Title

Wildfires and Human Health

Journal

JAMA, 332(12)

ISSN

0098-7484

Authors

Fadadu, Raj P
Solomon, Gina
Balmes, John R

Publication Date

2024-07-10

DOI

10.1001/jama.2024.13600

Peer reviewed

Title: Wildfires and Human Health

Authors: Raj P. Fadadu, MD, MS[1,2*]; Gina Solomon, MD, MPH[3]; and John R. Balmes, MD[3,4]

Affiliations:

1 – Department of Epidemiology and Population Health, Stanford School of Medicine, Stanford, CA, USA

2 – Department of Dermatology, University of California, San Diego, San Diego, CA, USA

3 – Division of Occupational, Environmental, and Climate Medicine, Department of Medicine, University of California, San Francisco, San Francisco, CA, USA

4 – Division of Environmental Health Sciences, School of Public Health, University of California, Berkeley, Berkeley, CA, USA

Corresponding author:

Raj P. Fadadu: Department of Epidemiology and Population Health Stanford School of Medicine

300 Pasteur Drive, Stanford, California, USA 94305

Phone: +1 510-862-3159; E-mail: rfadadu@stanford.edu

Key words: wildfires, health, climate change, climate crisis, natural disasters, air pollution

Word Count: 1,196 words

Conflicts of Interest: R.P.F, G.S., and J.R.B have no conflicts of interest to disclose.

Revision Date: June 3, 2024

Acknowledgements: None.

Background on Wildfires and Air Pollution

Climate changes related to temperature, humidity, and drought are associated with an increased frequency, duration, and severity of wildfires in many countries.[1,2] Recent wildfires include those in the US (2017-2023), Australia (2019-2020), Canada (2023), Greece (2023), Russia (2021), the Amazon rainforest (2019), and Bolivia (2010). Each year, approximately 44 million people are exposed to unhealthy air quality due to wildfires worldwide.[2] While fire patterns vary year-to-year, meteorological data on wildfires have demonstrated that worldwide, people on average, experienced 6 more days of high fire danger in 2018-2022 compared to 2003-2007, and this exposure is projected to increase by 9 extra days per person (11% increase) by 2050.[3] Since 1985, land burned by wildfires in the U.S. each year has increased from approximately 1,000,000 hectares (3,900 square miles) to over 3,000,000 hectares (11,500 square miles).[1] This trend is associated with climate change, geographic seasonal wind patterns, and historic suppression of fires, the practice of extinguishing all fires quickly leading to an accumulation of unburnt biomass that can fuel future, larger fires. Human inhabitation of forest lands increases wildfire risk through accidental and intentional fires and places human habitation closer to the wildland-urban interface.

The chemical composition of wildfire air pollution depends on the material burned, the fire temperature, and duration of burning. Wildfires emit harmful gases, such as carbon

monoxide, volatile organic compounds (VOCs), nitrogen oxides, and particulate matter.[2] Wildfires across the U.S. have accounted for up to 25% of $PM_{2.5}$ (particulate matter with diameter <2.5 μm) emissions annually.[1] Wildfire smoke $PM_{2.5}$ can emit more carbon [AU-OK?] more carbon and have more oxidative potential [AU- please replace "oxidative potential" with formal, precise language] than non-wildfire $PM_{2.5}$, making it up to 10 times more toxic than PM from other sources.[4] In a study of wildfires in Southern California from 1999-2012, exposure to wildfire-specific $PM_{2.5}$ was associated with greater respiratory hospital admissions than exposure to non-wildfire $PM_{2.5}$ (10% vs. 0.72% increase, respectively).[4] When wildfires extend into the wildland-urban interface, combustion of synthetic materials generates toxic pollutants, such as hydrochloric acid, phosgene, and hydrogen cyanide.

Adverse Health Effects

Exposure to poor air quality from wildfires is associated with adverse health effects, such as asthma, COPD, myocardial infarction, arrhythmias, and heart failure.[2] Exposure to poor air quality from wildfires is also associated with dermatologic (e.g., psoriasis), reproductive (e.g., low birth weight), neurologic (e.g., dementia and stroke), and infectious (e.g., coccidioidomycosis) diseases. Reactive oxygen species, localized and systemic inflammation, endothelial damage, nervous system dysfunction, and epigenetic modifications are potential biological explanations for these associations.[2] Individuals affected by wildfires have higher risk for post-traumatic stress disorder, depression, and substance use as a result of population displacement, trauma, and economic stress.

Wildfire smoke can spread, causing hazardous air quality in areas with typically low levels of air pollution. This results in adverse health effects for people living far away from the

wildfire. In 2023, when wildfire air pollution from Quebec spread to New York City, emergency department visits for asthma increased from 181.5 per day (reference) to 261(incidence rate ratio of 1.4; 95% CI, 1.3-1.6).[5] Smoke from the Camp Fire in 2018 [AU- please briefly describe the Camp Fire in 2018] led to a 9-fold increase in average weekly $PM_{2.5}$ concentration in San Francisco, California (10-$\mu g/m^3$ to 90-$\mu g/m^3$), which was associated with increased weekly pediatric atopic dermatitis physician visits: rate ratio of 1.5 (95% CI, 1.1, 2.1).[6] Wildfire-induced $PM_{2.5}$ in the U.S. from 2012-2014 contributed to approximately 4,000 premature deaths, corresponding to a $36 billion economic loss.[7]

Health risks of wildfires are distributed inequitably across society. While most counties in the U.S. have experienced increased days with wildfire smoke exposure (smoke days), census tracts in the highest social vulnerability index tertile experienced the largest increase in the mean number of heavy smoke days (high density of smoke on satellite imaging correlating to concentration of $PM_{2.5}$ >21-$\mu g/m^3$) per year, from 0.92 days (95% CI, 0.91-0.93) in 2011-2015 to 4.21 days (95% CI, 4.18-4.25) in 2017-2021.[8] Vulnerable populations include children (who inhale more air in proportion to their body size than adults), older patients with multiple comorbidities, those living in wildfire-prone areas, unhoused individuals, and those from low socioeconomic backgrounds. Wildland firefighters and other outdoor workers, such as agricultural and construction workers, are at higher risk of adverse smoke-related health outcomes due to occupational exposures.

Clinical Practice and Public Health Implications

Patients with preexisting diseases are at risk for exacerbations due to exposure to air pollution from wildfires. Patients with cardiopulmonary conditions, such as asthma or COPD,

should be advised to adjust medication use during wildfire events, for example by increasing use of inhaled bronchodilator rescue medications. Clinicians should counsel all at-risk patients to reduce their smoke exposure by staying indoors with windows closed, improving indoor air quality with portable High Efficiency Particulate Air (HEPA) air cleaners or Minimum Efficiency Reporting Value (MERV) 13 filtration in central ventilation systems, and wearing N95 respirators if going outdoors. These interventions reduce air pollution exposure at the individual level and can halve particulate matter infiltration rates into indoor settings[9]. A modeling study of the 2012 Washington state fire season estimated a 30% (SD: 22% - 39%) reduction in total smoke-related respiratory hospitalizations associated with wearing N95 respirators during wildfires, with greater benefits observed for high-risk populations wearing well-fitted masks.[10]

Clinicians can educate patients about wildfire-associated health risks, air pollution surveillance and exposure reduction strategies, and disaster preparedness resources (e.g., "grab-and-go" bags) during clinic visits and hospitalizations. A "grab-and-go bag" is a kit that includes non-perishable food, water, medications, first aid and survival materials, pet supplies, and toiletries sufficient to last several days and is prepared to facilitate rapid evacuations. Examples of patient communication methods include flyers or posters in waiting rooms, alerts sent through patient health portals, automated phone calls or text messages, and auto texts ("dot phrases") or quick-response (QR) codes linking to online resources added to after-visit summaries. Patients with certain health conditions, such as asthma or COPD, should be advised to develop a management plan that includes having an adequate supply of medications, monitoring local and indoor air quality, using HEPA air cleaners indoors, and forming an evacuation plan during wildfire season. Medical staff can facilitate patient enrollment in local phone emergency and evacuation alert systems that are available in most areas in the U.S. Clinicians should refer

patients to social workers and mental health clinicians to address the social determinants of health affected by wildfires.

Multiple online resources are available for patients to use to protect their health during wildfires (BOX). The U.S. EPA AirNow.gov website and app provide timely information about local air quality and possible health risks with a color scale. The EPA SmokeSense app provides current and forecasted information on wildfires, monitors personal health symptoms, and tests health risk communication messages. Regarding patient and clinician education, the Western States Pediatric Environmental Health Specialty Unit (PEHSU) website (https://wspehsu.ucsf.edu/projects/wildfires-and-childrens-health-2/) and UCSF Wildfires & Health Education Hub (https://climatehealth.ucsf.edu/wildfires-health-education-hub) have information on wildfire health risks and exposure reduction that is available in several languages.

Wildfires affect human health and healthcare systems in multiple ways, some of which are still being identified. Clinicians can mitigate the health threats of wildfires through clinical care, community education, academic research, political advocacy, and public health practice.

References:

1. Burke M, Driscoll A, Heft-Neal S, Xue J, Burney J, Wara M. The changing risk and burden of wildfire in the United States. *Proc Natl Acad Sci*. 2021;118(2):e2011048118. doi:10.1073/pnas.2011048118

2. Gould CF, Heft-Neal S, Prunicki M, Aguilera J, Burke M, Nadeau K. Health Effects of Wildfire Smoke Exposure. *Annu Rev Med*. Published online September 22, 2023. doi:10.1146/annurev-med-052422-020909

3. Romanello M, Napoli C di, Green C, et al. The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. *Lancet Lond Engl*. 2023;402(10419):2346-2394. doi:10.1016/S0140-6736(23)01859-7

4. Aguilera R, Corringham T, Gershunov A, Benmarhnia T. Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California. *Nat Commun*. 2021;12(1):1493. doi:10.1038/s41467-021-21708-0

5. Chen K, Ma Y, Bell ML, Yang W. Canadian Wildfire Smoke and Asthma Syndrome Emergency Department Visits in New York City. *JAMA*. 2023;330(14):1385-1387. doi:10.1001/jama.2023.18768

6. Fadadu RP, Grimes B, Jewell NP, et al. Association of Wildfire Air Pollution and Health Care Use for Atopic Dermatitis and Itch. *JAMA Dermatol*. 2021;157(6):658-666. doi:10.1001/jamadermatol.2021.0179

7. Pan S, Gan L, Jung J, et al. Quantifying the premature mortality and economic loss from wildfire-induced PM2.5 in the contiguous U.S. *Sci Total Environ*. 2023;875:162614. doi:10.1016/j.scitotenv.2023.162614

8. Vargo J, Lappe B, Mirabelli MC, Conlon KC. Social Vulnerability in US Communities Affected by Wildfire Smoke, 2011 to 2021. *Am J Public Health*. 2023;113(7):759-767. doi:10.2105/AJPH.2023.307286

9. Liang Y, Sengupta D, Campmier MJ, Lunderberg DM, Apte JS, Goldstein AH. Wildfire smoke impacts on indoor air quality assessed using crowdsourced data in California. *Proc Natl Acad Sci U S A*. 2021;118(36):e2106478118. doi:10.1073/pnas.2106478118

10. Kodros JK, O'Dell K, Samet JM, L'Orange C, Pierce JR, Volckens J. Quantifying the Health Benefits of Face Masks and Respirators to Mitigate Exposure to Severe Air Pollution. *GeoHealth*. 2021;5(9):e2021GH000482. doi:10.1029/2021GH000482