Inhalational Exposures as a Function of Chemical Types and Target Populations: Who Are the Sensitive Populations and What Are Their Major Risks?

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Wildfire

Increased Development - Wildland Urban Interface

Emissions from Wildfires

Primary air pollutants
- Particulate Matter (PM)
- CO
- NO_2
- Polycyclic aromatic hydrocarbons (PAHs)
- Volatile organic compounds (VOCs)

Secondary air pollutants
- Particulate Matter (PM)
- Ozone

Camp Fire – Nov. 9, 2018

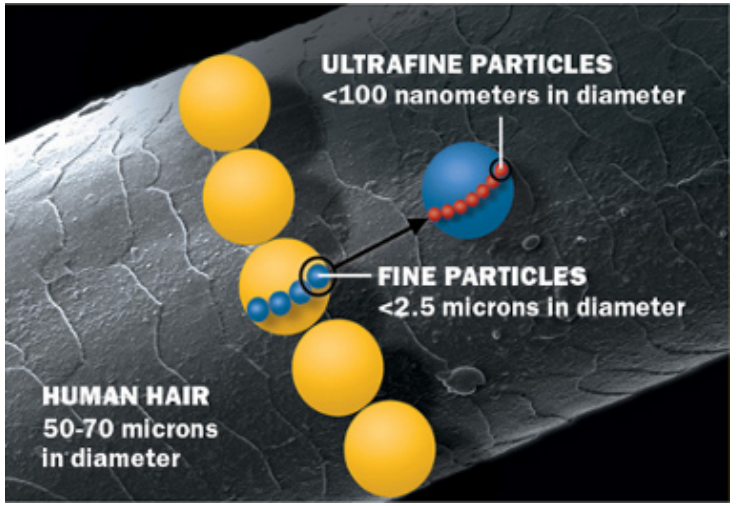
When Buildings and Vehicles Burn

- Structural fire smoke contains other toxic air contaminants, including
  - HCN, HCl, phosgene, metals
  - toluene, styrene, dioxins

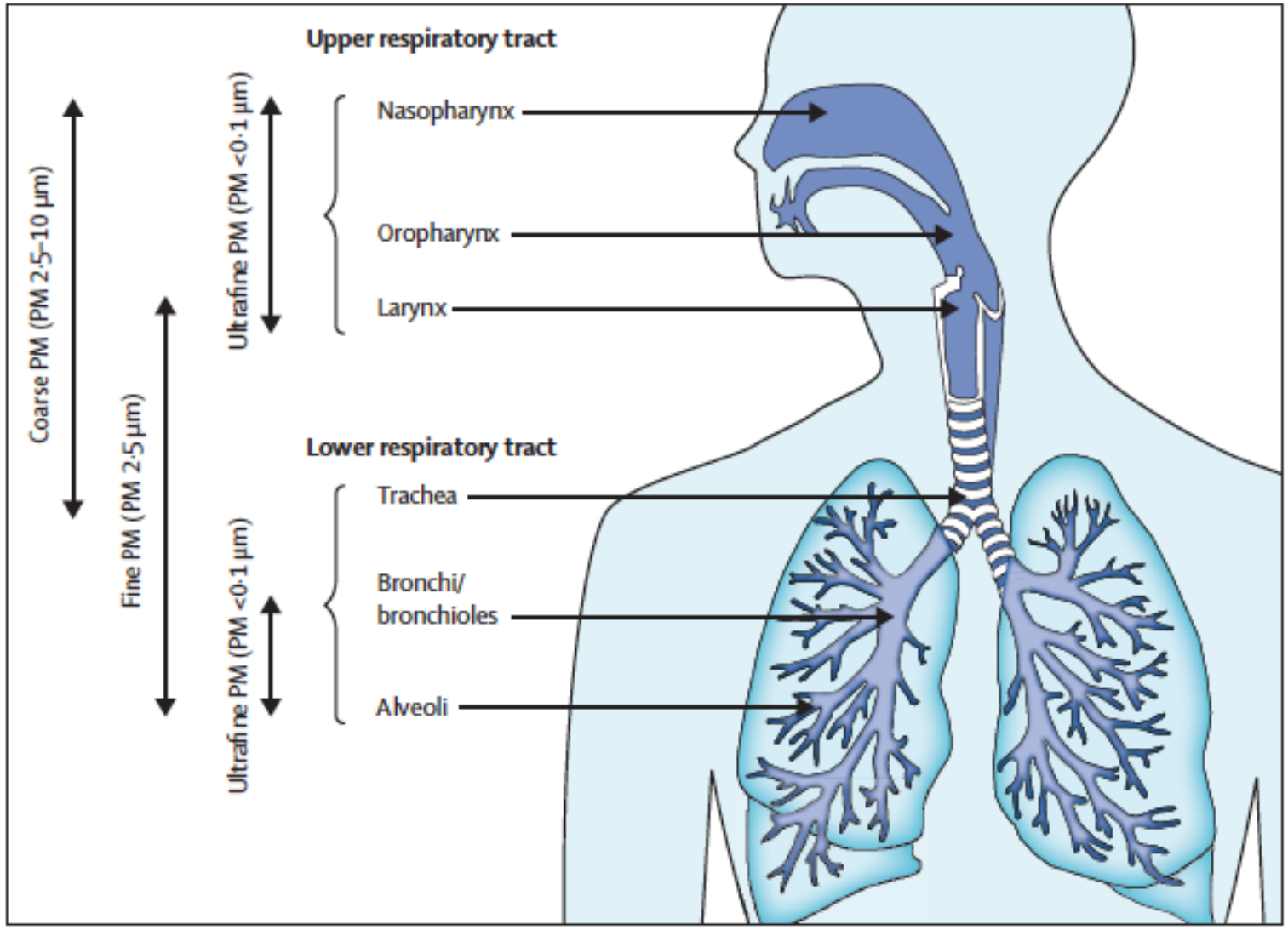
- The Sonoma-Napa, Thomas, and Camp fires caused many buildings and motor vehicles to burn
  - Local residents exposed to more than wood smoke

Respiratory Tract Deposition

- For gases, water solubility is the key
  - Highly soluble gases deposit in the larger airways and tend to be irritating (e.g., ammonia)
  - Less soluble gases penetrate to the alveoli and tend to be relatively non-irritating (e.g., phosgene)
- For particles, size matters



Particle deposition



Guarnieri M, Balmes J. Lancet 2014;383(9928):1581-92

Wildland Firefighter Exposures

- Higher concentrations
- No feasible respiratory protection
- Long durations
- Recurrent over a fire season
- Cumulative over years for a career wildland firefighter

Photo by George Broyles, USFS

Community Exposures

- Community exposures are typically much lower than those of WLFFs
- Levels of community exposures depend on multiple factors
  - Outdoor concentrations, time outdoors, respiratory protective equipment, indoor penetration, indoor ventilation/filtration

Most Vulnerable Populations

- Young children
- Older adults
- Persons with pre-existing respiratory and cardiovascular disease
- Pregnant women
- Low-income people of color
- Outdoor workers

CalOSHA Emergency Wildfire Smoke Standard for Outdoor Workers

- If feasible, provide an enclosed location with filtered air so that employee exposure to $PM_{2.5}$ is less than an AQI of 151
- Provide N95 respirators if employers cannot reduce workers' exposure to $PM_{2.5}$ to an AQI of 150 or lower

Acute health impacts of short-term community wildfire smoke exposures

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. Elliott[3,8]

Environ Health Perspect 2016;124:1334–1343

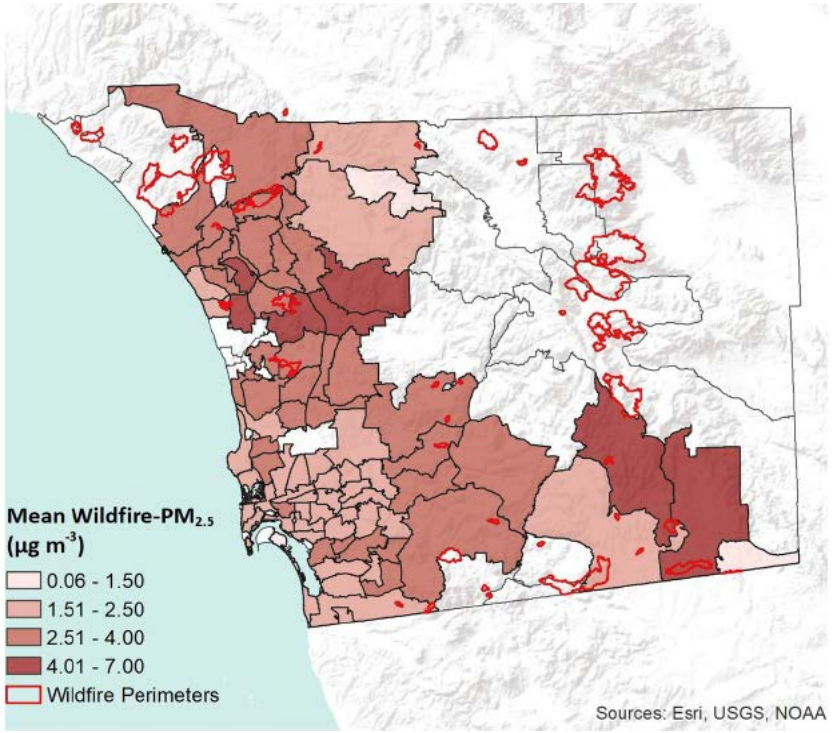
Clear evidence of an association between wildfire smoke and respiratory health

- Asthma exacerbations significantly associated with higher wildfire smoke ***in nearly every study***
- Exacerbations of chronic obstructive pulmonary disease (COPD) significantly associated with higher wildfire smoke in most studies
- Growing evidence of a link between wildfire smoke and respiratory infections (pneumonia, bronchitis)

Environ Health Perspect 2016;124:1334–1343

Fine Particles in Wildfire Smoke and Pediatric Respiratory Health in California

Rosana Aguilera, PhD,[a] Thomas Corringham, PhD,[a] Alexander Gershunov, PhD,[a] Sydney Leibel, MD,[b,c] Tarik Benmarhnia, PhD[a,d]

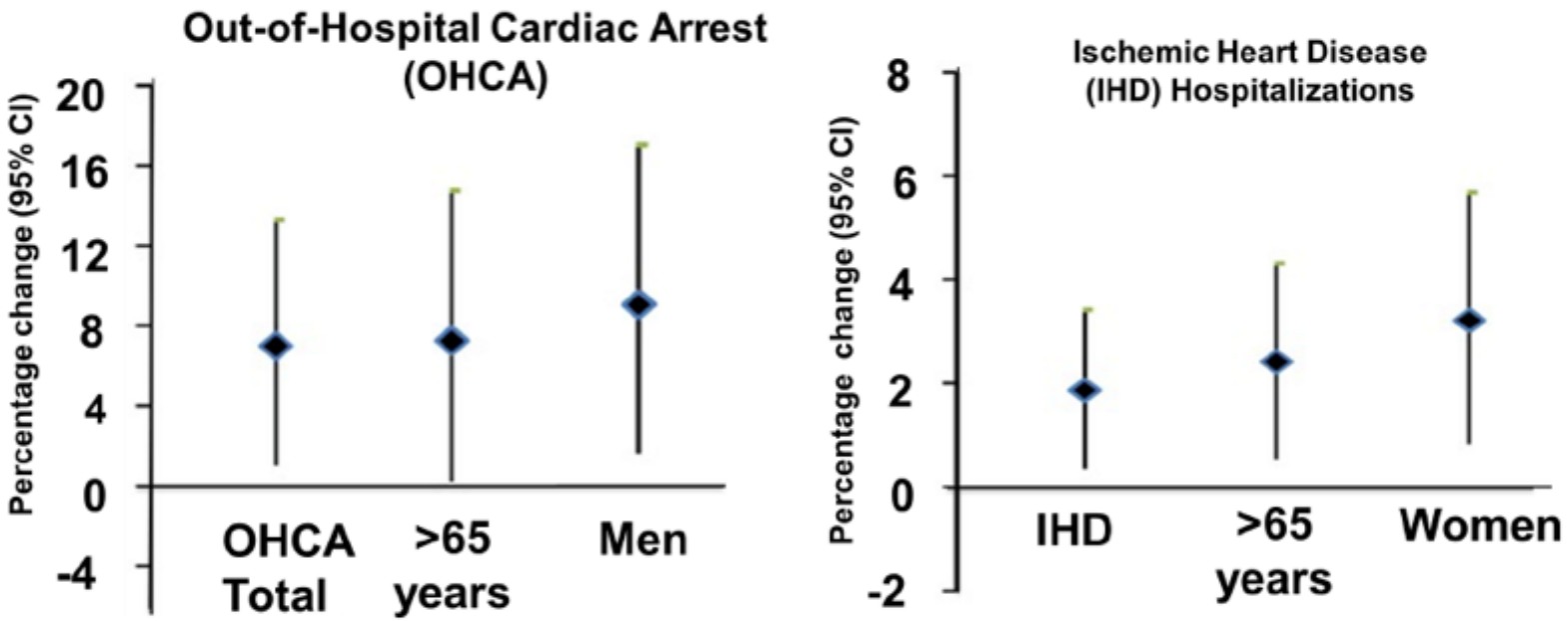


- Examined the associations between wildfire-specific $PM_{2.5}$ and pediatric respiratory health during 2011–2017 in San Diego County and compared the results with other sources of $PM_{2.5}$
- A 10 µg/m^3 increase in $PM_{2.5}$ (from nonsmoke sources) was associated with a 3.7% increase in ED and urgent care visits (95% CI: 1.2%-6.1%) while $PM_{2.5}$ from wildfire smoke was associated with a 30% (26.6%-33.4%) increase in visits

Pediatrics 2021;147(4):e2020027128

Cardiovascular effects

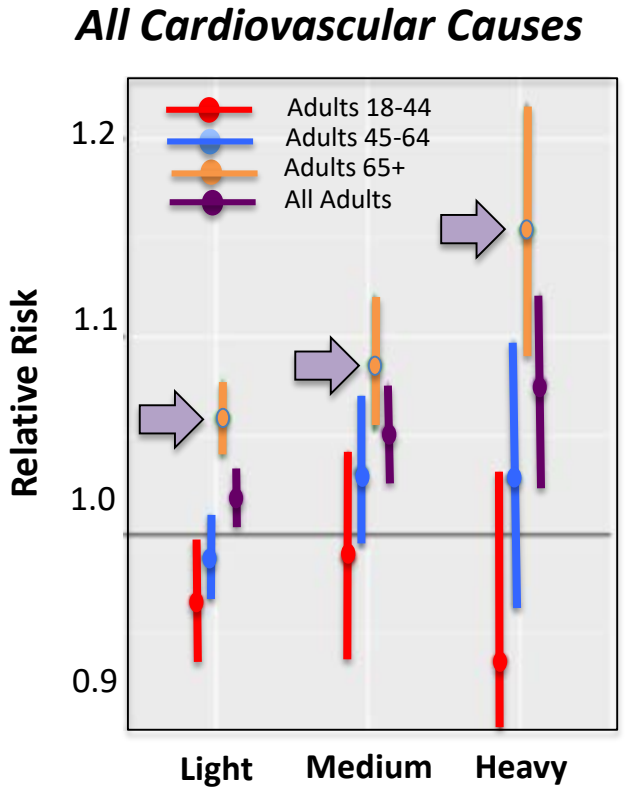
Victoria, Australia - Dec 1, 2006 - Jan 31, 2007



Haikerwal et al. 2015 J Am Heart Assoc

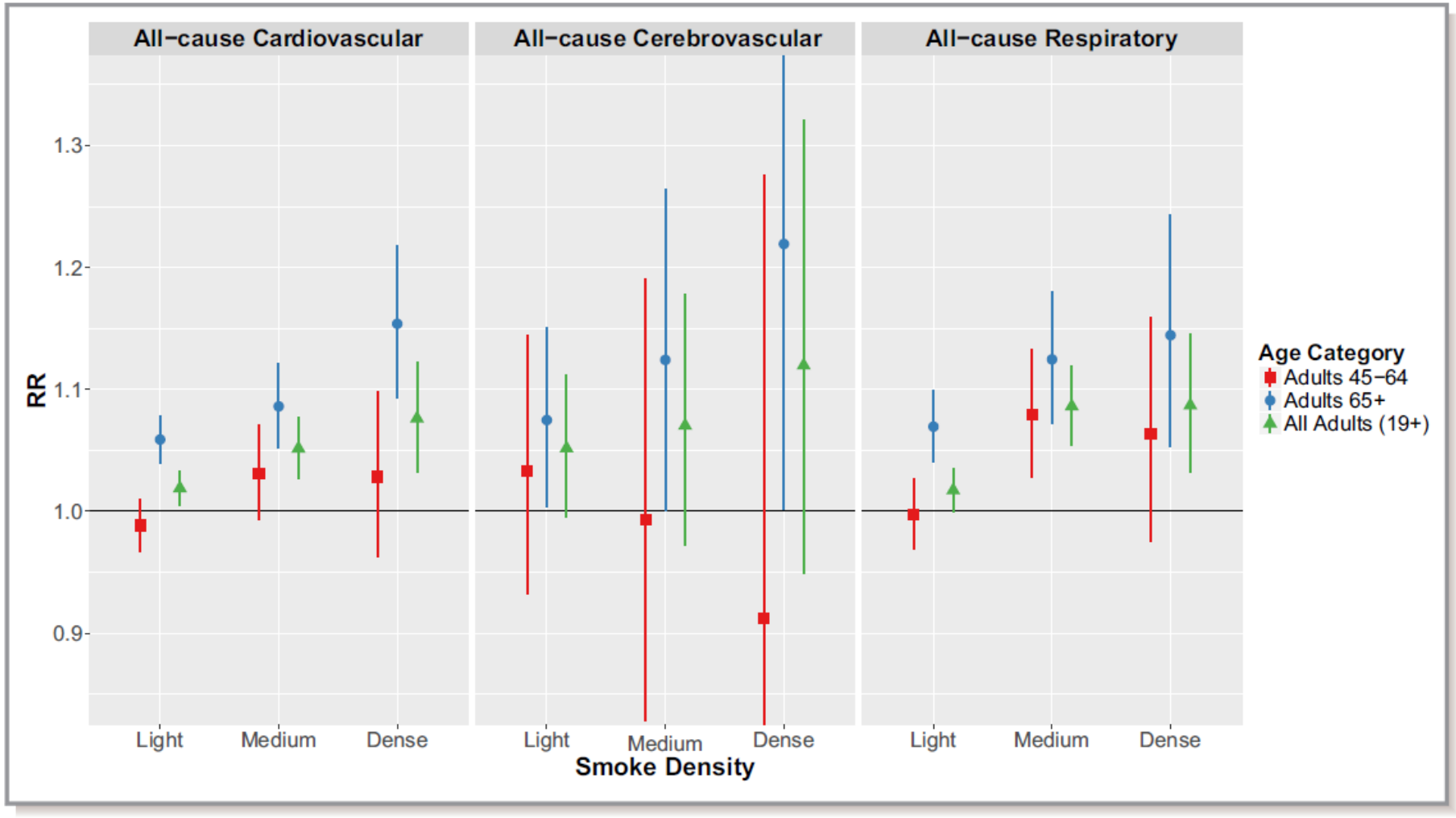
Wildfire-$PM_{2.5}$ Increases Heart Attack & Stroke

- ***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)



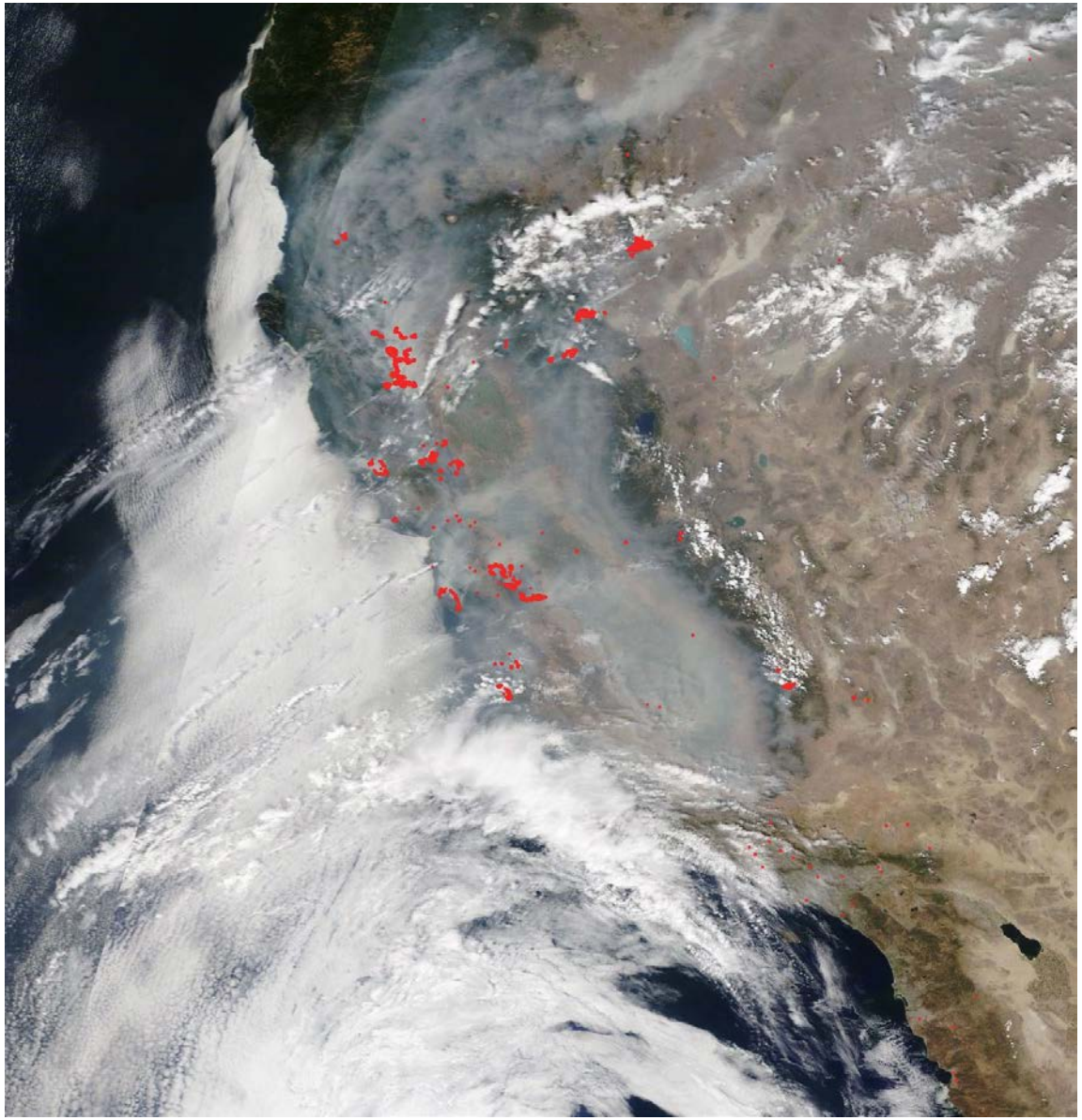
Wettstein Z, Hoshiko S, Cascio WE, Rappold AG et al. JAHA April 11, 2018

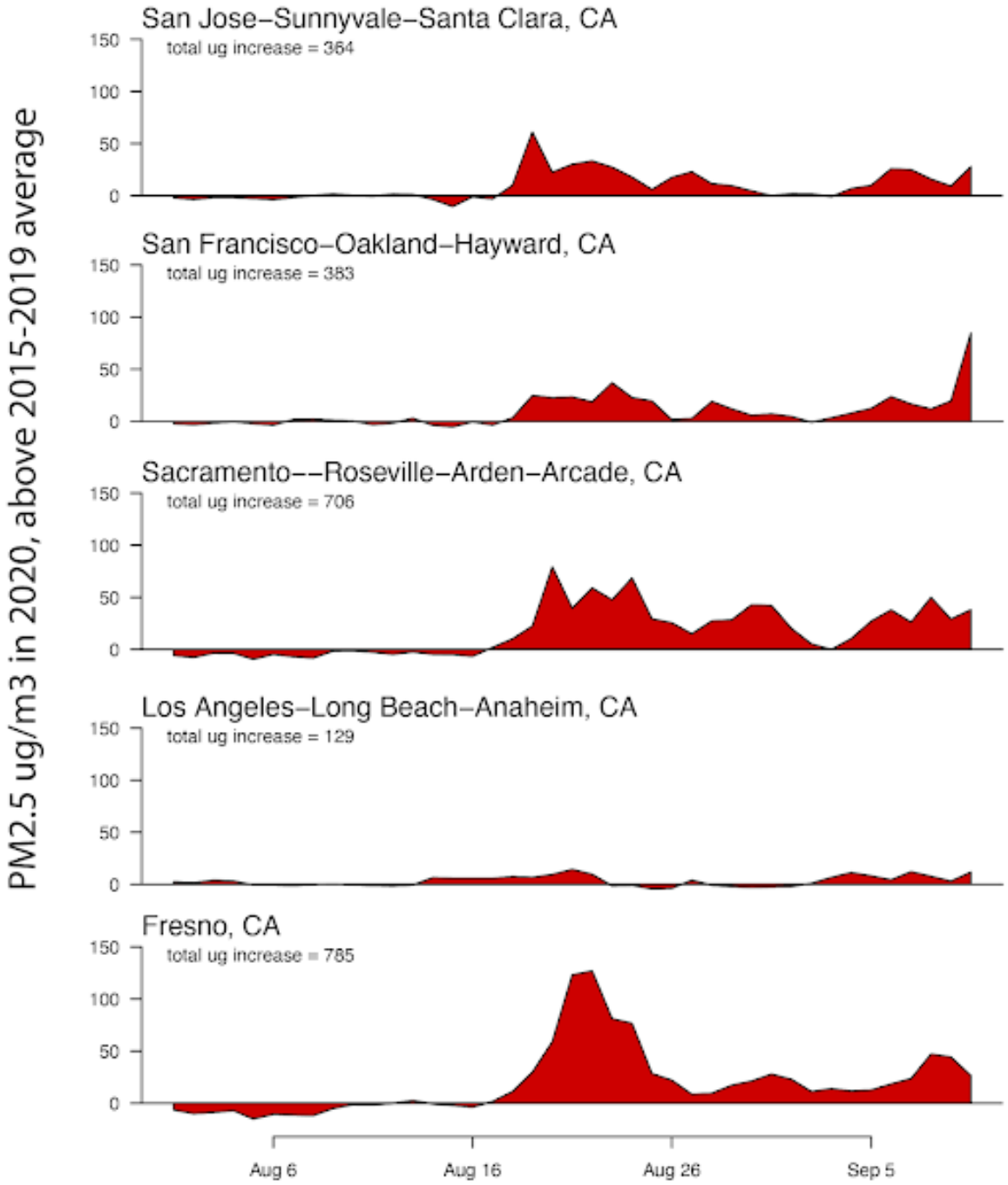
Slide credit: Wayne Cascio



Wettstein Z, Hoshiko S, Cascio WE, Rappold AG et al.
JAHA April 11, 2018

Aug. 24, 2020



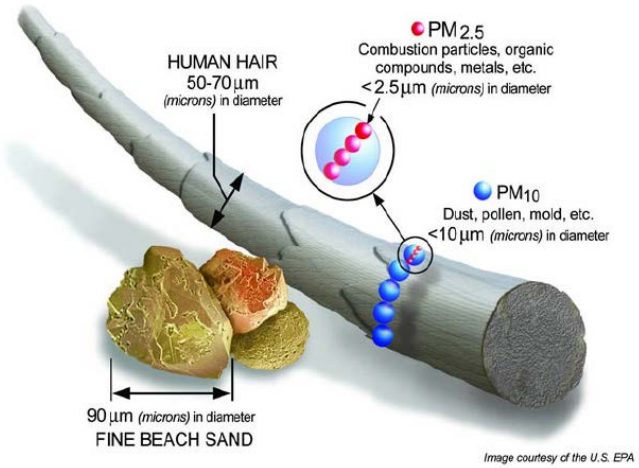


Estimated 1200-3000 excess deaths

Burke M, Stanford
PNAS 2021;118(2):e2011048118

Other Health Outcomes

- Adverse birth outcomes
  - Low birth weight, ? preterm birth
- Mental health
- ? Chronic effects from recurrent exposures based on the $PM_{2.5}$ literature
  - Metabolic outcomes
  - Cognitive decline
  - Child neurodevelopment
  - Decreased lung function growth
  - Health of pregnant mothers



Wildland Firefighter Health Effects

- Cross-shift changes in lung function, urinary biomarkers of exposure, and blood biomarkers of inflammation
- Pre-post season changes in lung function, airway responsiveness, and airway inflammation
- Do the fire season-associated changes persist?

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Wildland firefighter smoke exposure and risk of lung cancer and cardiovascular disease mortality

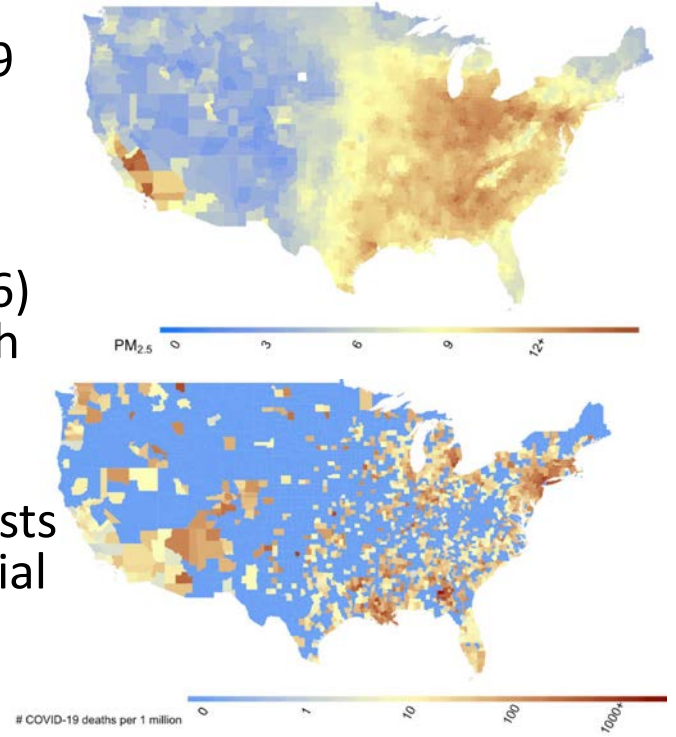
Kathleen M. Navarro[a], Michael T. Kleinman[b], Chris E. Mackay[c], Timothy E. Reinhardt[d], John R. Balmes[e], George A. Broyles[f], Roger D. Ottmar[g], Luke P. Naher[h], Joseph W. Domitrovich[i,*]

- Estimated the daily dose of wildfire smoke $PM_{2.5}$
- The daily dose for firefighters working 98 days per year of $PM_{2.5}$ ranged from 0.30 mg to 1.49 mg
- For career durations (5–25 years), wildland firefighters had an estimated increased risk of lung CA (8 percent to 43 percent) and CVD (16 percent to 30 percent) mortality

Environ Res 2019;173:462-468

Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study

- Examined county-level long-term $PM_{2.5}$ and COVID-19 mortality in 3,000 U.S. counties(~ 98% of the population)
- A 1 $\mu g/m^3$ higher in $PM_{2.5}$ (averaged for 2000 to 2016) associated with an 8% increase in the COVID-19 death rate (95% CI 2%, 15%)
- *April 24, 2020 revision:* data until April 22, 2020, adjusts for timing of the epidemic's spread, timing of the social distancing policies and population age distribution



Wu et al. Science Advances 2020

Summary

- Smoke from wildfires contains multiple toxicants, in both the particle and gas phases
- Smoke from catastrophic wildfires that burn buildings and motor vehicles contains many additional toxicants
- Vulnerable populations include young children, persons with heart and lung disease, pregnant women, outdoor workers
- Acute respiratory effects are well documented, but new studies suggest acute cardiovascular effects
- Other health effects are expected based on $PM_{2.5}$ studies
- Long-term effects of high and/or recurrent exposures need further study
- Risk of COVID-19 may be increased by wildfire smoke

Thank you