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AMBIENT AND PERSONAL EXPOSURE LEVELS OF BTEX AMONG SCHOOLCHILDREN RESIDING NEAR THE OIL REFINERIES IN CHONBURI PROVINCE

ระดับสารบีทีอีเอ็กซ์ในบรรยากาศและการรับสัมผัสในเด็กนักเรียนที่อาศัยอยู่ใกล้โรงกลั่นน้ำมัน ใน จังหวัดชลบุรี

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Abstract

Benzene (B), toluene (T), ethylbenzene (E) and xylene (X) known as BTEX are commonly observed in the refinery industrial area and acknowledged that pose a threat to human health, and possibly even more so to children. Personal exposure of 86 schoolchildren and the ambient air levels were measured simultaneously. The potential risks of BTEX exposure were also investigated. The results revealed that the highest BTEX personal exposures were observed in school children residing close to the oil refinery. The average ambient level of benzene and toluene were comparable to these level of personal exposure which indicated the large impact of outdoor air pollution on personal exposure. The non-cancer risks for BTEX exposure were within the acceptable limits (HQ<1), meaning that no adverse effects were expected as a result of these exposures. Despite that the benzene level was lower than the daily guideline value, the estimate of cancer risk showed that the lifetime cancer risk of children was not negligible and therefore monitoring measure should be taken into account to preserve the health

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of children.

Keywords: benzene, toluene, ethylbenzene, xylene, schoolchildren, oil refinery

บทคัดย่อ

เบนซีน, โทลูอีน, เอทธิลเบนซีน และไซลีน หรือที่รู้จักกันในชื่อสารบีทีอีเอ็กซ์ มักพบในบรรยากาศในบริเวณอุตสาหกรรมกลั่นน้ำมันและเป็นที่ทราบกันดีว่าสารกลุ่มนี้ทำให้เกิดผลกระทบต่อสุขภาพของผู้ที่ได้รับสัมผัส โดยเฉพาะในเด็ก การศึกษานี้ดำเนินการตรวจวัดการรับสัมผัสในกลุ่มตัวอย่างที่เป็นเด็กนักเรียนจำนวน 86 คน และเก็บตัวอย่างอากาศแบบพื้นที่ ตลอดจนประเมินความเสี่ยงของการรับสัมผัสสารบีทีอีเอ็กซ์ ผลการศึกษาพบว่าระดับการรับสัมผัสสารบีทีอีเอ็กซ์มีระดับสูงที่สุดในเด็กนักเรียนที่อาศัยใกล้หรือติดกับโรงกลั่นน้ำมัน โดยค่าความเข้มข้นเฉลี่ยของสารเบนซีนและโทลูอีนที่ตรวจวัดในบรรยากาศและที่ตัวบุคคลมีค่าใกล้เคียงกัน ซึ่งชี้ให้เห็นถึงผลจากมลพิษอากาศจากภายนอกต่อการรับสัมผัสที่ตัวบุคคล ค่าความเสี่ยงของการไม่ก่อมะเร็งจากการรับสัมผัสสารดังกล่าวมีค่าน้อยกว่า 1 ซึ่งอยู่ในระดับที่ยอมรับได้ กล่าวคือไม่ก่อให้เกิดผลอันไม่พึงประสงค์ใด ๆ จากการรับสัมผัสสาร แม้ว่าค่าความเข้มข้นของสารเบนซีนต่ำกว่าค่ามาตรฐานรายวัน หากแต่ผลการประเมินค่าความเสี่ยงของการก่อมะเร็งชั่วชีวิตพบว่ามีค่าที่ละเลยไม่ได้ ดังนั้น จึงควรมีการพิจารณามาตรการเฝ้าระวังเพื่อสุขภาพเด็กต่อไป

คำสำคัญ: เบนซีน, โทลูอีน, เอทธิลเบนซีน, ไซลีน, เด็กนักเรียน, โรงกลั่นน้ำมัน

Introduction

BTEX in ambient air were largely originated from petroleum refinery industry and mobile source[1-3]. According to Environmental Protection Agency (EPA) reports, refinery emissions of benzene increased more than 8% between 2007 and 2008[4]. People living around oil refineries and solvent-based industrial production may increase residential BTEX exposure and health risk[5, 6]. These may be the result of fugitive and stack emission, and/or accidental leak. BTEX are responsible for the production of tropospheric ozone and further assist in the formation of photochemical smog [7]. Many epidemiological studies have shown that among BTEX, benzene is a potential human carcinogen (Group 1) and has strong evidence on the increase of childhood leukemia[8-10]. Benzene is also responsible for various toxicity effects including central nervous system depression, eye and airway irritation, general developmental toxicity, and genotoxicity. Chronic exposure to toluene over time can lead to problems in the nervous system, kidneys and liver. Ethylbenzene is possibly carcinogenic to humans (Group 2B) and longer term exposures may lead to ototoxicity, developmental toxicity, testicular toxicity, hepatotoxicity, and nephrotoxicity[11]. Chronic exposure to xylene can cause damage to the nervous system and possible effects on the kidneys [11, 12]. In considering the effects of BTEX on human health, it is of major importance to study and understand their concentration in the school areas of the industrial impact zones.

Children living in the vicinity of refinery industry may be exposed to BTEX and other toxicants simultaneously and sequentially as they mature. Chronic exposure may be more serious to children because of their potential longer latency period. Children's exposure to environmental pollutant is likely to be greater than that of adults because of their sensitivity and outdoor activities. Children are often vulnerable to the adverse effect of BTEX. These could entail a greater risk of carcinogenic and other toxic effects to children if they expose to BTEX at levels similar to those of adults.

Standard air pollution and control strategies are based on ambient measurements. For many environmental pollutants, individuals are closer to their sources and record actual levels of pollutants in the air, which is related directly to the individual. Thai primary schoolchildren spend 7-11 hours per day at school both indoors and outdoors, personal exposure studies in schoolchildren are needed, as a good representative for their exposure. Moreover, because of the special vulnerability of children to environmental chemical exposure and relatively few data on BTEX exposures in children, therefore this study determined levels of BTEX in ambient and estimated the inhaled BTEX exposure in children, healthy and non-occupational, during a study time, concurrently assessing their potential health risk significance.

Materials and Methods

Sampling sites

Sriracha, one of eleven districts in Chonburi, is located on the east coast of the gulf of Thailand, about 120 kms southeast of Bangkok. It is a big city near important industrial area including 3 oil refineries and 3 industrial estates. All three primary schools under study are located surrounding three oil refinery companies and one Industrial Estate (Figure 1). Selection criteria for sampling location were based on the primary governmental school, the location of the school situated in the petrochemical industrial area, and other factors including the consent of the headmaster and parents to conduct the research. All schools are located next to the temple and not far from Laemchabang Industrial Estate which consists of 62 factories including many solvent industrial types. There are no air conditioners in all classrooms of the 3 school buildings. The description of these schools was presented as followed.

School 1(S1): This s chool is a moderate school size composed of about 1,300 schoolchildren. It is situated near a major traffic interaction with high traffic density during the rush hour. Nevertheless, there are many big trees surrounding the fence of school. The oil refineries are located on the West of the school.

School 2(S2): This school is a small school size composed of approximately 500 students. It is located near the seashore (100 m from the football field). There is no fence thus allowing the vehicles can enter the school, low traffic density was observed. From the school, the North East is the oil refinery location.

School 3 (S3): This school is a small school composed of approximately 500 students with least area, compared to the S1 and S2. It is located near many refineries and solvent-related industries, as well as residential building. The back of the school is next to the seashore (200 m). It is also located close to a minor street with moderate traffic density all day long. The building configuration has less rotation of air than the open building found in the other two schools.

Figure 1 School locations (S_1-S_3) in the petrochemical industrial area

Study population

The schoolchildren recruited in this study consisted of 86 children. The boys who had age ranged between 9 to13 years or studied in pathom 4 to 6 were randomly selected from three primary government schools. The subjects selected for this study had to live near the oil refineries (within 5 kms) and studied in that school for at least 1 year. All subjects were healthy volunteers at the time of entry into the study. None of the children in this study were active smokers, nor were any of the children exposed in an occupational setting. A baseline questionnaire were administered to each participant and their parents in order to obtain information that could be used to understand personal exposure measured during sampling period.The questionnaire covered family history and family health status, occupation, passive smoking and routine lifestyle activities of the children. This study was approved by the Ethical Review Committees for Research on human subjects, Burapha University.

Determination of ambient BTEX

Ambient air sampling and analysis was conducted in February (dry season) by followed the standard method of United States Environmental Protection Agency[13]. Because of a small variation from day to day and a slightly increase from Monday to Friday, the exposure was determined on Wednesday as a representative of 5-day monitoring data. The ambient BTEX determination were done by the Thai Environmental Technic, Bangkok. Ambient air samples were collected in stainless steel canisters and are analyzed by Gas Chromotographic-Mass Spectrometric method. Prior to field deployment, canisters were cleaned and evacuated to a vacuum of 50 millitorrs. They are fitted with an appropriate sampling valve calibrated to manufacturer's specifications. Area sampling was conducted within in the breathing zone which was about 120 cms in height from the floor. The equipments were placed at the playground, in front of school locations starting at approximately 9 a.m. of the sampling day, and retrieved 24 hrs later. The sampling canisters were transported to the laboratory a few hours after completed sampling and prepared for analysis by pressurizing each canister with ultrahigh purity nitrogen to of approximately 2 atmospheres. Each ambient monitoring site was determined on the same personal sampling day.

Determination of personal exposure to BTEX

Personal monitoring was performed as directly approach to estimate daily exposure of BTEX. It was conducted by using Carbopack B™ solid adsorbent cartridges (60/80 mesh), packed into the stainless steel tube (8.9-cm long x 0.64-cm O.D.) which was set in the respiratory zone. These tubes were precleaned before reuse by cleaning tube system (Markes international TC-20) at desorption temperature 350^{O}C for 90 min with nitrogen gas , at flow rate 110 mL/min. Individual personal exposure to BTEX was monitored for a 8-hr period of a study time (from 8 a.m. to 4 p.m.), while subjects were performing their usual activities. At the end of sampling, the cartridge was sealed, transported to the laboratory and kept in refrigerated (-20 ^{O}C) until analysis. Sample tubes were loaded into Gas Chromatography system and were heated to 200 ^{O}C to desorb the toluene. The desorbed toluene gases were transferred via a heated line to the GC-MS (Agilent Technology, 7890A Series) where they were separated in a capillary column (300 mm x 0.25 mm, 2.5 μm by Agilent technology) and detected with a flame ionization detector.

Assessment of the chemical potential risks

Various factors should be considered in the determination of air contaminant intake including frequency, duration of exposure and body weight. The following Equation 1 was used to calculate the inhalation intake.

$$I_{inh} = \frac{C \times IR \times ET \times EF \times ED}{AT \times BW} \quad (1)$$

Where C represents the ambient concentration (μg/m^3); IR inhalation rate (0.625 m^3/hr assumed for children, and 0.875 m^3/hr assumed for adult [(14)]; ET exposure time 24 hr/d; EF exposure frequency 365 days/yr; ED exposure duration (presumably 50 yrs for general population), AT average time 76 yrs for Thai people and BW body weight (average 33.7 kgs for children, and 70 kgs for adult).

Health risk assessment were calculated in terms of non-cancer risk and cancer risk. Hazard Quotient (HQ) was used to estimate the non-cancer health effects as expressed in Equation 2. If the quotient is less than 1, then the systemic effects are assumed not to be of concern; if the hazard quotient is greater than 1, then the systemic effects are assumed to be of concern.

$$HQ = \frac{EC}{REF} \quad (2)$$

Where EC is the exposure concentration (μg/m^3), REF is the non-cancer reference concentration value of 30, 5000, 1000 and 100 μg/m^3 for benzene, toluene, ethylbenzene and xylene, respectively [(15)]. In addition, the sum of hazard quotients which targeted at the same organ was also estimated as shown in Equation 3.

$$HI = \sum \frac{C}{REFi} \quad (3)$$

The cancer risk was calculated by the following equation (Equation 4).

$$\text{Cancer risk} = I_{inh} \times SFI \ldots \quad (4)$$

Where I_{inh} is the air contaminant intake of a certain chemical and SFI is the inhalation slope factor value of the corresponding chemical [1.0×10^{-4} $(\mu g/kg\text{-}d)^{-1}$ for benzene, and 8.7×10^{-6} $(\mu g/kg\text{-}d)^{-1}$ for ethyl benzene][16].

Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS Inc., Version 17). Exposure levels for BTEX were analyzed and compared among three school locations by Independent T-test The correlation among BTEX concentrations was computed by Pearson's correlation. A p-value <0.05 was considered statistically significant.

Results

Demographic data

Table 1 showed the detail characteristics of study subjects in three schools. Schoolchildren have mean ages of 10.98 yrs (ranged 9-13 yrs), with mean body weight of 33.7 kgs. Most schoolchildren (>80%) had duration of study in the school at least 5 yrs. Time spent indoor were much greater in S2 schoolchildren. On average, children spent less time in a vehicle or on the street. Potential exposure to gasoline vapor from travelling duration between home and school was slightly greater in S1 schoolchildren. The remaining variables showed similar pattern in three school. The education level in the majority of children's parents was at primary schools. Most of the occupation of parents were industrial work (45%), merchant and general employee (35%) (data not shown).

Table 1 Comparison of descriptive demographics among children in each school location

Characteristics	School 1 (n=28)	School 2 (n=29)	School 3 (n=29)	Average
Age(yrs)†	11.32±0.55 (11-13)	10.66±0.77 (9-12)	10.97±0.50 (10-12)	10.98±0.67 (9-13)
Body weight (kgs) †	36.6±7.2 (25-55)	34±11.8 31 (21-70)	30.7±8 (20-52)	33.7±9.5 (20-70)
Study time in this school (yrs)†	6.3±2.1 (1-9)	5±2.5 (1-8)	4.8±2.2 (1-8)	5.4±2.4 (1-9)
Vehicle used				
- Walking	1 (3.57)	2 (6.90)	6 (20.69)	9 (10.46)
- Bicycle	-	12 (41.38)	1 (3.45)	13 (15.12)
- Motorcycle	6 (21.43)	6 (20.69)	11 (37.93)	23 (26.74)
- Bus	13 (46.43)	8 (27.59)	7 (24.14)	31 (36.05)
- Car	8 (28.57)	1 (3.44)	4 (13.79)	10 (11.63)
Time spent from home to school				
- 5-15 min	16 (57.14)	21 (72.42)	23 (79.31)	60 (69.77)
- >15-30 min	8 (28.57)	4 (13.79)	5 (17.24)	17 (19.77)
- >30-45 min	4 (14.29)	4 (13.79)	1 (3.45)	9 (10.46)
Children activity (hobby) at home				
- Indoor (e.g., playing computer game, reading)	9 (32.14)	20 (68.97)	12 (41.38)	41 (47.67)
- Outdoor (e.g., playing sports, selling)	19 (67.74)	9 (31.03)	17 (58.62)	45 (52.33)
Passive smoking*				
- No passive smoking	8 (28.57)	11 (37.93)	11 (37.93)	30 (34.88)
- Low	7 (25)	-	3 (10.345)	10 (11.63)
- Medium	1 (3.57)	3 (10.35)	3 (10.345)	7 (8.14)
- High	12 (42.86)	15 (51.72)	12 (41.38)	39 (45.35)
Cooking by usage of petroleum-related fuels for cooking				
- No	18 (64.29)	25 (86.21)	18 (62.07)	61 (70.93)
- Yes	10 (35.71)	4 (13.79)	11 (37.93)	25 (29.07)

' Values were expressed as number (weighted %).

† Values were expressed as mean±SD, (min-max).

* Low level = family members smoke 1-5 cigarettes/d, Medium level = family members smoke 5-10 cigarettes/d, High level = family members smoke >10 cigarettes/d.

Ambient air levels of BTEX in the school area

Highest ambient benzene and total xylene levels were present at the inside S3 area whereas the lowest levels were shown in S2 area. The BTEX ratios of S1, S2, S3 and total sites were (1: 5.8: 1.3: 1.4), (1: 12: 1.4: 2.3), (1.5: 2.2: 1: 1.7), and (1: 4.4: 1: 1.4), respectively. The T/B ratios in S1, S2, S3 and total sites were 5.8, 12, 1.5, and 4.4, respectively. The X/E ratios in S1, S2, S3 and total sites were 1.1, 1.5, 1.7, and 1.3, respectively. Benzene is the only compound from BTEX regulated by the Thai National Environmental Committee B.E.2550. There was no exceedance of applicable 24 hrs guideline of benzene of 7.6 μg/m^3, but over 1 yr guideline of 1.7 μg/m^3. A summary of ambient BTEX levels and meteorological conditions were provided in Table 2.The sum of the detected compounds (VOC sum) and sum of BTEX in each sampling site were also reported as shown in Figure 2. On average, sum of BTEX level was as high as sum of other pollutants in the period of monitoring. Among VOCs, methanol was the most abundant (18.04 μg/m^3), followed by propanol (15.98 μg/m^3), 1,2-dichloropropane (10.83 μg/m^3) and toluene (8.63 μg/m^3) (data not shown).

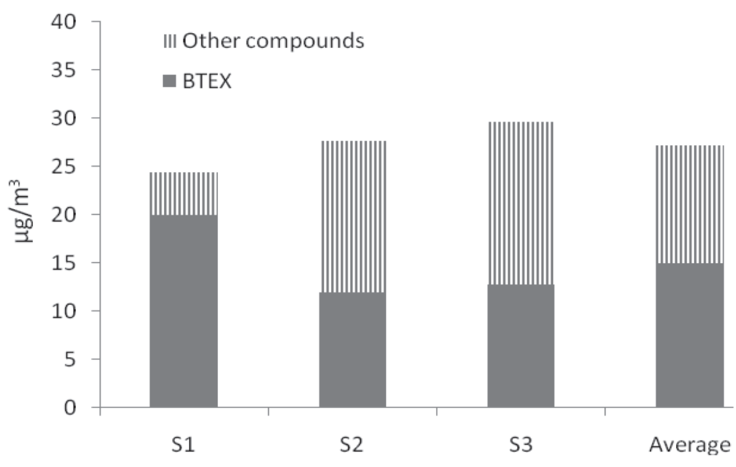

Figure 2 Trend of VOC sum, differentiated among BTEX and other compounds

* Other compounds mean 9 air quality standards of VOCs regulated annually in ambient air by National Environmental Board B.E.2550 including vinyl chloride, 1,3-butadiene, dichloromethane, chloroform, benzene, 1,2-dichloroethane, trichloroethylene, 1,2-dichloropropane, and tetrachloroethylene.

Table 2 Ambient BTEX concentration (expressed as mean or mean±SD) at the inside school areas

Locations	Concentration (μg/m^3)					Average Temperature (°C)	Relative humidity (%)	Wind speed (knots)
	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene			
S 1	2.25	13.04	2.92	1.79	1.30	28.94	74.75	1.13
S 2	0.71	8.49	1.11	0.87	0.74	28.66	77.75	3.13
S 3	2.97	4.37	1.97	2.00	1.39	29.04	74.00	1.63
Average	1.98±1.15	8.63±4.34	2.0±0.91	1.55±0.60	1.14±0.35	28.88± 0.20	75.50 ± 1.98	1.96 ± 1.04

Personal exposure of BTEX in schoolchildren

Personal exposure was determined by his daily routine and BTEX levels associated with his activities and related micro-environments in the school area. The levels of individual exposure showed the highest levels of BTEX in S3 schoolchildren. BTEX exposure levels in S2 schoolchildren was slightly higher than that in the S1 schoolchildren. The average benzene exposure level in S3 was about 8.5-10-fold higher than that in S1 and S2 ($P<0.001$). All schoolchildren in the three schools had the higher mean levels of ethylbenzene than those of the other solvents. Individual BTEX exposure levels in schoolchildren were summarized in Table 3.The correlation analysis among BTEX levels in all sites was also performed. The relationships between the 4 solvents for personal measurements of all sites were strongly correlated as shown in Table 4.

Table 3 Levels of BTEX (expressed as mean±SD, median (min-max)) exposure in schoolchildren

Exposure	Concentration (μg/m^3)			
	S 1 (n= 28)	S 2 (n= 29)	S 3 (n= 29)	Average (n= 86)
Benzene	0.39±0.03***	0.45±0.03***	3.81±0.92†††	1.44±0.33
	0.37 (0.18-0.78)	0.46 (0.001-0.78)	0.37 (0.001-10.23)	0.37 (0.001-10.23)
Toluene	1.08±0.17***	1.39±0.15***	22.01±5.49†††	7.72±2.02
	0.84 (0.37-3.30)	1.16 (0.001-3.49)	1.63 (0.001-67.08)	1.12 (0.001-67.08)
Ethylbenzene	7.57±0.41**	9.51±0.62**	22.65±4.97†	13.62±1.91
	7.29 (5.00-11.44)	8.35 (5.34-19.19)	6.04 (0.001-68.09)	7.82 (0.001-68.09)
m,p-Xylene	0.16±0.03***	0.17±0.04***	1.02±0.25††	0.46±0.10
	0.08 (0.001-0.45)	0.08 (0.001-0.77)	0.14 (0.001-3.36)	0.08 (0.001-3.36)
o-Xylene	0.40±0.10***	0.51±0.11***	2.10±0.51††	0.98±0.19
	0.28 (0.04-1.42)	0.20 (0.04-2.31)	0.55 (0.001-6.89)	0.28 (0.001-6.89)

,* Significant difference from School 3 at $p< 0.05$ and 0.001, respectively.

†,††,†††Significant difference from Total schools (average)at $p< 0.05$, 0.01 and 0.001, respectively.

Table 4 Correlation coefficients among personal exposure levels of BTEX in all investigated sites

	Site	logToluene	logEthylbenzene	log *m,p*-Xylene	log *o*-Xylene
logBenzene	S1	0.4574*	0.1766	0.1491	0.1860
	S2	0.5875***	0.4299*	0.2628	0.2600
	S3	0.9961***	0.9913***	0.9846***	0.9834***
	Total	0.9405***	0.9129***	0.8187***	0.7145***
logToluene	S1		0.5074*	0.3678*	0.4024*
	S2		0.9648***	0.8851***	0.8813***
	S3		0.9956***	0.9943***	0.9925***
	Total		0.8945***	0.8772***	0.7809***
logEthylbenzene	S1			0.4997*	0.5196*
	S2			0.9445***	0.9402***
	S3			0.9909***	0.9924***
	Total			0.7959***	0.7495***
log *m,p*-Xylene	S1				0.9690***
	S2				0.9902***
	S3				0.9983***
	Total				0.9221***

*,*** Significant at $P < 0.05$ and 0.001, respectively

Assessment of the potential risks

The non-cancer risks for BTEX exposure, as assessed by Hazard Quotient (HQ), were within the acceptable limits (HQ<1), meaning that the systemic effects were assumed not to be of concern. Furthermore, the hazard index (HI), determined by the adding up the HQs of BTEX at a certain location of petrochemical industrial area, was 0.0689.

The cancer risk of benzene and ethylbenzene which were confirmed human carcinogen or suspected carcinogen, respectively[17] were shown in Table 5. Risks of benzene exposure for children residing in the vicinity of refinery industry were approximately 9.75×10^{-5}. The average lifetime cancer risk for ethylbenzene exposure (8.57×10^{-6}) was lower than that of benzene exposure, however, the cancer risk for both compounds among schoolchildren in the area of oil refineries was more than the US EPA guideline (10^{-6}).

Table 5 Cancer and non-cancer risks of the detected compounds

Chemical	IARC category [a/]	Inhalation Intake (μg/kg-d)	Hazard Quotient (HQ)	Cancer risk
Benzene	1	0.9754	4.70×10^{-2}	9.75×10^{-5}
Toluene	3	4.2516	1.23×10^{-3}	-
Ethylbenzene	2B	0.9853	1.43×10^{-3}	8.57×10^{-6}
Xylene	3	1.3302	1.93×10^{-2}	-

[a/] IARC, 2012

Discussion

Air monitoring was important to determine BTEX concentrations in the region in the vicinity of the oil refinery. Individuals were also recorded actual levels of pollutants associated with his activities and related to micro-environments in school area. The diffusive samplers used in this study were an appropriate device due to inexpensive, ease of use, and no need for power supply[18, 19].

Infiltration of outdoor pollution into school building was the main source of BTEX exposure in our study. It showed that the average personal exposure levels were similar to the ambient concentration of benzene, toluene and xylene. School 3 located at the center of oil refineries and close to the narrow street showed several times higher exposure level of BTE than those of ambient measurement. Moreover, schoolchildren in S3 revealed the highest concentration of ambient and personal benzene levels. This may be due to its location very close to the refinery industries and a narrow street with low speed of travel. In this school, central site monitoring underestimated personal exposure levels. The location of S1 was quite farther from the oil refineries than the others and had a large open area in front of school which allowed better air ventilation, thus resulting in the lowest personal exposure levels of BTEX. Personal exposure to BTEX was actually influenced by various sources. Several studies found that among personal lifestyle sources: active smoking, usage of petroleum-related fuels for cooking, automobile-related activities (e.g. riding bicycle, motorcycle) and other outdoor activities may increase the individual exposure[20, 21]. This study mainly focused on school exposure with limited studies on the potential impact of other micro-environment (e.g., vehicle, indoor home). Nevertheless, the questionnaire also showed that up to 65% of schoolchildren may expose to cigarette smoking in their home. Most schoolchildren used more time outdoor (at home), so their exposure to BTEX may be more highly affected by outdoor source emissions. There was no continuous monitoring (24 hrs) in the indoor house of children and no completed data of time-activity of schoolchildren in this study. The individual exposure took only one sample at each schoolchildren for only 8 hrs at school because children's parents did not allow to monitor personally at their home due to their burden on any lost or damage of the device. Therefore the measurement of exposure level in this study may be lower than the real exposure of the subjects. However, the results of 24 hrs monitoring at school with many refineries and solvent-based industries surround, a representative of residential area, showed a slightly higher than personal exposure. Tovalin-Ahumada and Whitehead [22] found that elevated outdoor air pollution concentrations had a larger impact on personal exposures compared to the contribution from indoor pollution sources. The generally accepted view that the indoor level of VOCs is a more vital determination of individual exposure than ambient air levels. Children spent a large fraction of their days outdoors, especially in the areas with relatively high levels of pollutant in outdoor air, should be concerned.

Many studies showed that BTEX ratio in the industrial areas were similar to our study, such as (1: 5.1: 0.6: 1.6), (1: 5.8: 0.5: 0.9) and (1: 7.8: 1.2: 2.1) in Tainan, Taiwan, in Fuji, Japan and Hong Kong, respectively[18, 23, 24]. Different ratio of BTEX were also reported in other studies on vehicle exhaust, such as (4.5: 3.9: 1: 4) and (2: 1.4: 1.1: 1) in Hanoi, Vietnam and Delhi, India[25, 7]. The difference in BTEX ratios between this work and those above studies demonstrated that due to difference between the sources in the different sample areas. High T/B ratio (4.4) in the neighborhood of the school area suggested the emission of large additional sources of toluene. In certain sampling site (S1), higher concentration of toluene might result from nearby construction work (e.g. painting) and evaporation from solvent-based industries in Ind ustrial Estate. In the three schools located near industrial zone at Sriracha, Chonburi, the average T/B ratio was approximately 4.4, while in industrial area of southern Taiwan and urban atmosphere in Hong Kong had T/B ratios of 0-9-8.6 and 2-10, respectively [23, 24]. However, high or low T/B ratio was found in three different school neighborhoods. This observation result indicated that the measured BTEX should be considered a blend concentration associated with nearby landuse, industrial activities and traffic density. Ratios of X/E among 3 sampling school areas were quite low when compared to other measurements in the petrochemical neighborhood[23, 26]. Xylene is considered a highly reactive species while ethylbenzene is considered a low reactive species. Low X/E ratios (1.3) in these school areas indicated an aged air parcel. The same tendency of these ratios was seen in the personal measurement. School area 1 exhibited quite poor BTEX exposure correlation coefficient. This poor correlation can be explained by the mixed sources of BTEX that appeared at different time, or by the fact that some sources of BTEX only emitted at certain time. Notably, the schoolchildren in S3 displayed strong correlations in BTEX. Good correlations in TEX and quite poor correlations between benzene and TEX were observed in children of S2. TEX mainly derived from the vaporization of industrial solvents, while benzene mainly derived from nearby traffic road.

This report presented the BTEX data collected during cold and dry season. This period was more stable weather conditions with low wind speed, low temperature, and low humidity and thus influenced the highest concentrations of BTEX. The meteorology of Chonburi and reactivity behavior of BTEX could be responsible for the seasonal variation. The ambient levels tended to be lower in school located 200 m away from seashore (S2) for benzene, ethylbenzene and xylene. These may be due to the influence of meteorological properties such as wind speed, humidity and temperature. This is in agreement with the previous studies that low wind speed, humidity and temperature influenced higher BTEX levels [1].

In this study, the estimation of risk has focused on the inhalation pathway which is the main route of exposure[27], so, the study's data should give good approximately estimations for the total BTEX exposure. For non-cancinogenic effect, all the quantified BTEX showed average levels below their reference cancentration values, therefore the systemic effects were assumed not to be of concern.In according to previous studies, compounds with an attributable cancer risk of over 10^{-4} can be considered as a definite risk, 10^{-5} to 10^{-4} as a probable risk and 10^{-6} to 10^{-5} as a possible risk [5]. For cancer effects, although none of each detected compound presented average cancer risk over the definite lifetime cancer risk (10^{-4}), the cancer risk of the area was above the US EPA guideline (10^{-6}). It is nothworthy that other carcinogenic VOCs not considered in this study, but commonly found in petrochemical area (such as 1,3-butadiene or 1,4-dichlorobenzene) were also contributed to the estimated risk of this area.

Conclusion

This study provided ambient and

personal data for BTEX among schoolchildren living in the vicinity of oil refineries and other solvent-based industries, which are seldom reported in Chonburi. This study showed that highest BTEX personal exposures were observed at school residing close to the oil refineries. The average personal exposure levels of benzene and toluene in children were similar to the ambient concentration which indicated the large impact of outdoor air pollution on personal exposure. High or low T/B ratio found in three different school neighborhoods indicated a blend concentration of BTEX associated with nearby landuse, industrial activities and traffic density. Low X/E ratios in these school areas indicates an aged air parcel. The non-cancer risks for BTEX exposure were within the acceptable limits (HQ<1), meaning that no adverse effects were expected as a result of these exposures. Cancer risks of benzene and ethylbenzene exposure for children residing in the vicinity of refinery industry were approximately 9.75×10^{-5} and 8.57×10^{-6}, respectively, which was not negligible and therefore should be taken into account to preserve the health of children.

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