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Authors
Misztal, PK
Liu, Y
Xiong, J
et al.

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Tracking the sources of volatile organic compounds in an occupied home

Pawel K Misztal[1], Yingjun Liu[1], Jianyin Xiong[1], Caleb Arata[2], Yilin Tian[3], William W Nazaroff[3], and Allen H Goldstein[1,3]

[1]Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720, United States.
[2]Department of Chemistry, University of California, Berkeley, CA 94720, United States.
[3]Department of Civil and Environmental Engineering, University of California, Berkeley, CA 94720, United States.

[*]*Corresponding email: pkm@berkeley.edu*

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1 Introduction

Residences occupied by humans are highly heterogeneous environments where numerous sources and human activities can influence the abundance and composition of gas-phase volatile organic compounds (VOCs) (Weschler 2016). Measurements of indoor atmospheres are often made over long averaging times and focused on VOCs emitted from indoor materials. It is not well known how the full VOC spectrum varies at short spatial and temporal scales in residential indoor spaces. Overall, for a comprehensive evaluation of potential sources in homes, it seems important to address not only time-average concentrations but also instantaneous or short-term VOC levels, measurements of which are now possible in real time (Tang et al. 2016).
To explore holistically the contributions from individual VOC sources to the dynamic complexity of indoor gas-phase organics, we combined temporally and spatially resolved sampling using real-time measurements of VOCs, with concentration enhancements from numerous individual sources by "sniffing" them.

2 Materials/Methods

The "sniffing" approach used a long flexible inlet connected to a proton transfer reaction time-of-flight mass spectrometer (PTR-TOF-MS), which sampled full mass scans (1.000 to 500.0 amu) at high time resolution (1 second) in proximity to putative sources shortly after sampling a representative composition of the nearby indoor space. Preliminary findings are reported here in the context of an intensive indoor measurement campaign, the monitoring portion having been executed during summer/fall 2016 and winter 2017 in a wood-framed single-family home in Oakland, California (Liu et al., Healthy Buildings 2017).

3 Results and Discussion

The "sniffing" revealed diverse and distinctive chemical fingerprints from many sources, which contribute to the VOC complexity indoors. Analysed sources included cabinet interiors, fruits and vegetables present in the kitchen, furniture, wall cavities, appliances, and other potential hotspots in each room of the home including the attic and crawl space. In addition, we sniffed emissions associated with selected household activities such as dishwashing, cleaning, showering, and vacuuming to obtain activity-specific VOC signatures.
Many of the most prominent VOCs observed throughout the house, such as short chain

organic acids and short-chain alcohols, were commonly high in many of the specific sources sniffed. However, each source was also characterized by distinctive sets of compounds, which ranged in relative abundance, and which hold the promise of providing specific chemical fingerprints. The highest total VOC levels in the entire house were observed in the attic in the summertime afternoon when local temperatures were at maximum (~ 45 °C). However, relatively small enhancements were observed from "sniffing" specific sources in that space. We infer that the high levels of specific VOCs (including the characteristic wood emission compounds acetic acid and furfural) result from the high spatial area of wood frame indoor materials, driven by high temperatures, and even though the materials in this 80-year-old home are well aged. The smallest VOC enhancements and the lowest concentrations were found in the well-ventilated crawlspace below the house. After blocking the vents to the crawlspace, accumulation of some specific ions was observed, but the VOC levels in this space were generally low compared to other areas of the house.

A remarkable feature was the discovery of very high sesquiterpene levels (~20 ppb) in a spice cabinet (Figure 1); it appears that this localized source can explain a large portion of sesquiterpene variation in the house. Sesquiterpenes are known to form secondary aerosols by reacting rapidly with ozone, which was usually low in the house (<10 ppb) and often close to zero.

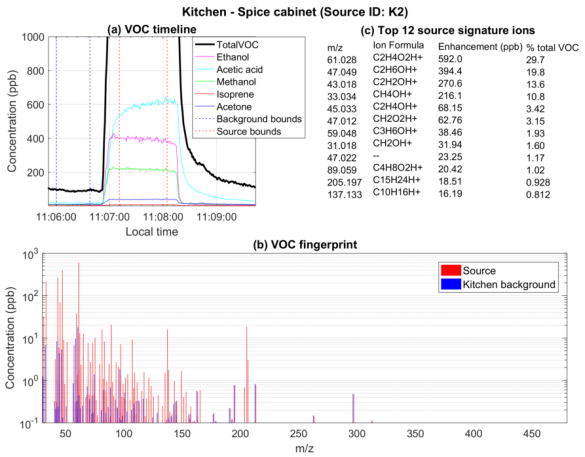

Figure 1: Example of VOC enhancement signature measurement in the spice cabinet. (a) Clear increase in VOCs measured from the spice cabinet (approximately 11:07-11:08) relative to kitchen background concentration. (b) Average steady-state mass spectra from the kitchen background and the cabinet source. (c) Top 12 most enhanced ions in the spice cabinet, including sesquiterpenes (m/z 205.197).

Cabinets in other areas of the residence were also prominent sources of specific volatiles from consumer care and cleaning products. Sniffing in enclosed wooden furniture spaces revealed characteristic wood emissions acetic acid and furfural, which were relatively abundant in the house, including in the coupled spaces of attic and wall cavities. Sniffing individual sources in the bathroom revealed nitrogen-containing compounds from the toilet water tank potentially related to microbial VOCs, which were also observed at very low concentrations in the indoor air. Other hotspots for microbial VOCs were observed under the kitchen sink and near garbage bins; however, overall, these did not significantly contribute to the household VOC levels.

4 Conclusions

Residential environments include a complex ensemble of numerous chemical sources contributing to the variable net chemical composition of an indoor space. The sniffing investigation, utilizing a flexible inlet that could be easily moved around the residence, showed significant value in pinpointing localized sources of VOCs, providing novel information on how episodic activities, such as fruit peeling or opening wooden cabinets, might affect short-term exposure to VOCs. While single compound tracers were often found to be nonspecific, the full mass spectral VOC fingerprints were generally found to be information rich for more specific source identification in an indoor space.

5 Acknowledgement

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6 References

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