

Assessing Human Exposure to Hazardous Air Pollutants in Various Microenvironments

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The main objective of this observational research is to reduce uncertainties in predicting exposure levels to volatile hazardous air pollutants (HAPs). To meet this objective, we measured personal exposure and outdoor, indoor, and workplace concentrations, as well as collected time activity data and the air exchange rate in the homes of 55 study participants, 34 of which participated in two seasons. To further understand the origins of indoor concentrations, the contribution of secondary source areas such as basements, attached garages, and common apartment hallways were estimated for each home. The mean percent of the total air flow within the occupied zone of the residence from the basement was 26 percent (standard deviation (SD) = 34 percent) in the summer and 47 percent (SD = 26 percent) in the winter, while the mean percent from apartment hallways was 22 percent (SD = 33 percent). Residences with garages attached to the basement had higher air flow rates to the adjacent zone (means from 50 to 887 cubic meters per hour [m^3/hr]) than those with garages attached directly to the occupied zone (means from 1 to 65 m^3/hr). Approximately 20 percent to 40 percent of the indoor concentration for compounds associated with gasoline sources can be attributed to an attached garage at the residence. At the median, basements contributed to approximately 10-20 percent of the estimated indoor concentrations. For apartments, approximately 5-10 percent of the estimated indoor concentrations confer with air from the hallway.

We used a series of time-weighted personal exposure models to compare measured personal concentrations using median regression models, with bias estimates representing the difference between measured and modeled personal exposures. We incorporated only the outdoor microenvironment results in an unbiased estimate of personal exposure for carbon tetrachloride. Adding the residential indoor microenvironment provides an unbiased estimate for trichloroethene as well. In addition, we developed a model that incorporates residential outdoor, indoor, and workplace microenvironments and provides an unbiased estimate for the above compounds in addition to chloroform, 1,4-dichlorobenzene, benzene, and R-pinene. Developing a fully saturated model, including outdoor, indoor, workplace, transportation, and all other microenvironments, allowed us to provide an unbiased estimate for the previously listed compounds along with tetrachloroethene and styrene. Methyl tert-butyl ether (MTBE), toluene, o-xylene, d-limonene, formaldehyde, and acetaldehyde were not fully characterized in these models, emphasizing that additional time-activity and concentration information would more fully characterize personal exposure.

Additionally, various types of retail stores, including hardware, grocery, furniture, drug, houseware, sporting goods, department, electronics, and multipurpose stores, were sampled using a composite sampling design. Smoking and non-smoking dining establishments were also sampled. Volatile organic compound (VOC) concentrations tended to be more skewed in dining and shopping microenvironments compared to inside home microenvironments. Using data from the Boston Exposure Assessment in Microenvironments (BEAM) study and the literature, a stochastic population exposure model was developed for four different cohorts – employed males/females and unemployed males/females. Mean contributions to personal exposure from leisure time shopping and dining range from 5 percent to 20 percent. People who work in shopping and dining had a greater fraction of their personal exposure from occupational exposure. At the median, workers tended to have from 20 percent to 60 percent of their total exposures from working in stores or restaurants.

Implications: Homeowners and apartment owners should be encouraged to retrofit existing doors with doors that will provide a good seal between garages and basements where chemicals are stored. In

addition, ventilation systems should be designed to limit air transfer from regions where chemicals are stored to living areas. Smoking bans in restaurants should continue to be implemented. Additional studies are necessary to determine if additional outside air is needed to ventilate stores and decrease risks to employees.

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Presentation(s):

Loh, M., Houseman, E.A., and Bennett, D.H. (2004). Characterization of microenvironmental VOC concentrations using a composite sampling method. Presented at the International Society of Exposure Analysis 2004 Annual Meeting, Philadelphia, PA.

Dodson, R.E. and Bennett, D.H. (2005). Impact of secondary source zones on indoor residential concentrations of VOCs. Presented at the International Society of Exposure Analysis 2005 Annual Meeting, Tucson, AZ.

Loh, M. and Bennett, D.H. (2005). Contribution to total personal exposure of VOC's from shopping and dining microenvironments. Presented at the International Society of Exposure Analysis 2005 Annual Meeting, Tucson, AZ.

Dodson, R.E., Levy, J.I., Shine, J.P., Spengler, J.D., and Bennett, D.H. (2006). Indoor source analysis of volatile organic compounds. Presented at the International Conference on Environmental Epidemiology and Exposure, Paris, France.

Dodson, R.E., Levy, J.I., Shine, J.P., Spengler, J.D., and Bennett, D.H. (2006). Measured and modeled personal exposures to volatile organic compounds. Presented at the International Conference on Environmental Epidemiology and Exposure, Paris, France.

Loh, L., Houseman, E.A., Spengler, J.D., and Bennett, D.H. (2006). Characterization of VOC exposures and risk in non-residential microenvironments. Presented at the Conference on Indoor Air Quality, Braunschweig, Germany.

Loh, M. and Bennett, D.H. (2006). Commuter exposures to VOC's in various transportation modes. Presented at the International Conference on Environmental Epidemiology and Exposure, Paris, France.

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Dodson, R.E., Houseman, E.A., Levy, J.I., Spengler, J.D., and Bennett, D.H. (2007). Measured and modeled personal exposures to and risks from volatile organic compounds. *Environmental Science and Technology* 41: 8498-8505.

Dodson, R.E., Levy, J.I., Shine, J.P., Spengler, J.D., and Bennett, D.H. (2008). Influence of basements, garages, and common apartment hallways on indoor residential volatile organic compounds. *Atmospheric Environment* 42(7): 1569-1581.

Loh, M.M., Houseman, E.A., Levy, J.I., Spengler, J.D., and Bennett, D.H. (2008). Contribution to volatile organic compound exposures from time spent in stores and restaurants and bars. *Journal of Exposure Science and Environmental Epidemiology*. (In press).

Dodson, R.E., Levy, J.I., Houseman, E.A., Spengler, J.D., and Bennett, D.H. Evaluating methods for predicting indoor residential volatile organic compound concentration distributions. *Journal of Exposure Science and Environmental Epidemiology*. (In press).

Other publications:

Dodson, R.E., Levy, J.I., Shine, J.P., Spengler, J.D., and Bennett, D.H. (2006). Impact of attached garages on indoor residential BTEX concentrations. *Healthy Buildings 2006*.

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