TECHNICAL BRIEF

A Strategic Research Initiative on The Effect of Wildfires and the Wildland Urban Interface (WUI) on Indoor Air Quality and Health in Residential Homes

Introduction

Extreme wildfires occur frequently around the world. These events have the potential to destroy property, disrupt lives, and expose millions of people to unhealthy and hazardous air every year, for days or even months. The frequency of these fire events is expected to increase in the coming years due to a changing climate, longer fire seasons, and a buildup of dry fuels. Additionally, there is an increasing number of homes in the wildland urban interface (WUI), putting more people in danger of being near a wildfire and/or exposed to dangerous smoke conditions. There are an estimated 60,000+ WUI communities at risk in the U.S. where fuels from the built environment can combine with wildland fuels.[1] WUI fires may occur in nearly every part of the U.S. In addition, wildfire and WUI fire smoke can travel hundreds and sometimes thousands of miles affecting millions of people outside the initial area of impact.

WUI/wildfire smoke is a global public health issue. It contains particulate matter (PM) including fine respirable particulate matter that is 2.5 microns and smaller ($PM_{2.5}$) and a wide variety of chemical pollutants, including inorganic and organic gases such as volatile organic compounds (VOCs), nitrogen oxides, and cyanates. It can also contain organic acids and heavy metals. Vulnerable populations including children, older adults, pregnant women, immunocompromised people, and those with preexisting respiratory and cardiovascular conditions should be aware of their surrounding air quality. This is of importance because smoke exposure can trigger asthma attacks, cause irritation, and increase risk of adverse cardiovascular events. WUI fire emissions can not only exacerbate existing health conditions but also lead to the development of additional diseases and premature deaths. Exposures to the toxic components of WUI fire emissions may occur via inhalation, ingestion and dermal absorption.[2] Although some toxicity data is available on both wildland and structural fire emissions, there is a recognized data gap related to the characterization of emissions from WUI fires.[3]

Typically, when communities are impacted by wildfire and WUI fire smoke, public health officials recommend people either evacuate to safe locations or shelter in-place indoors and run their HVAC systems to assist with removal of airborne particles. The use of additional air cleaners is also recommended to help further reduce smoke exposure. Recently, the Chemical Insights Research Institute (CIRI) evaluated the construction, use, and fire-safety of DIY air cleaners, which consist of a 20" x 20" furnace filter with a MERV #13 or higher rating attached to a standard box fan. They published a guidance document detailing their findings related to the construction, operation , and safe use of these devices.[4] A number of studies have shown that commercially available air cleaners with high-efficiency particulate air (HEPA) filtration can be effective at reducing $PM_{2.5}$, but evaluations for VOC removal by air cleaning devices are limited due to the complexity of VOC mixtures in the air and the challenges of quantifying low-level VOCs.[5–7]

CIRI is collaborating with the U.S. Environmental Protection Agency, Office of Research and Development/Center for Environmental Measurement and Modeling (U.S. EPA/ ORD/CEMM), and Duke University, Pratt School of Engineering, on a wildfire study within their air, climate, energy, and sustainable communities' research program. The study will chemically characterize WUI/wildfire smoke to measure its impact on air quality and human health within a community in California at high risk for WUI fires. In this study, U.S. EPA/ORD/CEMM is partnering with the community to recruit participants, monitor for pollutants, assess participant health, and provide air cleaners for use. CIRI is characterizing the chemical composition of the WUI/wildfire smoke by providing short-term (one hour) and extended (six day) indoor/outdoor VOC analyses and conducting novel toxicity assessments of settled dust in homes with smoke debris. This two-year research project is being conducted in homes located in Tulare County in central California, a WUI area often impacted by nearby wildfires. Data analysis will be a collaborative effort between the U.S. EPA, CIRI, and Duke University.

Study Objectives

Key objectives include particle and chemical characterization of WUI/wildfire smoke, identification of human health indicators of smoke exposure, and evaluation of air cleaning effectiveness for the removal of particle and chemical pollutants. These scientific insights will help inform processes for managing and reducing individual and community health risks of WUI fire emissions exposure.

CIRI Phase 1 Objectives: (completed July 2022)

- Collect baseline data to evaluate and optimize measurement approaches for characterization of residential chemical and particle pollution from WUI/wildfire smoke
- Evaluate different dust collection methodologies to optimize data collection and analysis capabilities

CIRI Phase 2 Objectives: (ongoing)

- Identify and measure levels of VOCs and aldehydes in the WUI for communities at risk (CAR)
- Compare CIRI's gas chromatography/mass spectrometric measurement methodology for airborne VOCs with emerging low-cost sensor technology measurements
- Evaluate toxicity of settled dust containing wildland fire debris using cellular assays and metal characterization
- Measure residential chemical and particle pollution resulting from WUI fires
- Analyze the efficacy of the DIY air cleaner for the removal of chemical and particle pollutants in indoor air

Study Plan Overview

The overall project consists of two stages:

1. The pilot study that included assessment of six homes in July 2022
2. A larger cohort study involving up to 50 homes that are being sampled in summer/fall of 2023

The 2022 pilot study allowed for measurement methodologies to be compared and optimized through the generation and analysis of initial household-level data.

Phase 1 Pilot Study: July 2022 with one sampling and analysis event

Six homes were selected for study in an underserved community in Tulare County, California, as coordinated by the Central California Environmental Justice Network (CCEJN) and Region 9 of the U.S. EPA.

The pilot study was conducted over two days. Each home had two sampling locations, one outside the house and one inside the house in a frequently occupied living area. Airborne VOCs were collected onto Tenax sorbent tubes and analyzed in CIRI laboratories via thermal desorption/gas chromatography/mass spectrometry (TD/GC/MS). Low-molecular aldehydes were collected using 2,4-dinitrophenylhydrazine (DNPH) cartridges and analyzed using high performance liquid chromatography (HPLC). These methods are described in the CIRI *Technical Brief: VOC and Aldehyde Analysis Methods Used in Research Studies*.[8] Settled dust was collected via a vacuum thimble and sterile collection bag. The dust was partitioned to be used for metal analysis and novel toxicity assessments.

Phase 2 DIY Air Cleaner Intervention Study: Summer Fall 2023 with five sampling and analysis events

Phase 2 of the study will consist of sampling fifty homes in Tulare County, California, as coordinated by the CCEJN and Region 9 of the U.S. EPA.

Phase 2 will consist of five separate home visits by study personnel. An initial visit to install indoor air monitoring equipment, conduct interviews with the participants, conduct passive VOC sampling, and measure biomarkers to serve as human health indicators, as determined by U.S. EPA. A second visit will be conducted prior to a smoke event to deliver modified box fans (DIY air cleaners) to serve as air cleaners, to retrieve the baseline sampling devices, and collect settled dust from homes using a vacuum. A third visit will be conducted during a smoke event to collect passive sampling devices for VOCs, collect biomonitoring samples, and to collect one-hour active samples of VOC's and aldehydes before and after activation of the DIY air cleaner. A fourth visit will occur one to two weeks after the third visit for collection of additional biomonitoring samples, and instrument retrieval. The fifth and final visit will be scheduled to interview and collect participants' feedback on the use of the DIY air cleaner and on the study experience overall.

Scientific Outcomes

1. Characterization of chemical pollutants in the indoor and outdoor environment during WUI/wildfire smoke events
2. Toxicity assessment of settled dust containing smoke debris using cellular assays
3. Measurement of metal contamination in settled dust containing smoke debris
4. Assessment of low-cost measurement sensors for chemical and particle pollution
5. Assessment of commercial and DIY air cleaners for the reduction of VOC and fine particle pollution contributions from WUI/wildfire fire smoke
6. Measurement of health indicators of smoke pollution and statistical association with chemical, particle, and toxicity measurements

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Research Partners

The United States Environmental Protection Agency/Office of Research and Development/ Center for Environmental Measurement and Modeling (U.S. EPA/ORD/CEMM)

Central California Environmental Justice Network (CCEJN)

Duke University/Pratt School of Engineering

San Joaquin Valley Air Pollution Control District

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