard (35µg/m³) = 486 µg PM_{2.5}/day

Seeley Lake Montana 2017 Wildfire Season Raised a New Public Health Issue Prolonged Exposure

(160,000 acres)
(54,000 acres)
(29,000 acres)

Courtesy of Dr. Paul Smith Missoula, MT
What are the health effects of wildfire smoke exposures under different exposure scenarios:

- Very high concentrations for a few hours?
- High concentrations lasting days, weeks to months?
- Low concentrations lasting for years?

*Seeley Lake 2017 Wildfire Season*

Average 24-hour PM$_{2.5}$ Concentration

Courtesy of Dr. Paul Smith
Missoula, MT
Different Types of Wildfire Smoke
Do Different Fuels Have Different Toxicity Profiles?

- Peat wildfire
- Forest wildfire
- Smoldering
- Flaming

Particulate Matter (PM)
- Ultrafine
- Fine
- Coarse

Fuel type
- Combustion phase

Combustion phase

Courtesy of Dr. Ian Gilmour
The Community Health-Vulnerability Index identifies the most vulnerable counties:

- shows that these communities experience more smoke exposures in comparison to less vulnerable communities
- may help prepare responses, increase the resilience to smoke and improve public health outcomes during smoke days

Golden Gate Bridge from Lands End Trail

Air Quality Index 156 Unhealthy

N-95 Use on Market Street, San Francisco
Cardiovascular and Lung Disease in the U.S.
Size of the Vulnerable Population

Cardiovascular Disease
- Number of adults with diagnosed cardiovascular disease: 121 million (48%)
- Number of adults with diagnosed heart disease: 28.2 million (11.5%)

Lung Disease
- Number of adults with diagnosed chronic bronchitis: 8.6 million
- Number of adults diagnosed with emphysema: 3.4 million (1.4%)

By 2035 –
- More than 130 million adults, or 45.1% of the US population, are projected to have some form of CVD.
- Total costs of CVD are expected to reach $1.1 trillion in 2035, with direct medical costs projected to reach $748.7 billion and indirect costs estimated to reach $368 billion.

Source: CDC Fast Facts, and American Heart Association Published: Jan. 31, 2019
Chronic Lung Diseases are Independently Associated with Heart Disease

- Between January 1, 2000, and March 31, 2013, patients with lung diseases were admitted to 7 National Health Service hospitals NW England.

- On multivariable analysis, chronic lung diseases are independently associated with ischemic heart disease, heart failure, atrial fibrillation, and peripheral vascular disease.

Kaplan-Meier survival curves illustrate the impact of heart disease on survival among patients with lung diseases.

**COPD**  31,646 Patients with follow-up of 5.2 ± 3.6 years

53% (16,812 patients) died.

Ischemic heart disease, heart failure, AF & peripheral vascular disease were independently associated with death.

**Asthma**  60,424 Patients with follow-up of 5.2 ± 3.6 years

11% (6,649 patients) died.

Ischemic heart disease and heart failure were independently associated with death.
Annual Personal Health Care Spending in U.S. for Chronic Disease is High

<table>
<thead>
<tr>
<th>Disease</th>
<th>Spending (in billions)</th>
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<tbody>
<tr>
<td>COPD</td>
<td>$53.8 billion</td>
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<tr>
<td>Asthma</td>
<td>$32.5 billion</td>
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<tr>
<td>Pneumonia</td>
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<td>Lung cancer</td>
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<td>Ischemic heart disease</td>
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<td>High blood pressure</td>
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<td>Stroke</td>
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<tr>
<td>Heart failure</td>
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<tr>
<td>Atrial fibrillation</td>
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<tr>
<td>Peripheral vascular disease</td>
<td>$2.7 billion</td>
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<tr>
<td>Diabetes</td>
<td>$101.4 billion</td>
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<tr>
<td>Preterm birth</td>
<td>$4.9 billion</td>
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</tbody>
</table>

Wildfire Smoke and/or PM Exposure is a Risk Factor for Each
- Establish more reliable exposure estimates and non-pulmonary health effects of wildfire emissions

- Identify biomarkers of exposure and health effects

- Identify intrinsic factors that increase susceptibility to wildfire smoke

- Identify built environment and socio-demographic factors that increase a community’s susceptibility to wildfire smoke-related health responses
Wildfire Smoke Research Needs for Better Public Health Protection

- Determine health effects associated with combustion of different types of biomass and those involving structures
- Evaluate effectiveness of clinical and public health intervention strategies to reduce short-term exposures in those at highest-risk and long-term exposures in all
Thank you

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• No conflicts of interest
• The presentation represents the opinions of the speaker and does not necessarily represent the policies of the US EPA