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Authors
Misztal, PK
Liu, Y
Tian, Y
et al.

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Time-resolved exposure to volatile organic compounds in two California residences

Pawel K. Misztal[1,*], Yingjun Liu[1], Yilin Tian[2], Caleb Arata[1,3], Kasper Kristensen[1], David Lunderberg[1,3], Jianyin Xiong[1], William W Nazaroff[2], Allen H. Goldstein[1,2]

[1] Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA, United States;
[2] Department of Civil and Environmental Engineering, University of California, Berkeley, CA, United States;
[3] Department of Chemistry, University of California, Berkeley, CA, United States.
[*]*Corresponding email: pkm@berkeley.edu*

SUMMARY

Knowledge of human exposures to volatile organic compounds (VOCs) is critical for understanding their impact on human health. We measured time-resolved concentrations in combination with collecting occupancy data for a wide range of VOCs in two residences in northern California. We report exposures to hundreds of volatile organic compounds present indoors, spanning orders of magnitude in abundance, toxicity and reactivity. We show that concentrations of most VOCs were considerably higher indoors than outdoors, with the sum of measured VOCs being of an order of magnitude higher, in each season and each residence. Occupant's activities were the largest source of short-term episodic exposures, while VOCs from wood degradation were prominent contributors to chronic exposures. We show a comprehensive account of known and newly observed air toxics, their sources, and quantify time-resolved and daily-integrated exposures. We found that daily-integrated measurements could underestimate total exposure to VOCs and point to the need for time-resolved concentration measurements to accurately assess exposures.

1 INTRODUCTION

Exposure to VOCs indoors can affect cognitive function and health (Allen et al., 2017). Short-term exposure to a full spectrum of VOCs is not typically measured and exposures to many potentially harmful chemicals may be unknown. Previous research focused predominantly on time-integrated exposures to a subset of known toxic VOCs from building materials in new homes or sick buildings. Creating a safe and healthy indoor environment requires rapid progress toward broader understanding of short and long-term exposures to a comprehensive suite of VOCs and expanding toxicological assays for an expanded suite of compounds.

2 METHODS

Measurements of spatiotemporal variability of a full VOC range were performed with a proton transfer reaction time of flight mass spectrometer (PTR-ToF-MS) which continuously measured the time-resolved mass spectrum (1.000-500.00 amu) in living spaces and outdoors. Three intensive measurement campaigns were conducted in two northern California residences (H1 summer 2016, H1 winter 2017, and H2 winter 2017/2018) for durations of 5-8 weeks. Complimentary lower time resolution measurements were made using sorbent tube collection and TD-GC×GC-VUV/EI-ToFMS analysis to further investigate compound speciation.

3 RESULTS AND DISCUSSION

We found hundreds of compounds with remarkably higher concentrations indoors than outdoors, and particularly higher during times of occupancy. The VOCs detected belong to many chemical families including aromatics, aldehydes, ketones, alcohols, organic acids, amides, amines, heterocyclics (e.g. furanoids), halogenated, and multifunctional. Incidental and cumu-

lative exposures to specific, categorized and sums of VOCs are reported in the context of their magnitude, duration and toxicity. For certain groups of compounds, such as monoterpenes from orange peeling, exposures largely differed by season but for many compounds exposures were comparable in two seasons. Figure 1 shows an example of daily-integrated exposures to acrolein – a respiratory toxicant mostly originating from cooking but also from wood, and to furfuranol – a neurotoxic compound (Savolainen and Pfaffli, 1983) emitted by wooden house structure but with episodic contributions from cooking. Exposure and risk assessments are performed for full suites of VOCs, with particular focus on aromatics, furanoids, and other compound families of known or suspected toxicity. Overall, toxicity of compounds was inversely associated with their abundance, and we show the risk assessment which includes extended suite of air toxics.

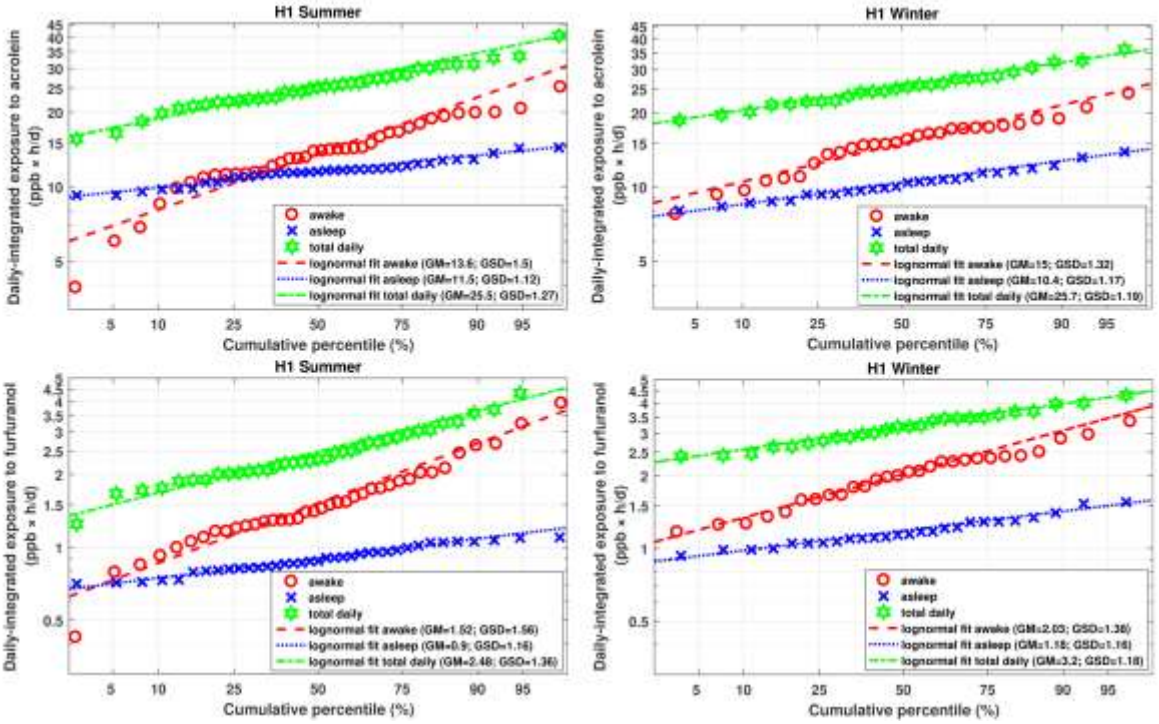

Figure 1. Daily integrated exposures to acrolein (top panels) and furfuranol (bottom panels).

4 CONCLUSIONS

Our data show that short-term episodic human exposures to VOCs can span orders of magnitude and are caused by occupant's activities, rather than the house structure. In contrast to other studies focused on new building materials, we point out that degradation of wood and other lignocellulosic content of the house is the considerable chronic source of exposure to a range of organic acids, aromatic and heterocyclic compounds. Not only formaldehyde but a series of organic aldehydes are present indoors despite the lack of new materials in these houses. Cooking activities in particular can expose occupants to a large number of semivolatile compounds which are deposited on the surfaces and are re-emitted as a function of temperature leading to secondary exposures.

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5 REFERENCES

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