Increasing wildfire smoke from the climate crisis: Impacts on asthma and allergies

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Catastrophic wildfires have been increasing around the globe, including in Australia, Chile, Indonesia, Portugal, Russia, the United States, and Canada. Over the past year alone, there have been massive fires in Canada that have blanketed major sections of North America with poor air quality because of wildfire smoke. Climate change is a major driver of the increased frequency and severity of wildfires owing to warmer temperatures, drought, and more extreme weather.[1] Because catastrophic wildfires fueled by high winds are more difficult to suppress and there has been an increase in the population living within the wildland-urban interface (WUI), fires are overrunning neighborhoods and whole towns. The recent devastation of the town of Lahaina on Maui reminds us of the extreme danger of WUI fires.

Smoke from catastrophic wildfires has also caused extended periods of poor air quality in large areas downwind. Wildfire smoke is a heterogenous mixture of carbon dioxide, carbon monoxide, nitrogen oxides, particulate matter (PM), complex hydrocarbons such as polycyclic aromatic hydrocarbons and dioxins, and irritant gases (eg, acrolein, benzene, and formaldehyde)—many of the same toxic and carcinogenic substances as found in cigarette smoke.[2] The composition of wildfire emissions varies depending on the type of fuel, meteorologic conditions, and burning conditions. Wildfire smoke undergoes chemical transformations in the atmosphere that alter its composition as the smoke travels downwind; secondary pollutants, such as ozone and secondary organic aerosol, are also generated. When synthetic materials burn in WUI fires, even more toxic materials such as phosgene and hydrochloric acid are emitted. Fine PM (particulate matter <2.5 μm in diameter [$PM_{2.5}$]) is a major toxic component of wildfire smoke and is used to assess public exposure to smoke. Concentrations of $PM_{2.5}$ because of wildfire smoke have been extremely high in US cities, with a peak of 200 $\mu g/m^3$ in New York City in June 2023.[3] For reference, the health-based US Environmental Protection Agency 24-hour average air quality standard is 35 $\mu g/m^3$.

ALLERGIC AND IMMUNOLOGIC EFFECTS OF WILDFIRE SMOKE

Studies assessing allergic and immunologic changes at the cellular level have shown changes in innate immunity and protein expression following exposure to wildfire smoke.[4] These allergic and immunologic effects of wildfire smoke are particularly problematic because climate change is increasing other allergic triggers in addition to the increases in wildfires and wildfire smoke. Global warming has led to higher allergen exposure owing to changes in growing seasons and areas (eg, wider distribution of ragweed in the United States).[5]

Perhaps the best-established health effect of short-term exposure to wildfire smoke is exacerbation of asthma in children and adults.[6] Whereas short-term exposure to ambient $PM_{2.5}$ from nonwildfire sources such as combustion of fossil fuels increases the risk of asthma exacerbations, wildfire-specific $PM_{2.5}$ may be even more toxic to children's respiratory health.[7] Wildfire-exposed individuals experience symptoms of conjunctivitis and rhinitis, especially if they have preexisting atopy.

Wildfire smoke likely affects the lower airways and lungs by mechanisms similar to those associated with nonwildfire $PM_{2.5}$ exposure, including alteration of T_H1/T_H2 cell responses, oxidative stress, and disrupted epithelial barrier function.[4] A specific example of a wildfire smoke component with known immunologic effects is polycyclic aromatic hydrocarbons. These compounds can affect regulatory T cells' function through an epigenetic mechanism, namely, methylation of FOXP3, which increases manifestations of atopic conditions such as asthma, conjunctivitis, and rhinitis.[8]

Similar to the evidence in studies regarding asthma, there is strong evidence supporting increased risk of exacerbations of chronic obstructive pulmonary disease in association with exposure to wildfire smoke.[6] Some studies also support increased risk of emergency department visits and hospitalizations for acute bronchitis and pneumonia with wildfire smoke exposure, but the evidence is mixed.[6]

In addition, there are other potential allergic and immunologic effects of wildfire smoke that are less well described. Increased health care utilization for symptoms of atopic dermatitis secondary to wildfire smoke exposure has been reported.[9] This is consistent with evidence from studies of nonwildfire $PM_{2.5}$ indicating that exposure increases the risk of atopic dermatitis.

Because exposure to high levels of wildfire smoke is usually short-term and episodic, little is known about recurrent exposures, even though catastrophic fires will increase for the foreseeable future, making recurrent exposures likely. On the basis of studies of long-term exposures to nonwildfire $PM_{2.5}$, the potential health impacts of recurrent exposures to high levels of wildfire-specific

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FIG 1. Tips to protect people with asthma and allergies from wildfire smoke. An infographic developed by the Western States Pediatric Environmental Health Specialty Unit.

$PM_{2.5}$ are of concern, especially for young children and during gestation.[10] Evidence from studies of human exposures to non-wildfire $PM_{2.5}$ and animal exposures to wildfire-specific $PM_{2.5}$ suggest that abnormal development of immune function, slowed growth of lung function, and new-onset asthma are possible outcomes of wildfire-specific $PM_{2.5}$ exposure, For example, a study of rhesus monkeys exposed to ambient wildfire smoke during infancy reported altered immune function and decreased growth of lung function in adolescence.[4]

As we have already noted, young children, who have developing organ systems, are likely at increased risk for adverse allergic and immunologic effects of wildfire smoke. Children and adults with asthma and other preexisting respiratory or atopic conditions are at risk for exacerbations. Outdoor workers are vulnerable because of increased duration of exposure and increased minute ventilation during exertion. It is also imperative to note that extreme heat is often present during episodes of poor air quality owing to wildfire smoke; the combined impacts of heat and wildfire smoke increase the risk of adverse health outcomes.

People from low-income communities of color have increased vulnerability to health effects of wildfire smoke exposure from the cumulative impacts of structural determinants of health, including poverty, racial/ethnic discrimination, poor-quality housing, lack of access to health care, food insecurity, and dirty jobs requiring work outside.[3,6,10] These factors increase both susceptibility to adverse health outcomes and exposure to wildfire smoke.

PROTECTING OUR PATIENTS

To prevent adverse health effects of wildfire smoke, especially in vulnerable patients, it is wise to take preemptive steps to make homes more resilient to exposure, especially in wildfire-prone areas (Fig 1). These include creating a clean air space in the home by installing a minimum efficiency reporting value (MERV) 13 filter in a central ventilation system and/or using portable high-efficiency particulate air (HEPA) filtration devices or "air cleaners" (ie, those that contain a mechanical HEPA filter rather than an ionizer). Although some commercial HEPA air cleaners are relatively inexpensive, do-it-yourself approaches (eg, a box fan with MERV 13 filters) have also been shown to be effective in the short term. If one must go outside during episodes of poor air quality owing to wildfire smoke, wearing a National Institute for Occupational Safety and Health–-certified N95 respirator (or "N95 mask") can substantially reduce exposure,[10] although further reductions in

exposure would be possible in the future if a respirator were designed and regulated for use by the general public. Avoiding exercise and heavy exertion outdoors will also reduce exposure. Those with asthma should be sure to have medications on hand during wildfire season and talk to their health care provider about including wildfire smoke and other air pollution events in their asthma action plan.

Efforts to tackle the climate crisis and improve forest management are urgently needed to reduce the risk of wildfires. Clinicians are uniquely poised to advocate for such efforts to minimize these adverse health effects for our patients.

DISCLOSURE STATEMENT

Disclosure of potential conflict of interest: The authors declare that they have no relevant conflicts of interest.

REFERENCES

1. Spreading like wildfire: the rising threat of extraordinary landscape fires. UN Environment Programme. 2022 Available at: http://www.unep.org/resources/report/spreading-wildfire-rising-threat-extraordinary-landscape-fires. Accessed July 22, 2023.
2. Jaffe DA, O'Neill SM, Larkin NK, Holder AL, Peterson DL, Halofsky JE, et al. Wildfire and prescribed burning impacts on air quality in the United States. J Air Waste Manag Assoc 2020;70:583-615.
3. Bhatia A, Katz J, Sanger-Katz M. Just how bad is the pollution in New York? New York Times June 9, 2023. Available at: https://www.nytimes.com/interactive/2023/06/08/upshot/new-york-city-smoke.html. Accessed July 19, 2023.
4. Noah TL, Worden CP, Rebuli ME, Jaspers I. The effects of wildfire smoke on asthma and allergy. Curr Allergy Asthma Rep 2023;23:375-87.
5. D'Amato G, Holgate ST, Pawankar R, Ledford DK, Cecchi L, Al-Ahmad M, et al. Meteorological conditions, climate change, new emerging factors, and asthma and related allergic disorders. A statement of the World Allergy Organization. World Allergy Organ J 2015;8:25.
6. Reid CE, Maestas MM. Wildfire smoke exposure under climate change: impact on respiratory health of affected communities. Curr Opin Pulm Med 2019;25:179-87.
7. Aguilera R, Corringham T, Gershuno A, Leibel S, Benmarhnia T. Fine particles in wildfire smoke and pediatric respiratory health in California. Pediatrics 2021;147:e2020027128.
8. Hew KM, Walker AI, Kohli A, Garcia M, Syed A, McDonald-Hyman C, et al. Childhood exposure to ambient polycyclic aromatic hydrocarbons is linked to epigenetic modifications and impaired systemic immunity in T cells. Clin Exp Allergy 2015;45:238-48.
9. Fadadu RP, Grimes B, Jewell NP, Vargo J, Young AT, Abuabara K, et al. Association of wildfire air pollution and health care use for atopic dermatitis and itch. JAMA Dermatol 2021;157:658-66.
10. 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 2021;31:1-20.