The 16th Conference of the International Society of Indoor Air Quality & Climate (Indoor Air 2020)
COEX, Seoul, Korea | July 20 - 24, 2020

Paper ID xxx.xx ISBN: …………………….

Quantifying volatile organic compounds and their sources in residences in Ahmedabad and Gandhinagar, India, and in suburban Shanghai, China

Christina Norris[1], Michael H. Bergin[1], Yinping Zhang[2], Ross Edwards[3], Chinmay Ghoroi[4], Karoline K. Barkjohn[1], Junfeng Zhang[5], Marilyn Black[6], James J. Schauer[3]

[1]Department of Civil and Environmental Engineering, Duke University, Durham, USA
[2]Department of Building Science, Tsinghua University, Beijing, China
[3]Department of Civil and Environmental Engineering, University of Wisconsin at Madison, Madison, USA
[4]Department of Chemical Engineering, Indian Institute of Technology Gandhinagar, Gandhinagar, India
[5]Nicholas School of the Environment, Duke University, Durham, USA
[6]Chemical Safety, Underwriters Laboratories Inc., Marietta, USA

**Corresponding email: christina.norris@duke.edu; michael.bergin@duke.edu*

Keywords: volatile organic compounds; indoor sources; source identification; India; China

1 Introduction

Many volatile organic compounds (VOCs) are measured at higher concentrations indoors than outdoors (Brown et al. 1994), with concentrations influenced by outdoor sources (e.g., vehicles, industry, solvents), a wealth of sources indoors (e.g., personal care products, food, construction materials, furniture), and human behaviours (e.g., opening windows and doors). Although people in urban environments spend the majority of their time indoors and many VOCs are associated with adverse effects on health (Kjærgaard et al. 1991; LBNL 2018; Ware et al. 1993), these pollutants and their sources remain poorly characterized indoors. This limited characterization extends to homes that do not rely on biomass fuels for cooking or heating in urban/suburban India (Goyal et al. 2012) and in China. With a growing middle class, these countries are seeing an increasing number of people living in newer homes, where sources of VOCs may be prevalent.

2 Materials/Methods

We collected integrated 90-minute samples of VOCs and aldehydes in suburban Shanghai, China, in spring 2017 (n=20 homes) and in Ahemedabad/Gandhinagar, India, in summer 2019 (n=20 homes) and winter 2020 (n=19 homes). Samples were collected during the early morning in all homes and in the afternoon/evening in a subset of homes in India. We used a questionnaire about household characteristics and activities during sampling to better understand factors driving quantities of pollutants measured in India. In Shanghai, we additionally assessed the effects of air filtration (HEPA, carbon) on compounds. In Shanghai, families were asked to keep their doors and windows closed during sampling. In India, doors and windows were often open in homes during the very hot summer and to some extent in the winter. We used non-negative matrix factorization - a variable reduction technique - to identify potential sources of compounds in both Shanghai and Ahmedabad/Gandhinagar.

3 Results and Discussion

In Shanghai, the total VOC level was substantially higher indoors (median: 235, min: 56, max: 793 μg/m^3) than outdoors (median: 62, min: 26, max: 629 μg/m^3). Concentrations in

Ahmedabad/Gandhinagar during the summer were higher indoors (median: 104, min: 17, max: 326 µgm^{-3}) than outdoors (median: 56, min: 21, max: 263 µgm^{-3}) in the morning, although they did not differ significantly in the afternoon (Figure 1).

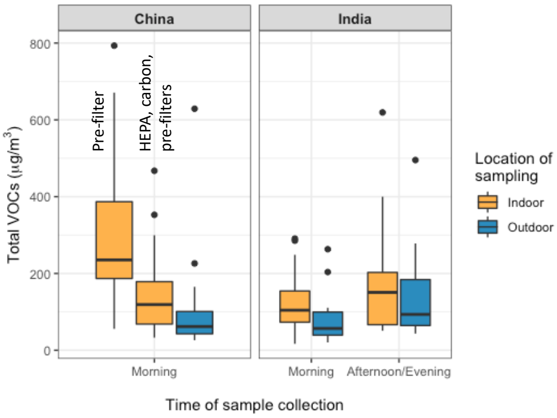

Figure 1: Total VOC concentrations measured indoors and outdoors at homes in Shanghai and Ahmedabad/Gandhinagar with and without the use of a functional air purifier (China) and at different times of day (India). Homes in India received no air filtration.

Temporal differences may relate to changing source emissions over the course of the day, activity patterns of individuals in the homes, and the fact that doors and windows were more likely to be closed at night, exacerbating indoor/outdoor differences. Concentrations indoors in Ahmedabad/Gandhinagar tended to be lower than in Shanghai. For individual compounds, substantial variation was observed between households with respect to both the compounds detected and the concentrations at which they were measured; some of these differences likely relate to the specific products and materials used in the home, local pollution near the home infiltrating the home, and the time of day that the sampling occurred. However, some compounds (i.e., toluene, acetaldehyde, formaldehyde) were nearly ubiquitous regardless of sampling location and time. There were distinct indoor (e.g., cooking-related, personal care product) and outdoor (e.g., solvents, traffic) pollutant sources at both sites, and many compounds were only detected indoors, further pointing to indoor sources. Pesticides were identified as a potential source indoors in India. In Shanghai, air filtration was associated with lower concentrations of total VOC and of numerous individual compounds – some hazardous. In Ahmedabad/Gandhinagar, 34 of the compounds quantified during the summer present an inhalation health hazard. Results from the winter sampling campaign are forthcoming.

4 Conclusions

Our ability to reduce exposures to VOCs and aldehydes, some of which present known hazards to health, relies on quantification of these compounds indoors, understanding indoor/outdoor relationships, and identifying sources of compounds. We begin this important quantification with a view to improving our understanding of the indoor environment in urban/suburban China and India. We measured VOCs at higher concentrations indoors than outdoors, pointing to the need to control indoor sources of these compounds, and found that air filtration may mitigate such exposures. Exposures in these indoor environments are likely to become increasingly important with the burgeoning middle class and continued growth and development in India and China.

5 Acknowledgement

We gratefully acknowledge the families who welcomed us into their homes for sampling, and our field technicians and collaborators for making the sampling possible. This work was funded by Underwriters Laboratories Inc.

6 References

Brown, S.K., Sim, M.R., Abramson, M. J. and Gray, C.N. 1994. Concentrations of volatile organic compounds in indoor air – A review. Indoor Air. **4**: p. 123-134.

Goyal, R., Khare, M. and Kumar, P. 2012. Indoor Air Quality: Current Status, Missing Links and Future Road Map for India. Civil and Environmental Engineering, 2012. **2**(4)

Kjærgaard, S.K., Mølhave, L., and Pedersen, O.F. 1991. Human reactions to a mixture of indoor air volatile organic compounds. Atmos Environ A-Gen. **25**: p. 1417-1426.

LBNL. VOCs and Cancer. 2018 [cited 2018 10/04]; Available from: https://iaqscience.lbl.gov/voc-cancer

Ware, J.H., Spengler, J.D., Neas, L.M., Sarnet, J.M., Wagner, G.R., Coultas, D., Ozkaynak, H and Schwab, M. 1993. Respiratory and Irritant Health Effects of Ambient Volatile Organic Compounds The Kanawha County Health Study. Am J Epidemiol. **137**: p. 1287-1301.