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PRELIMINARY ASSESSMENT OF BTEX CONCENTRATIONS INDOOR AND OUTDOOR AIR IN RESIDENTIAL HOMES IN HANOI, VIETNAM

Vo Thi Le Ha[1], Nguyen Thi Thu Hien[1], Nghiem Trung Dung[1], Minoru Yoneda[2], Thai Ha Vinh[3]

[1]*School for Environmental Science and Technology (INEST), Hanoi Univesity of Sience and Technology (HUST), 1, Dai Co Viet road, Ha Noi, Viet Nam*

[2]*Dept. of Environmental Engineering, Kyoto University, Kyoto Daigaku Katsura, Nishikyo-ku, Kyoto 615-8540, Japan*

[3]*Viet Nam National Institute of Occupational Safety and Health, 99 Tran Quoc Toan, Hoan Kiem Dist, Ha Noi, Viet Nam*

[*]Email: *hien.nguyenthithu@hust.edu.vn*

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ABSTRACT

Indoor air quality is considered to be of great concern due to its adverse impact on the human health nowadays. BTEX concentrations in 29 residential homes including (new/renovated and old) were studied in Hanoi Metropolis and influencing parameters such as smoke habit, cooking appliances, solvent consumption, and ventilation system were considered in this study. Samples were conducted using active diffusion monitors and analyzed by GC/FID. Concentrations of BTEX indoor and outdoor in new/innovated homes were significantly higher than those in old homes. Benzene was used as cancer risk maker, whereas toluene and xylene were used as non-cancer risk marker. Among BTEX compounds, xylene showed the most notable hazard quotient and was the main pollutants responsible for high risk for the toddlers. Benzene showed an upper-bound life time cancer risk that exceeds the US.EPA benmark, presenting moderate risk for the toddlers.

Keywords: indoor air, outdoor air, VOCs, benzene, hazard quotient.

1. INTRODUCTION

In most countries worldwide people spend more than 80 % of their time indoor [1]. Indoor air quality and its potential health consequences are much less investigated in comparison to ambient air quality. The volatile organic compounds (VOCs) are important pollutants of indoor and ambient air quality [2]. They can evaporate easily at room temperature and inhalation route of exposure becomes the most important pathway for intakes of these contaminants. The most commonly found within VOCs are BTEX (Benzene, Toluene, Ethylbenzene and Xylene) with high concentration in many public and residential indoor environment due to their high vapor pressure [2, 3, 4]. Primary sources for BTEX indoor include outdoor air, environmental tobacco, fuel combustion, household products, building materials [2, 3, 4]. BTEX compounds were occurred commonly indoor and outdoor, in which toluene and xylene are higher than benzene [2, 4, 5].These compounds may cause various health effects like eyes, nose and throat irritation, headaches, loss of coordination, nausea, damage to liver, kidney and central nervous system [6, 7]. Benzene is most toxic chemical within BTEX and long term exposure may increase incidence of leukemia and aplastic anemia in Human [7, 8]. International Agency for Research on Cancer (IARC) has classified benzene as carcinogenic to humans (group 1) and ethylbenzene as possibly carcinogenic to human (2B) [8]. To date, BTEX levels indoor and outdoor have not been well characterized in Hanoi, less is known about health risk of personal exposure to BTEX, therefore, preliminary study on BTEX exposure to personal risks was done in order to fill this gap. In this study, the main objective is to determine the BTEX concentration as well as the possible sources, and to evaluate human hazard to BTEX exposure via inhalation route.

2. MATERIAL AND METHOD

2.1. Sampling site description

Hanoi is the capital of Vietnam and is the second largest city of the country. It has humid tropical climate and experiences of four distinct seasons. Home interior renovation/decoration and new building are booming in the urbanization in this megacity. This study was carried out from March to April of 2017 at new/renovated and old homes. 29 air samples in urban areas within Hanoi metropolis were taken indoor/outdoor, of which, 18 homes are considered as the old (more than 1 year built) and 11 others are considered as the new/renovated homes (just completed for 1 year). Homes were located on/near the highway, roundabout and interior road in congested community randomly in 10 districts throughout Hanoi, which were from 5th to 10t^{h} floor.

2.2. Sampling and questionnaire collection

All air samples were taken following NIOSH Manual of Analytical Method 1501. Active samplers were placed in the living room/master room at homes at human breathing zone (1.5 m). SKC personal sampling pump equipped (constant flow rate of 0.2 l/min) for 120 minutes and charcoal sorbent tubes (SKC) were used to collect the samples both indoor and outdoor air. Outdoor samples also placed outside homes with height of 1.5 m from floor. In-depth interview administered questionnaires were used to investigate demographic information via questionnaires to collect integrated information on interior/exterior activities, lifetime styles and personal behaviors which may influence participant exposure to BTEX such as: home's characteristics, the transportation/ adjoining areas, the habit of residents (smoking habit, cooking style, cleaning products…) furniture status (new/old/renovated).

2.3. BTEX Analysis

BTEX compounds were extracted from charcoal tubes using 1 mL of carbon disulfide (CS_2, free Benzene), then were gently shaken for 30 min. BTEX compounds were quantified by using a gas chromatograph (GC 2010-Plus, Shimadzu-FID) using a HP-5 capillary column (30 m ×

0,32 mm × 0,25 μm).Injector and detector temperatures were set at 250 °C and 280 °C, respectively. Oven temperature was programmed at 40 °C for 10 min and then 8 °C/min to 165 °C [9].

2.4. Health risk assessment from BTEX exposure

In the risk assessment, the receptors of interest were four categories of communities including toddler, children, teen and adult living in studied homes. The inhalation intake was used to assess carcinogenic risk and non-carcinogenic effects from chronic exposure and was calculated by averaging daily intake over the exposure period. The carcinogenic and non-carcinogenic intakes of BTEX were calculated in equation 1, 2, 3:

$$CDI = \frac{C_{air} \times IR \times D_{hours} \times D_{day} \times D_{week} \times D_{year}}{24 \times BW \times 365 \times LE} \quad (1) \quad ILCR = CDI \times S_f \quad (2) \quad HI = \sum HQ = \frac{CDI}{RfD} \quad (3)$$

where C_c: contamination concentration (mg/m^3), IR the inhalation rate (m^3/h), D_{year}: Exposure time (year),D_{hour}: hour/day, D_{day}: day/week, $D_{week:}$ week/, LE: Life span (Non-carcinogenic effects ED = ED × 365 days/year. Carcinogenic effects LE = 70 years × 365 days/year). S_f: Cancer slope factor (kg day/mg).RfD: the reference dose (mg/kg/day).

3. RESULT AND DISCUSSION

3.1. BTEX concentration in residential old homes

Concentration of BTEX compounds detected all indoor/outdoor air samples at residential old homes were shown in Fig1 (a,b). Benzene was identified in more than of 50% indoor samples, except for outdoor samples. Besides, the concentration of ethylbenzene was below detected level in all samples. The results showed notably higher concentration of BTEX compound indoor of the old homes versus the outdoor. The concentration of benzene, toluene, xylene of indoor samples varied from 5 to 7.30 µg/m^3; 3.83 to 313.90 µg/m^3; 199 to 1559.53 µg/m^3, respectively, while those of outdoor samples ranged from < 5 µg/m^3, 90.34 to 174.70 µg/m^3, 158.77 to 714.53 µg/m^3, respectively. The concentrations of xylene and toluene were found significantly higher than those of benzene. In all observed samples, xylene was dominant compound, followed by toluene, benzene and ethylbenzene. It is due to toluene and xylene widely used as solvents and building materials and possibly derived from traffic activities, whereas benzene and toluene are main constituents of gasoline emitted into the environment [2, 3]. Among BTEXs, benzene was more stable due to longer lifetime than toluene, xylene and ethylbenzene, whereas, xylene has the shortest lifetime and did not exist long in the atmosphere [2]. These results are in line with previous studies monitored in India, Iran and China [2, 10, 11]. In this study, the mean levels of toluene (133.86 µg/m^3) and xylene (619.47 µg/m^3) were much higher than those in Iran and Beijing whereas concentration of benzene (8.75 µg/m^3) was lower in indoor samples. It was reported that the BTEXs indoor were significantly dependent on type of fuel, ventilation condition, chemical reagents for cleaning and air spray, cooking style and smoking habits, BTEXs outdoor were dependent on vehicles' emission [2, 3,10]. Indoor/outdoor ratios (I/O) were calculated for all samples. I/O ratios varied between BTEX compounds and was appeared more than 1, which indicated that the presence indoor sources for these compounds along with infiltration of outdoor air. Higher I/O for toluene and xylene pointed out stronger indoor sources for those VOCs [10, 12]. Some factors influencing on BTEX levels were considered in this study. For instance, concentration of benzene (6.9 µg/m^3, < 5 µg/m^3) was slightly higher in residential homes cooking by gas comparing those cooking by induction hob, respectively. Among all samples, residential home with most new furniture, smoking habitant and located at digested street posed the highest of BTEX concentration (benzene: 15 µg/m^3, toluene: 167 µg/m^3 and xylene 785 µg/m^3). The BTEX concentration in homes located in highway, congested street seems to be affected more by air ambient which can be attribute to vehicles [10, 11]. However, BTEX concentrations in such homes were significantly higher than the outdoor and the differences on concentration of BTEX were not statistically significant comparing the home located in small lane. The environmental tobacco smoke is one of the major sources of BTEX indoor and high concentration of benzene and toluene was detected in exhaled cigarette smoke [13]. It was found that concentration of BTEX in homes with smoking habitants were slightly higher than those of without smokers although the difference was not statistically significant. The high concentrations could be due to the remaining smoke of cigarette after the smoking sessions namely the third hand smoke.

3.2. BTEX concentration in residential new/renovated homes

Statistical concentration distribution parameters for target VOC compounds detected in all new/renovated homes indoors and outdoors were shown in Fig. 2 (a,b). More than 72 % of indoor samples detected benzene, except for outdoor samples. Etylbenzene was also undetected in all samples. Benzene concentration in indoor varied 5.433 to 31.20 µg/m^3 with mean value of 9.85 µg/m^3, in which toluene and xylene was ranged from 141 to 197.18 µg/m^3, 589 to 1590 µg/m^3 with mean value of 197.18 µg/m^3 and 818.39 µg/m^3, respectively. Toluene and xylene was predominant in new/renovated homes and their mean values followed in line with old homes: xylene>toluene>benzene>ethylbenzene. BTEX concentrations indoor air, in this study, was significantly higher than those qualified in outdoor air and those in previous study in Shanghai [4]. But, benzene concentration was lower in renovated homes in Beijing [14]. This study showed the comparable BTEX concentrations between new/renovated and old homes. Concentrations of BTEX were found were dramatically higher than those in old homes. Xylene and toluene was also most abundant in indoor samples. It is likely to due to the strict regulation of benzene use in solvents or dilutes in civil building engineering in Vietnam recently. However, as alternatives for benzene, toluene and xylene are widely used in interior decoration and decoration, leading to elevated levels of these compounds indoor air. The ration of indoor concentration (I) to outdoor (O) concentration of each BTEX compounds studied reflects the important of outdoor sources versus indoor sources. The I/O ratios of benzene, toluene and xylene in new/renovated exceeded 1 and higher than those in old homes. These ratios indicated that the presence indoor sources for these compounds along with infiltration of outdoor air. Higher I/O for toluene and xylene pointed out stronger indoor sources for those VOCs.

3.3. Health risk assessment

Risk assessment analysis was carried out assuming the quantified indoor concentrations of BTEX in all homes as the average concentrations for whole year. Health risk assessment was carried out for 4 categories, including toddler, children, teen and adult following 4 steps.The quantitative cancer risk and non-cancer risk were calculated based on equation 1-3 and Table 1.

Since, ethylbenzene was below limit of detection that was not accounted for cancer risk. The study found the cancer risk of benzene were up 1.13×10^{-5}, 5.19×10^{-6}, 3.1×10^{-6}, 2.7×10^{-6} for toddler, children, teen and adult, respectively. All groups were posing moderate cancer risk, in which, the toddler group was determined as the most cancer risk behavior becausethe toddler was most sensitive group. Cancers risk for lifetime exposure to residents in Beijing was higher than those in this study due to higher benzene concentration [14]. It also could be occurred due to the differences in the assumptions of risk assessment parameters and potency factor.

For non-cancer risk, among BTEX compounds, the values of HQ for xylene were 1.64, 0.76, 0.47, 0.40, whereas, those for toluene were 0.09, 0.04, 0.02 and 0.02 for toddler, children, teen and adult, respectively. Although all groups had the HQ values lower than 1 except for the toddler, indicating low risk, the toddlers were posing high risk due to xylene exposure. It was notable that, the toddler was suffering moderate cancer risk and high non-cancer risk. Even the smaller body weight, less of inhalation, but longer exposure time, BTEX intake of toddlers were believed to be greater than other studied group. Thus, the hazard health risk for this group is thought to be greater.It has been reported thatlong time exposure of toddlers and children to benzene increases the risk childhood leukemia [1], chronic exposure to benzene is associated with decrease in hemoglobin (Hb), platelet count and while blood cell count [15]. Chronic exposure to xylene has been associated with subjective findings of depression, fatigue, headache, and sleep disrobers [1].

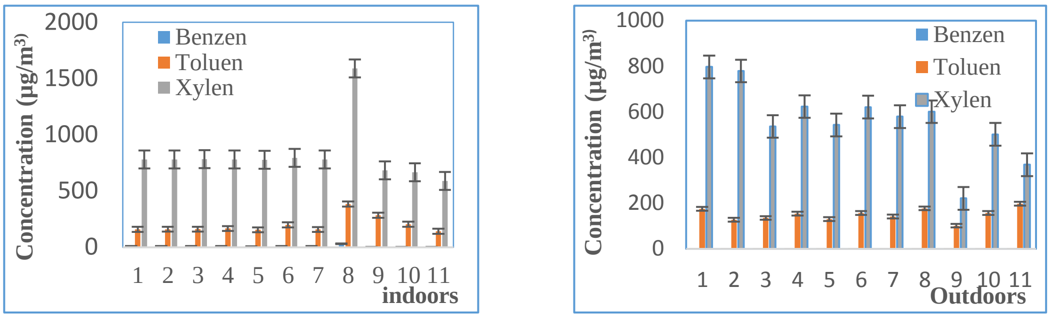

Figure 1 (a,b). Concentration BTEX versus indoors and outdoors at old homes.

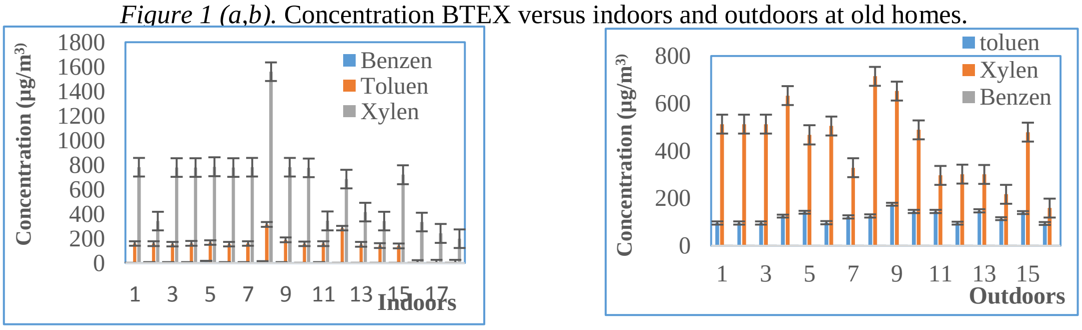

Figure 2 (a,b). Concentration of BTEX versus indoors and outdoors at new/renovated homes.

Table 1. Exposure and risk assessment factors.

Parameters	**Toddler (7 month-4 year)**	**Child(5 – 11 year)**	**Teen (12 - 19 year)**	**Adult >=20 year**	**Source**
Inhalation rate (m^3/d)	9,3	14,5	15,8	15,8	[16]
Hour (h/day)	19	13	12	14	This study
D day	7	7	7	7	This study
D week	52	52	52	52	This study
Dyear	10	10	10	10	This study
BW (kg)	10	23	43	55	This study
LE (year)	70	70	70	70	[16]
Concentration (mg/m^3)					This study

4. CONCLUSION

This paper reported the results of a preliminary investigation of indoor and outdoor of BTEX compounds in Hanoi residences. Our results may provide information that is useful for understanding the characteristics indoor/outdoor of BTEXs, their exposure in homes and their potential health risks. The results revealed that toluene and xylene was predominant in BTEX indoors and outdoors and concentrations of BTEX indoor were higher than outdoor. BTEX in new/renovated homes were prevailing than old homes. The most sensitive group was toddlers posing moderate cancer risk and high non-cancer risks. These results would also improve the accuracy of health risk assessments and support more effective indoor air pollution countermeasures and risk management.

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