HEALTH RISK ASSESSMENT AND BTEX EXPOSURE AMONG CAR PARK WORKERS AT A PARKING STRUCTURE IN BANGKOK, THAILAND

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ABSTRACT:

Background: Nowadays, the demand for parking places in Bangkok, the capital city of Thailand, is growing dramatically. To utilize the land to its full value, the trend has changed tobuilding multi-story car parks with underground parking, especially at department stores and hotels, inducing poor air quality. Vehicle emissions from their activity in car parks has become a main source of toxic air pollutants like carbon monoxide, particulate matter and volatile organic compounds (VOCs) which can contribute to the health problems.

Methods: This study aimed to estimate the level of benzene, toluene, ethylbenzene and xylene (BTEX) exposure among car park workers during weekdays and weekend in summer of 2014 at a parking structure in the Bangkok Metropolitan area. Carcinogenic and non-carcinogenic health risks were assessed by US Environmental Protection Agency (U.S. EPA) approaches. Personal active sampling through activated charcoal tube, followed by National Institute for Occupational Safety and Health (NIOSH) standard method, was used to collect air sample at the breathing zone of workers for 8 hours continuously. Gas chromatography with flame ionization detector (GC-FID) was performed for BTEX analysis.

Results: Mean concentrations (±SD) of benzene, toluene, ethylbenzene, and xylenes were 11.28 (±5.03), 56.13 (±73.96), 7.17 (±9.20), and 10.59 (±6.32) $\mu g/m^3$ respectively. BTEX concentrations on weekdays were higher than on weekends. The different working location among car park workers showed the difference of BTEX mean concentrations where underground floor were higher than the upper storey's levels. Risk of cancer from benzene exposure was at 4.37×10^{-6} and for ethylbenzene at 1.47×10^{-6} which were over acceptable levels of less than 10^{-6}. Derived lifetime risks of developing cancer were 5 in one million and 2 in one million for benzene and ethylbenzene respectively. The non-carcinogenic risks were within acceptable limits (HQ<1) and were at 0.360, 0.010, 0.006, and 0.105 for benzene, toluene, ethylbenzene, and xylene, respectively.

Conclusion: The study suggests that the car park workers carry cancer health risks likely due to exposure of BTEX, and for health promotion of these workers, appropriate education and risk communication should be given, and use of PPE such as masks should be encouraged. The suitability of this risk assessment method for Thailand and other Asian countries should also be assessed.

Keywords: Health risk assessment, VOCs, BTEX, Exposure, Car parking, Thailand

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INTRODUCTION

Urbanization and rapid economic development in Thailand has led to ever increasing vehicle population. Nowadays, the demand for parking slots in Bangkok, the capital city of Thailand, has also been grown dramatically. To utilize the land to its full value, the trend has changed to building multi-storey car parks with underground parking, especially department store and hotels, inducing poor air quality. Vehicle emissions from their activity in car parks has become a main source of toxic air pollutants like carbon monoxide, particulate matter and volatile organic compounds (VOCs) which contribute to the

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health problems [1].

Benzene, toluene, ethylbenzene and xylenes, known as the BTEX group of VOCs are common toxic air pollutants emitted from vehicle fuel combustion [2]. Health effects from BTEX exposure depends on dose and duration of exposure and present as chronic or acute exposure effects. Chronic exposures may cause adverse effect like cancer, especially benzene which has been widely recognized as a human carcinogen by the International Agency for Research on Cancer (IARC) [3] and the United States Environmental Protection Agency (U.S. EPA) [4]. In addition, chronic exposure of BTEX compounds might damage liver, kidneys, eyes and central nervous system. Acute effects of high concentration BTEX exposure leads to adverse effects of the respiratory system, irritation of throat and eyes and central nervous system effect such as headache, dizziness, vomiting and confusion [2].

Due to poor air ventilation, BTEX level in multi-story car park and underground car park would be worse than ambient air [5]. Car park workers have to face with high risk for occupational disease. However, few studies have been reported on this occupational exposure to air pollutants, especially BTEX compounds, and its health effects among car park workers. Therefore, this study aimed 1) to measure BTEX concentrations among car park workers 2) to assess the health risk through inhalation pathway and 3) to compare weekday and weekend BTEX concentration and to find a difference concentration according to location of workers.

MATERIALS AND METHODS

Study area and study population

The study was conducted in the summer 2014 in a parking structure, located in Pathumwan District in the central of Bangkok (13°43'59.2"N 100°31'39.3"E) which was purposively selected. This multistory car park is one of the largest parking complex in the Pathumwan area and had 9 parking storeys, including underground, and about 2000 parking spaces. This car park was busy because it was surrounded by offices and department store. Mechanical ventilation systems were operated regularly during the measurement period. Twenty-six workers in this parking structure were selected for monitoring personal BTEX exposure during their working period and personal air sampling was done and their BTEX samples were analyzed. Locations of workplace were classified into 4 working locations as motorcycle parking, basement parking (underground area), ground floor area, and up in the building zone. There are two kinds of jobs stations, 14 workers were making convenient at parking (refer to worker who had duty to look after the traffic in parking), and 12 workers were working at entrance/exit (refer to worker who had to sit at the entrance or exit and give parking passes to visitors). This study was approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University (Code of approval number 053/2014).

Personal air sampling and analysis

The concentrations of BTEX compounds were monitored continuously for 8 hours at the worker's breathing zone during their work period. The method of sample collection was followed the NIOSH 1501 method [6]. Briefly, charcoal glass tube (SKC 226-09; coconut charcoal; 8 x 110 mm; 200 mg/400 mg) was connected to a personal air pump (SKC, Eight Four, PA, USA) at flow rate of 0.2 liter/min. Pump flow-calibration checks were performed before and at the end of the sampling period. At the completion of sampling, each sampler was capped at its both ends with plastic caps and packed for shipment. After collection, the sample was labeled and frozen in an icebox and transported to the laboratory.

The analysis of BTEX was performed within a week after data collection. The analysis procedure was modified from the NIOSH 1501 method [6] by using carbon disulfide (CS_2) for extraction. The extracted CS_2 was analyzed for benzene by gas chromatography (GC) analyses. Internal standard (alpha, alpha, alpha-Trifluorotoluene; Ehrenstorfer, Germany) was added to each sample to perform the quantification. Briefly, the activated charcoal was desorbed in 1.0 ml of CS_2 for 30 min with occasional shaking. The extract was analyzed using gas chromatography with flame ionization detector (GC-FID) and a capillary column (CP-SIL-24 CB - 30m x 0.32mm ID x 0.25µm film thickness). A 2 µL of sample was used for one injection. Twice injections for one sample were done. The average results were reported. The initial oven temperature was set at 40ºC for 2 min and was programmed to increase at 10ºC/min to 100ºC. Injector and detector temperature were set at 150°C.

A calibration curve was constructed using five working standards containing benzene, toluene, ethylbenzene, xylene (0.5, 1, 5, 10 and 15 µg/ml) and internal standard (IS) (5 µg/ml). The linear calibration curve showed correlation coefficients of 0.991, 0.992, 0.992, 0.993 and 0.991 for analyses of benzene, toluene, ethylbenzene, m,p-xylene and o-xylene,

Table 1 Descriptive of BTEX personal exposure (μg/m^3) (n = 52)

VOCs	LOD	Mean	SD	Min	Max
Benzene	0.200	11.28	5.03	1.29	25.84
Toluene	0.300	56.13	73.96	3.28	354.90
Ethylbenzene	0.200	7.17	9.20	2.16	46.11
Xylenes	0.030	10.59	6.32	1.60	30.33

respectively. The limit of detection (LOD) of benzene, toluene, ethylbenzene, and xylene were 0.200, 0.300, 0.200, and 0.030 μg/m^3 respectively.

Health risk assessment

Inhalation risk assessment in this study was followed Risk Assessment Guidance for Superfund (RAGS) [7]. The estimated inhalation exposure of each chemical was calculated using equation 1.

$$\text{EC } (\mu g/m^3) = \frac{CA \times ET \times EF \times ED}{AT} \qquad \text{eq 1.}$$

Where EC is an exposure concentration (μg/m^3); CA is a contaminant concentration in air (mg/m^3); EF is an exposure frequency (days/year); ED is an exposure duration (years); AT is averaging time (for carcinogenic contaminant, AT calculated by lifetime in years (70 years) x days/year x hours/day and for non-carcinogenic contaminant AT calculated by ED in years x 336 days/year x 8 hours/day). The risk was calculated for 8 hours day-shift and 336 days of annual working days (2 days a month holiday). Exposure duration (ED) is based on their work experience.

Cancer risk for benzene was calculated by the following equation (eq 2.)

$$\text{Cancer risk} = \text{EC x IUR} \qquad \text{eq 2.}$$

Where EC is an exposure concentration (μg/m^3) and IUR is the Inhalation Unit Risk (per μg/m^3) given by EPA - Integrated Risk Information System. The IUR for benzene is 7.8 x 10^{-6} per μg/m^3 (maximum in range) [8]. The IUR for ethylbenzene according to Office of Environmental Health Hazard Assessment (OEHHA) is 2.5 x 10^{-6} per μg/m^3 [9]. Cancer risk of more than 10^{-6} was considered as an unacceptable level for carcinogenic effect of the compound concerned.

Non-carcinogenic risk for benzene, toluene, ethylbenzene and xylene was calculated following equation (eq 3.)

$$\text{Hazard Quotients (HQ)} = \frac{EC}{RfC \times 1000\ \mu g/mg} \qquad \text{eq 3.}$$

Where EC is an exposure concentrations (μg/m^3) and RfC is an inhalation reference concentration (mg/m^3). RfCs were also given by EPA - Integrated Risk Information System as 0.03, 5, 1 and 0.1 mg/m^3 for benzene, toluene, ethylbenzene and xylene [8, 10-12] respectively. The HQ of each chemical was able to combine as the sum of more than one, and HQ for multiple substances, defined as Hazard Index (HI). HQ and HI > 1 was considered as unacceptable levels for non-carcinogenic effects of the compounds.

Statistical analysis

The licensed SPSS version 17 for windows was used. All study parameters were tested for normality by the one-sample Kolmogorov–Smirnov test. Mann-whitney U test and Kruskal wallis test were used for comparing BTEX concentration means differences.

RESULTS

General characteristic

For the general characteristic of twenty six workers participating in this study (13 men and 13 women), they were 35.85 (± 12.09) years old, worked 8 hours per day, 336 days in a year, and had work experience in the parking lot of average of 3.61 ± 2.78 years.

BTEX personal exposure

The mean (±SD) concentrations of benzene, toluene, ethylbenzene, and xylenes (m, p, o-xylene) were 11.28 (±5.03), 56.13 (±73.96), 7.17 (±9.20), and 10.59 (±6.32) μg/m^3 respectively. Table 1, the average concentration of each chemical was derived from mean of weekday and weekend exposure concentration. Toluene had the highest exposure concentration among car park workers, followed by benzene and xylene, and ethylbenzene had the lowest exposure.

Comparisons for BTEX concentrations showed in Table 2. Toluene, ethylbenzene, and xylene concentrations in weekdays were statistically significantly higher than weekend ($p < 0.05$, $p < 0.05$, and $p = 0.001$ respectively). According to work location, the samples taken from the motorcycle parking recorded highest concentration for toluene (114.160 ± 1.768 μg/m^3), ethylbenxene (21.904 ± 2.135 μg/m^3) and xylene (21.904 ± 2.135 μg/m^3) while those taken from the underground parking showed the highest concentration of

Table 2 Comparisons for BTEX concentrations difference regarding to weekday and weekend, working location, and job station (n = 52)

Comparisons	Benzene		Toluene		Ethylbenzene		Xylene		BTEX	
	Mean ± SD	**Mean rank**	**Mean ± SD**	**Mean rank**	**Mean ± SD**	**Mean rank**	**Mean ± SD**	**Mean rank**	**Mean ± SD**	**Mean rank**
Weekday and weekend										
Weekday	12.580 ± 5.188	29.04	65.551 ± 63.852	30.38	7.257 ± 6.350	30.42	13.347 ± 6.523	33.54	92.168 ± 74.402	31.31
Weekend	10.083 ± 5.033	22.23	47.433 ± 73.963	21.00	7.081 ± 9.198	20.96	7.827 ± 6.324	19.46	72.426 ± 87.901	21.69
p-value		0.099		0.023*		0.022*		0.001*		0.022*
Working location										
Motorcycle parking	13.369 ± 3.258	36.00	114.160 ± 1.768	44.00	21.904 ± 2.135	43.00	21.904 ± 2.135	49.33	160.482 ± 6.206	46.00
Parking at Underground	15.278 ± 6.264	36.38	107.524 ± 108.924	35.54	14.014 ± 5.620	34.54	14.014 ± 5.620	36.08	151.356 ± 128.544	38.69
Basement	9.924 ± 3.877	20.47	28.891 ± 21.481	21.74	10.054 ± 6.249	22.37	10.054 ± 6.249	25.32	52.839 ± 26.039	24.00
Building zone	9.121 ± 3.302	20.33	34.484 ± 60.833	17.87	6.568 ± 2.868	18.13	6.568 ± 2.868	16.47	48.613 ± 64.892	16.53
p-value		0.005*		0.001*		0.003*		0.000*		0.000*
Jobs station										
Making convenient	11.986 ± 5.731	26.36	67.682 ± 88.259	28.48	9.418 ± 12.331	28.12	11.263 ± 6.956	27.81	93.751 ± 105.032	28.70
Sitting at Entrance/Exit	10.577 ± 4.222	24.64	44.577 ± 55.691	22.52	4.914 ± 3.182	22.88	9.857 ± 5.812	25.08	69.927 ± 64.504	24.12
p-value		0.677		0.148		0.204		0.516		0.276

Test concentration difference using Mann-Whitney U Test and kruskal wallis test and the level of significant set at 0.05

**Statistics significant ($p < 0.05$)*

Table 3 The Cancer and non-cancer risk of workers exposed to BTEX

Risk characterization	VOCs	EC (μg/m^3)	IUR (per μg/m^3)	Cancer risk		
				Average	**Min**	**Max**
Carcinogenic effect	Benzene	0.56	7.8 x 10^{-6}	4.37×10^{-6}	4.83×10^{-7}	1.94×10^{-5}
	Ethylbenzene	0.59	2.5 x 10^{-6}	1.47×10^{-6}	2.31×10^{-7}	5.26×10^{-6}
		EC (μg/m^3)	**RfC (mg/m^3)**	**Hazard Quotient (HQ)**		
Non-carcinogenic effect	Benzene	10.85	0.03	0.36	0.14	0.61
	Toluene	53.97	5	0.01	0.00	0.04
	Ethylbenzene	6.89	1	0.01	0.00	0.02
	Xylene	10.59	0.1	0.11	0.03	0.25
	Hazard Index (HI)			0.49	0.17	0.82

benzene (13.369 ± 3.258 μg/m^3) The highest and the lowest BTEX concentrations were found among workers in the motorcycle parking (160.482 ± 6.206 μg/m^3) and the upper parking zones (48.613 ± 64.892 μg/m^3) respectively. Comparison mean rank between locations found significantly differences for benzene, toluene, ethylbenzene and xylene ($p<0.01$, $p=0.001$, $p<0.01$ and $p<0.001$ respectively).

Post-hoc pairwise comparisons were analyzed to confirm the concentration difference (mean ± SE) of each pair of working locations (result not displayed). The results found that BTEX air samples taken from the underground parking and the motorcycle parking were higher than those of other locations. Benzene concentration in underground parking was statistically significantly higher than that of the building zone parking for 6.156 ± 1.691 μg/m^3 (*p-value* = 0.004) and that of the basement area for5.353 ± 1.605 μg/m^3 (*p-value* = 0.009). Toluene concentration in the underground parking was statistically significantly higher than that of the parking in building zone for 73.039 ± 25.141μg/m^3 (*p-value* = 0.028) and also higher than that of the basement area for 78.632 ± 23.881 μg/m^3 (*p-value* 0.01). In addition, ethylbenzene concentration in the underground parking was statistically significantly higher than that of the building zone parking for 10.493 ± 3.087 μg/m^3 (*p-value* = 0.007) and also higher than that of the basement area for 10.571 ± 2.933 μg/m^3 (*p-value* = 0.004). For xylene concentration, the concentration in the underground parking was not only higher than that in the parking in building zone for 73.039 ± 3.161 μg/m^3 (*p-value* = 0.028) but also it was found that the concentration of the motorcycle parking was recorded the highest concentration and higher than that of the basement area for 11.850 ± 3.136 μg/m^3 (*p-value* = 0.002) and than that of the building zone for 15.338 ± 1.859 μg/m^3 (*p-value* < 0.001) at statistically significant levels.

However, comparisons BTEX concentrations according to job station found that they were not statistically significant for all of individual chemicals and total BTEX concentrations.

Health risk assessment of car parking workers

We saw in Table 3 that benzene presented average cancer risk (for leukemia) [8] at 4.37 x 10^{-6} considered as an unacceptable level for carcinogenic effect, while ethylbenzene presented an average cancer risk (for kidney cancer) [9] at 1.47 $\times10^{-6}$ which was also considered as unacceptable level for carcinogenic effect (cancer risk higher than 10^{-6}). From these risk figures, the chance of developing cancer from benzene exposure among these group of workers during their lifetime of 70 years was 5 in 1,000,000 for benzene exposures and 2 in 1,000,000 for ethylbenzene exposures.

For non-carcinogenic risk estimated as Hazard Quotients (HQ), the study found that HQ of benzene for lowering lymphocyte count [8] was 0.361, HQ of toluene for neurological effects [12] was 0.010, HQ of ethylbenzene for developmental toxicity [10] was 0.006, and HQ of xylene for decreased rotarod performance [11] was 0.105. These were considered as acceptable level (lower than 1) and even the total non-carcinogenic risk on BTEX exposure in this study presented a HI of 0.485 which didn not exceed the reference value of HI. In addition, the highest HI of car park workers was 0.821 and therefore none of workers in this study had non-carcinogenic risks from BTEX exposure.

DISCUSSION

BTEX concentrations measured in this study were lower than time-weighted average (TWA) recommended by NIOSH [13] and OSHA [14]. The occupational exposure concentration of benzene, toluene and ethylbenzene were also under exposure limits recommended by Thailand labor law, Notification of Ministry of Interior regarding working safety in respect to environmental condition (chemicals) B.E.2522 [15]. In addition, this study also compared BTEX results with other studies (Table 4).

Table 4 BTEX concentrations (μg/m^3) in other studies in literature

Reference / Location	Study area/ Study population	Benzene	Toluene	Ethyl-benzene	Xylene
This study	Car parking/ workers	10.848	53.971	6.890	10.587
Kitwattanavong et al./ Bangkok, Thailand [16]	Gas station/ workers	220.29	297.03	34.96	139.89
Thaveevongs et al./ Bangkok, Thailand [17]	Gas station in Bangkok/ workers	518.70	498.46	10 - 27	41.03
Ruangtrakula et al./ Bangkok, Thailand [18]	Tollway stations workers	99.29	146.06	29.92	48.75
Soldatos et al./ Athens, Greece [19]	Enclosed parking/ stationary and personal air samples	366	374	102	403
Jo & Song./ Korea [20]	Non-smoker gas station attendant	72.1	126	12.1	50.7
Kuntasal et al./ Turkey [21]	Gas station	27.52	52.28	11.47	48.54
Manini et al./ Italy [22]	Taxi drivers and taxicab	7.7	35.2	6.2	27.7
Tunsaringkarn et al./ Bangkok, Thailand [23]	Gas station workers	107.68	226.68	7.25	11.56
Tunsaringkarn et al./ Bangkok, Thailand [24]	Motorcycle-taxi	35.69	142.17	5.70	61.98
	street vender	30.27	102.40	5.91	40.88
Bono et al./ Italy [26]	Gas station attendant (summer)	502.7	711.6	-	379.4
Carrieri et al./ Italy [27]	Gas station	44	-	-	-
Periago & Prado/ Spain [28]	Refuelling stations/ personal air samples	163	753	-	316
Pekey & Yılmaz/ Turkey [29]	Ambient air near industrial city	2.26	35.51	9.72	49.33
Wang et al./ China [30]	Urban roadside	51.5	77.3	17.8	81.6

BTEX concentrations measured in this study were lower than those measured in some previous studies in Bangkok, Thailand [16-18]. There was a study conducted in Greece [19] which reported higher concentrations of BTEX in enclosed parking than our study. They reported that concentrations of BTEX in the first and second underground floors were higher than the third floor which was consistent with our findings of this study. Patterns of BTEX concentration obtained from previous studies demonstrated that toluene was the highest concentration, followed by benzene and xylene while ethylbenzene was found for the lowest concentrations [16, 17, 20-22]. The motorcycle parking area showed higher concentrations of toluene, xylene, ethylbenzene, and BTEX than those found in the underground, basement and building zone parking areas. This was simply due to much higher number of motorcycles parked per square feet comparing to lower number of car parked per square feet in other parking areas. Thus the high concentrations found in the motorcycle area were rather due to high emission than poor ventilation or parking level altitude.

Comparing concentration of BTEX between weekday and weekend, we found that weekday benzene concentration was also higher than weekends but their difference was not statistically significant because the standard deviation might influence the comparison of mean difference. Moreover, the number of car in weekday was different from those in weekend. During the weekend period, especially Sunday, we found lower density of cars than weekday period.

This study showed a potentially increased health risk for underground workers compared to workers who work in the higher parking floors. The average cancer risk for benzene was at 4.37 x 10^{-6}, which was lower than previous studies conducted in gas station workers in Bangkok [17, 23] Comparing with other studies, the assessed risk for outdoor workers in Bangkok, showed a lower cancer risk in these subjects compared to tollway station workers [18] and motorcycle-taxi and street vendors [24]. The non-carcinogenic risk of benzene, toluene, ethylbenzene, and xylene were considered in the acceptable range, like several previous studies [16-18, 23-25]. Small number of participants and a short period of data collection should be noted as limitation of this study. However, this study result would be an important baseline data on BTEX exposure of parking workers in Bangkok, Thailand. Further studies should investigate BTEX concentration at different parking structures to compare with this current study. In addition, comparing BTEX concentration among each storey of parking structures should be investigated.

CONCLUSION

Concentrations of BTEX in the air measured in car park workers which were lower than those of earlier studies. The 8-hour average of BTEX concentrations in this study was in the lower limits as defined by international organizations. On comparing BTEX concentrations in different working locations, it was found BTEX concentrations at the underground structure were higher than those on higher-floor parking zones in multistory parking structures. Human health risk analysis through inhalation exposure to BTEX found that workers may be at risk of cancer from benzene exposure via inhalation pathway. Thus, risk communication should be introduced to the participants to protect themselves from BTEX exposure such as using masks.

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REFERENCES

1. Li Y, Xiang R. Particulate pollution in an underground car park in Wuhan, China. Particuology. 2013; 11(1): 94-8.
2. Agency for Toxic Substances and Disease Registry. Interaction profile for: benzene, toluene, ethylbenzene, and xylenes (BTEX). Atlanta, GA: U.S: Department of Public Health and Human Services, Public Health Service; 2004.
3. International Agency for Research on Cancer [IARC]. Agents classified by the IARC monographs volumes 1–109 [Monograph on the internet]. Lyon, France: 2014 [cited 2014 April 21]. Available from: http://monographs.iarc.fr/ENG/Classification
4. U.S. Environmental Protection Agency, Integrated Risk Information System [IRIS]. Substance file – benzene [Monograph on the internet]. 2012 [cited 2014 April 21]. Available from: http://www.epa.gov/iris/subst/0276.htm#woe
5. Zhu J, Newhook R, Marro L, Chan CC. Selected volatile organic compounds in residential air in the city of Ottawa, Canada. Environ Sci Technol. 2005; 39(11): 3964-71.
6. National Institute for Occupational Safety and Health [NIOSH]. Manual of analytical methods, no.1501: hydrocarbon, aromatic. 4th ed. Cincinnati, OH: NIOSH; 2003.
7. U.S. Environmental Protection Agency [U.S, EPA]. Risk assessment guidance for superfund vol.I: human health evaluation manual (Part F, Supplemental Guidance for Inhalation Risk Assessment). Washington, D.C: Office of Emergency and Re medial Response; 2009.
8. U.S. Environmental Protection Agency, Integrated Risk Information System [IRIS]. Integrated risk information for benzene [Monograph on the internet]. Washington, DC: U.S. Environmental Protection Agency; 2014 [cited 2014 May 6]. Available from: http://www.epa.gov/iris/subst/0276.htm
9. Office of Environmental Health Hazard Assessment [OEHHA]. Long-term health effects of exposure to ethylbenzene. Sacramento: California Environmental Protection Agency; 2007.
10. U.S. Environmental Protection Agency, Integrated Risk Information System [IRIS]. Integrated risk information for ethylbenzene [Monograph on the internet]. Washington, DC: U.S. Environmental Protection Agency; 2012 [cited 2014 April 16]. Available from: http://www.epa.gov/iris/subst/0051.htm
11. U.S. Environmental Protection Agency, Integrated Risk Information System [IRIS]. Integrated risk information system for xylene [Monograph on the internet]. Washington, DC: U.S. Environmental Protection Agency; 2012 [cited 2014 May 6]. Available from: http://www.epa.gov/iris/subst/0270.htm
12. U.S. Environmental Protection Agency, Integrated Risk Information System [IRIS]. Integrated risk information for toluene [Monograph on the internet]. Washington, DC: U.S. Environmental Protection Agency; 2013 [cited 2014 April 16]. Available from: http://www.epa.gov/iris/subst/0118.htm
13. National Institute for Occupational Safety and Health [NIOSH]. NIOSH pocket guide to chemical hazards [Monograph on the internet]; 2011 [cited 2014 April 21]. Available from: http://www.cdc.gov/niosh/npg/
14. Occupational Safety & Health Administration [OSHA]. Chemical sampling information [Monograph on the internet]; 2012 [cited 2014 April 21]. Available from: https://www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html/
15. Notification of Ministry of Interior regarding working safety in respect to environmental condition (Chemicals). The Royal Government Gazette No. 94 Part 64 dated January 14, B.E.2520. [S.l: S.n; 1979].
16. Kitwattanavong M, Prueksasit T, Morknoy D, Tunsaringkarn T, Siriwong W. Health risk assessment of petrol station workers in the inner city of Bangkok, Thailand, to the exposure to btex and carbonyl compounds by inhalation. Human and Ecological Risk Assessment: An International Journal. 2013; 19(6): 1424-39.
17. Thaveevongs P, Panyamateekul S, Prueksasit T. Exposure assessment of Volatile Organic Compounds (VOCs) at gas station in Bangkok. Engineering Journal. 2010; 2(3): 1-12.
18. Ruangtrakula S, Prueaksasit T, Morknoy D. Health risk assessment of toll way station workers exposed to

BTEX via inhalation in Bangkok. Journal of Environmental Management. 2013; 9(1): 1-22.

19. Soldatos P, Evangelos BB, Panayotis AS. Occupational exposure to BTEX of workers in car parkings and gasoline service stations in Athens, Greece; 2002. [cited 2014 April 21]. Available from: http://www.siskos.gr/pegasus/content04/show.php?hert20=3000079&pcode=HERT20_CD3000079
20. Jo WK, Song KB. Exposure to volatile organic compounds for individuals with occupations associated with potential exposure to motor vehicle exhaust and/or gasoline vapor emissions. Sci Total Environ. 2001; 269(1-3): 25-37.
21. Kuntasal OO, Karman D, Wang D, Tuncel SG, Tuncel G. Determination of volatile organic compounds in different microenvironments by multibed adsorption and short-path thermal desorption followed by gas chromatographic-mass spectrometric analysis. J Chromatogr A. 2005; 1099(1-2): 43-54.
22. Manini P, De Palma G, Andreoli R, Poli D, Mozzoni P, Folesani G, et al. Environmental and biological monitoring of benzene exposure in a cohort of Italian taxi drivers. Toxicol Lett. 2006; 167(2): 142-51.
23. Tunsaringkarn T, Siriwong W, Rungsiyothin A, Nopparatbundit S. Occupational exposure of gasoline station workers to BTEX compounds in Bangkok, Thailand. Int J Occup Environ Med. 2012; 3(3): 117-25.
24. Tunsaringkarn T, Prueksasit T, Morknoy D, Siriwong W, Kanjanasiranont N. Health risk assessment and symptoms of outdoor workers in Central Bangkok, Thailand. Int J Res Chem Environ. 2014; 4(2): 72-8.
25. Maspat V, Prueksasit T. Health risk assessment of workers exposure to BTEX from incense smoke at worship places in Bangkok. J Health Res. 2013; 27(3): 149-56.
26. Bono R, Scursatone E, Schiliro T, Gilli G. Ambient air levels and occupational exposure to benzene, toluene, and xylenes in northwestern Italy. J Toxicol Environ Health A. 2003; 66(6): 519-31.
27. Carrieri M, Bonfiglio E, Scapellato ML, Macca I, Tranfo G, Faranda P, et al. Comparison of exposure assessment methods in occupational exposure to benzene in gasoline filling-station attendants. Toxicol Lett. 2006; 162(2-3): 146-52.
28. Periago JF, Prado C. Evolution of occupational exposure to environmental levels of aromatic hydrocarbons in service stations. Ann Occup Hyg. 2005; 49(3): 233-40.
29. Pekey B, Yılmaz H. The use of passive sampling to monitor spatial trends of volatile organic compounds (VOCs) at an industrial city of Turkey. Microchemical Journal. 2011; 97(2): 213-9.
30. Wang XM, Sheng GY, Fu JM, Chan CY, Lee SG, Chan LY, et al. Urban roadside aromatic hydrocarbons in three cities of the Pearl River Delta, People's Republic of China. Atmospheric Environment. 2002; 36(33): 5141-8.