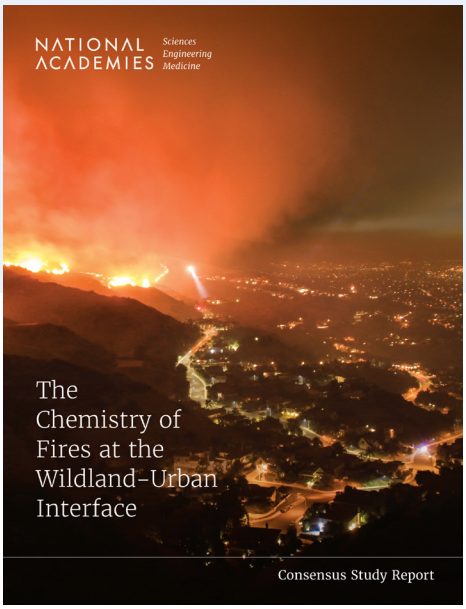
The Chemistry of Fires at the Wildland – Urban Interface



The number, size, and intensity of wildland fires in the United States is increasing, driven by more frequent heat waves and droughts, and by land management practices that have allowed the build-up of potential wildland fire fuels. At the same time, more homes are being built at the wildland-urban interface (WUI)—the place where housing and other structures intermix or interface with wildland. Since 1990, 41% of new housing units in the United States have been built at the WUI. As communities continue to expand into surrounding forests, they are at increasing risk of experiencing wildfires including in geographies not typically associated with wildfires. Today, an estimated 70,000 communities and 43 million U.S. homes are at risk from WUI fires.

The chemistry and ultimate health impacts of WUI fires are still poorly understood. WUI fires can lead to higher human exposures than remote wildland fires because of their proximity to communities. They also have unique chemistry due to the combination of natural and human-made fuels that are burned, which may lead to the formation or release of toxic emissions not found in purely wildland fires.

This report, produced at the request of the National Institute of Standards and Technology (NIST), the Centers for Disease Control and Prevention (CDC), and the National Institute of Environmental Health Sciences (NIEHS), evaluates how information about chemistry can be used to inform decision-makers charged with mitigating wildfire impacts and their potential health impacts. The report examines what is known of wildland fires and urban fires and uses that information to identify potential emissions, exposures and health impacts of WUI fires as well as near- and long-term research needs.

FUEL, COMBUSTION, EMISSIONS

Emissions from fires in the WUI can differ greatly from emissions from wildland fires. The fuels burned in WUI fires have different compositions, densities, and quantities of combustible materials than the vegetative biomass combusted in wildland fires. Combustion reactions for materials at the WUI (e.g., household components such as siding, insulation, textiles, plastic, as well combustion of biomass) result in significant emission of potential toxicants to the surrounding environment.

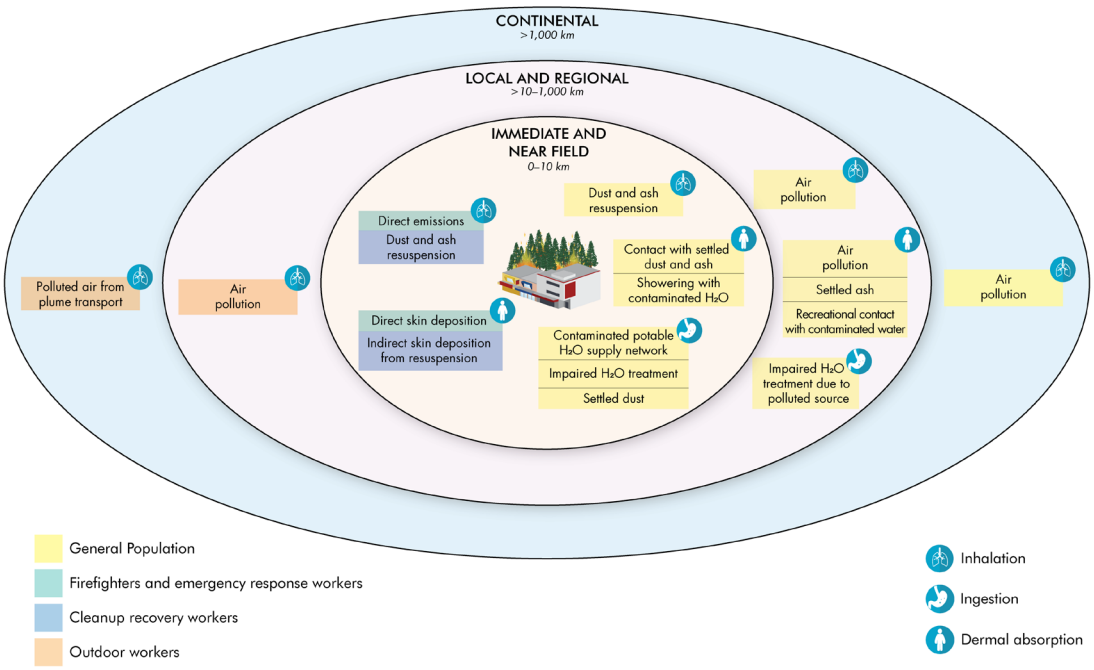


FIGURE 1 Impacts of WUI fires can affect millions of people outside the fire zone, depending on the location of nearby cities. Smoke from major fires sometimes affects air quality on a continental scale.

The research community's knowledge of emissions from the combustion of urban materials is derived largely from studies of the toxicity of emissions from enclosure fires (i.e., a fire within a room or compartment inside a building) or from laboratory simulations. While these studies have demonstrated how both the material composition and the amount of oxygen available strongly impact the emissions of some toxicants, they do not reflect how WUI fires actually behave. More research is needed on urban fuels' effects on combustion processes, the types of species emitted, and species' interactions under different fire conditions.

ATMOSPHERIC TRANSPORT AND WATER AND SOIL CONTAMINATION

Emissions from WUI fires can substantially, negatively impact human health and quality of life, not only in the vicinity of the fire but also hundreds to thousands of kilometers downwind. For example, the 2018 Camp Fire affected air quality 240-km-downwind for millions of California Bay Area residents, and the 2016 Horse River Fire, which started near Fort McMurray, Alberta, Canada, and resulted in smoke transport and impacts on air quality more than 4,000 kilometers away in New York City. Impacts to nearby communities include toxicants in nearby buildings, soils, and water streams.

National monitoring networks provide some data for assessing exposures of routinely monitored air pollutants, such as fine particulate matter, that are associated with emissions from WUI fires; however, data are very sparse on the gas- and particle-phase smoke composition specifically associated with WUI fires, and how it is transformed over short and long distances. The resulting plume composition changes over time (from minutes to days) due to atmospheric chemistry and physical processing, leading to changes in pollutant composition, and the resulting exposures, downwind of fires. While a dominant route of exposure is inhalation, contaminated water and soil downwind of wildfires can also impact exposures through ingestion.

HUMAN HEALTH IMPACTS

As is the case with understanding emissions and exposures, there is limited information about health impacts that are specific to WUI fires. Current literature

largely focuses on exposures and health impacts related to smoke inhalation, but do not include ingestion and dermal pathways for fire pollutants. Effects of smoke inhalation include myocardial infarction, ischemic heart disease, dysrhythmia, heart failure, pulmonary embolism, ischemic stroke, and transient ischemic attack. Asthma exacerbations are significantly associated with exposure to wildfire smoke, and exacerbations of chronic obstructive pulmonary disease (COPD) are significantly associated with greater contaminant amounts and exposure to wildfire smoke in most studies.

Within exposures to the general public, specific groups may experience greater impacts, such as children, pregnant people, older adults, and immunocompromised people, as well as communities who experience disproportionate environmental and social stressors. For example, children are especially vulnerable to air pollution effects due to their small body mass and rapid breathing rates, leading to higher exposure doses than adults. Low-income communities often do not have adequate cooling in their homes to allow for keeping the windows closed during the wildfire season or to afford home air cleaners for particle and chemical filtration.

Emergency responders, such as firefighters, are at risk for injury, death, and acute and chronic health impacts of wildfires, as well as mental health effects due to trauma. Outdoor workers, such as farmworkers and utility workers, are at elevated risk for respiratory effects of smoke and associated pollutants, and this may be coupled with pre-existing medical conditions.

MEASUREMENT SCIENCE

The report outlines the diverse data needs associated with understanding the chemistry of WUI fires and their emissions, which range from collecting data on fuel characteristics of heterogeneous structures, to measuring the concentrations, exposures, and health impacts of large numbers of toxicants, many of which will be present at trace levels. Collecting much of this data is challenging, since identifying toxicants in WUI fire plumes requires fine spatiotemporal resolution. Data and measurement needs are interconnected, as shown in Figure 2. Because of this interconnection, a coordinated approach to data collection, from fuel and emission characterization to exposures, is desirable. Use of consistent measurement methods and collection of data on chemical species over their entire cycle from emission

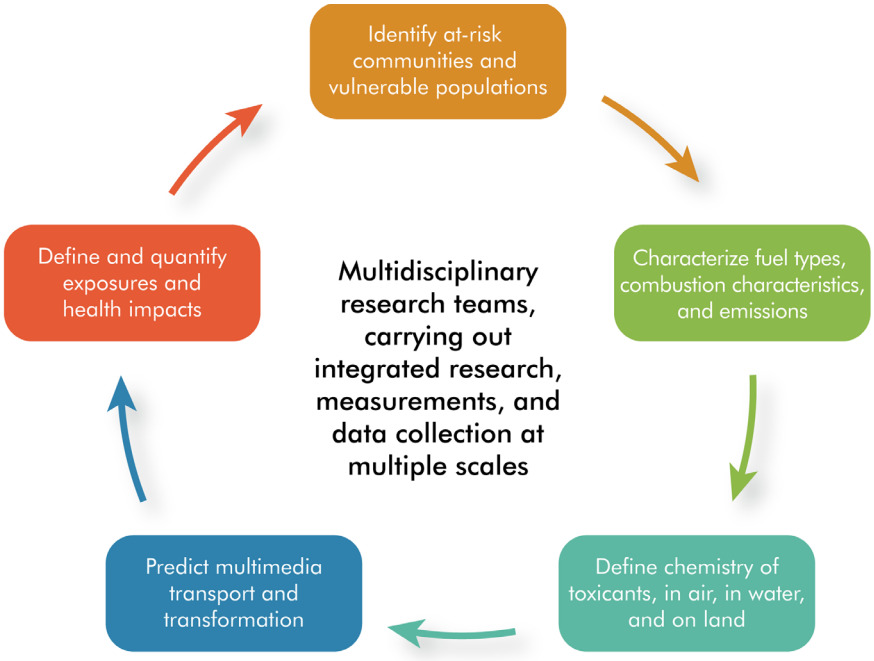


FIGURE 2 Data collection and research needs for WUI fires are interdependent. Information about at-risk communities and vulnerable populations can help define the types of structures and potential fuels at the WUI. Data on fuel compositions will determine combustion pathways. The chemical species formed will determine which atmospheric reaction pathways will be most important. The atmospheric chemistry and transport will determine the toxicants to which communities are exposed and the manner of the exposure. Exposures will determine health impacts.

to exposure will enhance the value of all of the data that are collected.

RESEARCH AGENDA

Research on emissions from WUI fires can build on the extensive knowledge base developed for wildland fires, but understanding the impacts of WUI fires will require new information. The report recommends that researchers and agencies that fund research implement an integrated, multidisciplinary research agenda to study the impacts of WUI fires. Agencies funding and investigators performing research should coordinate their research plans and create widely accessible repositories for data and information relevant to WUI fires.

Commitment to both long term progress and immediate action on improving understanding of WUI fires would benefit communities throughout the United States and the world. Policy-relevant research findings and actionable messaging could include recommendations for building materials to be used in WUI communities, strategies for reducing fire risks, public information regarding the effectiveness of measures to mitigate exposures, and community mappings of toxicant precursors, accessible to decision-makers. Areas where rapid action could have immediate benefits include:

- Developing data systems to enable communities to predict the chemical composition of materials present in structures at threat from WUI fires. These data systems could include estimates of metal, halogen, and other chemical loadings in structures.

- Adding measurements of targeted WUI toxicants to air and water quality monitoring systems; these measurement systems could be rapidly deployed to areas impacted by WUI fires.

- Establishing information repositories on toxicant data, best practices for mitigation measures, and best practices for information dissemination; state agencies could lead in coordination of data collection; data consistency, quality and access could be addressed at a national level, and at all levels, communication and dissemination strategies for vulnerable and at-risk community populations could be developed.

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