

# Indoor Air Quality in Retail Stores: A Review

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## 1 Introduction

Retail stores are understudied given the energy, occupant health, and potential sales impacts associated with poor indoor air quality. In the U.S. alone, approximately 15 million people work in the retail sector and 45% of retail buildings energy consumption is used for indoor environmental conditioning (ESource, 2006). The purpose of this extended abstract is to summarize the literature on indoor air quality in retail environments.

## 2 Methods

The peer-reviewed literature was searched using ISI Web of Science and Google Scholar. A total of only 14 papers were found to match our criterion of measured contaminant concentrations in any type(s) of retail store. Some papers included more than just retail environments, but only the retail data were used. Papers are categorized and summarized in Table 1.

Table 1. Summary of Literature Reviewed

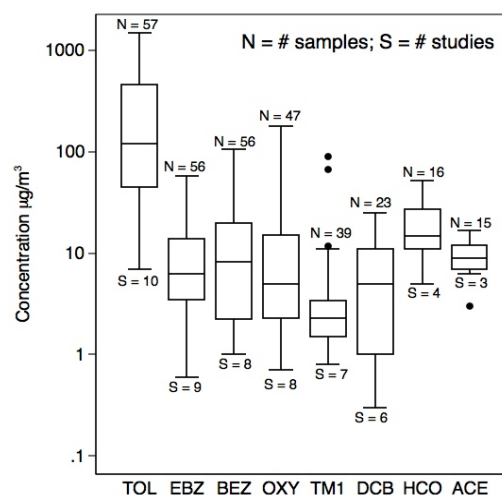
Author	Year	Types <sup>1</sup>	Pollutants <sup>2</sup>	N <sup>3</sup>
Bruno et al	2008	PH,CS,GR, CC,HD	VOC	11
Caselli et al	2009	NS	VOC	16
Chao & Chan	2001	MA	VOC	2
Eklund et al	2008	MA	VOC	1
Geiss et al	2010	CD	VOC	4
Hartman et al	2004	FN, ES	SVOC	5
Hotchi et al	2006	BB	VOC, SVOC	1
Kim et al	2001	DS PF	VOC	5
Lee et al	2002	MA	VOC, Bio, PM	9
Loh et al	2006	HW,MP,GR, PH,SG,FN, HO,DS,ES	VOC	113*
Maskey et al	2010	UM	PM	1
Tang et al	2005	MA	VOC	1
Tringe et al	2008	MA	Bio	2
Yu et al.	1997	UM	Radon	10

<sup>1</sup>Pharmacy (PH), Mall (MA), Big Box (BB), Hardware (HW), Multipurpose (MP), Grocery (GR), Sporting (SG), Furniture (FN), House wares (HO), Department (DS), Newspaper stands (NS), Electronics (ES), Copy center (CC), Hairdresser (HD), Car dealership (CD), Underground malls (UM) <sup>2</sup> Volatile organic compounds and aldehydes (VOC), Semi-volatile organic compounds (SVOC), Biological pollutants (Bio), Particulate matter (PM) <sup>3</sup>Number of buildings, \* = composite sample

## 3 Results

By far VOCs and aldehydes were the most common pollutant groups studied with measurements in ten of the 14 papers. Figure 1 summarizes a select group of studied VOCs. Benzene, toluene, ethyl-benzene, and xylenes, known as the group BETX were represented heavily in the results summary. Most BETX compounds have both indoor and outdoor sources with the exception of ethyl-benzene, which is mainly a fuel additive. Toluene always had an indoor/outdoor ratio (I/O) above unity, indicating strong indoor sources, possibly such as printed material and wall coatings (Bruno et al. 2008). Formaldehyde was observed to be the highest in stores selling home wares and furniture (Loh et al. 2006). Dichlorobenzene also had a very high I/O ratio in malls (Tang et al. 2005), suggesting strong indoor sources, including disinfectants and deodorizers.

Figure 1. Summary of VOC concentrations



<sup>1</sup>Toluene (TOL), Ethyl Benzene (EBZ), O-Xylene (OXY), 1,2,4-Trimethylbenzene (TM1), 1,4 Dichlorobenzene (DCB), Formaldehyde (HCO), Acetaldehyde (ACE)

There are limited investigations of other pollutants. Yu et al. (1997) is the only study known to have investigated radon, and found

that exposure was not elevated in the retail environments they investigated. Lee et al. (2002) reported PM<sub>10</sub> concentrations were highest in those retail environments that were in the closest vicinity to smokers and gas stoves, namely malls and the restaurants therein. Maskey et al. (2010) reviewed the chemical make-up of particles in an underground mall, and found strong seasonal variation in the chemical composition, reflecting higher air exchange rates in the spring and a significant baseline concentration of textile particles. Hartmann et al. (2004) found acceptable SVOC inhalation exposure levels in electronics and furniture stores, but noted that even with vastly reduced usage, TCEP (tris(2-chloroethyl) phosphate) was still the second most abundant measured compound indicating significant TCEP reservoirs. Lee et al. (2002) quantified total bacterial counts and found higher levels in air-conditioned malls. Tringe et al. (2008) also studied two malls and found that the indoor microbial community is different from the ambient community.

#### 4 Conclusions

We reviewed 14 papers on indoor air quality in retail environments. There is evidence of increased concentrations of several types of pollutants in some retail environments, but there is insufficient data to make firm conclusions about the health risks or even comparisons to non-retail environments. There is a clear need for additional research on this topic and particularly the connection between indoor air quality and ventilation in retail stores.

#### 5 References

- Bruno, P., G. De Gennaro, S. Iacobellis, and M. Tutino. "Monitoring of Volatile Organic Compounds in Non-residential Indoor Environments." *Indoor Air* 18.3 (2008): 250-56. Print.
- Chao, C. "Quantification of Indoor VOCs in Twenty Mechanically Ventilated Buildings in Hong Kong." *Atmospheric Environment* 35.34 (2001): 5895-913. Print.
- Eklund, B. M., S. Elkund, B., Burkes, P. Morris, and L. Mosconi. "Spatial and Temporal Variability in VOC Levels within a Commercial Retail Building." *Indoor Air* 18.5 (2008): 365-74. Print.
- ESource. "Managing Energy Costs in Retail Buildings." *CEA\_Retail*. ESource. Web. 30 Dec.2010. <[http://www.esource.com/BEA/demo/PDF/CEA\\_retail.pdf](http://www.esource.com/BEA/demo/PDF/CEA_retail.pdf)>.
- Geiss, O., J. Barrero-Moreno, and D. Kotzias. "Measurements of Volatile Organic Compounds in Car Showrooms in the Province of Varese (Northern Italy)." *Indoor Air* (2010). Pre-print. Web.
- Hartmann, P., D. Burgi, and W. Giger. "Organophosphate Flame Retardants and Plasticizers in Indoor Air." *Chemosphere* 57.8 (2004): 781-87. Print.
- Hotchi, Toshifumi, Alfred T. Hodgson, and William J. Fisk. "Indoor Air Quality Impacts of a Peak Load Shedding Strategy for a Large Retail Building." *IA2006 Conference Proceedings* LBNL-59293 2006
- Kim, Young Min, Stuart Harrad, and Roy M. Harrison. "Concentrations and Sources of VOCs in Urban Domestic and Public Micro-environments." *Environmental Science & Technology* 35.6 (2001): 997-1004. Print.
- Lee, Shun-Cheng, Hai Guo, Wai-Ming Li, and Lo-Yin Chan. "Inter-comparison of Air Pollutant Concentrations in Different Indoor Environments in Hong Kong." *Atmospheric Environment* 36 (2002): 1929-940. Web.
- Loh, Miranda M., E. Andres Houseman, George M. Gray, Jonathan I. Levy, John D. Spengler, and Deborah H. Bennett. "Measured Concentrations of VOCs in Several Non-Residential Microenvironments in the United States." *Environmental Science & Technology* 40.22 (2006): 6903-911.
- Maskey, Shila, TaeHee Kang, Hae-Jin Jung, and Chul-Un Ro. "Single particle Characterization of Indoor Aerosol Particles Collected at an Underground Shopping Area in Seoul, Korea." *Indoor Air* (2010). Pre-print. Web.
- Tang, J., C. Chan, X. Wang, L. Chan, G. Sheng, and J. Fu. "Volatile Organic Compounds in a Multi-storey Shopping Mall in Guangzhou, South China." *Atmospheric Environment* 39.38 (2005): 7374-383. Print.
- Tringe, Susannah G., Tao Zhang, Xuguo Liu, Yiting Yu, Wah Heng Lee, Jennifer Yap, Fei Yao, Sim Tiow Suan, Seah Keng Ing, Matthew Haynes, Forest Rohwer, Chia Lin Wei, Patrick Tan, James Bristow, Edward M. Rubin, and Yijun Ruan. "The Airborne Metagenome in an Indoor Urban Environment." *PLoS ONE* 3.4 (2008): E1862.
- Yu, K. "A Survey of Radon Properties in Underground Shopping Centers in Hong Kong." *Applied Radiation and Isotopes* 48.6 (1997): 863-66. Print.