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Benzene, toluene and xylenes in newly renovated homes and associated health risk in Guangzhou, China

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ABSTRACT

Decoration and refurbishment in homes is associated with rapid urbanization in China. Its popularity has led to indoor elevated levels of benzene, toluene, and xylenes (BTX), posing adverse health effects to occupants. In this study, concentration levels of BTX and associated health risk were investigated in homes with new renovations in urban and suburban areas in Guangzhou, China. All air samples were collected with passive samplers for 24 h exposure in winter 2012. The average concentrations of benzene, toluene, *m*/*p*-xylene and *o*-xylene were 18.5 μg/m^3, 173.2 μg/m^3, 58.1 μg/m^3 and 40.8 μg/m^3 respectively, similar to or higher than those reported in previous studies for new homes or recently renovated homes, but generally greater than those measured in old homes. Higher BTX concentrations were observed in urban homes than in suburban homes. The mean incremental lifetime cancer risk induced by inhalation exposure to benzene in newly renovated homes in Guangzhou was 6.8×10^{-6}, higher than the acceptable risk level of 1.0×10^{-6} and those estimated for old homes. Taking into consideration the variation in exposure concentration, potency factor and exposure factors, the incremental risk decreased to 4.7×10^{-6}. Monte Carlo simulation provides a clearer picture of cancer risk with a range of 1.0×10^{-6} -1.2×10^{-5} for the selected population. Results of sensitivity analysis show that the accuracy of risk assessment could be enhanced by specifying the dose–response characterization and increasing the sample size. This study provides representative statistics regarding the BTX exposures and benzene cancer risk in newly renovated homes.

1. Introduction

Public concern regarding indoor airborne volatile organic compounds (VOCs) continues to grow worldwide due to their widely distributed indoor emission sources, their adverse human health effects and the fact that modern people spend around 90% of their lifetime in indoor [1]. Among these VOCs, benzene, toluene and xylenes (BTX) have been recognized as principal indoor air pollutants and were ranked the most frequently detected compounds in indoor [2,3]. Their concentrations were generally higher in indoor air than in outdoor air [4,5]. In addition, epidemiologic and case studies provide clear evidence of a causal association between exposure to indoor BTX and adverse health effects such as irritation of the eyes, skin, mucous membranes and respiratory tract [6–9]. There is also suggestive evidence that they can be associated with the etiology of chronic asthma and cancer [6,10]. And benzene has been reported as the predominant risk entity in indoor air compared with formaldehyde, naphthalene [11,12].

Exposure in homes represents a significant proportion of the total population exposure to BTX [11,13]. Indoor elevated BTX levels can result from widely-presented indoor sources such as building materials, decoration and renovation materials, adhesives, solvents, cooking and Environmental Tobacco Smoking (ETS) [7,14–16] and outdoor air pollution [17]. Loh et al. [11] ranked the cancer risks of organic air pollutants in different microenvironments in the USA, concluding that the exposures occurred at home accounted for over 40% of the total exposures and the associated risks accounted for over 50% of the total.

In association with its economic boom of the last three decades, China has experienced rapid and massive urbanization with large growth in urban populations and both absolute and per capita housing area. For example, the permanent population in Guangzhou grew from 9.97 million to 12.75 million from 2006 to 2011 and the per capita housing area in Guangzhou increased from 3.97 m^2 to 21.89 m^2 from 1980 to 2011 [18]. Accompanying these trends, decoration and refurbishment in residential

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buildings has become popular in China [5,6,19]. However, the newly renovated homes are often detected with elevated levels of BTX [16,20–22] and even show significant associations with the occurrence of sick building syndrome for inhabitants [23]. Brown [16] found that decoration materials or new furniture in new or renovated dwellings led to much higher indoor VOC concentrations, which could persist above "baseline" levels for several weeks. Other studies have shown that BTX levels in new or renovated dwellings remained elevated for 2 or 3 years [20,21]. In China, Liu et al. [22] compared the VOC levels in homes with renovation age less than 5 years and renovation age more than 5 years, finding that the former had nearly 2 times higher benzene levels than the latter. In terms of other developing countries, such as India [24], Thailand [25], Argentina [26], Egypt [27], available BTX measurements were mainly relevant to outdoor and occupational environments and there are few studies relevant to indoor residential VOC measurement; much less is known about VOC levels in newly renovated homes.

Therefore, close inspection of previous studies reveals that the health risk associated with exposure to BTX for homes with new renovations in China or other countries have been rarely evaluated. The objectives of this study were to characterize BTX exposure in homes with new renovations in urban and suburban areas in Guangzhou, China; to identify possible sources for indoor BTX; to estimate and compare the daily inhalation exposures and cancer risks with those estimated for other cities in China and abroad. In addition, we assessed the uncertainty of risk assessment.

2. Methods

2.1. Sampling site and study design

The field study was carried out in urban and suburban districts of Guangzhou, the capital city of Guangdong Province, which has been one of the most rapidly developing regions in China over the last three decades. Guangzhou has a permanent population of 12.75 million distributed over a 7434.4 km^2, and belongs to the Pearl River Delta in the south of China.

In this study, 30 urban and 13 suburban homes/apartments distributed in urban and suburban areas in Guangzhou were selected for exposure assessment based on (a) recent renovations and (b) locations with relatively high population density. All were voluntarily selected and checked for recent renovation with the help of a local company (Amway) in Guangzhou and all are located in business or residential district. Diffusive samplers (THPDS, Tsinghua Passive Diffusive Sampler) developed in our previous study [28] were used for indoor BTX investigation. Within addition to field sampling, a questionnaire was given to participants to collect information on apartment characteristics and potential sources of the selected analytes during the sampling period. Of the measured apartments, over 60 percent were constructed after 2000 and all have been renovated (decorated and/or refurnished) within the past two years. To evaluate the contribution of ETS to BTX concentrations, ETS during sampling was recorded and 15 smoking homes were identified. Table 1 gives main details about the investigated dwellings. More specific information regarding the renovation of the investigated houses is provided in Table S1.

Table 1
Characteristics of measured dwellings in Guangzhou.

		Number	Percentage
Location	Urban	30	70%
	Suburban	13	30%
Building age	Before 1980	0	0%
	1980–1990	7	16%
	1991–2000	10	23%
	2001–2010	20	47%
	After 2010	6	14%
Renovation	Within 2 years	43	100%
Smoking	No	28	65%
	Yes	15	35%
Bedroom		34	79%
Living room		9	21%

2.2. Sampling method and analysis

Air samples in the investigated residences were collected with passive sampling method for 24 h in December 2012. Diffusive samplers (THPDS) were mailed by the Building Environment Testing Center, Tsinghua University, to householders of these apartments with instruction materials. As the bedroom and living room are the most frequently occupied areas at home, the samplers were placed in the bedroom (preferred) or living room at a height of approximately 1.5 m from the floor and away both from local sources of VOCs and the ventilation system. After sampling, the samplers were stored in sealed aluminum bags before being sent back to the center via mail.

BTX samples on passive samplers were analyzed by an automated thermal desorber (Series 2 ULTRA, Markes International Ltd) interfaced with a gas chromatograph (Agilent GC-6850) and a mass spectrometer (Agilent MS-5975C). The desorber was operated in a two-stage mode; the cold trap was filled with Tenax TA 60/80 mesh. An analytical column with a structure of 30 m × 0.25 mm × 0.25 μm (Agilent 19091S-433E) was used for chromatographic separation. Table 2 presents the details of analytical parameters.

Quality control implemented in analysis of the target compounds included measuring desorption efficiency using field blanks and measuring method detection limits (MDLs) and storage life. Accuracy of this method has been confirmed by comparison with a commonly-used active sampling method during the field test [28]. Although only one sample was taken at each selected home, the repeatability of six parallel samples had been evaluated in our previous study [28] and results showed that the average repeatability was typically below than 10%. Besides, the linearity of ATD-GC/MS in response for the target organics was evaluated before each analysis series, and the linear regression of the spiked masses and the peak areas showed that R^2 exceeded 0.998 [28]. More details can be found in the reference [28]. BTX levels that were below the MDLs or were not detected were replaced with half of the MDLs in the statistical analyses.

Table 2
Details of analytical parameters.

	Parameter	Value
ATD	Desorption temperature	300 °C
	Desorption time	30 min
	Temperature of the focusing trap	−10 to 300 °C
	Trap package	Tenax TA
	Split flow	54.8 ml/min
GC	Carrier gas	Helium
	Column flow	1.0 ml/min
	Column temperature program	3 min at 40 °C 5 °C/min–55 °C 10 °C/min–100 °C 20 °C/min–280 °C
Auxiliary parameter	Total split ratio	1:30 (1/31 of analytes reaches column and detector)