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The Impact of Megafire Smoke on Human Health and Effective Remediation Strategies

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Executive Summary

The increasing frequency and severity of megafires pose a significant threat to public health, property, and the environment. Driven by climate change, prolonged droughts, and urban expansion into fire-prone areas, these large-scale wildfires release hazardous pollutants that have both immediate and long-term health consequences.

This paper, initiated by After The Fire USA, a leader in community-led recovery following the 2017 North Bay Fires, aims to examine the health risks associated with wildfire smoke exposure. These risks include respiratory diseases, cardiovascular conditions, cancer risks, and emerging neurological effects. Recent research highlights the dangers of fine particulate matter ($PM_{2.5}$), volatile organic compounds (VOCs), and heavy metals such as arsenic, lead and hexavalent chromium, which can persist in fire-damaged environments long after the flames have been extinguished. Vulnerable populations—including children, the elderly, and individuals with pre-existing health conditions—face heightened risks of complications.

In addition to outlining the dangers of wildfire-related pollutants, this paper explores effective remediation strategies for fire-damaged homes and buildings, including air quality monitoring, professional decontamination, and best practices for removing hazardous residues. Policy recommendations emphasize the need for stronger building codes, expanded government aid, and improved public awareness initiatives to mitigate future health risks.

Without decisive action, the long-term health impacts of megafire smoke exposure will continue to grow, placing increasing strain on healthcare systems and affected communities. Immediate investment in remediation, public health initiatives, and climate adaptation strategies is critical to protecting human health and resilience against future wildfire disasters.

Introduction

What is a “megafire?” This term has been used in many contexts to describe exceptionally large and intense wildfires; however, the definition can vary depending upon the source of the information. According to the U.S. Fire Administration, megafires are wildfires of unprecedented size, intensity and frequency, which are now exacerbated by the effects of climate change (2023). Factors that contribute to the interpretation of a megafire include intensity, behavior and impact (Stoof et al., 2024). Intensity is defined by the energy output and heat generated by a fire. Behavior refers to how a fire spreads and the resistance to any of the suppression efforts, while impact focuses on the effect of the fire on infrastructure, human communities and ecosystems. With each passing year, wildfires have become more extreme with new terms being developed to

describe their growth in size. While megafires are defined as one that burns more than 100,000 acres, there are now "gigafires" which categorize a fire that burns at least a million acres of land, well beyond a megafire (Kaur, 2020).

Recent Megafires and Their Impacts:
In August of 2023, the wildfires in Maui burned approximately 6,500 acres of land and destroyed over 2,200 structures, causing $5.5 billion in damages, and resulting in over 100 fatalities (U.S. Fire Administration, 2023). However in January 2025, the recent Los Angeles wildfires burned almost 60,000 acres, destroying over 16,000 structures, and causing 29 deaths (MacCarthy & Richter, 2025). According to the UCLA Anderson Forecast (2025), the total property and capital losses from the Los Angeles fires could range from $76 billion to $131 billion, with insurance losses estimated to reach $45 billion.

Rising Concern for Short- and Long-Term Health Effects:
With the increase in frequency of wildfires comes the growing concern about the short- and long-term effects on human health based upon exposure to wildfire smoke. According to the *Stanford Report*, wildfire smoke is about 10 times as toxic as regular air pollution that comes from the burning of fossil fuels, and there is no level of safe exposure (2025). Ultimately, the more smoke that people breathe, the worse the range of health outcomes (Jordan, 2025). Studies have found that short term exposure to particulate matter from wildfires can result in minor issues including eye and respiratory tract irritation to more severe health implications such as reduced lung function, pulmonary inflammation, bronchitis, exacerbation of asthma and other lung diseases as well as irritation for existing cardiovascular issues leading to heart failure and in some cases premature death (EPA 2021; National Academies of Science 2020).

While there are numerous studies on the short-term health impacts, long-term health ramifications have not been studied as much. To begin to learn about potential long-term health effects, The Los Angeles Fire Human Exposure and Long-Term Health Study, also referred to as the L.A. Fire HEALTH Study, was recently launched to characterize the composition, concentration and distribution of pollutants created by the 2025 L.A. fires (Kilkenny, Frishman, & Alpert, 2025). This study intends to test the air, soil, water and dust in people's homes (Schrank, 2025). The consortium for this study is being led by researchers from Harvard, USC, Stanford University, UCLA, UC Davis and the University of Texas (LA Fire HEALTH Study Consortium, 2025). The researchers have established 15 monitoring locations throughout Los Angeles County to track pollution levels over time, along with vans equipped with advanced instruments to collect more data than the standard Air Quality Index (AQI) information, with the main focus being to help residents understand when it is safe to return to their homes (Schrank, 2025). The study will also integrate advanced machine learning to model and predict how smoke may have entered into the 14 million homes in the L.A. Region (Schrank, 2025). One distinctive feature of this 10-year

study is the availability of real-time updates, which will be continuously shared on the LA Fire HEALTH study website at lafirehealth.org, or people can sign up to receive email updates and advisories.

Project Firestorm is another rapid-response epidemiological study being led by USC researchers who realize the need to study the health impacts from the recent L.A. fires. According to Frank Gilliland, MD, PhD, professor and air pollution research expert, there is a gap in scientific literature in terms of what the health effects are from the fires in more densely populated areas (Muigai, 2025). While there are many concerns, one is the high level of smoke exposure and byproducts that people inhaled. Second is the mental health impact and the financial stress experienced by people in the fires. Another is the cleanup process, removal of debris and the rebuilding phase (Muigai, 2025). Ultimately Project Firestorm hopes to create the evidence base to reveal the risks people face during these major fires and help people understand how to minimize exposure during the cleanup process (Muigai, 2025).

With the rise in megafires and the fallout that occurs afterwards, After The Fire USA is focused on ensuring that response and recovery efforts evolve to meet these growing challenges. Founded by fire survivors following the 2017 North Bay Fires in Sonoma County, After The Fire has supported wildfire-impacted communities across the West through long-term, community-led recovery. The organization's work draws from lived experience to offer strategic guidance, leadership support, and advocacy, always centering upon equity and resilience. This paper has been created to inform and empower communities, policymakers, and other stakeholders to better understand the cascading impacts of megafires and to collectively build healthier, more prepared futures.

The Problem = The Growing Threat of Megafires

Increasing Frequency and Intensity

The threat that wildfires pose to people and the environment is growing, driven by a range of factors – including climate change (United Nations Environment Programme, 2022). As one of the primary drivers, climate change is fueling hotter temperatures, prolonged droughts, and more extreme fire conditions (U.S. Fire Administration, 2023). In addition to climate being a primary driver, factors such as land use, land management practices, and shifting demographics also contribute to wildfire risk. These dynamic elements lead to wildfires emerging in new areas and increase the unpredictability of fires in regions that have previously burned (United Nations Environment Programme, 2022). Human development and activities play a major role in the development of the fire landscape, with the majority of fires in the United States caused by humans (Kumar et al., 2025) Projections indicate that wildfire events will continue to increase in frequency across numerous regions, including California, through the end of the century. (Kilkenny, Frishman, & Alpert, 2025). While many studies examine individual wildfire risk factors,

few explore how human activity and climate change interact to intensify fire risk and shape fire management and policy implications (Kumar et al., 2025).

Urban Fire Challenges and Close Proximity Risks

The wildland urban interface or WUI is a term that is used to describe the area where structures and any other human development meets with undeveloped wildland or vegetative fuels (U.S. Fire Administration, n.d.). According to the National Academies of Sciences, Engineering, and Medicine (2023), approximately 70,000 communities and 43 million U.S. houses are now at risk of experiencing WUI fires, an increase of 31 million homes from 1990. In addition, an estimated 41% of new homes have been built in WUI areas (National Academies of Sciences, Engineering and Medicine, 2023). From 1970 through 2000, the WUI area expanded 52% in the United States. According to researchers, the WUI is expected to grow by more than 10% by 2030 (National Academies of Sciences, Engineering and Medicine, 2023).

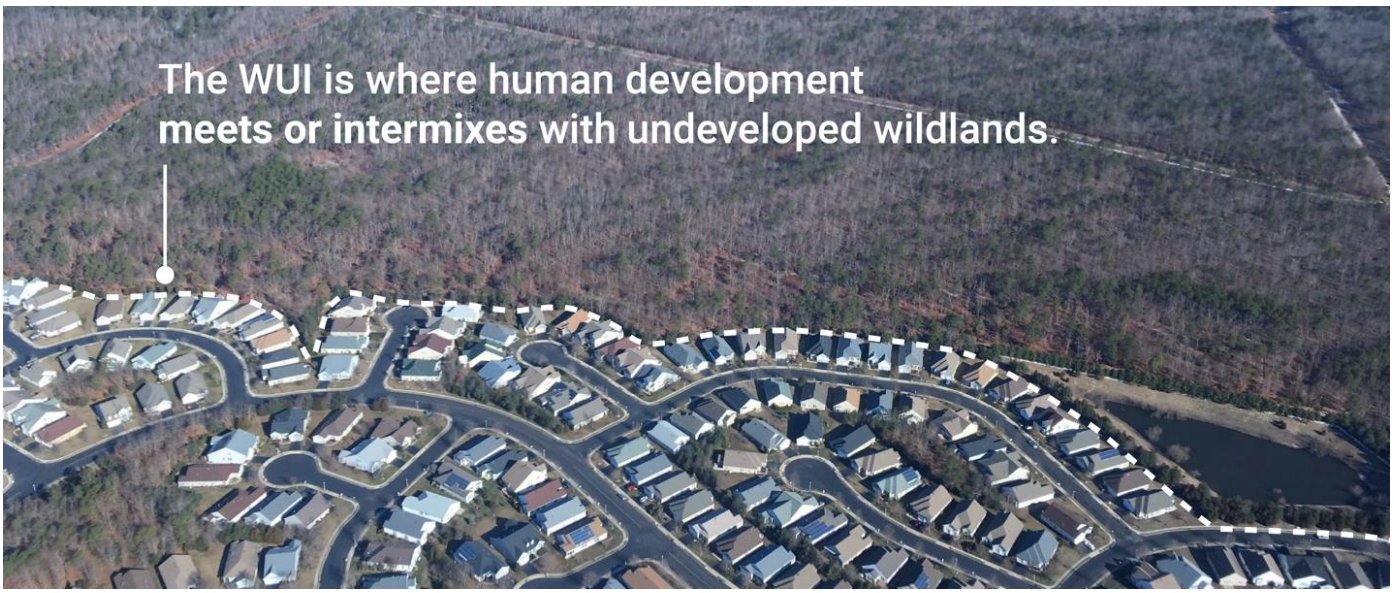

Figure 1
Image of a Wildland-Urban Interface (WUI) fire. Reprinted with permission from Chemical Insights Research Institute (n.d.). *Wildfires*. Underwriters Laboratories. https://chemicalinsights.org/wildfires/

More than three-quarters of extreme-impact wildfires—defined as the top 20 largest, most destructive, or deadliest events on record—originated within 1 km from the wildland-urban interface. The deadliest and most destructive wildfires—90% of which were human-caused—primarily occurred in the fall, while the largest wildfires—56% of which were human-caused—mostly took place in the summer. (Kumar et al., 2025). Between 1990 and 2022, California alone experienced a 4.1-fold increase in compounded wildfire risk, as measured by the Integrated Human-centric Wildfire Risk Index (IHWRI)—a metric combining fire-prone area, housing exposure, and critical fire-weather days. During this period, critical fire-weather days rose from 14

to 34 annually (a 2.5-fold increase), the wildland-urban interface (WUI) area grew by 1.2 times, and the number of homes in these areas rose by 1.4 times. Among these, IHWRI showed the fastest growth rate at 12% per year, meaning that the combined wildfire risk to people and property in California alone has been increasing by 12% every year on average, demonstrating exponential growth over time. Critical fire-weather conditions accounted for nearly half (49%) of the increased risk, while WUI area and housing growth contributed 23% and 28%, respectively (Kumar et al., 2025). The 12% annual growth rate in risk highlights the accelerating danger posed by wildfires, where a small issue can rapidly become a significant threat over time. This trend directly impacts communities, especially those in the wildland-urban interface (WUI), emphasizing the need for effective fire management systems, smart land-use planning, and updated building codes. Without proactive planning and infrastructure investments, traditional emergency response systems may be overwhelmed, exacerbating the danger to both people and property (Kumar et al., 2025).

Local mitigation measures, such as defensible space, are equally vital to wildfire resilience in WUI communities. According to the California Department of Forestry and Fire Protection (n.d.), defensible space is the area between a structure or home and the surrounding area. Having adequate defensible space is important to help slow or stop the progress of a fire and also helps ensure the safety for firefighters. Therefore in WUI settings, having a lack of defensible space increases the risk of rapid fire spread (California Department of Forestry and Fire Protection, n.d.).

Understanding the Health Ramifications of Fire Residue

As more communities expand into wildfire-prone areas, wildfires are increasingly encroaching on urban environments. When fires burn in these wildland-urban interface (WUI) zones, the combustion of human-made materials releases a complex mix of toxic pollutants—posing heightened environmental and public health risks (California Air Resources Board [CARB], 2022; U.S. Environmental Protection Agency [EPA], 2022). Unlike wildland fires that primarily burn vegetative biomass, WUI fires involve a wider range of materials with diverse chemical compositions, densities, and volumes (Chemical Insights Research Institute, n.d.). The image below shows the different types of emissions based upon wildfire and WUI fires.

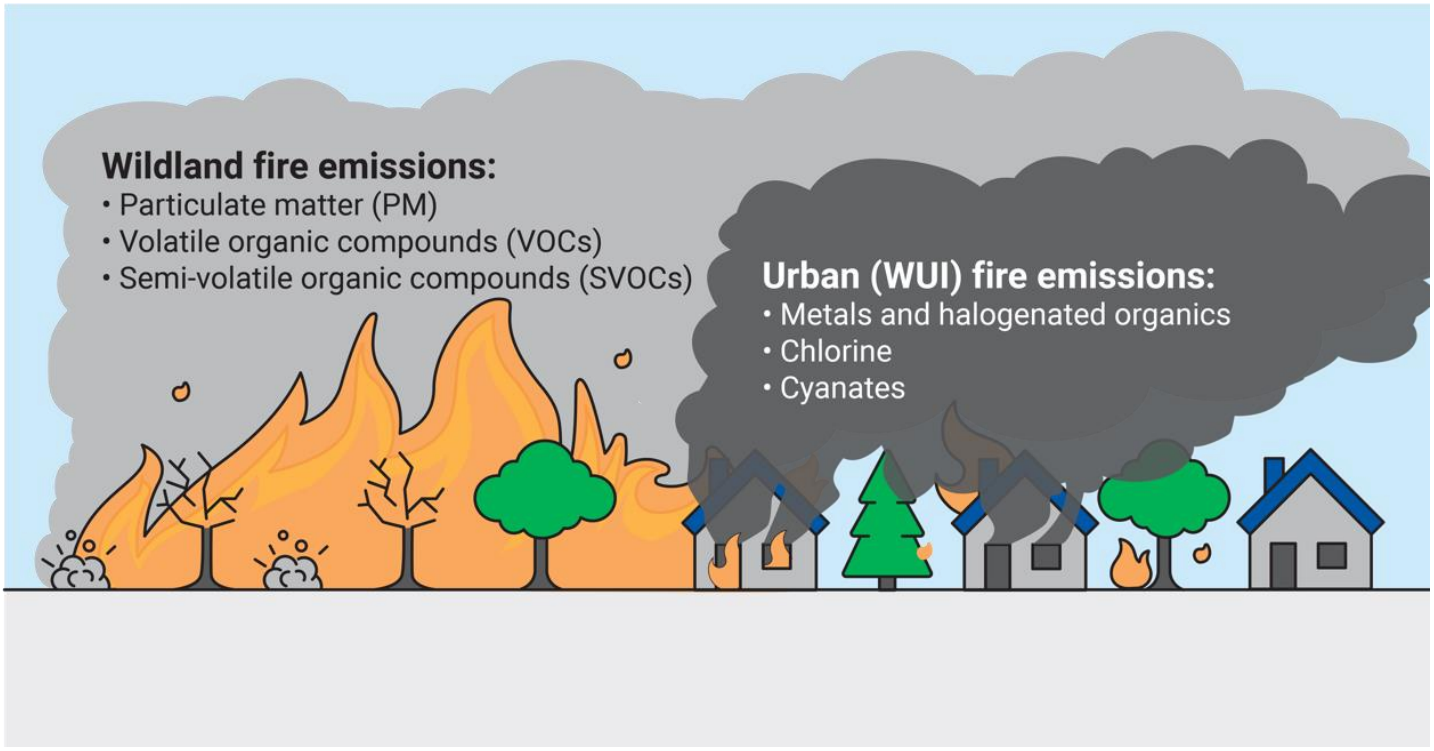

Figure 2
Image of a Wildland and Urban fire emissions. Reprinted with permission from Chemical Insights Research Institute (n.d.). *Wildfires*. Underwriters Laboratories. https://chemicalinsights.org/wildfires/

These complex fire events produce a wide range of hazardous pollutants—many of which persist long after the fires are extinguished. As homes, buildings, and natural vegetation burn, the resulting smoke and residue introduce toxic substances into both indoor and outdoor environments (EPA, 2025). Some of the chemicals found in the runoff may include soot, ash, char or other solids, combustion products from other buildings, and materials as well as the firefighting agent used to extinguish the fire (National Academies of Sciences, Engineering and Medicine, 2023). These contaminants can settle on surfaces, infiltrate the air and soil, and pose ongoing health risks to nearby communities. Char, soot, and ash—byproducts of incomplete and complete combustion—each carry unique properties and risks. Char, composed of partially burned organic material, is carbon-rich and often visible to the naked eye. Soot, made of fine carbonaceous particles, can travel deeply into indoor environments and cling to surfaces. Ash, left after complete combustion, may contain alkaline and corrosive minerals that damage property and affect health (Delia & Baxter, 2017).

To fully understand the public health implications, it is important to examine the specific types of pollutants that result from fire residue. These include the following:

- **Fine particulate matter ($PM_{2.5}$ and PM_{10}),**
- **Volatile organic compounds (VOCs) and semi-volatile compounds (SVOCs), heavy metals and toxic ash,**
- **Mold and water damage.**

Each of these presents unique challenges for health, safety, and environmental recovery—especially in communities increasingly impacted by wildfires in wildland-urban interface (WUI) areas. These fires can negatively impact human health, visibility and quality of life in the vicinity of the fire, but also large distances away and outside of the fire zones (Chemical Insights Research Institute, n.d.). For instance, approximately 7 million people in California's Bay Area were impacted by increased particulate matter from the Camp Fire in 2018, which was over 240 kilometers away. (National Academies of Sciences, Engineering and Medicine, 2023).

Particulate Matter ($PM_{2.5}$ and PM_{10})
What is PM? This stands for particulate matter or particle pollution, and describes the mixture of solid particles and liquid droplets in the air (U.S. Environmental Protection Agency [EPA], 2024). Some of these particles can be seen with the naked eye and include smoke, soot and ash. However, others are only visible through an electron microscope (EPA, 2024). For perspective, these particles can be much smaller than the width of a human hair or a particle of fine beach sand (Reid and Maestas, 2019; Reid et al 2016). PM_{10} represents particle pollution, which are inhalable particles and are usually 10 micrometers or smaller, while $PM_{2.5}$ are fine inhalable particles that are usually 2.5 micrometers or smaller (EPA, 2022).

Wildfire smoke, which accounts for approximately 40% of total particulate matter (PM) emissions in the United States, contains both coarse and fine particles that can penetrate deep into the lungs and cause significant biological harm (EPA, 2022). With this in mind, some research has found that PM can also affect the cardiovascular system by causing pulmonary oxidative stress, inflammation and triggering of the autonomic nervous system in addition to other health challenges discussed in more detail later in this paper (National Academies of Science, 2020; Reid and Maestas, 2019; Reid et al., 2016).

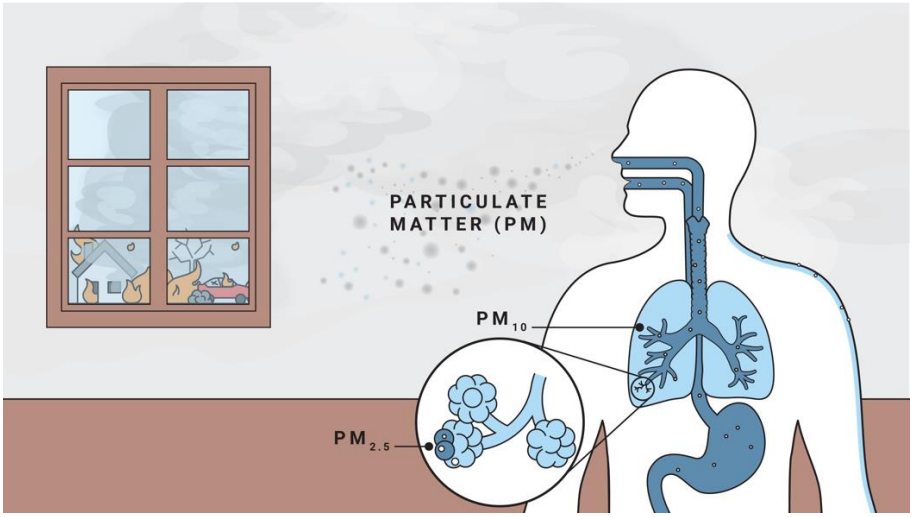

Figure 3
Image demonstrating where particulate matter (PM) from smoke can enter into the lungs and bloodstream. Reprinted with permission from Chemical Insights Research Institute (n.d.). *Wildfires*. Underwriters Laboratories. https://chemicalinsights.org/wildfires/

Volatile Organic Compounds (VOCs), Semi-Volatile Compounds (SVOCs), Heavy Metals and Toxic Ash

Megafires are a significant source of harmful environmental pollutants, including volatile and semi-volatile organic compounds, heavy metals, and toxic ash. According to the NOAA Climate Program Office, wildfires are the second largest source of volatile organic compound (VOC) pollutants (2023). VOCs are chemicals released into the air during combustion, contributing to poor air quality and posing health risks. Semi-volatile organic compounds (SVOCs), on the other hand, tend to exist as liquids or solids at lower temperatures and include substances such as pesticides, oil-based products, and fire retardants (EPA, 2025).

When wildfires occur in residential or industrial zones, the combustion of materials such as painted furniture, flooring, electronics, and vehicles releases a dangerous mix of pollutants—including VOCs, carbon monoxide, polycyclic aromatic hydrocarbons (PAHs), nitrogen oxides, and particulate matter (PM) (Wang et al., 2024). These compounds can infiltrate the indoor environment as well. Laboratory directors Alice Delia and Daniel Baxter (2017) also highlight that VOCs and SVOCs can penetrate porous building materials, contaminating surfaces long after a fire has been extinguished. Smoke, ash, and soot can leave behind VOCs such as benzene and other hazardous residues on furniture, walls, floors, and additional surfaces (Delia & Baxter, 2017). Visual assessment alone may not reveal these contaminants, and proper testing is often required to assess exposure risks accurately.

In addition to VOCs and SVOCs, wildfires often release toxic heavy metals. Arsenic, lead, mercury, and asbestos have been detected following wildland-urban interface (WUI) fires, contaminating

both soil and air (California Air Resources Board, 2024). These pollutants pose long-term risks to environmental and human health.

Recent research has also uncovered a lesser-known consequence of wildfire residue: the transformation of naturally occurring metals into more toxic forms. During high-temperature fires, especially in geologically metal-rich regions such as those containing serpentinite, chromium can convert into its carcinogenic form—hexavalent chromium. This toxic compound has been found in wind-dispersible ash, posing a serious inhalation risk. Alarmingly, elevated levels have been observed in surface soils for up to ten months post-fire, indicating prolonged exposure hazards (Lopez, Lezama Pacheco, & Fendorf, 2023). These findings highlight the unique and severe nature of pollution resulting from wildfires compared to other sources.

Ultimately, megafires produce a complex and toxic mix of pollutants—from VOCs and PAHs to heavy metals and transformed soil compounds—that threaten both immediate and long-term health. The health consequences of these exposures are discussed further in the section entitled "Identifying the Specific Medical Conditions Linked to Smoke Exposure."

Mold and Water Damage

The thousands of gallons of water used during fire suppression efforts can lead to water damage in homes and buildings. Porous materials such as drywall, insulation and carpeting are particularly susceptible to absorbing large amounts of water, therefore creating ideal conditions for mold growth (Hoang, 2025). Following a fire, when standing water and other residual moisture may exist and ventilation is limited, mold may begin to develop. The mold development process occurs quickly—beginning within 24-48 hours—making water removal and drying essential (Hoang, 2025). While the structural integrity of a home or building can be compromised from mold development, mold exposure also has human health ramifications. When mold spores become airborne, they can be inhaled and contribute to a vast array of respiratory issues and allergic reactions (CDC, 2023; Hoang, 2025).

Identifying the Specific Medical Conditions Linked to Smoke Exposure

As mentioned throughout this paper, exposure to smoke from megafires poses numerous significant health risks, both in the short- and long-term. While many studies have looked at health impacts from one particular wildfire, there are very few that considered the lasting impact on human health over time. Many previous studies assessing wildfire smoke effects on human health have been restricted to single wildfire events based on the limitations in estimating human exposure to wildfire-specific $PM_{2.5}$. (Aguilera et al., 2021). However, with the enormity of the recent L.A. fires, long-term studies, as mentioned in the introduction of this paper, are gaining traction in order to identify long-term health impacts from megafire smoke.

Studies completed to date have identified both short- and long-term health consequences as a result of exposure to wildfire smoke. According to Tinling et al., exposure to extreme wildfire smoke can increase all-cause mortality by up to 12% (2016). According to Frumento & Ţălu, the respiratory and gut microbiome, both influential for immune responses, have shown to be impacted by smoke exposure potentially contributing to immune dysregulation and increased susceptibility to infections and inflammatory diseases (2024). Following are additional health challenges, both short- and long-term, based upon megafire smoke exposure:

Short-Term Health Effects:

- ***Eye and Skin Irritation:*** Wildfire smoke can cause immediate issues such as burning eyes and skin problems due to the presence of various chemicals and irritants (Lapid, 2025).
- ***Respiratory Issues*:** Even in healthy individuals, inhaling fine particles can lead to temporary reductions in lung function and pulmonary inflammation. Symptoms may include coughing, phlegm, wheezing, and difficulty breathing. Studies have shown increases in emergency room visits for respiratory conditions as well (EPA, 2022; Lapid, 2025).
- ***Cardiovascular Events*:** Exposure to wildfire smoke has been associated with increased risks of heart murmurs, heart attacks and strokes. Studies have shown that as $PM_{2.5}$ concentrations rise due to wildfire smoke, the incidence of high blood pressure and other heart-related outcomes also increases (Frumento & Ţălu, 2024).
- ***Autoimmune Diseases***: Wildfire smoke can trigger or exacerbate rheumatoid arthritis and systemic lupus, increase responses to allergens, and increase the risk of developing asthma or allergic rhinitis (Frumento & Ţălu, 2024).

Long-Term Health Effects:

- ***Chronic Respiratory Conditions*:** Prolonged exposure to wildfire smoke can exacerbate existing respiratory diseases like asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) (Frumento & Ţălu, 2024).
- ***Cardiovascular Diseases:*** Long-term inhalation of wildfire smoke has been linked to an increased risk of developing heart disease, including conditions like heart attacks, cardiac arrests and strokes (Lapid, 2025).
- ***Cancer Risks:*** Emerging evidence suggests that repeated exposure to wildfire smoke may contribute to an increased risk of cancers, particularly lung and brain cancers, due to the carcinogenic nature of some of the pollutants involved (Korsiak et al., 2022).
- ***Neurological Effects & Brain Health*:** There is growing concern that long-term exposure to wildfire smoke may have adverse effects on brain health, potentially leading to cognitive impairments and mood disorders such as depression, dementia, and Alzheimer's. Research indicates that fine particulate matter (PM2.5) from wildfire smoke can induce neuroinflammation and impact cognitive functions (Lapid, 2025; Elser, 2025). Researchers have also found that even those that live outside of major cities but within 50 kilometers of a wildfire in the past decade had a 10% higher risk of brain tumors (Lapid, 2025).

- ***Cognitive Performance:*** Research from the University of New Mexico revealed that wildfire smoke exposure can trigger brain inflammation lasting over a month, leading to reduced attention span in adults within hours of exposure (Haederle, 2023). According to Matt Campen, PhD, at the University of New Mexico, many people do not consider the neurological outcome from exposure to wildfire smoke—most think about the lungs and maybe the cardiovascular system, but not memory and cognition (Haederle, 2023).
- ***Fungal Infections*:** Research in California shows an increase in fungal infections months following wildfire smoke exposure due to fungal spores in the wildfire smoke (Lapid, 2025).
- ***Mental Health*:** The psychological impact of wildfires impacts everyone from children and teens to firefighters and evacuees. Studies indicate an increase in major depressive disorder (MDD) and post-traumatic stress disorder (PTSD) (Pennington et al., 2017; Neria et al., 2008).

Vulnerable Populations:

While exposure to megafire smoke is detrimental to many, certain groups are more susceptible to the health impacts of smoke, including the following:

- ***Children:*** Children have a higher respiratory rate and ingest more water for their body weight. For instance, babies take a breath 40 times per minute compared to adults who breath 12-20 times per minute Additionally, children still have developing organs and an immature immune response system. Finally, children spend more time outdoors and are unable to identify risks (National Academies of Sciences, Engineering, and Medicine, 2023). Children and pets are particularly vulnerable to heavy metal toxicity (National Institute of Environmental Health Sciences, 2023).
- ***Older Adults:*** The elderly population often has compromised immune responses making them more vulnerable to wildfire smoke (National Academies of Sciences, Engineering, and Medicine, 2023).
- ***Individuals with Pre-existing Health Conditions:*** Those with existing heart or lung diseases are at higher risk for exacerbation of their conditions due to smoke exposure (CDC, 2024). Often, the elderly population falls into this category as well.
- ***Pregnant Individuals:*** Exposure during pregnancy has been linked to adverse outcomes such as pregnancy losses, preterm births and low birth weights (Lapid, 2025). A California study conducted by Basilio et al., determined that there was a connection between exposure to wildfire smoke and cellular damage to the placentas in first- and second-trimester pregnant individuals (2022).

Understanding and addressing the health impacts of wildfire smoke is critical, especially as the frequency and intensity of megafires continues to increase.

The Solution = Building Safer, Healthier, and More Resilient Communities

While wildfires cannot be entirely eliminated, there are meaningful strategies that can help manage and significantly reduce the risks they pose—particularly for the communities most

affected. Recovery involves more than repairing physical damage; it requires restoring health, safety, and stability across neighborhoods. This section presents community-centered approaches that address both immediate and long-term needs. From effective home remediation techniques—such as decontamination, material replacement, and air quality monitoring—to broader policy solutions that include stronger building codes, expanded government assistance, and public education initiatives, these strategies are designed to support residents in navigating recovery and building resilience.

Mitigation and Protective Measures

Reducing exposure to wildfire smoke begins with personal and community-wide protective measures. According to guidance from public health experts and environmental hygienists, individuals can significantly limit health risks by monitoring local air quality indexes (AQI) and following public advisories (California Department of Public Health, 2022). The AQI, which measures the concentration of pollutants such as particulate matter ($PM_{2.5}$), is a key indicator of air quality. Reliable AQI sources include the U.S. Environmental Protection Agency (EPA) AirNow platform, which provides real-time air quality data, and local government air quality monitoring systems (U.S. Environmental Protection Agency, 2022). During periods of poor air quality, limiting outdoor activity and using N95 or P100 masks can help prevent respiratory exposure to particulate matter (U.S. Environmental Protection Agency, 2022). Indoors, high-efficiency particulate air (HEPA) filtration and portable air purifiers improve air quality, especially in newer or weatherized homes where leakage is less prevalent. Older homes, as noted by Dr. Lynn Hildemann of Stanford University, may offer less protection from outdoor pollutants due to air leakage, reducing the effectiveness of indoor air filtration systems (Hildemann, 2023). Therefore, community education, home weatherization, and the promotion of protective behaviors are essential mitigation tools in the face of growing wildfire threats.

Effective Home Remediation Strategies

Effective home remediation after wildfire smoke exposure involves a multi-step approach to ensure the safety and health of occupants. The initial step is a thorough assessment of fire damage, which includes professional inspections with air quality testing and surface residue analysis to detect contaminants like soot, ash, and volatile organic compounds (VOCs) (Delia & Baxter, 2017). Structural integrity checks are also essential to confirm the building's safety (California Building Standards Commission, 2024). According to Michael Polkabla, Principal and Certified Industrial Hygienist at BioMax Environmental, Inc., all remediation companies are not created equal, and proper qualifications and experience are critical for ensuring thorough and effective recovery (personal communication, March 25, 2025).

Cleaning and decontamination are critical next steps. HVAC systems often accumulate soot and ash, requiring professional cleaning to prevent the recirculation of harmful particles (Environmental Protection Agency [EPA], 2024). Experts recommend upgrading HVAC systems

with MERV 13 filters or higher and incorporating portable air cleaners with HEPA filters to improve indoor air quality (Harvard T.H. Chan School of Public Health, 2025). For surface cleaning, damp wiping is preferred over dry methods to prevent resuspending particles into the air (National Institute for Occupational Safety and Health [NIOSH], 2024). Using safe chemical or enzyme-based cleaning agents further supports effective decontamination (California Department of Public Health, 2024). Harvard also advises controlling indoor dust by removing shoes at entry points, frequently cleaning with damp cloths, and using vacuums equipped with HEPA filters to capture fine particles (Harvard T.H. Chan School of Public Health, 2025).

When materials have been heavily contaminated, removal and replacement may be necessary. Carpeting, insulation, and drywall often absorb chemicals and require replacement (NIOSH, 2024). Similarly, porous furniture and soft goods that retain VOCs might need to be disposed of (EPA, 2024; Polkabla, 2025). Addressing water damage promptly is also crucial to prevent mold growth and structural degradation (Centers for Disease Control and Prevention [CDC], 2024; Polkabla, 2025).

Finally, long-term air quality monitoring is vital to ensure the continued safety of the indoor environment. Installing indoor air quality monitors to track $PM_{2.5}$ and total volatile organic compound (TVOC) levels, as recommended by Harvard, provides ongoing data to support health-based decision-making (Harvard T.H. Chan School of Public Health, 2025). Continuous use of air purifiers and periodic testing for residual VOCs and particulate matter help ensure that remediation efforts have been successful (EPA, 2024; NIOSH, 2024). Polkabla further emphasizes that success should be verified through visual inspection, the absence of lingering odors, and professional clearance sampling, particularly in hard-to-clean areas (personal communication, March 25, 2025).

Policy and Community Response

Effective policy and community response play a pivotal role in strengthening the resilience of communities affected by wildfires. Policies that prioritize fire prevention, recovery, and public health can significantly reduce the long-term impact of wildfire events on communities. Below are several key strategies to improve resilience through policy changes and community engagement.

1. Strengthening Building Codes for Fire Resilience

One of the most effective ways to mitigate the risks of wildfire damage is by strengthening building codes to promote fire resilience. The implementation of fire-resistant construction materials, such as non-combustible siding, roofing, and fire-resistant windows, can significantly reduce the risk of structures catching fire during an event (California Building Standards Commission, 2022). Additionally, establishing defensible space requirements in urban planning ensures that structures are built with sufficient clearance from flammable vegetation, thus

limiting the potential for fire spread (U.S. Fire Administration, 2023). Communities that integrate these building and planning strategies will be better prepared to withstand wildfires and protect both their residents and infrastructure.

2. Expanding Government Aid Programs

Expanding government aid programs is essential to support homeowners, businesses, and communities in fire-affected areas. Increasing financial support from federal and state agencies helps residents rebuild homes, replace lost goods, and access temporary housing during recovery periods (FEMA, 2024). Additionally, improving insurance frameworks for wildfire recovery will allow homeowners to recover more quickly and efficiently. As noted by *The Restoration Triangle: Homeowner, Contractor, and Insurance Company* (2024), developing clear communication and collaboration between these stakeholders ensures that recovery efforts are not delayed by financial or logistical challenges.

Crucially, having the proper environmental testing conducted at the outset of remediation can streamline the entire insurance claim process. When contaminants like soot, ash, and char are identified accurately from the start, remediation can be performed thoroughly the first time, reducing the need for repeated efforts and associated delays. This leads to faster, safer reoccupation of homes, improves health outcomes, and minimizes costs. Additionally, this approach benefits both homeowners and insurers by enabling families to return to safe environments more quickly while also reducing the likelihood of additional remediation costs resulting from inadequate initial evaluations (Delia & Baxter, 2017).

3. Public Education on Fire Safety and Health Risks

Public education and awareness campaigns are critical in reducing the health risks associated with wildfire exposure. Training communities on post-fire remediation best practices can help residents protect their homes and health by providing them with actionable steps to remove toxins and pollutants (California Department of Public Health, 2024). Raising awareness about the long-term health effects of wildfire smoke is equally important. Research has shown that individuals living in areas affected by wildfires are at increased risk for cardiovascular events, respiratory diseases, and other health conditions (Kilkenney, 2025). Programs that educate residents on monitoring air quality, understanding evacuation advisories, and recognizing the signs of smoke-related health issues can lead to more informed decision-making during wildfire events (Harvard T.H. Chan School of Public Health, 2025).

A recent study examining the 2018 California wildfires found a significant increase in cardiovascular events among residents exposed to smoke. However, this pattern was not observed during the 2018 Camp Fire. The authors postulated that heightened public awareness, along with more robust public health measures such as school closures, stay indoors advisories, and the promotion of N95 mask usage, may have contributed to the differing health outcomes.

These public health interventions, which were more actively communicated and enforced during the 2018 wildfires, likely mitigated the severity of the health impacts on the population (Kilkenney, 2025). This underscores the critical importance of timely and transparent public health communication in preventing the escalation of health issues during wildfire events.

Clear communication from public health officials about the risks of wildfire smoke exposure and recommended precautions—such as using air filtration systems, wearing masks, and limiting outdoor activity—can reduce cardiovascular events and mortality rates (Kilkenney, 2025). As public health experts continue to study the long-term effects of repeated smoke exposure, targeted health interventions will be vital in reducing the burden on vulnerable populations.

4. Addressing Uncertainties in Wildfire Health Impacts

While the immediate risks of wildfire smoke exposure are well-documented, several uncertainties remain regarding the long-term effects. Researchers are investigating the cumulative health impacts of repeated wildfire exposure over multiple seasons and its potential links to chronic respiratory conditions, cardiovascular disease, and neurological issues (Lapid, 2025). Additionally, studies are exploring the impact of wildfire smoke on water supplies, crops, and livestock, which could have far-reaching consequences for public health and the environment (Pace et al., 2023). Olson et al. (2023) also highlight that wildfire smoke may contribute to the mobilization of nutrients, which can lead to harmful algae blooms in downwind areas. These blooms can have serious implications for water quality, affecting drinking water reservoirs and lake ecosystems. Such findings suggest that the impact of wildfires extends beyond the immediate vicinity of the fire and highlights the need for comprehensive environmental monitoring and proactive policy responses to protect both public health and the environment.

Lapid (2025) further emphasizes that the long-term effects of repeated wildfire smoke exposure remain unclear. As wildfires become more frequent due to climate change, the risks associated with exposure to smoke from multiple fire seasons are not yet fully understood. Researchers are investigating whether multiple exposures to wildfire smoke could amplify health risks, particularly in vulnerable populations such as children, the elderly, and individuals with pre-existing respiratory or cardiovascular conditions. Additionally, the effects of wildfire smoke on water quality, including the potential contamination of drinking water sources and agricultural crops, are still being studied, as are the neurological impacts of exposure during pregnancy. These uncertainties point to the importance of continued research and adaptive policies that can respond to the evolving threats posed by wildfires (Pace et al., 2023; Lapid, 2025).

Conclusion and Call to Action

The frequency and intensity of megafires, driven by climate change, pose significant challenges, not only through their immediate destruction but also through long-term health risks. According

to research by the UCLA School of Public Health (2025), megafires cause substantial, lasting health consequences, particularly in terms of respiratory and cardiovascular issues. As these risks continue to grow, it is essential to adopt proactive measures aimed at minimizing the impacts on affected communities.

Proactive remediation and mitigation strategies are critical in safeguarding communities from both the immediate and long-term effects of wildfire exposure. The Environmental Protection Agency (EPA, 2024) emphasizes the importance of effective remediation, which includes actions such as air quality testing, HVAC system cleaning, and the replacement of contaminated materials. In addition to remediation, stronger policies and safer building practices must be advocated to enhance resilience. Strengthening building codes, incorporating fire-resistant materials, and ensuring defensible space in urban planning are essential steps in reducing fire risks and improving community safety (NIOSH, 2024).

Ongoing research is vital to understanding the full scope of health and environmental impacts of wildfires. The provision of tools and resources to assist homeowners in navigating the complexities of insurance claims is also a critical aspect of post-fire recovery. As highlighted by Delia and Baxter (2017), challenges in proving the extent of contamination and damage often hinder homeowners' recovery, making clear guidelines and accessible resources indispensable.

Furthermore, continuous support for live updates on studies such as the L.A. Fire HEALTH Study, which examines the long-term health effects of wildfire exposure, is necessary. These updates will provide crucial insights for public health interventions and inform better preparation for future wildfire events.

Strengthening building codes, enhancing public education, improving insurance processes, and supporting ongoing research should be prioritized as part of a comprehensive strategy to mitigate the impacts of megafires. These efforts are critical to building more resilient and healthier communities in the face of an increasing wildfire threat.

About the Authors

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Nicole Della Santina, MPH, is a public health professional, health educator, and wildfire survivor based in Sonoma County, California. With over 15 years of experience in community health education, environmental health, and emergency preparedness, she combines professional expertise with lived experience to support vulnerable populations during crises. Through her consulting practice, Della Santina Consulting, she works with families, schools, and community organizations to build resilience and improve access to health resources. Nicole has authored white papers and literature reviews on a wide range of public health topics, translating complex evidence into actionable solutions for academic, policy, and general audiences. She also develops crisis preparedness tools to help address the unique needs of underserved communities during emergencies. Nicole holds a Master of Public Health in Community Health Sciences from Baylor University and has completed FEMA training in disaster response, community preparedness, and crisis communication.

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Jenn Kaaoush is a nationally recognized disaster recovery leader and wildfire survivor advocate with deep expertise in post-megafire smoke damage remediation. After suffering severe smoke damage to her home in the 2021 Marshall Fire, she co-founded Superior Rising, helping hundreds of families navigate insurance, testing, and rebuilding. She has supported recovery efforts in Lahaina, HI, Los Angeles, CA, and across Colorado, working closely with After the Fire USA to implement evidence-based remediation strategies and community-led solutions. A key voice in federal advocacy, Jenn helped pass the Fire Survivor Tax Relief Bill in 2024 and has testified in Washington, D.C., to demand stronger protections and resources for wildfire survivors. A U.S. Army Veteran and former Diplomat, she now serves as a Councilmember for the Town of Superior, championing equitable recovery, housing resilience, and survivor-centered policy.

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