

Growing Up in a Warming World

How Wildfire Smoke Affects Early Childhood Development

The year 2024 was the hottest on record and had the greatest number of global wildfires in history.¹ In the last two decades, the frequency and intensity of “extreme” wildfires—those that have significant social, economic, or ecological impacts or are beyond the limits of fire control²—have more than doubled. In the forests of the western United States, extreme fires have increased more than tenfold in the last 20 years.³ Trees are drier and, therefore, more likely to catch fire due to extended droughts, now more common because of climate change. Prolonged heat waves weaken the resilience of plants, and warmer year-round temperatures have enabled invasive beetles to flourish and leave large swaths of dead trees that serve as fuel and help spread and intensify fires.⁴

Wildfire smoke increasingly affects the daily lives of millions of Americans and presents a major threat to the health and development of young children. It is critical that we understand how wildfire smoke impacts children’s development and health. We must also implement available solutions to protect young children while taking action to limit the burning of fossil fuels like oil, coal, and gas, which is worsening the conditions that lead to longer, more frequent, and more intense wildfires. Solutions can be implemented in ways that help safeguard all the places where children spend time, including homes, early care centers, schools, businesses, and communities. (See below for more detail on solutions.)

Wildfire smoke begins outdoors, but it quickly gets inside buildings via open windows, invisible cracks and crevices, and ventilation systems without high-quality filters.⁵ It includes a potent and harmful mixture of particulate matter, black carbon, chemicals such as carbon monoxide and nitrogen dioxide, as well as hundreds of other toxins that are formed when fuel sources such as furniture, homes, and cars are burned. All of these pollutants can cause negative consequences for children’s development and health when they enter the body.⁶ **Developing a strategy to protect people from wildfire smoke during pregnancy and early childhood—both indoors and out—represents a critical opportunity to improve the lifelong health and well-being of children.**

While wildfires have acute and immediate health impacts for nearby communities, wildfire smoke can also travel thousands of miles from the source and still be highly toxic—as much as 10 times more toxic than airborne particles from sources such as auto and factory emissions or cigarette smoke.⁷ If a fire consumes buildings, gas stations, landfills, or industrial facilities, smoke can become even more toxic, carrying heavy metals such as arsenic, lead, cadmium, and mercury at concentrations far higher than typical air pollution. These toxic metals stick to pieces of ash and dust, which float in the air and can be inhaled.⁸ For example, in California cities affected by smoke from the Camp Fire in 2018, lead levels in the air were 50 times higher than normal.⁶ And months after the wildfires in Maui in 2023, dangerous levels of arsenic, lead, cobalt, and copper were found in ash that had settled in the affected area.⁹ When wildfire smoke exposure occurs together with other harmful exposures, such as emissions from factories, highways, toxic chemical waste, and extreme heat, the compounding effect is particularly harmful to children’s development. These compounded exposures are more likely to occur in neighborhoods that have experienced longstanding discrimination and disinvestment.^{10,11}

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Exposure to wildfire smoke during pregnancy can have a significant negative impact on healthy birth outcomes. During pregnancy, wildfire smoke can trigger the body’s inflammatory response and lead to gestational hypertension as well as adverse pregnancy outcomes such as preeclampsia, low birth weight, and preterm birth. These effects are significant: One California study estimated that nearly 7,000 excess preterm births were attributable solely to wildfire smoke between 2006 and 2012.⁶ Preterm births are linked to a greater risk of a range of poor outcomes later in life, including impaired cognition, reduced growth, and chronic health issues such as cardiovascular disease and diabetes in adulthood.¹²⁻¹⁸

Beyond birth outcomes, studies indicate that children who live in areas with exposure to wildfire smoke have increased rates of emergency room visits for asthma during periods of smoke exposure, as well as increased upper respiratory infections, pneumonia, and bronchitis.¹⁹ Wildfire smoke also affects learning. In a nationwide study, smoke exposure in the year leading up to a test, particularly on school days, significantly decreased student test scores—the more smoke that children were exposed to, the lower the average test scores.²⁰

A wide range of strategies already exists to protect children from the threat of wildfire smoke. Together, we can help ensure that all children have the opportunity to thrive in environments that support their development and lifelong health.

Strategies to Reduce the Impact of Wildfire Smoke on Child Health and Development

All of us—whether we are policymakers, health care providers, community leaders, or caregivers—can help enact and advocate for a range of already available solutions, prioritizing those who face the greatest risk due to longstanding discrimination and disinvestment.

- **Support access to air filtration systems and masks** to ensure we protect children during wildfire events and after, when pollution remains high. When air quality levels are unsafe, infants and children—particularly the youngest children who are unable to wear masks—should avoid being outdoors and should have access to an indoor space with clean air. Air filtration systems should use high-efficiency filters to prevent as many airborne particles as possible from reaching the lungs—surgical masks, bandanas, and systems with lower-quality or uncleaned filters are not sufficient. In situations where masks are needed, it is important to note that masks were not designed for infants’ and young children’s faces and should not be relied upon as adequate protection against the effects of wildfire smoke. Critically, masks for caregivers and older children who can wear them should be rated N95 or higher.
- **Create clean air spaces in the places where young children spend time.** Schools, childcare centers, businesses, and other places where infants and young children spend time should be adapted to serve as clean air shelters that can provide protection during wildfire events: Windows should be well-sealed to prevent outdoor air from coming in, and central air conditioning systems should be fitted with filters that are rated MERV13 or higher to effectively capture the particles in wildfire smoke. When portable air cleaners are used to clean indoor air, they should be appropriately sized for the room they clean. Filters in portable units must be changed after a wildfire, as reactions with the smoke can render them much less effective.^{19,21}
- **Activate localized air quality alerts and ensure that pregnant people and caregivers receive them.** For example, the AirNow website and smartphone app partner with multiple national, tribal, state, and local agencies to communicate about air quality in any given area of the US. If the Air Quality Index is red or purple (or orange for sensitive groups), it should alert people to take action,²² such as wearing N95 masks outside or inside, keeping unhealthy air out of indoor spaces, seeking clean air shelters, and preparing to evacuate if necessary.²² Pediatric and prenatal care providers can counsel patients about the availability of these alert systems and what to do when air quality is unsafe.
- **Implement policies for improved forest management.** To address conditions like higher temperatures and increased droughts caused by climate change—which make forests more likely to burn—there is a critical need for expanded forest management policies. In 2022, the US Department of Agriculture’s Forest Service announced a \$500 million, 10-year strategy to reduce wildfire risk, focusing initially on 21 priority landscapes across the West. The program includes prescribed burns and a risk reduction effort with partners representing underserved communities. It has since expanded to include collaboration with the Environmental Protection Agency (EPA), the Department of the Interior (DOI), and the Centers for Disease Control and Prevention (CDC) to address the health and community impacts of wildfire smoke.²³ Ongoing support for the Forest Service and EPA to continue these cross-agency collaborations is critical to preventing and limiting the effects of future wildfires.
- **Embrace and incorporate Indigenous knowledge and practices to make forests more resilient.** Indigenous knowledge is increasingly being included in public policy and practice as a mainstream method for reducing the intensity and severity of wildfires, as well as improving biodiversity, reducing pests, and increasing water availability.^{24,25} A combination of recent studies, Indigenous knowledge, and historical photographs demonstrates that prescribed burns, as practiced by many Indigenous communities—strategically targeting relatively small portions of a landscape—can reduce the amount of dead trees and undergrowth that serve as fuel. This can greatly moderate extreme wildfires—with less available fuel, fires burn more slowly and are easier to extinguish. Increasing the variety of tree and plant species in forests, including areas of open space and areas where there is not abundant natural fuel, has also been shown to promote landscape resilience to severe fire while rejuvenating shrubs and other plant and animal species.²⁴
- **Reduce reliance on fossil fuels.** Each of the above efforts is important, but it is also urgent and essential that federal and local policymakers and business leaders take steps to drastically reduce our use of and reliance on fossil fuels, including oil, coal, and gas.^{26,27} Such efforts must include community engagement, input, and support, leveraging the full range of available solutions, including converting to cleaner energy sources.

Resources to Learn More and Take Action

- [US Forest Service: Confronting the Wildfire Crisis Initiative](#)
Addresses the growing threat of wildfires in the US by focusing on forest restoration, fire management, and protecting communities at risk from large-scale wildfires.
- [Community Planning Assistance for Wildfire \(CPAW\)](#)
Supports communities in wildfire-prone areas by providing planning tools, strategies, and resources to reduce wildfire risks and enhance community resilience to fire hazards.
- [Fire Adapted Communities Learning Network](#)
Helps communities develop and implement fire-adapted practices to mitigate wildfire risks and protect lives, property, and ecosystems.
- [AirNow Fire and Smoke Map](#)
Provides real-time data on air quality and wildfire smoke to help track pollution levels and make informed decisions to protect health during wildfire events.
- [National Park Service: Indigenous Fire Practices Shape our Land](#)
Explores the role of traditional Indigenous fire practices in managing ecosystems and restoring fire resilience through sustainable land stewardship.
- [Healthy Buildings Program at the Harvard T.H. Chan School of Public Health](#)
Focuses on research and strategies to improve indoor air quality and reduce health risks in buildings, especially schools, by adopting evidence-based health and safety measures.

References

1. National Oceanic and Atmospheric Administration. 2024 was the world’s warmest year on record. Published Jan 10 2025. Accessed Jan 16 2025. <https://www.noaa.gov/news/2024-was-worlds-warmest-year-on-record>
2. Castro Rego F, Morgan P, Fernandes P, Hoffman C. Extreme Fires. In: Rego FC, Morgan P, Fernandes P, Hoffman C, eds. *Fire Science: From Chemistry to Landscape Management*. Springer International Publishing; 2021:175-257.
3. Cunningham CX, Williamson GJ, Bowman DMJS. Increasing frequency and intensity of the most extreme wildfires on Earth. *Nature Ecology & Evolution*. Jun 24 2024. doi:10.1038/s41559-024-02452-2
4. US Geological Survey. Wildfire and Climate Change. Accessed Jul 14 2024. <https://www.usgs.gov/science-explore/climate/wildfire>
5. Ghetu CC, Rohlman D, Smith BW, et al. Wildfire Impact on Indoor and Outdoor PAH Air Quality. *Environ Sci Technol*. Jul 19 2022; 56(14):10042-10052.
6. Basilio E, Chen R, Fernandez AC, Padula AM, Robinson JF, Gaw SL. Wildfire Smoke Exposure during Pregnancy: A Review of Potential Mechanisms of Placental Toxicity, Impact on Obstetric Outcomes, and Strategies to Reduce Exposure. *Int J Environ Res Public Health*. Oct 22 2022;19(21). doi:10.3390/ijerph192113727
7. Wegesser TC, Pinkerton KE, Last JA. California Wildfires of 2008: Coarse and Fine Particulate Matter Toxicity. *Environmental Health Perspectives*. 2009;117(6):893-897. doi:10.1289/ehp.0800166
8. State of Hawaii, Dept of Health. Lahaina Ash Characterization Testing Show Elevated Levels of Toxic Substances. Accessed Dec 10 2023. <https://health.hawaii.gov/news/newsroom/lahaina-ash-characterization-testing-show-elevated-levels-of-toxic-substances/>
9. State of Hawaii, Dept of Health. Maui Wildfire Data: Ash. Accessed Jan 16 2025. <https://health.hawaii.gov/environmental-data/ash/>
10. Do V, Chen C, Benmarhnia T, Casey JA. Spatial Heterogeneity of the Respiratory Health Impacts of Wildfire Smoke PM(2.5) in California. *Geohealth*. Apr 2024;8(4):e2023GH000997. doi:10.1029/2023GH000997
11. Chen C, Schwarz L, Rosenthal N, Marlier ME, Benmarhnia T. Exploring spatial heterogeneity in synergistic effects of compound climate hazards: Extreme heat and wildfire smoke on cardiorespiratory hospitalizations in California. *Science Advances*. 2024;10(5):eadj7264. doi:10.1126/sciadv.adj7264
12. Harder T, Rodekamp E, Schellong K, Dudenhausen JW, Plagemann A. Birth weight and subsequent risk of type 2 diabetes: a meta-analysis. *Am J Epidemiol*. Apr 15 2007;165(8):849-57. doi:10.1093/aje/kwk071
13. Ferrie JE, Langenberg C, Shipley MJ, Marmot MG. Birth weight, components of height and coronary heart disease: evidence from the Whitehall II study. *Int J Epidemiol*. Dec 2006;35(6):1532-42. doi:10.1093/ije/dyl184
14. Palatianou ME, Simos YV, Andronikou SK, Kiortsis DN. Long-term metabolic effects of high birth weight: a critical review of the literature. *Horm Metab Res*. Dec 2014;46(13):911-20. doi:10.1055/s-0034-1395561
15. Svandova L, Ptacek R, Vnukova M, et al. Cognitive and Socioemotional Development at 5 and 9 Years of Age of Children Born with Very Low Birth Weight and Extremely Low Birth Weight in the Czech Republic. *Med Sci Monit*. Mar 29 2022;28:e935784. doi:10.12659/MSM.935784
16. Jarjour IT. Neurodevelopmental outcome after extreme prematurity: a review of the literature. *Pediatr Neurol*. Feb 2015;52(2):143-52. doi:10.1016/j.pediatrneurol.2014.10.027
17. UNICEF-WHO. UNICEF-WHO Low birthweight estimates: Levels and trends 2000-2015. Updated May 2019. Accessed Sept 23 2023. <https://www.who.int/publications/i/item/WHO-NMH-NHD-19.21>
18. Konkel L. Taking the Heat: Potential Fetal Health Effects of Hot Temperatures. *Environ Health Perspect*. Oct 2019;127(10):102002. doi:10.1289/ehp.6221
19. Holm SM, Miller MD, Balmes JR. Health effects of wildfire smoke in children and public health tools: a narrative review. *J Expo Sci Environ Epidemiol*. Feb 2021;31(1):1-20. doi:10.1038/s41370-020-00267-4
20. Wen J, Burke M. Lower test scores from wildfire smoke exposure. *Nature Sustainability*. Nov 1 2022;5(11):947-955. doi:10.1038/s41893-022-00956-y
21. Fadau RP, Solomon G, Balmes JR. Wildfires and Human Health. *JAMA*. Jul 10 2024. doi:10.1001/jama.2024.13600
22. AirNow. Air Quality Index (AQI) Basics. Accessed Jul 31 2024. <https://www.airnow.org/aqi/aqi-basics/>
23. USDA Forest Service. Confronting the Wildfire Crisis. Accessed Jul 14 2024. <https://www.fs.usda.gov/managing-land/wildfire-crisis>
24. Long JW, Lake FK, Goode RW. The importance of Indigenous cultural burning in forested regions of the Pacific West, USA. *Forest Ecology and Management*. Nov 15 2021;500:119597. doi:10.1016/j.foreco.2021.119597
25. White G, McDuff E. Embracing Indigenous Knowledge to Address the Wildfire Crisis. US Department of the Interior. Accessed Jul 27 2024. <https://www.doi.gov/wildlandfire/embracing-indigenous-knowledge-address-wildfire-crisis>
26. Xu R, Yu P, Abramson MJ, et al. Wildfires, Global Climate Change, and Human Health. *N Engl J Med*. 2020;383(2):2173-2181. doi:10.1056/NEJMsr2022895
27. MacCarthy J, Richter J, Tyukavina S, Weisse M, Harris N. The Latest Data Confirms: Forest Fires Are Getting Worse. World Resources Institute. Updated Aug 13 2024. Accessed Aug 28 2024. <https://www.wri.org/insights/global-trends-forest-fires>