Research Institutes | Chemical Insights

When the Dust Settles: Reducing Chemical and Particle Health Risks Following a Large-Scale Urban Fire

How Large-Scale Urban Fire Events Generate Hazardous Dust

Large-scale urban fire events pose unique hazards to nearby communities not just during the fire, but in its aftermath. While people may primarily associate air and water contamination with the combustion of a fire, there is an often overlooked hazard — residual dust. This hazardous dust contains a chemical history of the fire and can settle in our soil, migrate into our waterways, and infiltrate our homes and buildings, presenting chronic exposure for the community that requires careful mitigation.

THE IMPACT OF URBAN FUELS ON THE COMBUSTION PROCESS AND EMISSIONS

Fire is the product of a chemical reaction called combustion. Combustion requires heat, oxygen, and fuel, often referred to as **The Fire Triangle**. Since different types of fires contain different types of fuels, the combustion process and the contaminants they leave behind vary greatly. For example, the primary fuel in a traditional wildfire includes natural materials, like trees and shrubs, and the combustion process typically produces particulate matter (PM) and a range of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). However, when a fire spreads to an urban area where manmade fuels enter the mix, in the form of cars, buildings, and their contents, the combustion process may produce a complex mixture of more hazardous pollutants, such as metals, halogenated organics, and cyanates. Therefore, the combustion byproducts of a traditional wildfire will likely be very different from those of a wildfire that reaches the wildland urban interface (WUI).

Point source fires, such as the one in East Palestine, Ohio in 2023 that involved a derailed train containing chemicals, can produce a wide range of chemicals and particles reflective of the fuel, combustion products, and atmospheric transformation products. Combustion chemicals may include the original fuels, their additives, and combustion and reaction products, such as VOCs, polycyclic aromatic hydrocarbons (PAHs), dioxins and furans, polychlorinated biphenyls (PCBs), inorganic acid gases, organic and inorganic metals, isocyanates, reactive oxygen species, and particulate matter. Specific emissions depend on numerous variables and require a range of measurement techniques to identify.

A black plume rises from an explosion at the Husky Energy Refinery in Superior, Wisconsin in 2018.

An ammonium nitrate explosion at the West Fertilizer Company storage facility in West, Texas in 2013.

An explosion at the Carribean Petroleum Corporation near San Juan, Puerto Rico in 2009.

EMISSIONS, PLUMES, AND ATMOSPHERIC TRANSFORMATION

A large-scale fire generates what is called a smoke or fire **plume**. A plume is a giant mass of emissions, including particles and chemicals, that occurs downwind of a combustion zone. Once these emissions are put into the atmosphere, the plume evolves over time and changes its chemical nature through a process called atmospheric transformation. Initially, gas-based compounds condense onto particles. Some compounds react with other atmospheric compounds to create new compounds. The transformation continues as the plume emissions mix with other urban pollutants in the air, such as vehicular or industrial emissions. Sunlight also drives photochemical reactions within the plume.

As the plume moves downwind, there are slower processes that continue to occur. Particles fall out of the plume in the form of ash and dust. While larger ash particles may be visible, the smaller dust particles may be harder to detect and take longer to settle, leaving residents in the **near-field** vulnerable. Plumes can travel great distances. While less is known about the health effects from a transformed fire plume at regional and continental scales, we do have a greater understanding of the health effects from immediate exposure to emissions.

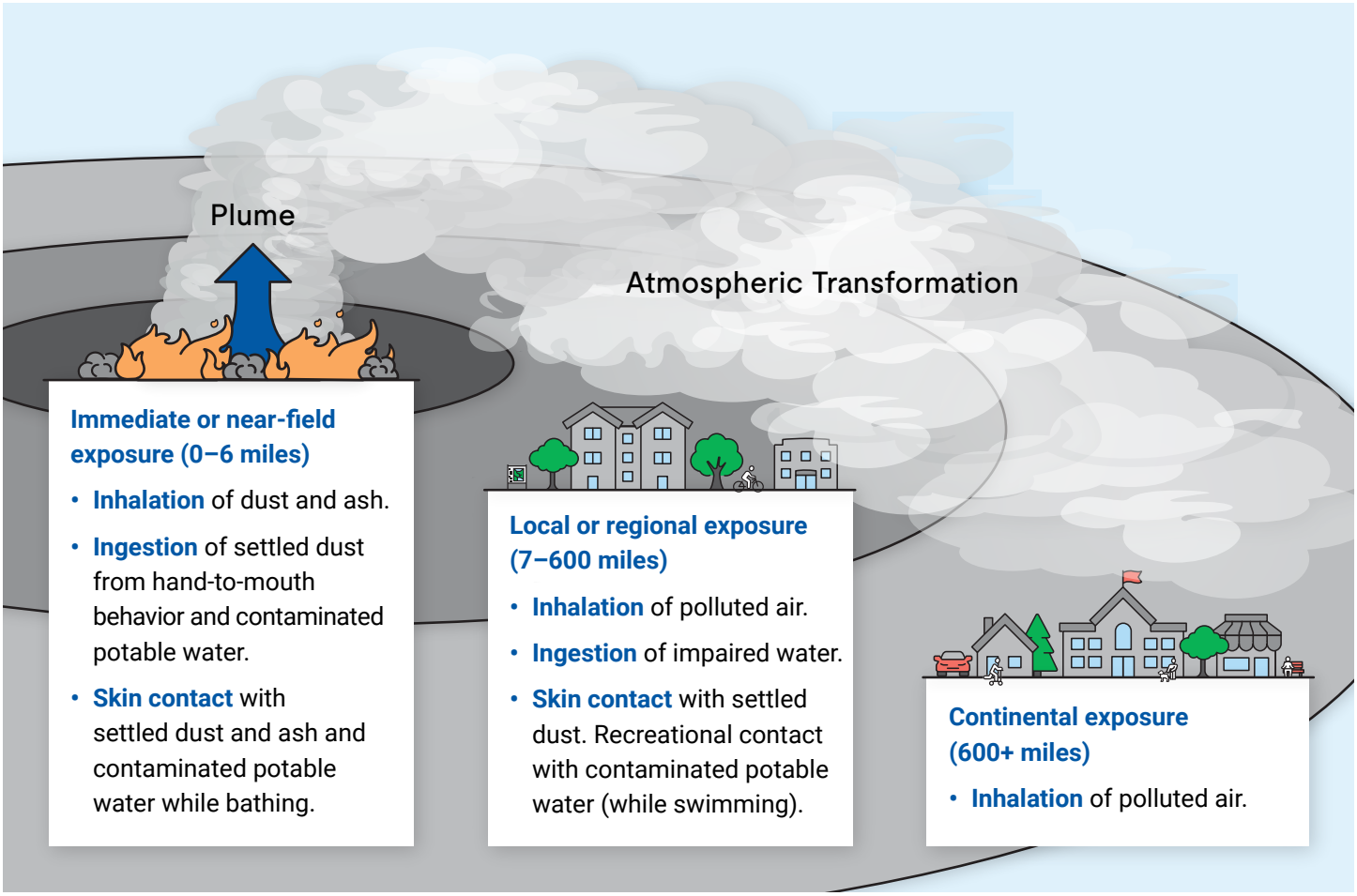

Figure 1: Scales of Exposure and Human Exposure Routes. Human exposure to smoke emissions is possible at all spatial scales away from a large-scale urban fire event. As depicted in the figure, the health impacts and routes of exposure vary across the different zones; however, immediate or near-field exposure is greatest. Figure adapted from National Academies of Sciences, Engineering, and Medicine 2022. *The Chemistry of Fires at the Wildland-Urban Interface.* Washington, DC: The National Academies Press.

The Health Effects After an Urban Fire Disaster

After a fire event, even after the sky clears, hazardous dust particles may settle in the environment for several days or weeks. Depending on what occurred during the atmospheric transformation process, this dust may contain a complex mixture of contaminants.

HOW EXPOSURE OCCURS

People are then exposed to the contaminants left by a fire through three primary routes: inhalation, ingestion, and skin exposure. In the immediate or near-field, the following exposure may occur:

Inhalation: Residents may inhale suspended or resuspended dust and ash. First responders and clean-up crews may also be exposed to direct emissions.

Ingestion: Residents may ingest settled dust, typically from hand-to-mouth behavior. They may also drink contaminated potable water.

Skin Exposure: Residents may come into contact with settled dust and ash. They may also shower with contaminated potable water. First responders may also experience skin exposure from direct or indirect contact with wet and/or dry deposits from the plume.

Negative health effects from immediate or near-field exposure to emissions, specifically settled dust, may include eye, nose, and throat irritation, exacerbation of asthma, skin eczema, chronic obstructive pulmonary disease, and circulatory effects, such as heart attacks and stroke.

VULNERABLE POPULATIONS

Certain members of the population, such as children, individuals with chronic lung or cardiovascular disease, aged people, pregnant women, those with weakened immune systems, and people with lower socioeconomic status may be more vulnerable than others. Since these fires cannot be left to naturally burn out, the individuals who work near them, such as firefighters, emergency response teams, and clean-up recovery crews are increasingly being exposed to emissions, smoldering and resulting residues, or dust. Additionally, outdoor workers in surrounding areas, such as farmers and landscapers, may be at a greater risk.

CHRONIC EXPOSURE RISKS

Since settled dust is hard to clean up and can remain in environments for an extended period, it presents a long-term (chronic) exposure risk for people, beyond the short-term (acute) risk posed in the immediate aftermath of a fire event. The dust will typically be a complex mixture of particles containing residues from the fire, including organic and inorganic substances, fibers, metals, and soil minerals. Specific chemicals originating with the fire fuel and their reaction/combustion products can be adsorbed onto the dust particles and be present and available for human exposure though inhalation, ingestion, and dermal transfer. As a result, dust is an important facilitator of toxicant exposure.

For more information on hazardous settled dust, see TB 500: Health Hazards of Building Dust.