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Volatile organic compounds in a multi-storey shopping mall in guangzhou, South China

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Abstract

Volatile organic compounds (VOCs) specified in the USEPA TO-14 list were analysed in microenvironments of a multi-storey shopping mall in Guangzhou city, South China. The microenvironments studied include both indoor (department store, supermarket, fast-food court, electronic games room, children's playground, gallery and book store) and outdoor ones (rooftop and ground level entrance). The characteristics and concentration of VOCs varied widely in differing microenvironments. The average concentrations of the total VOCs in the indoor microenvironments ranged from 178.5 to 457.7 $\mu g\,m^{-3}$ with a maximum of 596.8 $\mu g\,m^{-3}$. The fast-food court and a leather products department store had the highest concentrations of benzene, toluene, ethylbenzene, xylenes and chlorinated hydrocarbons. A high level of 1,4-dichlorobenzene was found in all indoor microenvironments with an average of 12.3 $\mu g\,m^{-3}$ and a maximum of 44.3 $\mu g\,m^{-3}$. The ratios of average indoor to outdoor concentrations (I/O ratio) in all indoor microenvironments fell between 1 and 3, except an average of 24.6 and a maximum of 77.8 in the fashion department store for 1,4-dichlorobenzene. Indoor emission sources of monocyclic aromatic hydrocarbons in the shopping mall might include cooking stoves, leather products and building materials. Chlorinated hydrocarbons, however, were possibly connected with their use as cleaning agents or deodorizers.

Keywords: Volatile organic compounds; Indoor air quality; Shopping mall; Indoor microenvironments; Aromatic hydrocarbons; Chlorinated hydrocarbons

1. Introduction

Concerns over the effects of poor indoor air quality have been increasing in recent years (Jones, 1999), and a wide spectrum of symptoms and illnesses are related to non-industrial indoor air pollution (Redlich et al., 1997). Indoor levels of volatile organic compounds (VOCs) often exceed outdoor levels by up to five times (Wallace, 1991a), and most individuals, particularly in developed countries, spend most of their time indoors (Robinson and Nelson, 1995), so that people's exposure to VOCs might be much higher indoors than outdoors. VOCs from various sources in indoor environments will accumulate if there is poor ventilation, and thus cause both acute and

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chronic health effects from sensory irritation, drowsiness, and headaches to cancer (Norbäck et al., 1995; Hodgson et al., 1991; Otto et al., 1992; Wallace, 1991b). Exposure to VOCs has frequently been attributed as a cause of sick building syndrome (Kostiainen, 1995). In developed countries, indoor VOCs have been widely studied (e.g., Baek et al., 1997; Edwards et al., 2001; Kim et al., 2001; Sakai et al., 2004) and regulated. Concerns over indoor environments are increasing in developing countries like China, which issued an indoor air quality standard (GB/T 18883-2002) in 2002.

In China, especially in important economic zones like the Pearl River Delta (PRD) region, poor air quality accompanying rapid urbanization and industrialization may pose serious health risks. The World Bank (1997) estimated that about 178,000 and 111,000 deaths per year would be prevented if the urban and indoor air quality of China met the Chinese Class 2 Air Quality Standards, respectively. High levels of particulate matters, VOCs, ozone and other pollutants in ambient air have been reported in PRD including Hong Kong and Macao (Chan and Chan, 2000; Chan et al., 2002a, b, Wang et al., 2002; Zhao et al., 2004). Indoor air quality in PRD, however, has not attracted attention from the public and research groups until recently. People may be exposed to various indoor environments including shopping malls. In recent years, the number of shopping malls in China has increased sharply. These shopping malls are large in capacity and may house many different kinds of polluting emission sources such as cooking stoves. Another distinction compared to their counterparts in Europe and North America is that almost all of these shopping malls are located in highly populated urban areas. Indoor air pollution in the malls may add to shopping-mall workers' and customers' exposure to air toxics. However, there are relatively limited reports on the air quality in shopping malls in China. In the present study, VOCs were measured in various microenvironments of a multi-storey shopping mall in Guangzhou, the central city in PRD. Their characteristics and major sources are also discussed.

2. Method and experiment

2.1. Field sampling

The studied shopping mall is located in the centre of urban Guangzhou. The mall has 10 floors altogether, and the area of each floor exceeds 10,000 square meters. Three floors are underground. The second and third underground floors are used as car parks, and the first underground floor is occupied by a supermarket, a department store and other small shops. At its northern front entrance, the shopping mall faces a trunk road with four lanes on each side. About 40 bus routes pass by the front gate of the mall. The southern entrance has a metro exit at its first underground floor. The mall is centrally air-conditioned and smoking is not allowed. During the experimental period (close to the Chinese lunar new year), there were about 200,000 customers visiting the mall daily. Thirteen microenvironments, including 11 indoor ones, were selected for the measurement of VOCs. The two outdoor sampling sites include a site at the front entrance at ground level and a site on the rooftop of the building. Table 1 describes the characteristics of the microenvironments. The shopping mall opens at 10:00 am and closes at 10:00 pm. Field sampling in this study was conducted from 25 January 2002 to 2 February 2002 between 10:30 and 16:20. Air was drawn at 1.2 m above ground by a portable sampling pump (Air-check 52, SKC Inc., USA) through stainless steel multi-sorbent tubes (Tekmar Company, USA). The sampling pumps were loaded in a sampling box, which was carried on the back of a sampling person. The person walked around the microenvironments of interest during sampling. The multi-sorbent tubes are 7 in in length and 1/4 in in diameter, and packed with Tenax TA and Carbonsieve S-III. The pump was calibrated before and after sampling. The sampling airflow rate was $100\,mL\,min^{-1}$. The sampling duration was 30 min. Thus, the sample volume was 3 L in each sample. The sorbent tubes were contained in a capped glass cartridge after sampling, and then sent back to the laboratory and stored in a refrigerator at $-20\,^{\circ}C$. Samples were analysed within 96 h after sampling.

2.2. VOC analysis

The air samples were analysed by a system consisting of a thermal desorption system (Tekmar 6000 Thermal Desorber) and a gas chromatograph/mass selective detector (Hewlett-Packard 5972 GC/MSD). The analysis procedure is briefly described below and the details are available in the literature (Wang et al., 2002; Zhao et al., 2004). The sorbent tubes were thermally desorbed at $225\,^{\circ}C$ for 20 min, and the desorbed VOCs were carried by ultra-pure helium gas (99.9999%) to a charcoal trap cooled