TECHNICAL BRIEF

A Strategic Research Initiative on the Development of a Dust Volatile Organic Compound Method for Chemical Characterization of Settled Dust and Environmental Residues

Chemical Insights Research Institute (CIRI) of UL Research Institutes is developing a methodology to collect dust samples and characterize chemical contaminants to further understand both human health and environmental risks.

Introduction

Contaminants found in dust constitute complex, ubiquitous, and often overlooked components of environmental pollution. Current environmental analysis needs to include characterizations of residual dust and debris resulting from natural disasters such as wildland urban interface (WUI) fires and settled dust in the indoor environment, which can be released from everyday materials or be introduced by certain processes, such as 3D printing. Settled dust might seem innocuous, but it holds within it a complex mixture of contaminants that can impact human health. Exposure to contaminated dust can present an insidious long-term chronic exposure potential for people in the built environment as well as areas impacted by disasters. Human exposure can occur by inhalation when the dust is airborne and by ingestion and dermal transmission from contaminated materials and surfaces. External dust from disaster areas such as wildfires can easily infiltrate homes, schools, and other buildings. It can fall on surfaces, enter building cracks and crevices, contaminate porous materials, and be resuspended into the air.

Dust-bound contaminants can be comprised of various organic and inorganic substances, including volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and heavy metals. Chemicals of concern include VOCs and SVOCs like formaldehyde, toluene, PFAS, phthalates, and flame retardants found in typical indoor environments. In fire-affected areas, dust may also contain combustion-related chemicals such as polycyclic aromatic hydrocarbons (PAHs), benzene, dioxins and furans, aldehydes, and cyanates. Many of these chemicals of concern are carcinogens, reproductive toxins, neurotoxins, and/or endocrine disruptors. This is especially concerning for young children, for whom primary ingestion and dermal exposures are possible through hand-to-mouth activity and by absorption through the skin following dermal contact.[1]

Understanding the composition of environmental dust is crucial when assessing potential chemically mediated health and environmental risks. CIRI is developing a specific methodology to characterize the wide range of chemical contaminants in environmental dust. This method, called dust VOC (DVOC), complements the VOC analysis of air samples. It will provide VOC and SVOC characterization of dust and residues originating from indoor environmental sources and combustion sources like WUI fires. These data will allow for health-risk evaluations and inform mitigation strategies.

Sample Collection

Collecting representative environmental dust samples is a critical first step for accurately analyzing and understanding the contaminants that are present. Several methods are being evaluated for use, depending on the spatial situation. The first is a vacuum sampling method, where a portable vacuum equipped with an in-line filter or sample bag is used to collect settled dust from various indoor surfaces. The other method uses filter cassettes connected to a calibrated air sampling pump. This approach may be employed as a micro-vacuum to collect dust from defined areas or surfaces, or can be used to sample air for suspended dust particles. As air flows through the cassette, dust samples are collected on a pre-weighed filter, typically 37 mm in diameter. The filter pore size and material composition are matched to the requirements of the downstream chemical analysis methods. Sampling cassettes are a convenient method of examination, as the filter is protected in a plastic cassette, but the amount of sample collected is minimal compared to the vacuum method. Dust can be characterized as total weight collected (μg) or amount obtained for a defined square area ($\mu g/m^2$).

Figure 1: Dust sample on quartz wool prior to testing.

Direct Thermal Desorption–Gas Chromatographic/Mass Spectrometric (TD-GC/MS) Analysis

While Soxhlet extraction has been traditionally used for organic chemical analysis, it has several limitations. These include the use of toxic organic solvents, prolonged extraction time, the requirement of large sample amounts, and insufficient analysis sensitivity. Several research groups have demonstrated the feasibility of performing direct thermal desorption–gas chromatography/mass spectrometer (TD-GC/MS) analysis of dust samples.[4,5] CIRI is advancing these studies to develop a DVOC technique specifically for the characterization of hazardous VOCs present in settled building dust and contaminants left in the wake of natural disasters. Dust samples are thermally desorbed and analyzed by gas chromatography/mass spectrometry. CIRI's custom spectral database for indoor contaminants is being used in tandem with a mass spectral library from the National Institute of Standards and Technology (NIST) to identify VOCs detected.

The chemical characterization of settled dust and environmental residues will provide valuable insights into pollution sources, exposure pathways, and associated health risks. By identifying contaminants of concern and understanding their distribution and behavior in the environment, stakeholders can develop targeted mitigation strategies to protect human health and the environment.

Study Objectives

- Establish an analytical method for the analysis of chemical contaminants in dust and environmental residues.
- Evaluate the application of the methodology for detecting VOCs resulting from WUI fire environments where biomass fuel mixes with synthetic materials from the built environment.

Scientific Outcomes

1. Validated methodology for chemical characterization of settled dust and environmental residues.

2. Identification of specific chemicals associated with WUI fires and their corresponding human health impacts.

3. Development of exposure models based on route of exposure, synergistic reactions, and exposure environments.

Research Partners

Duke University

West Virginia University

East-West Center

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