BTEX Levels in the Indoor Air of New School Buildings: A Case Study

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Abstract. *Volatile organic compounds (VOCs) are a common group of indoor air pollutants. VOCs cause adverse health effects, both short- and long-term to exposed residents. This study investigated the BTEX (benzene, toluene, ethylbenzene, and xylene) levels in the indoor air of the new buildings of Surawiwat School, Nakhon Ratchasima, Thailand. Samples were taken from classrooms, dormitory rooms and laboratory rooms, both new and in-used, from December 2018 to February 2019. The sampling was done biweekly. Two samples were collected in each room at a time, resulting in a total of 12 samples per room. Each BTEX sample was done using two Tenax tubes connected in series with a personal air pump. The air flow rate was equal to 50 mL/min and the duration was 60 minutes. The samples were analyzed by a GC/MS instrument. For most types of gas, the concentration levels of the new rooms were lower than those of the in-used rooms, except for the dormitory rooms. Decreasing trends of BTEX concentrations were found in the classrooms and the new laboratory room, while the in-used dormitory room had near constant concentration levels. The BTEX concentration values found in this study were in the acceptable range Time-weighted Average (TWA) of that defined by NIOSH, OSHA, and Thailand state agency.*

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Indoor air, VOCs, BTEX, Air quality, School

1. Introduction

Volatile organic compound (VOC) is a common group of indoor air pollutants. VOCs cause adverse health effects, both short- and long-term to exposed residents that people spend around 90% of their lifetime in indoor [1]. Among these VOCs, benzene, toluene, ethylbenzene, and xylenes (BTEX) have been recognized as principal indoor air pollutants and were ranked the most frequently detected compounds both domestic and international research [2,3,4].

Indoor pollution arises from the use of cleaning agents, personal care products, deodorizers, paints, lacquers, solvents [4], including the construction of new buildings with new furnishings, floor coverings, building materials, as well as renovation activities [5]. Related studies of BTEX measurements were mainly focused on the outdoor environment, occupational environment, and indoor residential environment [1-13]. There are few studies relevant to the indoor air concentration of commercial or school buildings.

This study aims to measure BTEX levels in the indoor air of selected new school buildings and examine the temporal variations.

2. Methods

2.1 Sampling Site and Study Design

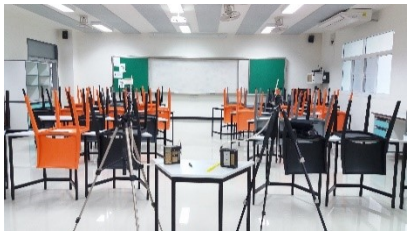
The field study was carried out in the indoor air of the new buildings of Surawiwat School, Nakhon Ratchasima, Thailand. Most of the construction of the school buildings was finished around June 2018, when the school opened for its new academic year. The furnishing works were completed a few months later.

Samples were taken from 3 types of rooms – classrooms, laboratory rooms, and dormitory rooms. For each type, a new or unused room and an in-used room were selected. Therefore, a total of 6 rooms were sampled in this study. The sampling period started from December 2018 to February 2019, which were about 6 months after the buildings were first used. The sampling was done biweekly. Two samples were collected in each room at a time, resulting in a total of 12 samples per room.

2.2. Sampling Method and Analysis

Indoor air samples were collected and analyzed following US EPA compendium methods TO–17 [14]. Air samples were collected from indoor of six selected rooms in the school at the height of 1.5–2.0 m. above the floor. Each BTEX sample was done using two Tenax tubes connected in series with a personal air pump. The air flow rate was equal to 50 mL/min and the duration was 60 minutes. Tenax tubes were stored at 4 °C in a refrigerator until further analysis was undertaken. The analyses were done within 30 days of each sampling. Fig. 1 shows the sampling set-up in the three types of rooms.

The samples were analyzed by an automated thermal desorber interfaced with a gas chromatograph and a mass spectrometer. An analytical column with a structure of 30 m. x 0.25 mm. x 0.25 mm. was used for chromatographic separation. Table 1 presents the details of the analytical parameters.



(a)

(b)

(c)

Fig. 1: (a) sampling in a classroom, (b) sampling in a laboratory room, and (c) sampling in a dormitory room.

Parameter		Condition
ATD		
	Pre-Desorption	Inject Internal Standard = 4 min
		Prepurge tire N_2 99.9999% = 10 min
	Tube/Sample desorption	Temp 250 °C at 10 min
		Pre-Trap Fire Pure/min = 2 min
		Trap Low = -30 °C
		Heating Rate = Max
		Trap Hing = 250 °C
		Trap Hold = 15 min
GC/MS		GC-MS (Bruker/Series 3XO)
	Carrier gas	Helium, flow rate 1.3 ml/min
	Initial column temperature	35 °C

Table 1 Details of analytical parameters.

3. Results and Discussion

The classroom consists mainly of tables, chairs, whiteboards, and audiovisual media equipment. The laboratory room consists mainly of laboratory benches, chairs, glassware cabinets, whiteboards, and fume hoods. The dormitory room, which accommodates 3 students, consists mainly of beds, wardrobes, tables, chairs, and a bathroom. All types of rooms are air-conditioned.

The main indoor sources of VOCs can be categorized into 2 groups. The first group is construction-related sources, such as painted walls, built-in furniture, new furniture, floor coverings, and other building materials. The second group is activity-related sources, such as the use of whiteboard markers, the use of chemicals in laboratory activities, and personal care products in the dormitory.

3.1 Concentration of BTEX

The mean and standard deviation values of BTEX levels measured in the classrooms, laboratory rooms, and dormitory rooms are shown in Table 2. The mean concentrations of all 4 species in the in-used classroom were higher than the new classroom. Similarly, the mean levels of benzene, ethylbenzene, and xylene in the in-used laboratory were higher. This showed that the emission from construction-related sources have diminished after several months of construction completion, and the majority of VOCs came from the school's activities.

It should be noted, however, that the toluene level in the new laboratory room is higher than the in-used one. This could be because of the new furniture which has recently been moved inside.

In contrast, for the dormitory, the BTEX levels were higher in the new room than the in-used room. The reason may be that there is a lot of built-in furniture in a dormitory room which is a major source of VOCs. Also, the room is smaller and has less air infiltration than the other room types. On the other hand, the in-used room had more ventilation from the air conditioning system and no significant emission from occupants' activities, so the VOCs levels were lower.

The results also show that all of BTEX concentrations have wide ranges and the standard deviation values were high. Toluene had the highest mean concentrations, which was following the literature. The patterns of BTEX concentrations in several indoor air studies demonstrated that toluene was present at the highest concentration, followed by benzene and xylene, while ethylbenzene has shown the lowest concentrations [6,7,8,13].

Regarding the occupational limits of BTEX, as shown in Table. 2, all the concentrations measured in this study were lower than the corresponding Time-Weighted Average (TWA) defined by NIOSH, OSHA, and Thailand state agency [15,16].

Chemicals	Classroom (Mean ± S.D.)		Laboratory room (Mean ± S.D.)		Dormitory room (Mean ± S.D.)		NIOSH:TWA	OSHA: TWA	Thailand Labor Law: TWA
	new	in-used	new	in-used	new	in-used			
Benzene	1.99 ± 1.15	2.47 ± 0.85	2.92 ± 0.91	8.04 ± 3.18	3.10 ± 1.59	2.37 ± 0.46	320	1,597	31,947
Toluene	5.60 ± 1.67	43.36 ± 16.04	47.61 ± 26.75	18.19 ± 10.40	6.70 ± 1.28	4.23 ± 0.84	376,850	753,700	753,700
Ethylbenzene	0.31 ± 0.20	0.48 ± 0.21	0.62 ± 0.33	1.54 ± 1.06	0.81 ± 0.32	0.46 ± 0.06	434,233	86,846	-
Xylene	0.23 ± 0.32	0.54 ± 0.25	0.57 ± 0.45	1.96 ± 0.86	0.99 ± 0.58	0.69 ± 0.25	434,192	434,192	434,192

Table 2 Comparison of BTEX Concentration with the Occupational Limits (μg/m^3)

3.2 Temporal Trends of BTEX Levels

Fig. 2-13 show the changes of BTEX levels in each room over the sampling period. For the classrooms, decreasing trends of most BTEX species can be observed in both the new and in-used rooms. Although there was fluctuation of values from time to time. As for the laboratory rooms, the new room had a slightly decreasing trend for benzene, ethylbenzene, and xylene. The in-used room had rather fluctuating trends in most species, which may be caused by different chemicals used in laboratory works. The trends of BTEX in the in-used dormitory room seemed to be rather constant over the sampling time. This may be because the concentration in the room approaches an equilibrium level. On the other hand, the new dormitory room showed no clear temporal trend.

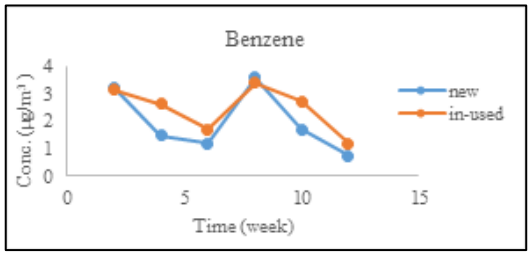


Fig. 2 Trends of benzene levels in the classroom

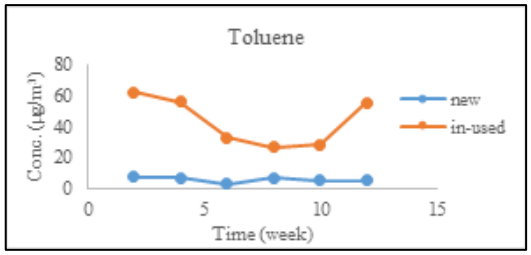


Fig. 3: Trends of toluene levels in the classroom

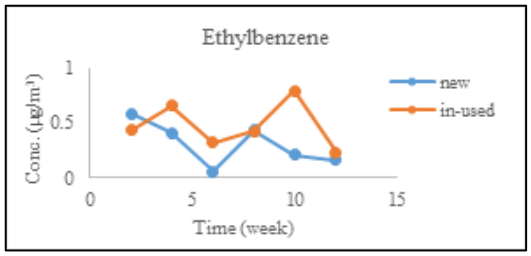


Fig. 4: Trends of ethylbenzene levels in the classroom

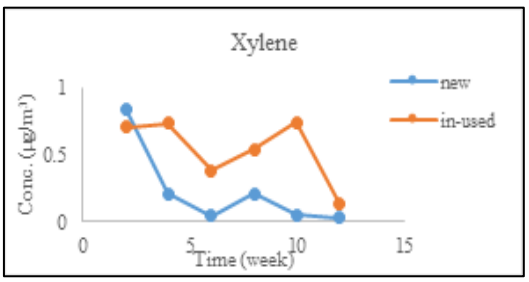


Fig. 5: Trends of xylene levels in the classroom

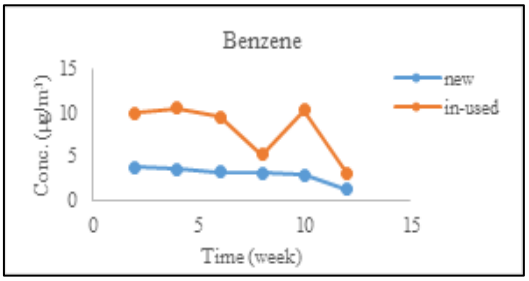


Fig. 6: Trends of benzene levels in the laboratory room

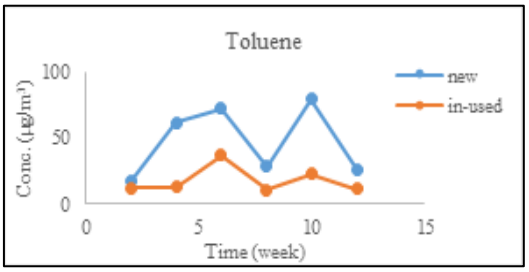


Fig. 7: Trends of toluene levels in the laboratory room

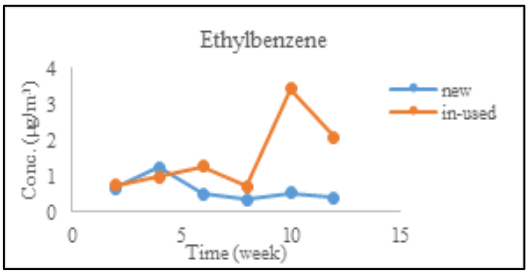


Fig. 8: Trends of ethylbenzene levels in the laboratory room

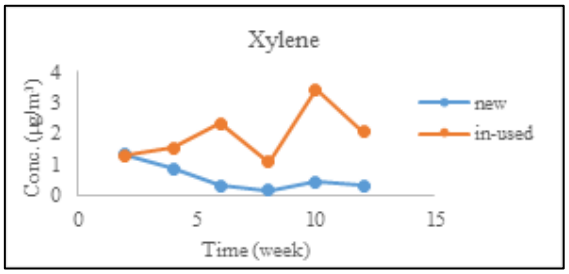


Fig. 9: Trends of xylene levels in the laboratory room

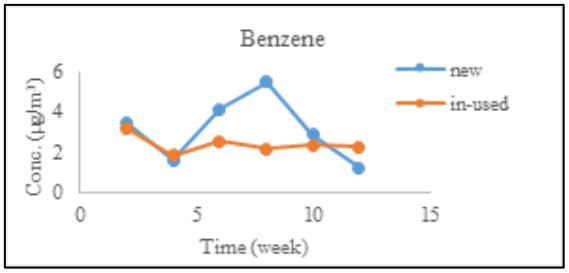


Fig. 10: Trends of benzene levels in the dormitory room

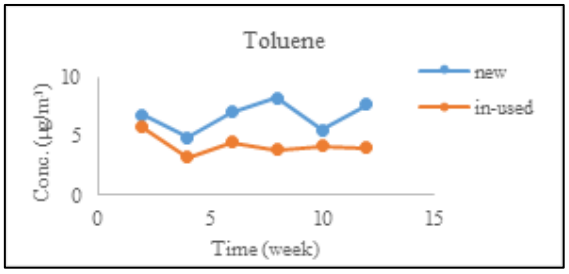


Fig. 11: Trends of toluene levels in the dormitory room

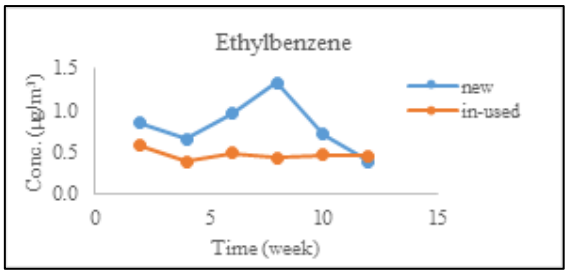


Fig. 12: Trends of ethylbenzene levels in the dormitory room

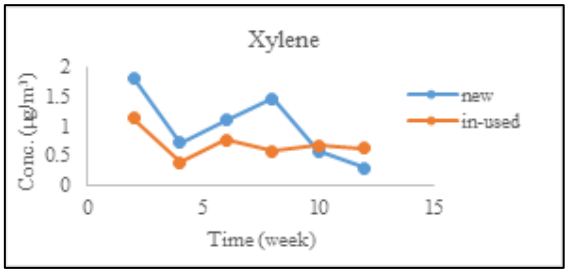


Fig. 13: Trends of xylene levels in the dormitory room

4. Conclusions

The BTEX levels in the 3 types of rooms of the newly constructed Surawiwat School's buildings were measured in this study over a period of 12 weeks. In many cases, it was found that the in-used rooms had higher levels of BTEX than the new rooms, except for the dormitory rooms. The major sources of VOCs in the classrooms and laboratory rooms were most likely the school's activities. High levels of toluene in the new laboratory could have resulted from the recently added furniture. High BTEX levels in the new dormitory rooms may be caused by a lot of built-in furniture. The classrooms and the new laboratory room showed decreasing trends, while the in-used dormitory room had little temporal variation. Limitation of this study is the small sample size and thus future studies should consider alternative sampling methods such as using portable gas analyzers. The findings could help to understand the levels and variation of BTEX in new buildings.

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Biographies

Siriporn Wongmanee received her bachelor of science's degree in environmental health from Suranaree University of Technology in 2015. She is currently pursuing her master of engineering's degree in industrial systems and environmental engineering at the same institute. She has been working as a teaching assistant and also participating in several research projects.

Sudjit Karuchit received a bachelor's degree from Chulalongkorn University in 1992, a master's degree from Asian Institute of Technology in 1995, and a Ph.D. degree from Illinois Institute of Technology, USA., in 2001 – all in the field of environmental engineering. He has been working as a faculty member of the School of Environmental Engineering, Suranaree University of Technology for more than 18 years.