A Low Cost Tube-Type Passive Sampler for Ambient BTEX Monitoring in Urban Settings, Thailand

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***Abstract*—** This study validates the laboratory made tube-type passive sampler as a low cost BTEX sampling device for an urban environment in Thailand. Glass vials (10 ml, 70 mm height, 15 mm ID) packed with activated carbon, 20/40 mesh size, were tested in both laboratory and urban settings. The sampling device was filled and packed for 0.5, 1.0, 1.5, and 2.0 cm depth with activated carbon and exposed in a closed chamber for 1, 3, 5, and 7 days at specific BTEX concentrations usually found in urban environment in Thailand. The results showed that the passive samplers were capable of collecting BTEX compounds at low concentrations within 24-hour period. An appropriate depth for activated carbon adsorbent was suggested at 2.0 cm with 0.5 cm for breakthrough for 24-hr sampling duration.

***Keywords*—** BTEX, VOCs, Passive sampler, Tube-type passive sampler, Thailand

I. INTRODUCTION

BTEX represents a group of chemical compound known as Benzene, Toluene, Ethylbenzene and Xylene, the components of volatile organic compounds (VOCs). BTEX is constituted in petroleum products such as gasoline, diesel [1-2]. VOCs are of concern in Thailand along the roadside and industrial areas according to the yearly report on the state of air pollution during 2013-2015 [3]. The concentrations were found higher than other areas. However, the annual average was within the country's limit, except benzene that exceeded the annual standard of 1.7 µg/m3 [4].

Road traffic was the mainly source of VOCs release into the ambient air [5-7]. When BTEX compounds were released into the atmosphere, they are potentially exposed to human, animals and plants, causing an increasing risk of disease to the population, such as traffic police, motorcycle vendors, people who use public bus service, including people who live in areas near the streets.

Ambient BTEX measurements can be achieved by active or passive sampling techniques. Passive sampling technique has advantages in terms of simplicity, cost, easy to use, small and lightweight. It can also be easily installed at many areas simultaneously by non-specialists which make the spatial collection of concentrations data. The passive devices are commercially available either with different designs, sapes and characteristics of the devices depending on the manufacture and supplier. This study recognizes the importance of the tube-type passive sampling device for BTEX compounds monitoring that can be prepared and used locally with budget-constrained agency.

II. MATERIALS AND METHOD

A. *Preparation of passive sampler*

The 10 ml glass vials (70 mm height, 15 mm ID) with screw caps were used as passive sampler devices. Activated carbon, 20/40 mesh size, was used as the adsorbent. Activated carbon was activated through the clean-up process by heating at 150 °C for 1 hour and to remove contaminants from the adsorbent prior to use. The passive samplers were filled with adsorbent and separated into four layers, 0.5, 1.0, 1.5, and 2.0 cm. Each layer contained 650 mg activated carbon and was separated with compressed cotton. Each layer was packed at 2,000 g force ensuring uniform pack of the adsorbent (Fig. 1). The passive samplers were capped and stored in a desiccator prior to use in the sampling.

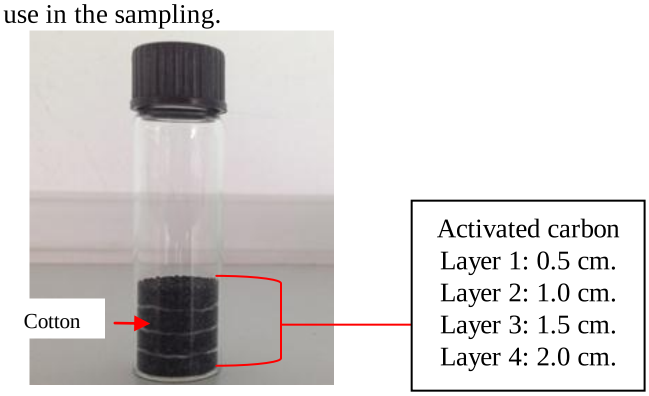

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Fig. 1: A tube-type passive sampler for BTEX measurement

B. *Exposure chamber*

An acrylic chamber was built and used in the experiment. The chamber was 35 cm x 40 cm x 30 cm (wide x length x high), attached with a small chamber opening to minimize draft inside the exposure chamber during the experiment (Fig. 2). A thermometer was placed inside and outside of the chamber to monitor change in temperature.

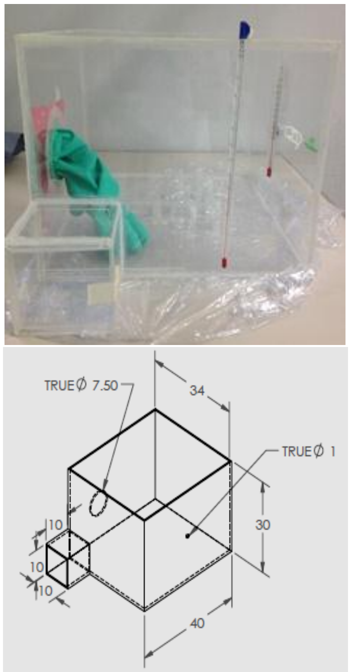


Fig. 2: An exposure chamber

C. *Validation of the laboratory-made passive samplers*

Three concentration levels of BTEX were set in the exposure chamber to examine the optimum conditions for the tube-type passive samplers. The levels were the conditions commonly found in Thailand (Table 1). BTEX were added in a beaker placed inside the chamber until the equilibrium concentration reached. Gas samples inside the chamber were constantly taken for the analysis by a gas chromatography to determine the concentrations When the equilibrium was established, the set of five tube-type passive samplers were placed inside the chamber during the exposure conditions of 1, 3, 5 and 7 days.

TABLE I:
CONCENTRATION LEVEL OF BTEX COMPOUNDS IN CHAMBER

Compounds	**Level of concentration (ppb)**		
	Low	**Medium**	**High**
Benzene	2-6	10-15	20-25
Toluene	6-10	15-20	30-35
Ethylbenzene	3-5	7-10	13-15
m-Xylene, p-Xylene	5-7	9-11	15-17
o-Xylene	3-5	7-9	11-13

Upon the completion of exposure periods, each layers of the adsorbent were separately extracted by carbon disulfide according to NIOSH method 1501. Once the optimum conditions of the tube-type passive samplers were determined, field sampling was conducted in the urban setting of Nakhon Ratchasima Municipality, the fifth largest municipality in Thailand. The passive samplers were placed next to the busy intersections downtown, 2 m above ground and 1.5 m away from the streets. After that, the tube-type passive samplers tested BTEX sampling in the ambient air. The passive samplers were retrieved at the end of exposure period and immediately extracted to determine BTEX concentrations of each layers.

D. *BTEX Analysis*

Optimum conditions for BTEX analysis were determined prior to the analysis. Each layer of activated carbon was separately extracted with 1.5 ml carbon disulfide. Then, 200 µl of extracted solution was drawn and place into 2 ml vials. 2 µl of sample was injected into a gas chromatograph equipped with a flame ionization detector (GC-FID) (Agilent 7890A, USA). The samples were separated inside the 30 m, 0.32 mm and 1.00 µm, HP-624 capillary column. The chemical peaks were determined and confirmed according to detention time of the column and BTEX standards (Arcos, USA). The detection limits of BTEX were 1.55, 1.61, 1.28, 1.52 and 1.45 ppb, respectively.

III. RESULTS AND DISCUSSIONS

Rainfall had potential to influence the average concentrations of lead, nickel, and mercury in groundwater in the study area. Groundwater samples obtained during rainy season clearly showed higher levels of lead, nickel, and mercury than those found in dry season. Cadmium was not detected. Location of the waste dumping site posed environmental and health risk to the wells nearby, especially the wells located in the east and southeast direction of the site. The reservoir is subjected to contamination in the long-term if groundwater is contaminated from leachate of the dump site.

A. *Optimum GC-FID conditions for BTEX analysis*

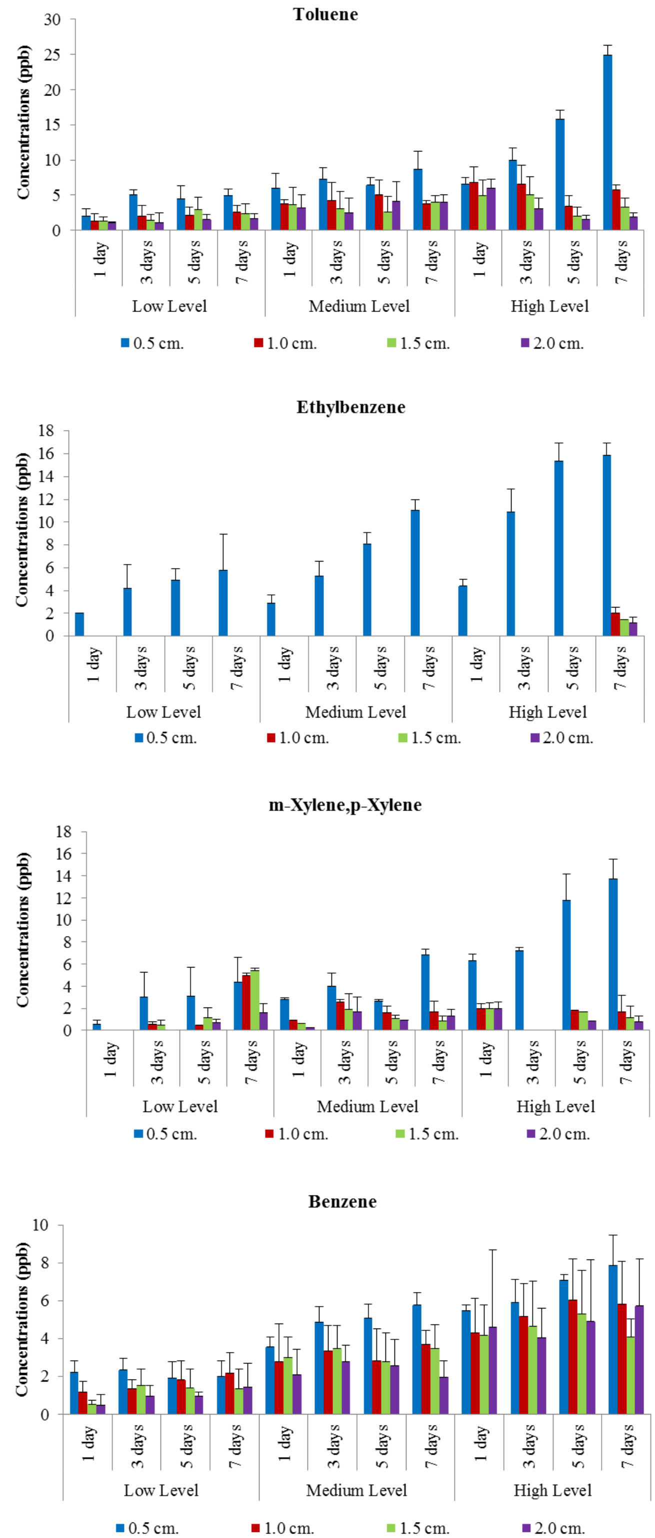
Criteria to consider the optimum conditions of GC-FID for analysis of BTEX compounds were to achieve high resolution of signal respond and peak areas of BTEX compounds were clearly separated. Extracted solutions from the tube-type passive sampler yielded a good separations according to conditions described in Table 2.

TABLE II:
OPTIMUM GC-FID CONDITIONS FOR BTEX ANALYSIS

Parameters	**Optimum conditions**
Flow rate of He (ml/min)	2.5
Flow rate of H_2 (ml/min)	30
Flow rate of N_2 (ml/min)	30
Flow rate of O_2 (ml/min)	300
Inlet Temperature (°C)	200
Oven Temperature :	
Initial Temperature (°C)	35
Initial holding Time (min)	2
Ramp Rate (°C/min)	4
Final Temperature (°C)	110
Final holding Time (min)	1
Detector Temperature (°C)	250

B. Validation of the tube-type passive samplers for BTEX

Under chamber conditions, exposure to equilibrium concentrations of BTEX showed that the tube-type passive samplers adsorbed BTEX in all four layers of activated carbon through 2.0 cm depth when they were exposed at high concentrations, 11-35 ppb, for 7 days (Fig. 3). Benzene and toluene were detected within one day of exposure at low concentrations, 2-10 ppb. Ethylbenzene was clearly found in the top layer in low, medium, and high concentrations but it was absent in the lower layers within 1 – 5 days of exposure. Only high concentrations of the Ethylbenzene were found in 1.0 – 2.0 cm depth after exposed for 7 days. Two congeners of Xylene, m-Xylene and p-Xylene, were quantified together. Low concentrations were detected at the top layer, but they showed up more clearly at medium and high concentrations. Therefore, the tube-type passive samplers had potential in the application of collecting BTEX in the air with 2.0 cm depth of activated charcoal.



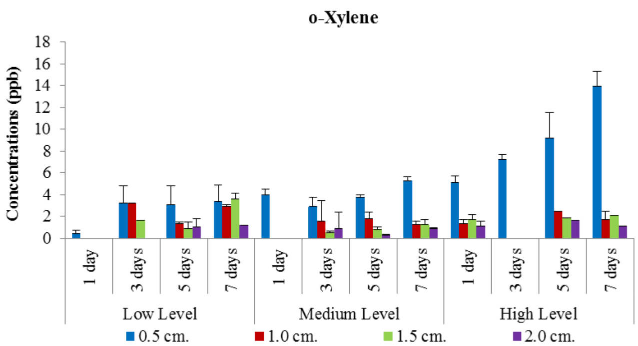


Fig.3: Concentrations of BTEX compounds at low, medium, high concentrations on 1, 3, 5, and 7 days exposure in the test chamber

Real world scenario was tested with a modified configuration. Another 0.5 cm of activated charcoal was added at the bottom to detect any breakthrough during the sampling (Fig. 4). Road-side sampling was performed for 24-hr period in the urban setting of Nakhon Ratchasima Municipality, Thailand. The results founded that benzene and toluene were found in backup layer. Therefore, the author had compact the activated carbon up to 3,000 g with the adsorbent layer of 3.0 cm. A 24-hr sampling at four road-side settings showed no breakthrough for Benzene, Toluene, Ethylbenzene, m-Xylene, p-Xylene and o-Xylene (Fig.5).

Fig. 4: Configuration of tube-type passive sampler for ambient BTEX measurement

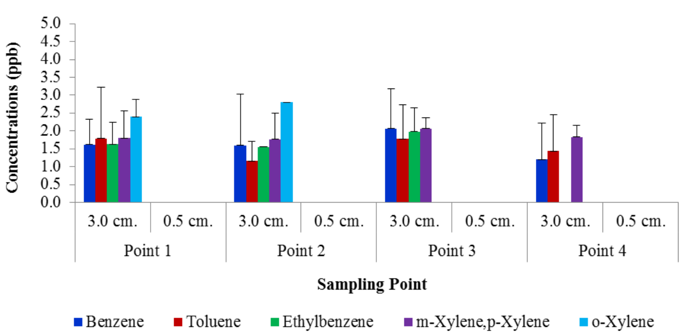


Fig. 5: Concentrations of BTEX compounds in the ambient air

IV. Conclusions

Our tube-type passive sampler was capable of collecting ambient BTEX in an urban environment. A glass vial, 70 mm height, 15 mm ID, with screw caps packed with activated carbon cost less than $5 US/vial was demonstrated to detect BTEX with 24-hr sampling time. The depth of activated carbon as adsorbent was 3.0 cm with 0.5 cm bottom section to detect any breakthrough. Adsorbent required compaction strength of 3,000 g during packing in the glass vials. The glass vial can be reused to reduce cost and minimize waste. Commercial passive samplers cost between $12–$75 US [8]. The construction, installation and maintenance costs are cheaper than any other air monitoring techniques [9]. The tube-type passive sampler offers an alternative for BTEX monitoring in urban settings in Thailand.

Acknowledgment

This study was supported and funded by Suranaree University of Technology, Nakhon Ratchasima, Thailand.

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