HEALTH RISK ASSESSMENT OF WORKERS EXPOSURE TO BTEX FROM INCENSE SMOKE AT WORSHIP PLACES IN BANGKOK

Vee Maspat[1, 2], Tassanee Prueksasit[2, 3, *]

[1]International Postgraduate Programs in Environmental Management, Graduate School, Chulalongkorn University, Bangkok 10330, Thailand, [2]National Center of Excellence for Environmental and Hazardous Waste Management (NCE-EHWM), Chulalongkorn University, Bangkok 10330, Thailand, [3]Department of Environmental Science, Faculty of Science, Chulalongkorn University, Bangkok 10330 Thailand

ABSTRACT: This study aimed to evaluate potential occupational exposure and estimate their health risk in worship places. The sampling was performed on Sunday (high number of visitor or peak day) and Wednesday (non peak day) during April (dry season) to July (rainy season) 2012 at two famous worship places which are Tao Maha Bhrama (TMB) and Kanlayanamit Woramahawiharn (KW) temple. Each sampling was performed for 8 working hours using an activated charcoal filled glass tube connected to a personal air pump with an air flow rate of 100 ml/min. At both temples, four different locations were sampled at 1.50 m above the ground. The benzene, toluene, ethylbenzene and xylene (BTEX) contents were extracted and analyzed by gas chromatography with flame ionization detection. The highest 8-h average BTEX exposure among workers was the janitor at the TMB temple who was exposed to high levels of benzene (119.7 μg/m^3), ethylbenzene (19.9 μg/m^3) and o-xylene (19.0 μg/m^3). At the KW temple, the ambient position was found to have the highest average concentration of benzene, toluene, m,p-xylene and o-xylene at 31.1, 58.8, 59.2 and 2.94 μg/m^3, respectively. At TMB (but not KW), the 8-h average concentration of toluene, ethylbenzene, m,p-xylene and o-xylene on non-peak days (143.7, 24.5, 32.9, and 12.9 μg/m^3, respectively) were significantly (1.3- to 2.0-fold) higher than those on peak days (109.3, 12.0, 16.6, and 9.84 μg/m^3, respectively). The 95% confidence interval of lifetime cancer risks of the workers at the TMB temple were in range of 5.88×10^{-5} to 1.02×10^{-4}, which was 2.3-fold higher than those at the KW temple (2.08×10^{-5} to 3.6×10^{-5}), whilst the lifetime cancer risks of the workers at both temples were higher than the acceptable criteria (10^{-6}). Thus workers at both temples have unacceptable potential cancer risks from exposure to benzene and ethylbenzene. However, the hazard quotients (HQs) for the workers exposure to the non-carcinogenic compounds (toluene, m,p-xylene and o-xylene) at both temples were lower than 1 and so of no increased health risk (no concern) from these agents.

Keywords: Health risk assessment, BTEX, Incense smoke, Worship place

INTRODUCTION

Human exposure to the volatile organic compound (VOCs) of benzene, toluene, ethylbenzene and xylenes (BTEX) can occur by ingestion (e.g. drinking water contaminated with BTEX), inhalation (breathing contaminated air) and dermal absorption. Short term exposure of benzene, toluene and xylenes causes problems with the skin (sensory irritation), central nervous system (tiredness, headache and loss of control) and respiratory system [1]. BTEX can be found in many household products, such as resin, paint, detergent, ink and pesticides, as well as in incomplete combustion products of many complex organic compounds, and so people are exposed to it every day. The incense and mosquito coil burning can cause significant levels of BTEX exposure as well as cigarette smoking [2].

Incense is produced from many components including resin, spices, aromatic woods and barks, herbs, seeds, roots, flowers, essential oils, and synthetic substitute chemicals used in the perfume industry [3]. Incense burning is a long, slow and incomplete combustion process that produces a continuous smoke stream (visually important for its use) that is an important source of indoor pollution, including the emission of particulate matter (PM) of less than 10 or 2.5 mm diameter (PM_{10} and $PM_{2.5}$, respectively), carbon monoxide (CO) and VOCs including BTEX [4]. The PM and benzene levels emitted from the burning of all tested incense sticks

* *Correspondence to: Tassanee Prueksasit*
E-mail: tassanee.c@chula.ac.th

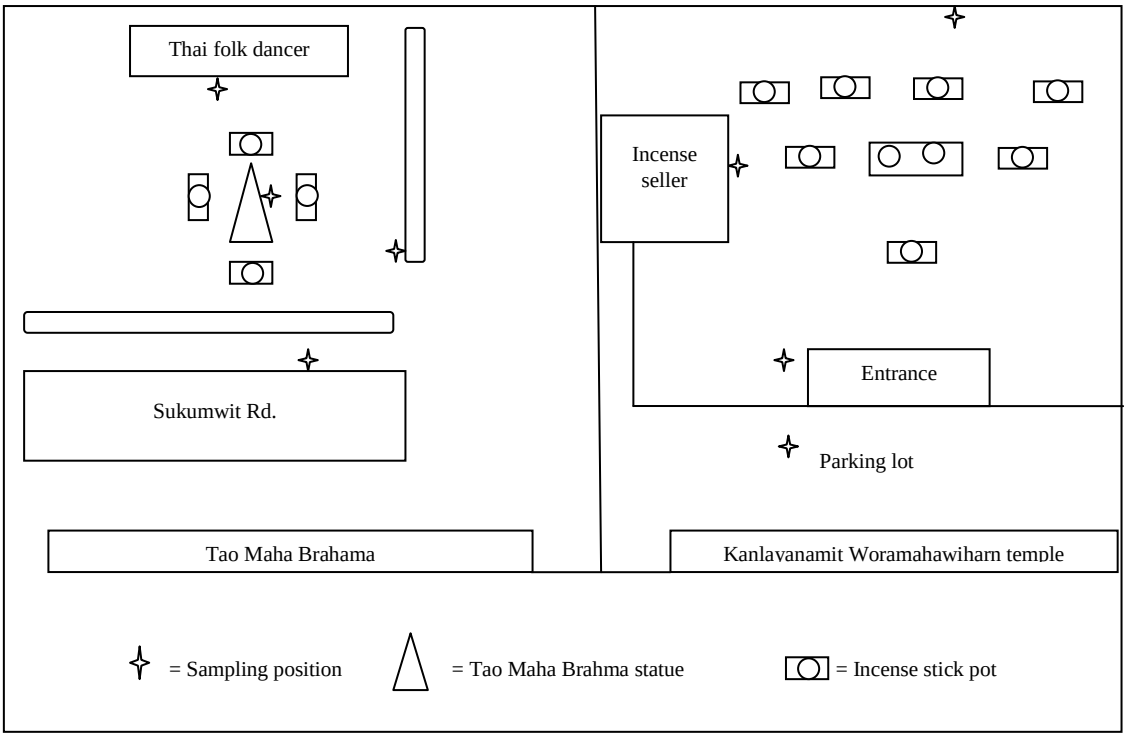


Figure 1 The sampling position at two worship places

significantly (eight-fold for benzene) exceeded the indoor air quality standard recommended in Hong Kong [4]. Similarly, the total BTEX concentration in incense smoke, as evaluated in an environmental chamber, derived from the burning of all grades was 1.61-fold higher than the smokeless incense at 11.4 and 7.1 mg/m^3, respectively [5]. Thus, people should be concerned about the health risk from exposure to incense smoke.

Exposure to BTEX can cause many health problems, such as respiratory irritation, central nervous system damage and cancer. The observation of and concern about cancer (leukemia and lymphoma) has increased in the past few decades in Thailand like in most other countries [6, 7]. In Bangkok (Thailand), people who work near BTEX sources, such as temples and other places of incense burning, tend to have a risk from exposure to BTEX contaminated incense smoke because a lot of people visit the worship place and burn incense every day. This study, therefore, attempted to investigate the ambient air concentration of BTEX, the essential baseline of inhalation exposure and the health risk information on specific groups of temple workers who are accordingly exposed to burning incense (and so BTEX) in their workplace. The distribution of BTEX in the working area of some occupations (a Thai folk dancer, incense and flower seller, janitor and security guard), at two popular worship plaves in Bangkok were investigated. The results of this study can then be applied for further studies and other occupations in other related workplaces.

MATERIAL AND METHODS

Air sampling site

The sampling was performed at two famous worship places, the Tao Maha Brahma shrine (TMB) next to the Erawan hotel, and the Kanlayanamit Woramahawiharn (KW) temple. The TMB is situated in the open air and is located at the intersection of two main roads (Ratchaprasong intersection, Ratchadamri and Sukhomwit Roads) in the Pathum Wan district, and so has a high car exhaust fume background. Three of the four sampling sites at this place were close to Thai folk dancers, guards and janitors, respectively, and the fourth is the ambient position. These are shown schematically in Figure 1.

The KW temple is located in a semi-open area aside the Chao Phaya River in the Thonburi district, Bangkok, and so has a much lower car exhaust background. Inside Kanlayanamit Woramahawiharn temple, there is a big statue of Buddha call “Laung Por To” which is very sacrosanctity for people a long time. The four sampling positions at this temple covered an incense seller, janitor, lottery seller and ambient position, and are shown schematically in Figure 1.

Sampling program

Sampling was performed using activated charcoal. A glass tube containing 400 and 200 mg of 20-40

mesh activated charcoal in the upper and lower portion, respectively, to physically absorb the BTEX, was connected to a personal air pump operated at 100 ml/min. These devices were placed one at each of four different sampling points per place (Figure 1) at 1.50 m above the ground. Sampling was performed for 8 h during work time (7 am to 3 pm) on four peak (Sunday) and four non-peak (Wednesday) days during April (dry season), and on four peak and four non-peak days, respectively, in July (rainy season) of 2012. The peak and non-peak days were supposed to represent the maximum and minimum number of visiting people within a week, and so the likely highest and lowest BTEX exposure levels, respectively, from incense burning. Due to limitation of amount of workers in this study area, only eight workers at each sampling site (Figure 1) were asked to collect their general information, including gender, body weight, age, health information, by face to face interview technique. Some necessary information for calculating the inhalation exposure of BTEX was also included. This information was gathered as the same group as the ongoing study by Nonthakanok [8] which was approved by the Ethical Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University, COA No. 104/2555 (on 3 July 2011).

Sample preparation and analysis

The charcoal tubes were closed with air-tight caps immediately after the 8-h continuous sampling period and were kept cold (< 4 ºC) until further analysis. To analyze the BTEX, the upper 400 mg of activated charcoal was removed separately from the lower 200 mg portion, with the upper portion used to represent the actual amount of BTEX whilst the lower portion was used for test for saturation, in terms of BTEX breakthrough. The internal standard of Toluene-d8 (100 and 50 µl for the upper and and lower portins, repectively) was spiked into each sample, and separate portions of carbon disulfide (CS_2) were sequentially added (2 and 1 ml for the upper and lower portions, respectively) and mixed to extract the BTEX samples. The respective CS_2 extracts were pooled, and the BTEX levels resolved and qualitatively and quantitatively analyzed by gas chromatography (GC; model HP 6890N, Algilent Technology), using a HP-5 capillary column (Agilent 19091J-413; 30 m x 0.32 mm x 0.25 µm) and a flame ionization detector (FID). The carrier gases were nitrogen, helium, hydrogen and air zero. The temperature profile was an initial temperature at 35 ºC increasing at 5 ºC/min to 120 ºC and then increasing at 20 ºC/min to 230 ºC and held at this temperature for 5 minutes. Splitless injection with the temperature at 300ºC and injection volume of 1µl was set. The temperature of FID at 300 ºC is the best condition for analysis of BTEX.

Qualitative and quantitative analysis of BTEX in the samples was determined by using the BTEX standard. The calibration curve consisted of seven concentrations of 125 - 8000 ng/ml with internal standard Toluene-d8 concentration of 8,115 ng/ml, and the coefficients of determination or R^2 values were ≥0.99. For the part of analysis by GC/FID, determination method of BTEX in this study was the same as the method studied by Kitwattanavong [8]. The GC/FID (Algilent Technology model HP 6890N), HP-5 capillary column, the BTEX standard, the method and the run control condition for BTEX was also the same as the previous study mentioned. The reference values of LOD and LOQ (unit of $\mu g/m^3$) were then used in this study, 0.05 and 0.17 for benzene, 0.57 and 1.88 for toluene, 0.47 and 1.55 for ethylbenzene, 0.08 and 0.26 for m,p-xylene, and 0.79 and 2.62 for o-xylene, respectively [9].

Health risk assessment

Risk assessment processes generally consist of the four steps of (i) hazard identification, (ii) exposure assessment, (iii) dose-response assessment and (iv) risk characterization. Each step in this study was applied according to RAGS volume I: Human Health Evaluation Manual parts A and F [10, 11]. Typically, the first step of risk assessment provides the information of the target organ and critical effects of the chemical. BTEX are classified as toxic compounds. Benzene and ethylbenzene are classified as carcinogenic substances, while toluene, m,p-xylene and o-xylene are classified as non-carcinogenic but hazardous to health substances. The second step is the dose-response assessment that qualifies the relationship between the adverse effects and the dose level. The inhalation cancer slope factor (CSF_i) of carcinogenic compounds for benzene and ethylbenzene were obtained from Risk Assessment Information System (RAIS) as 2.73×10^{-2} $mg/kg.day^{-1}$ and 3.85×10^{-3} $mg/kg.day^{-1}$, repectively [12]. The Inhalation Reference Concentration (RfC) of the non-carcinogenic compounds toluene and xylene was obtained from the Integrated Risk Information System (IRIS) as 5 and 0.1 mg/m^3, respectively [13, 14].

The mean exposure concentration of each contaminant for the exposed population variables were used to estimate the contaminant intake in the third step. The calculation of the chronic daily

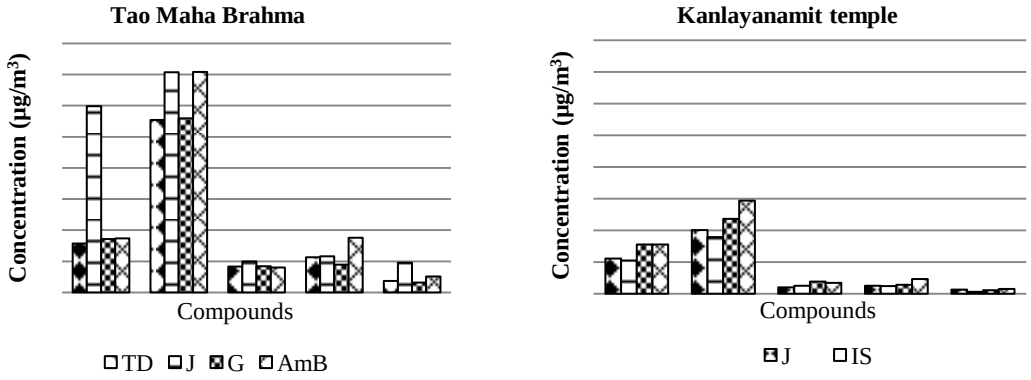


Figure 2 The 8-h average BTEX concentration measured at the four working sites at the Tao Maha Brahma (TMB) and Kanlayanamit Woramahawiharn (KW) temples. Sampling locations (see Figure 1) are represented as (TD) Thai dancers, (G) guards, (J) janitors, IS (incense seller), (LS) lottery seller and (AmB) ambient position. Means with a significantly different ($p < 0.05$).

intake (CDI) for carcinogenic substances and exposure concentration (ECs) for non-carcinogenic substance are shown in Eqs. (1) and (2), respectively [10]:

$$CDI = (CA \times IR \times ET \times EF \times ED)/ (BW \times AT) \quad (1)$$

$$EC = (CA \times ET \times EF \times ED)/AT \quad (2)$$

where CA is the chemical concentration (µg/m^3) and was calculated in this study, IR is the contract rate (0.875 m^3/hr) [10], BW is the body weight (kg), ET is the exposure time (8 h/day) [10], EF is the exposure frequency (350 days/year) [10], ED is the exposure duration (30 year) [10], and AT is the averaging time (25,500 days for CDI and 262,800 h for EC) [10]. The CDI of each chemical and the CSF_i, obtained from the environmental protection agency's IRIS database, were then used to determine the cancer risk level (Eq. (3)), where a cancer risk of more than 10^{-6} means a risk of carcinogenic effects that are of concern, and a value of equal to or less than 10^{-6} means the risk is in the generally acceptable level.

$$\text{Cancer risk} = CDI \times CSF_i \quad (3)$$

For the non-cancer risk, the hazard quotients (HQs) were calculated as shown in Eq. (4), where a HQ of more than 1 means an increasing health risk of concern, and less than 1 means no increasing health risk effect above generally acceptable levels.

$$HQ = EC/(RfC \times 1000\ \mu g/mg) \quad (4)$$

RSULTS AND DISCUSSION

Comparison of BTEX exposure levels among workers in the temple vicinity

The 8-h average concentration of BTEX measured at the four sites in the working area of each place is shown in Figure 2. The janitor at the TMB had the highest average exposure level to benzene (119.7 µg/m^3), ethylbenzene (19.9 µg/m^3) and o-xylene (19.0 µg/m^3), while there was a significant difference in the benzene exposure levels between these four sampling locations at the TMB ($p < 0.05$) using compare mean one way ANOVA, SPSS 17.0 for Window. For toluene and m,p-xylene, the janitor at the TMB was also exposed to high concentrations (141.5 and 23.2 µg/m^3, respectively), but not as high as the ambient (AmB) concentration (141.7 and 35.2 µg/m^3, respectively).

With respect to the KW temple, the ambient position had the highest average concentration of benzene, toluene, m,p-xylene and o-xylene at 31.1, 58.8, 59.2 and 2.94 µg/m^3, respectively, but there was no significant difference between the BTEX concentrations among the four different sampling sites at the KW temple. The difference in the benzene concentration exposed to the janitors at the two places from might arise from the different configuration of the sampling position (Figure 1) as we could not install sampling equipment at the center of the KW temple. Moreover, the average number of visitors (and so potentially burning incense sticks) during the observation periods at the TMB (approximately 4,250 people, unofficial report from Tao Maha Brahma foundation) was 4.7-fold higher than that at the KW temple (905 people), while the background BTEX concentration at the center of Bangkok next to a the intersection of two main roads (and so higher car exhaust levels) might contribute to the higher BTEX level at the TMB as well.

Comparison of the BTEX concentrations between the peak and non-peak days

The 8-h average BTEX concentrations on the peak

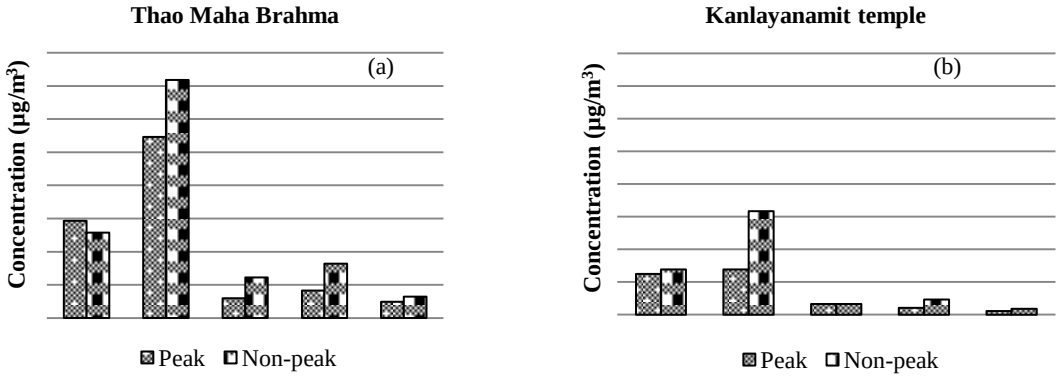


Figure 3 The 8-h average BTEX concentrations on the peak and non-peak days at the (**a**) Tao Maha Brahma (TMB) and (**b**) Kanlayanamit Woramahawiharn (KW) temples. Means with a significantly different ($p < 0.05$).

and non-peak days are shown in Figure 3. At the TMB, counter to expectations, the 8-h average concentration of toluene, ethylbenzene, m,p-xylene and o-xylene on the non-peak days were actually 1.31-, 2.04-, 1.98- and 1.31-fold higher, respectively, than those on the peak days, but only that for toluene, ethylbenzene and m,p-xylene were statistically significantly different using compare mean Paired-sample T test, SPSS 17.0 for Window (for compare the mean different between two sample groups). Thus, only benzene was slightly (1.14-fold) but not significantly higher on the peak days than the non-peak days. Similarly, the 8-h average concentration of benzene, toluene, m,p-xylene and o-xylene on the non-peak days at the KW temple were 1.11-, 2.28-, 2.20- and 1.61-fold higher, respectively, than those on the peak days, although this difference was only significant for toluene. The higher average BTEX concentrations on the non-peak days at the TMB might be due to the heavy traffic on those days (Wednesday), and that this open worship place is located in the center of Bangkok and so easily influenced by nearby activities, such as BTEX emissions from vehicles. Truc and Onah [15] also found BTEX concentrations at the peak-hour in roadside traffic in Vietnam on a weekday (110 µg/m^3) were some 2.34-fold higher than at a weekend (47 µg/m^3). With respect to the KW temple, the different BTEX concentrations might be caused by the different behaviors of the janitor, since the incense sticks were left to burn out on the non-peak days but removed every hour on peak days.

Comparing the 8-h average BTEX concentrations of the peak and non-peak days of this study with the result of two temples in Hong Kong [16] revealed that the average benzene concentration on the peak day at the TMB (58 µg/m^3) was 1.5-fold lower than at the corresponding indoor temple in a semi-urban area in Hong Kong (85.8 µg/m^3), whilst the average peak day benzene concentration at the KW temple (24 µg/m^3) was 6-fold lower than the semi-open area but larger temple in Hong Kong. However, the average toluene concentrations in the TMB and KW temples (109.3 and 27.8 µg/m^3) were 1.26- and 5.1-fold higher than those in the two temples in Hong Kong (87 and 5.46 µg/m^3).

With respect to the seasonal variation in the BTEX concentrations at the TMB and KW temples, no significant difference between the dry and rainy seasons were observed (analysis not shown). Therefore, seasonal variation was not a significant factor in determining the BTEX concentration at these two sites.

The average 8-h concentration of total BTEX components was significant higher at the TMB than at the KW temple ($p < 0.05$). This could be explained by the temple location (exposed or covered, and nearby activities), the sampling area configuration and the number of visitors. Certainly the number of visitors to the TMB was much higher (4.7-fold) than to the KW temple resulting in larger amount of incense burning. In addition, as already mentioned, the TMB is located at the intersection of two main roads (Ratchaprasong and Sukhomwit Roads) where there is always traffic congestion and so the BTEX emission from vehicles is likely to be a considerable additional source of BTEX.

Benzene and toluene concentration ratio (B:T)

The main BTEX components found (from incense burning) in the two temples in this study were benzene and toluene. The proportion of benzene to toluene (B: T ratio) was calculated for each of the sampling points at these two worship places and then compared in Table 1 between each other as well as with the data obtained by another study at two temples in Hong Kong [16] and from the direct

Table 1 Comparison of benzene and toluene ratio (B:T) of workers of the worship places with other studies

Sampling/Location	City/Country	B : T
Tao Maha Brahma	TD	0.03-0.52
	J	0.53-1.15
	G	0.009-0.72
	AmB	0.16-0.46
Kanlayanamit Woramahawiharn temple	J	0.03-1.12
	IS	0.003-1.38
	LS	0.06-1.43
	AmB	0.02-1.3
Temple	Hong Kong [16]	0.03-1.67
Environmental chamber	Thailand [5]	3.07-5.58
	Hong Kong [4]	0.77-5.64

AmB = ambient background, G = guard, IS = incense seller, J = janitor, LS = lottery ticket seller and TD = Thai dancer.

Table 2 Chronic daily intake (CDI) and lifetime cancer risk (LCR) of workers' exposure to BTEX at the Tao Maha Brahma (TMB) and Kanlayanamit Woramahawiharn (KW) temples in Bangkok, Thailand (n = 24).

Carcinogenic compound	TMB		KW temple	
	CDI (μg/kg.day)	95% CI of LCR ($\times 10^{-6}$)	CDI (μg/kg.day)	95% CI of LCR ($\times 10^{-6}$)
Benzene	0.138 – 7.38	51 - 106	0.0477 – 2.76	21.8 – 43.2
Ethylbenzene	0.214 – 4.86	2.24 – 7.43	0.0657 – 0.899	0.574 – 1.12
Total	0.352 – 12.2	58.8 - 102	0.113 – 3.66	20.8 - 36

Table 3 Exposure concentration (EC) and hazard quotients (HQ) for non-cancer risk of workers exposure from BTEX at the Tao Maha Brahma (TMB) and Kanlayanamit Woramahawiharn (KW) temples in Bangkok, Thailand (n = 24)

Non-carcinogenic compound	TMB		KW temple	
	EC ($\mu g/m^3$)	95% CI of HQ	EC ($\mu g/m^3$)	95% CI of HQ
Toluene	20.0 - 82.1	0.0071 - 0.011	9.00 - 32.9	0.0031 - 0.0049
m,p-Xylene	2.14 - 15.7	0.08 - 0.13	1.09 - 5.92	0.021 - 0.035
o-Xylene	1.54 - 9.55	0.031 - 0.054	0.65 - 4.29	0.011 - 0.021
Total	23.6 -107.3	0.095 -0.14	10.7 - 43.1	0.02 - 0.04

burning of Thai or Hong Kong incense in an environmental chamber [4, 5]. The B: T ratios for the four sampling positions at the TMB were not in the same range, particularly for the working area of the janitor (sampling position close to the incense stick pot) that had a much higher B: T ratio range (0.53-1.15). In contrast, for all B: T ratios at the KW temple were in the same broad range of about 0.03-1.31, although this covered the highest range found at the TMB. The major source of BTEX dispersion at the TMB (janitor's position) and all four positions at the KW temple was likely to be from incense burning and not influenced by other sources, whereas the other three positions at the TMB were likely to have been influenced by road traffic BTEX emissions that result in the lower B: T ratios. The B: T ratios obtained from all four locations at the KW temple and the site of the janitor at the TMB were similar to the range of B: T ratios found at the temples in Hong Kong (0.03-1.67) (Table 1). However, the B: T ratios rise up to 5.58 and 5.64 for Thai and Hong Kong incense, respectively, when burnt in environmental chambers, which in part supports that the high B: T ratios found (over 1.0) in this study are due to incense burning and are shifted to lower ratios without a decrease in the net BTEX concentration by high background levels (such as car exhaust fumes).

Health risk assessment

The risk levels of workers at the TMB and KW temples from exposure to the carcinogenic (benzene and ethylbenzene) and non-carcinogenic (toluene, m,p-xylene and o-xylene) BTEX components are summarized in Tables 2 and 3, respectively. The CDI levels of the workers at the TMB for benzene, ethylbenzene and both combined were 2.67- to 2.89-fold, 3.26- to 5.40-fold and 3.11- to 3.33-fold higher, respectively, than those at the KW temple (Table 2).

Correspondingly, the 95% CI of lifetime cancer risks (LCR) of the workers at the TMB from

benzene, ethylbenzene and both were some 2.34- to 2.45-fold, 4.18- to 6.19-fold and 2.82- to 2.83-fold higher, respectively, than those at the KW temple. Regardless, the LCR for the workers at both temples were higher than the acceptable criteria of 10^{-6} (The level of a safety hazard which is considered to present the cancer risk for the people exposure to benzene and ethylbenzene at the probability of one in a million) [10], and were in the same range as those previously reported for gas station workers in Thailand (1.47×10^{-6} to 4.99×10^{-4}) [9], landfill workers in Turkey (9.53×10^{-6} to 3.73×10^{-4}) [17] and a smoker's home in Hong Kong($1.41x10^{-6}$to$8.35x10^{-5}$) [18].

Likewise, the exposure concentration of the workers at the TMB to the non-carcinogenic components of toluene, m,p-xylene and o-xylene, plus the total of all three components, were also significantly higher than those at the KW temple by 2.21- to 2.49-fold, 1.96- to 2.66-fold, 2.23- to 2.64-fold and 2.20- to 2.49-fold, respectively (Table 3). However, all the 95% CIs of the HQs of the workers exposed to these non-carcinogenic compounds at both temples were not more than 1, and so, in contrast to the carcinogenic components of BTEX, the non-carcinogenic components offered no increased health risk concern above generally acceptable levels.

According to the guideline method used for calculating LCR was recommended by USEPA, some factors, i.e. inhalation rate, would be represented by the people in US. This factor might not be appropriate to Thailand worker regarding different weather condition, and then this factor is considerable to cause the uncertainty of this study. Moreover, the BTEX concentration only obtained from two worship places and did not represent for all workers in the worship places in Bangkok. Particularly, TMB has some specific condition that is located near the road and traffic junction. Therefore, the BTEX concentration measured in this area might come from the exhaust gas as additional source not only from incense smoke resulting in the overestimated LCR. However, this study result would be an important baseline data of the worker exposed to BTEX in Bangkok, Thailand.

CONCLUSION

From the proximity of their work place to the site of incense burning, it was found that the janitor at the TMB was exposed to higher BTEX levels than the other workers at different locations (further away from incense burning) at that temple, and some six-fold higher benzene levels than the janitor at the KW temple. In contrast, at the KW temple the lottery seller was exposed to similar BTEX levels as the ambient background concentration, which is the highest BTEX concentration at the KW temple. With respect to peak and non-peak days, only the level of benzene on peak days at the TMB was higher than that on the non-peak day, whilst all BTEX concentrations on the non-peak days at the KW temple were higher than on the peak days. There was no significant variation in the BTEX concentration between the dry and wet seasons at both places and so seasonal variation may not be a key factor in BTEX exposure levels at these sites. Estimation of the LCR at these two worship places exceeded the acceptable risk of 10^{-6} in all tested locations, whilst for the non-cancer risk the HQs at all positions tested (workers' locations) were lower than 1 and so of no increased health risk. Regarding to breathing high concentration of BTEX can cause some critical effects, including leukemia (for benzene) and may effect for kidney damage (for toluene and ethylbenzene) and problem with the lung (for xylene) [8]. The workers in such areas should have warning information of health effects, and should be recommended to wear personal protection equipment such as standard respirator mask and glove to avoid exposure of BTEX and some chemicals from breathing incense smoke.

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