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BRIEF REPORT

The Burden of Air Pollution on Skin Health: a Brief Report and Call to Action

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ABSTRACT

Introduction: Air pollution in North America has intensified due to wildfires in recent years. In 2023, the wildfires in the Canadian province of Quebec caused a southward spread of pollutants, negatively affecting air quality and thereby aggravating certain health conditions in northeastern USA. This study examines the impact of air pollution on atopic dermatitis (AD) and skin health and how wildfires can exacerbate the burden of disease.

Methods: Carbon monoxide levels measured by the U.S. Environmental Protection Agency (EPA) in the Boston region during the months following the Canadian wildfires of 2023 were collected from the U.S. EPA Outdoor Air Quality webpage. Patient records on dermatology clinic visits for dermatitis and eczema at the Mass General Brigham (MGB) hospital system, 300 miles from the wildfires, were examined, and the data compared with data from the corresponding months in 2019–2022 for historical control. No individual patient data were collected.

Results: A notable rise and atypical summer peak in carbon monoxide (CO) levels in the Boston region during 2023 correlated with a spike in AD, dermatitis, and eczema-related dermatology clinic visits within the MGB hospital system, as compared with the prior 4 years.

Conclusion: The synchronized atypical peaks of CO levels and AD-related visits during the summer of 2023 highlight the potential impact of acute air pollution events such as wildfires on air quality and the consequences for skin health. Air pollution, exacerbated by wildfires, can damage the skin through the smoke and chemicals utilized for extinguishing fires, which contain multiple potential allergens and irritants to the skin, such as CO, particulate matter (PM2.5), and ammonium phosphates, triggering airway and skin inflammation and flares of AD. This issue disproportionately affects vulnerable populations, including low-income

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communities and the geriatric and pediatric populations. Healthcare professionals and government agencies must work together to improve air quality and purification policies and initiatives to lower the burden of skin disease, especially for vulnerable communities.

Keywords: Air pollution; Atopic dermatitis; Carbon monoxide; Climate change; Eczema; Public health; Skin health; Vulnerable populations; Wildfires

Key Summary Points

Why carry out the study?

Acute air pollution events triggered by wildfires have been negatively affecting air quality and public health in major cities in the USA, with peak levels of air pollution leading to exacerbations in skin conditions in the northeast region of the USA after the Canadian wildfires in 2023.

The study aimed to investigate the short-term effects of wildfire-associated air pollution, in particular carbon monoxide (CO), on the number of atopic dermatitis (AD)-related dermatology visits in a hospital system in Boston, MA (USA).

What was learned from this study?

A notable rise and atypical summer peak in CO levels in the Boston region during 2023 correlated with a spike in AD, dermatitis, and eczema-related dermatology clinic visits within the Mass General Brigham hospital system.

These synchronized peaks in CO levels and dermatitis-related visits highlight the potential impact of air pollution on exacerbations of skin disease. Given the disproportionate impacts of air pollution on vulnerable communities, including the socioeconomically disadvantaged, children, and the elderly, public health and government agencies must work together to improve air quality purification policies to lower the burden of air pollution on skin disease.

INTRODUCTION

In June of 2023, New York City reached the highest levels of air pollution in its recorded history following wildfire events in Canada [1]. Such elevated pollution levels have not been confined to New York City: many other cities, including San Francisco (CA) and Portland (OR), have experienced comparable extremes during wildfire events (Fig. 1) [1]. Most recently, wildfires in Maui were the deadliest in the USA in over a century [2]. While the USA historically has had few air pollution crises, it now faces the ominous consequences of worsening air quality on human health, similar to those being experienced by other nations across the world. These recent events bring to mind the infamous London Fog in 1952 in which over 10,000 citizens lost their lives due to an acute smog event [3, 4]. China has been grappling with smog problems for decades, and the country's air pollution is estimated to cause over 1 million deaths annually [5, 6]. As the frequency and intensity of wildfires has reached new heights, it is becoming increasingly crucial to assess the exacerbating effects of air pollution on dermatologic conditions such as atopic dermatitis (AD), which affects 31 million people in the USA. [7].

The World Health Organization's (WHO) global air quality guidelines recommend that annual mean air concentrations of fine particulate matter (PM2.5) not exceed 5 $\mu g/m^3$; currently, less than 5% of the world population live in places where these air quality guidelines are met [8, 10]. Fine particulate matter (PM2.5) stems from a multitude of sources, including natural sources, such as wildfires, and anthropogenic ones, such as agriculture, vehicular traffic, power plants, and certain ingredients in fire extinguishing methods used to contain wildfires [11–13]. Studies from various countries have linked elevated levels of air pollutants, including PM2.5, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO), with increased prevalence and severity of AD [14, 15]. More recently, wildfires in North America have resulted in downwind air pollution, causing rises in CO concentrations [16] to levels that have been associated with a higher

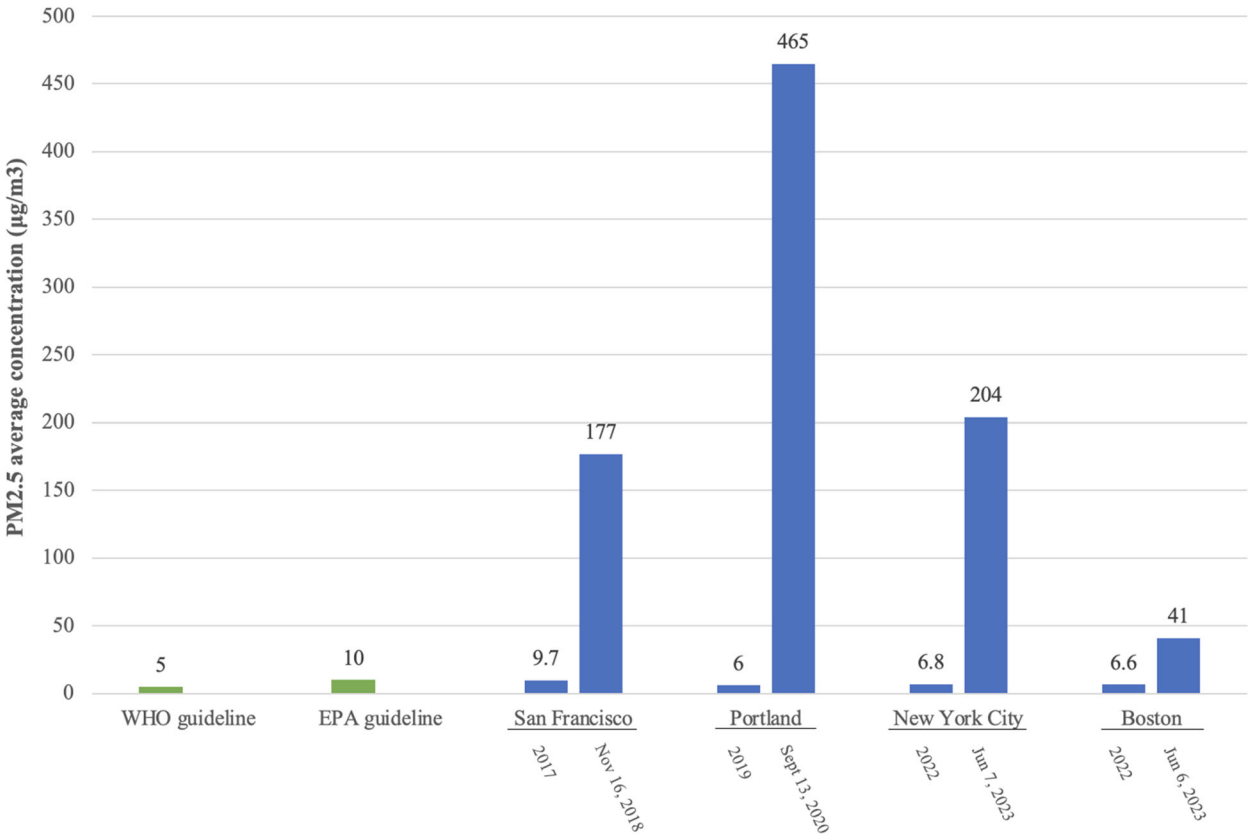

Fig. 1 Peak fine particulate matter (*PM2.5*) concentrations (µg/m^3) across recent air pollution events in North America, in comparison with baseline average concentrations, and guidelines established by the U.S. Environmental Protection Agency (*EPA*) and the World Health Organization (*WHO*) [8, 9, 30]

prevalence of AD [17]. Notably, fire retardants spread aerially during wildfires contain ammonium phosphates [12], which contribute to dermatitis [18] and lead to emissions of ammonia, a precursor for PM2.5 [13]. The pathophysiology of AD flares secondary to air pollution is multifaceted, involving skin barrier impairment, oxidative stress, activation of inflammatory pathways, and changes in skin flora [19]. Particulate matter coated with lipophilic polycyclic aromatic hydrocarbons (PAHs) can penetrate the skin to induce oxidative stress and activate inflammatory signaling receptors, including the pregnane X receptor (PXR) and the aryl hydrocarbon receptor (AhR) [20–22]. Upregulation of these receptors by PAHs can lead to disruption of the skin barrier and skewing of the immune response towards a Th2 phenotype, which is central to the development and progression of AD [23–25].

Wildfire events such as the California Camp Fire in November of 2018 have starkly demonstrated the impact of short-term air pollution spikes on skin health. Following the fire, San Francisco experienced a surge in air pollutants such as PM2.5, which triggered a heightened demand for healthcare services for AD and pruritus [26]. Notably, adults aged ≥ 65 years were disproportionately affected, indicating a potential for increased vulnerability of the aging skin barrier to acute pollutant exposure [27].

The impacts of air pollution on human health extend beyond immediate vicinities, affecting communities both near and downwind of wildfires [16], and wildfire pollutants (other than PM2.5) can also play a central role

in the negative impacts on skin health. For example, the atmospheric longevity of CO, which arises from incomplete combustion during wildfires, serves as a marker for tracking the transport of pollutants [16], and thus may be useful in examining the downstream impacts of acute air pollution events such as the 2023 Quebec (Canada) wildfires in the northeastern USA. The aim of our study was to investigate the short-term outcomes of the Quebec wildfire-associated air pollution on skin health and subsequent AD, dermatitis, and eczema-related visits in Boston (MA, USA), a large city center located approximately 300 miles from the fires in Quebec.

METHODS

Carbon monoxide levels measured by the U.S. Environmental Protection Agency (EPA) in the Boston region were collected from the U.S. EPA Outdoor Air Quality webpage for May through July of 2023, the months including and following the wildfires in the Canadian province of Quebec. A system-wide query was performed of patient encounters in dermatology clinics of the Mass General Brigham hospital system with International Classification of Diseases, Tenth Revision (ICD-10) codes involving AD, dermatitis, and eczema for May through September of 2023. The query was performed with the assistance of Massachusetts General Hospital Information Systems. Air quality data for CO levels and clinical visit data for the corresponding months (May through September) in the 4 years prior to this event (2019–2022) were then compared as a historical control. No individual identifying patient data were collected. This article does not contain any new studies with human participants or animals performed by any of the authors.

RESULTS

Carbon monoxide concentrations rose in the Boston region from an average of 0.22 ppm in the months of May–September of 2019–2022 to 0.6 ppm in July of 2023. A spike in AD and eczema-related dermatology clinic visits within the Mass General Brigham hospital system was correlated with this notable rise in CO levels (Fig. 2).

DISCUSSION

As CO concentrations typically peak in the winter and are at the lowest levels in the summer [16], the unusual peak in the summer serves to illustrate how large-scale wildfire events can affect air quality and contribute to unseasonable exacerbations of a skin disease that also tends to flare in the winter months [29]. While PM2.5 is more commonly used to illustrate the impact of air pollution events (Fig. 1), and while it was also notably higher in Boston during the spike of these dermatitis-related clinic visits (41 ug/m^3 in July 2023 vs. 6.6 ug/m^3 during the year prior) [30], we chose to highlight CO in this study due to its atmospheric longevity and utility for tracking downstream air pollution during wildfires [16].

Exposure to pollutants from wildfires and chronic air pollution causes cumulative damage to the skin. For example, ozone affects the skin's stratum corneum, depleting antioxidants and triggering a stress response that impacts dermal collagen metabolism, while exposure to PM2.5 and CO is associated with premature aging of the skin, all of which reflect a weakening of the skin barrier due to pollution over time and vulnerability to further inflammation and damage [31–33]. In a manner analogous to acute-on-chronic manifestations of disease, declines in air quality not only compound the ongoing urban pollution burden but also precipitate acute flare-ups in individuals with pre-existing skin disease.

These exacerbations of skin disease from acute increases in air pollutants harken back to the time of the miasma theory, in which diseases were attributed to environmental emanations or foul vapors. Revisited through the filter of modern events, the concept of miasmas as a cause of disease long dismissed as antiquated because it was applied in wrong settings, now inspires a somber second look. The current levels of harmful particulates in the air leading

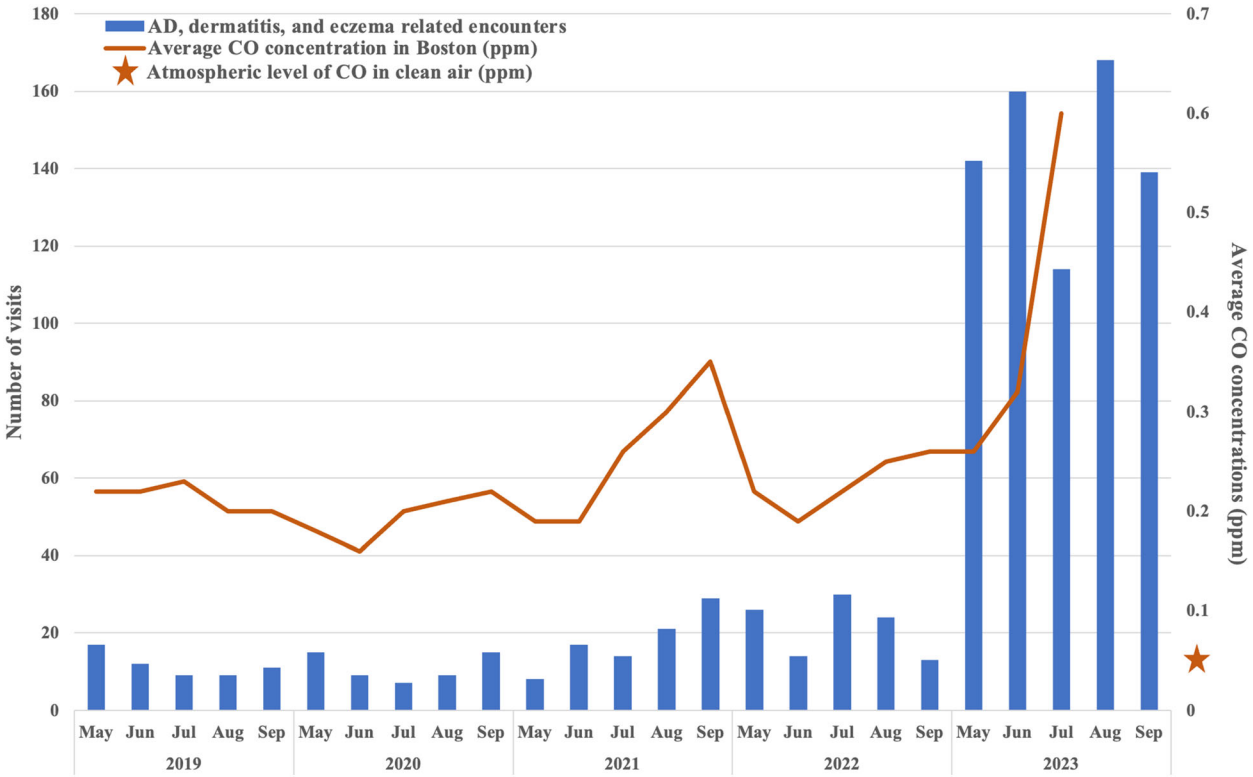

Fig. 2 Dermatology clinic visits for atopic dermatitis (*AD*), dermatitis, and eczema during the months of May through September in the years 2019 through 2023. Average carbon monoxide (*CO*) concentrations in Boston are recorded by the U.S. Environmental Protection Agency [28, 30]. Data were collected with the assistance of staff from MGH Information Systems

to exacerbations of diseases like AD and asthma mirror the essence of that theory [26, 34]. Additionally, miasmas were particularly associated with the spread of disease among the poor [35], and the socioeconomic factors and environmental inequities that made those groups in the eighteenth century more prone to cholera make some in the twenty-first century more vulnerable to the effects of air pollution, including poor living conditions, greater exposure to natural disaster events, psychological stress, and a lack of access to medical care [36]. Recent research has shown that households near roadways and with frequently open windows, both more common in low-income households lacking air conditioning units, are exposed to significantly higher levels of indoor air pollution [37]. The current environmental injustices experienced by low-income communities are highlighted in certain areas of the USA, such as Chelsea, a small town home to one of our Massachusetts General Hospital dermatologic clinics in the outskirts of Boston. Industrial facilities, highways, and the neighboring international airport have led to increased exposure to harmful pollutants in this area [38]. As air pollution disproportionately affects vulnerable communities, such as the socio-economically undeserved, as well as the elderly [27] and the pediatric population [15], it raises important social justice concerns [39]. Existing variations in regional pollution levels can result in unequal distributions of AD exacerbations linked to air pollution from wildfires [39]. Addressing disparities in exposure to air pollution within these communities requires effective environmental policies and resources for mitigation and adaptation to protect skin health in disadvantaged and displaced populations.

In response to the escalating air pollution crisis, various initiatives and policies have been implemented worldwide. In Xi'an, China, the world's largest air purifier tower was trialed, with the results showing improved air quality in the surrounding community [41]. Similar smog-free towers have been installed in other countries, including Poland and the Netherlands. In the USA, the Clean Air Act of 1990 marked a significant achievement in reducing concentrations of harmful air pollutants [42]. However, with the emergence of new challenges from wildfires and shifting environmental conditions, ongoing efforts to mitigate air pollutants are crucial. To mitigate the health risks posed by wildfires, public health authorities, such as the Centers for Disease Control and Prevention (CDC), recommend measures to keep smoke outside, wearing N95 masks for personal protection, and use of portable air filters, which can help prevent AD exacerbations through reduction of PM2.5, CO, and volatile organic compounds [43, 44]. The CDC has also encouraged collaboration in establishing cleaner air spaces in places like schools and libraries to offer at-risk individuals an alternative to reducing smoke exposure when they cannot adequately protect themselves at home. In response to record-breaking atmospheric events in New York, the U.S. Congress introduced the 2023 Cleaner Air Spaces Act which established so-called "clean air centers" to provide a haven for individuals before, during, and after wildfire events [45]. With additional provisions in this bill to provide free air filtration units to at-risk individuals in low-income communities and funding to organizations focused on reducing air pollution, the Cleaner Air Spaces Act is an important initial step in addressing the effects of wildfires and air pollution on public health.

This study has several limitations. The air pollution data, provided by the U.S. EPA, are restricted to certain neighborhoods equipped with sensors, and are not available in real-time. For example, CO data for the Boston region are reported up to July 2023. Additionally, the EPA does not report data on other pollutants, such as aromatic hydrocarbons and lead, which may be relevant to wildfires and AD [14, 21, 46]. Thus, the role other pollutants may have had in the observed increase in dermatitis-related visits remains unknown. Another limitation is the potential diagnostic overlap between AD and irritant and allergic contact dermatitis. The difficulty in distinguishing between these conditions poses a challenge in accurately assessing the impact of airborne allergens and irritants on each condition. Determining the relative contribution of airborne allergen exposure to the presenting disease manifestation may be difficult to fully delineate, potentially leading to the use of general dermatitis diagnosis codes by the diagnosing physician.

CONCLUSIONS

The nineteenth century physician and public health advocate Rudolf Virchow taught that "physicians are the natural attorneys of the poor," stressing the role of social institutions in influencing public health and the ethical duty of government officials and physicians in the healing and improvement of society [47]. While progress has been made, there is yet much to be done by these groups to protect the skin and overall health of vulnerable communities. Dermatologists can play an active role in educating patients and trainees about the dermatologic effects of air pollution and can actively participate in local and national organizations to advocate for policies aimed at combating air pollution [48]. Addressing environmental injustices requires a multifaceted approach, including the implementation of effective environmental policies, improved access to medical care, and the investment in air filtration systems and other methods to prevent worsening health exacerbations during wildfires and other acute air pollution events.

According to the United Nation's Environment Programme of 2022, we must learn to live with fires [49]. Amidst the escalating frequency of wildfires and other contributors to pollution, physicians and government agencies must work together to improve air quality conditions and safeguard the well-being of patients, especially those who are most vulnerable.

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Data Availability. The datasets generated during and/or analyzed during the current study are available in the Environmental Protection Agency Outdoor Air Pollution repository (https://www.epa.gov/outdoor-air-quality-data/download-daily-data). The Mass General Brigham dermatology clinic visit data are not publicly available as these data are protected by the Mass General Brigham health system, and thus a report of clinic visit numbers for certain skin conditions was prepared by members of MGH Information Systems and provided for this publication. We acknowledge the contributions of Karina Bradford and Allan J. Bonomi from MGH Information Systems, Digital Mass General Brigham, who assisted with data collection.

Declarations

Conflict of Interest. Kathyana P. Santiago Mangual, Sarah Ferree, Jenny E. Murase, and Arianne Shadi Kourosh have nothing to disclose.

Ethical Approval. This article does not contain any new studies with human participants or animals performed by any of the authors.

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