TECHNICAL BRIEF

A Strategic Research Initiative for Environmental Field Study Knowledge

Chemical Insights Research Institute (CIRI) is enhancing its sampling methodology for assessing chemicals in environmental field studies with spatial mapping and real-time chemical monitoring capabilities.

Introduction

A significant component of robust environmental monitoring for chemical and elemental hazards requires understanding of the following criteria:

- **Identification** – What hazardous agents are present?
- **Location** – Where are the hazardous agents located?
- **Distribution** – How do hazardous agents move in the environment?
- **Quantification** – How much of the hazardous agents are present in the environment?

CIRI has a well-established sampling methodology for the assessment of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs), which allows for the determination of both the identity and levels of chemical agents in outdoor and indoor air.[1] This methodology relies on actively moving air through a device that retains chemicals of interest using a calibrated air sampling pump followed by downstream analysis with analytical chemistry in a laboratory setting.

CIRI is augmenting its abilities to evaluate hazard location and distribution with the addition of spatial mapping capabilities using Global Navigation Satellite System (GNSS) receivers. In addition, near real-time monitoring of VOC levels in the ambient environment, using a field-portable Fourier transform infrared spectroscopy (FTIR), is being evaluated for its applicability. The operation and benefits of these new devices and capabilities are discussed further in this document.

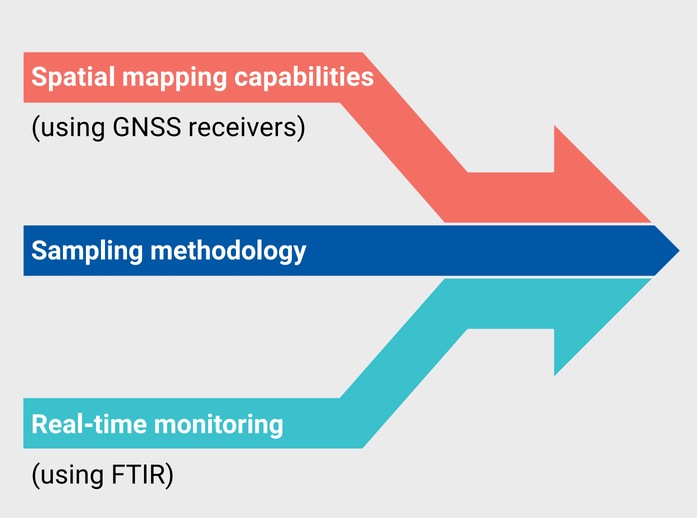

Figure 1: Diagram of augmented sampling methodology.

GNSS Receivers

The GNSS is comprised of United States (GPS), Russian (GLONASS), Chinese (BeiDou), European (Galileo) and other supplemental regional satellites to allow receivers – satellite navigational devices – to determine their exact location on Earth with a precision of 1-40 cm depending on the receiver's connection at any given time. This gives anyone with a satellite-connected GNSS receiver the ability to incorporate high-resolution spatial mapping into field-based research studies.

Emergency responses to environmental, chemical, and physical hazards all involve multiple phases. The first phase is the initial event that led to the emergency responders being deployed (e.g., the flood, the hurricane, the chemical spill, wildfire, among others). The second phase is the data and sample collection phase, where trained professionals go into the area of contamination and take measurements, readings, and/or samples to properly characterize the hazards in the impacted zone. The third phase is the evaluation phase where the samples and data are analyzed, the results are compared to individual health impact outcomes, and the types and levels of environmental hazards are communicated to all necessary parties. The fourth phase is the cleanup and remediation phase. For each phase, it is important to have geo-located data to address the issues that may arise further down the timeline comprehensively.

First responders frequently use GNSS receivers to precisely capture locations of sources of contamination (e.g., underground storage tanks, burnt car batteries, downed power lines, demolition debris, etc.) so they can do bulk removal at a later and safer date. In the second phase, trained professionals take advantage of GNSS receivers to delineate the extent(s) of the hazardous area(s) to capture precisely where samples were taken and to provide more data to better predict where the hazard could spread. The spatial data collected can also be used in the analysis to communicate the hazards to the wider community to give them the ability to make health-conscious decisions for themselves. The ability to properly remediate and clean a contaminated area relies heavily on the previously collected and analyzed sample results and spatial data. With properly collected spatial data integrated with analytical results, it is possible to identify the spatial properties of the contamination and, in turn, allow for monitoring if the contamination has migrated to other areas over time.

CIRI plans to use GNSS spatial data to assist with repeat sampling of specific sites in long-term research studies to monitor the extents of contamination over time and to monitor the efficacy of remediation techniques. Spatial data integration is an important tool when developing accurate models for future exposure assessments to environmental contaminates.

Portable FTIR

When unknown environmental and chemical hazards (solid, liquid, or gas) are present in an area, an FTIR can be used to identify the potential hazards. A gas FTIR operates by shining a light beam that utilizes many frequencies through a gas sample into a series of motorized mirrors with a specific configuration (Michelson interferometer). The motorized mirrors quickly switch back and forth between blocking the wavelength and transmitting the wavelength through the sample. The FTIR is constantly measuring how much light is being absorbed by the gas sample at varying wavelengths and distances from the mirrors. Computer processing takes this raw data and, using the Fourier transform algorithm, can decipher what light is being absorbed and is not being absorbed for each wavelength. Because each wavelength is modulated at different rates and at different distances, each unique gas mixture will have a different readout or spectrum. A spectrum is the visible representation of what light has been absorbed into the gas inside of the chamber of the FTIR and is depicted by what scientists call "peaks" and "valleys." Scientists take these spectra and analyze the differences in "peaks" and "valleys." These differences are where additional gases could be potentially hiding and suggest to analysts whether to further investigate the sample.

Traditional uses of an FTIR have been largely deployed in lab settings due to the size and weight of the internal components of an FTIR. CIRI is utilizing a portable FTIR that allows for in-situ samples in the areas of potential contamination and live readings of the concentrations of gases in the impacted areas.

CIRI uses unique applications of the FTIR in laboratory environmental chamber studies to measure and assess what is present in the exhaled breath of electronic nicotine delivery systems (ENDS) users and in field studies to evaluate the presence and levels of chemicals of concern in the environment after a wildland-urban interface (WUI) fire. While this instrument does not have the analytical sensitivity of thermal desorption-gas chromatography/mass spectrometry (TD-GC/MS) with VOC evaluation, it adds almost real-time monitoring capabilities to ongoing research studies involving gases.

Near real-time environmental monitoring and high-resolution spatial mapping capabilities substantially increases the understanding of how the chemical hazard landscape varies by location and time during a sampling event. This data can be combined with time-integrated high-performance liquid chromatography (HPLC) and GC/MS analytical chemistry results from traditional active air sampling with sorbent tubes and spatially resolved allowing for the determination of "hot spots" of potential exposures. This integrated spatial and chemical data set provides a more complete picture of the identity, location, distribution, and levels of environmental chemical hazards and provides useful parameters for human health risk assessment modeling.

Scientific Objectives

1. Add spatial analysis capacity to field sampling and analysis workflows.

2. Increase real chemical monitoring capacity in field and laboratory settings.

Scientific Outcomes

1. Integration of chemical analysis with spatial analysis capabilities to assist with long- and short-term environmental monitoring and human health risk studies.

References

1. Chemical Insights Research Institute. *Technical Brief 080: VOC and Aldehyde Analysis Methods Used in Research Studies*, 2022, https://ulchemicalsafety.org/wp-content/uploads/2019/09/VOC_Aldehyde_Methods.pdf (accessed 2024-9-04).

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