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

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การประเมินความเสี่ยงจากการรับสัมผัสสารระเหยบีเทคในควันธูปของผู้ปฏิบัติงาน
ในสถานประกอบพิธีกรรมในกรุงเทพมหานคร

นายวีร์ มาสภัสร์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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วีร์ มาสภัสร์ : การประเมินความเสี่ยงจากการรับสัมผัสสารระเหยบีเทคในควันธูปของผู้ปฏิบัติงานในสถานประกอบพิธีกรรมในกรุงเทพมหานคร (HEALTH RISK ASSESSMENT OF WORKERS EXPOSURE TO BTEX FROM INCENSE SMOKE AT WORSHIP PLACES IN BANGKOK) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : อ.ดร. ทรรศนีย์ พฤกษาสิทธิ์, 112 หน้า.

งานวิจัยนี้มีจุดประสงค์เพื่อหาความเข้มข้นของสารประกอบบีเทคและประเมินความเสี่ยงต่อสุภาพของผู้ปฏิบัติงานในสถานประกอบพิธีกรรม ทำการเก็บตัวอย่างที่ศาลท้าวมหาพรหมและวัดกัลญาณมิตรวรมหาวิหาร โดยเก็บ 2 วันในหนึ่งสัปดาห์คือ วันหยุด (วันอาทิตย์) และวันทำงาน (วันพุธ) ในเดือนเมษายน (ฤดูแล้งฝน) กรกฎาคม (ฤดูฝน) และพฤศจิกายนถึงธันวาคม (ฤดูหนาว) พ.ศ. 2555 เก็บตัวอย่างสารประกอบบีเทคเป็นเวลา 8 ชั่วโมงทำงานโดยใช้ Charcoal glass tube ต่อเข้าเครื่องดูดอากาศที่อัตราการไหล 100 มิลลิลิตรต่อนาที ติดตั้งอุปกรณ์ไว้ในบริเวณสถานประกอบพิธีกรรม จำนวน 4 จุดที่ระดับความสูงประมาณ 1.5 เมตรเหนือพื้นดิน นำตัวอย่างสารประกอบบีเทคมาสกัดและวิเคราะห์ด้วยเครื่อง GC/FID ผลการศึกษาพบว่า ตำแหน่งบริเวณใกล้กระถางธูปที่ศาลเท้ามหาพรหมพบความเข้มข้นฉลี่ยของสารเบนซีนและโอไซลีนสูงที่สุดมีค่าเท่ากับ 107.14 และ 16.59 ไมโครกรัมต่อลูกบาศก์เมตร ตามลำดับ ที่วัดกัลญาณมิตรตำแหน่งบริเวณทางเข้าของวัดมีความเข้มข้นเฉลี่ยของเบนซีน โทลูอีน และเอ็ม-พีไซลีนสูงที่สุด เท่ากับ 36.23 46.67 และ 8.48 ไมโครกรัมต่อลูกบาศก์เมตร ตามลำดับ ความเข้มข้นเฉลี่ยของสารโทลูอีน เอธิลเบนซีน เอ็ม-พีไซลีน และโอไซลีนที่พบที่ศาลเท้ามหาพรหมในวันพุธ มีค่าสูงกว่าวันอาทิตย์คิดเป็นจำนวน 1.32 1.96 1.76 และ 1.15 เท่า ตามลำดับ เช่นเดียวกับที่วัดกัลญาณมิตรที่พบความเข้มข้นเฉลี่ยของเบนซีน โทลูอีน และเอ็ม-พีไซลีนในวันพุธสูงกว่าวันอาทิตย์คิดเป็นจำนวน 1.15 1.84 และ 1.37 เท่า ตามลำดับ ที่ศาลท้าวมหาพรหมพบโทลูอีนมีความเข้มข้นสูงที่สุดที่ 105.77 ไมโครกรัมต่อลูกบาศก์เมตร รองลงมาคือเบนซีน (57.28 ไมโครกรัมต่อลูกบาศก์เมตร) และ ที่วัดกัลญาณมิตรพบปริมาณโทลูอีนสูงสุดเช่นกัน (39.12 ไมโครกรัมต่อลูกบาศก์เมตร) แต่ต่ำกว่าที่ศาลท้าวมหาพรหมประมาณ 2.7 เท่า จากผลการประเมินความเสี่ยงพบว่าค่า lifetime cancer risk จากการรับสัมผัสสารเบนซีนที่ตำแหน่งของภารโรงที่ศาลท้าวมหาพรหมมีค่าสูงที่สุดและอยู่ในช่วง 3.07×10^{-6} - 103×10^{-6} ซึ่งมากกว่าตำแหน่งของพนักงานรักษาความปลอดภัยและนางรำ 4.41 และ 1.7 เท่า ตามลำดับ สำหรับที่วัดกัลญาณมิตรพบว่า ผู้ขายของบริเวณร้านขายธูปมีค่า lifetime cancer risk จากการรับสัมผัสสารเบนซีนสูงที่สุด (0.85×10^{-6} -5.71×10^{-6}) ซึ่งสูงกว่าตำแหน่งของภารโรงและผู้ขายสลากกินแบ่งเป็นจำนวน 4.32 และ 1.65 เท่า ตามลำดับ เมื่อพิจารณาค่า CDI และ 95% CI ของ LCR พบว่า ที่ศาลท้าวมหาพรหมมีค่าสูงกว่าที่วัดกัลญาณมิตร 2.25 และ 2.21 เท่า ตามลำดับ ค่าความน่าจะเป็นของผู้ปฏิบัติงานที่มีความเสี่ยงจากการรับสัมผัสสารเบนซีนและเอธิลเบนซีนเกินกว่าค่าที่ยอมรับได้ (1×10^{-6}) ที่ศาลท้าวมหาพรหม คิดเป็นร้อยละ 100 (3.79×10^{-6}-3.45×10^{-4}) และร้อยละ 84 (2.91×10^{-7}-1.87×10^{-5}) ตามลำดับ และที่วัดกัลญาณมิตร คิดเป็นร้อยละ100 (1.72×10^{-6}-8.99×10^{-5}) และร้อยละ 42 (3.29×10^{-7}-5.71×10^{-6}) ตามลำดับ สำหรับค่าความเสี่ยงของสารที่ไม่ก่อมะเร็ง พบว่า ค่า 95 % CI ของ HQ ของผู้ปฏิบัติงานทั้งหมดมีค่าอยู่ในเกณฑ์ที่ยอมรับได้ (HQ < 1) ชี้ให้เห็นว่า ไม่พบโอกาสเพิ่มความเสี่ยงต่อการเกิดโรคอื่นๆ

สาขาวิชา : การจัดการสิ่งแวดล้อม ลายมือชื่อนิสิต ....

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VEE MASPAT : HEALTH RISK ASSESSMENT OF WORKERS EXPOSURE TO BTEX FROM INCENSE SMOKE AT WORSHIP PLACES IN BANGKOK. ADVISOR : TASSANEE PRUEKSASIT. Ph.D., 112 pp.

This study aimed to determine BTEX (benzene, toluene, ethylbenzene, and xylene) concentration, to evaluate the potential health risk and estimate wokers health risk for the workers at worship places. The sampling was performed on weekend (Sunday) and non peak (Wednesday) days in April (dry season), July (wet season) and December (cold season) 2012 at Tao Maha Bhrama (TMB) shrine 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 places, the sampling equipments were set at four different sampling points covering a worship area at 1.50 m height above the ground. The BTEX samples were extracted and analyzed by gas chromatography with flame ionization detector. The highest 8-h average BTEX concentration was found at the point close to incense stick pot at the TMB with the value of benzene (107.14 µg/m^3) and o-xylene (16.59 µg/m^3). At the KW temple, the ambient sample near the entrance was found to have the highest average concentration of benzene, toluene, and m,p-xylene at 36.23, 46.67 and 8.48 µg/m^3, respectively. At the TMB, the 8-h average concentration of toluene, ethylbenzene, m,p-xylene, and o-xylene on the non-peak days were 1.32-, 1.96-, 1.76-, and 1.15-fold higher, respectively, than those on the peak days. Similarly all of the 8-h average concentration of benzene, toluene, and m,p-xylene on the non-peak days at the KW temple were 1.15-, 1.84-, and 1.37-fold higher than those on the peak days. At TMB, toluene was found the highest concentration as 105.77 µg/m^3 follow by benzene (57.28 µg/m^3). For KW temple, toluene was also found the highest concentration as 39.12 µg/m^3 but lower than the highest exposed of toluene at TMB (2.70-fold). For benzene, the janitor at TMB had the highest lifetime cancer risk (3.07×10^{-6}-103×10^{-6}) of all workers from both places which 4.41 and 1.7-fold higher than guard and Thai folk dancer, respectively. The highest lifetime cancer risk at KW temple was found for the incense seller (0.85×10^{-6}-5.71×10^{-6}) which 4.32- and 1.65-fold higher than janitor and lottery seller. The total chronic daily intake and 95% confidental interval of lifetime cancer risk of the worker at TMB was 2.25- and 2.21- fold higher than that of KW temple. The probability of the workers exposed to benzene and ethylbenzene at the risk (95% CI of LCR) higher than acceptable criteria of 10^{-6} was found at 100 % (3.79×10^{-6}-3.45×10^{-4}) and 83.82 % (2.91×10^{-7}-1.87×10^{-5}), for TMB, and 100% (1.72×10^{-6}-8.99×10^{-5}) and 42% (3.29×10^{-7}-5.71×10^{-6}), for KW temple. For non-carcinogenic substances, all the 95% CIs of the HQs of the workers was no more than 1 and indicated that no increased health risk concern above generally acceptable levels.

Field of Study : Environmental Management Student's Signature ....

Academic Year : 2012 Advisor's Signature ....

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LIST OF ABREVIATIONS

ACGIH	The American Conference of Government Industrial Hygienists
ADD	Average daily dose
AmB	Ambient
AT	averaging time
ATSDR	The agency for Toxic Substances and Disease Registry
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
BW	Body Weight
CA	Contamination in air
CDI	Chronic daily intake
CR	Contract rate
CSF_i	Inhalation cancer slope factor
EC	Exposure concentration
ED	Exposure duration
EF	Exposure frequency
ERTC	Environmental Research and Training Centre
ET	Exposure time
G	guard
GC/FID	Gas chromatography with F lame Ionization Detector
HI	Hazard index
HKIAQO	Hong Kong Indoor Air Quality Objectives for Office Buildings and Public Places
HQ	Hazard quotient
I	Intake
IR	Inhalation rate

IRIS	Integrated Risk Information System
IS	The Incense seller
J	The janitor
KW	The Kanlayanamit Woramahawiharn
KWL	Large size of incense from KW temple
KWM	medium size of incense from KW temple
KWS	Small size of incense from KW temple
LCR	The lifetime cancer risk
LOD	The limit of detection
LOQ	The limit of quantification
LS	The Lottery seller
n	The number of samples
NiOSH	The National Institute for Occupational Safety and Health
OSHA	The Occupational Health and Safty Administration
PCD	The Pollution Control Department
R^2	A symbol for the coefficient of determination of a linear regression
RAGS	The original Risk Assessment Guidance for Supeerfund
RAIS	The Risk Assessment Information System
R_fC	Reference concentration
RSD	Relative standard deviation
SD	Standard deviation
TD	Thai folk dancer
TMB	Tao Maha Brahma shrine
TOSC	Technical Outreach Services for Communities

US EPA	The United State Environmental Protection Agency
USA	The United States of America
VOCs	Volatile organic compounds
WHO	World Health Organization

CHAPTER I

INTRODUCTION

1.1 Rationale background and problem addressed

BTEX is the abbreviation of four compounds; benzene, toluene, ethylbenzene and xylenes and classified in a group of volatile organic compound (VOCs). Human can expose to BTEX by ingestion (i.e. drinking water contaminated BTEX), inhalation (i.e. breathing contaminated air from gasoline) and dermal absorption (i.e. oil spill to the skin). Short term exposure of benzene, toluene and xylenes has an effect with skin and sensory irritation, central nervous system problem (tiredness, headache, and loss control) and respiratory system. BTEX can be found in many household products such as resin, paint, detergent, ink, and pesticide, and people use it every day. The result of Lofroth *et al.* (1991) suggested that incense and mosquito coil burning can cause BTEX exposure as well as cigarette smoking.

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 (Jetter *et al*., 2001). The process of incense burning is a long, slow and incomplete combustion. From the reproduction of a continuous smoke stream, there was an important source of indoor pollution and the emission of PM_{10} and $PM_{2.5}$, carbon monoxide (CO) and volatile organic compounds (VOC) (Lee and Wang, 2004). Lee and Wang (2004) confirmed the result also of environmental test chamber that burning incense is an important source for BTEX. The result showed that the particulate matters emitted from all incenses significantly exceed the standard. For benzene, the concentration was 8 times higher than the indoor air quality standard recommended in Hong Kong. Similarly, there was the study in Thailand by Tawanwong and Lorjitsieng (2010), which was the study of BTEX from incense burning in environmental chamber. The total BTEX concentration in smoked incense of all prize grades was higher than the smokeless incense, with the value of 11.407 and 7.059 mg/m^3, respectively. From these evidences, people should have concern about their health risk from exposure to incense smoke.

The exposure of BTEX can cause many health problems such as respiratory irritation, central nervous system damage and cancer. The observation and concern about the cancer (i.e. leukemia and lymphoma) has increased in the past few decades in Thailand and some countries (Navasumrit *et al*., 2008 and Yeung *et al.*, 2003). In Bangkok, Thailand, the workers who work near the BTEX source (i.e. temple and other worship places) tend to have risk from exposure to BTEX contaminated in incense smoke because there is a lot of people visit to the famous worship places and burn incense every day. This study, therefore, attempts to investigate the ambient air concentration of BTEX, the essential baseline of inhalation exposure and the health risk information on specific groups among the workers in worship places exposed to BTEX in their workplaces. The distribution of BTEX in the workign area of some occupations such as Thai folk dancer, incense and flower seller, janitor and security guard in worship places were investigated in this study. This study would get the results of the ambient air concentration of BTEX, the essential baseline of inhalation and the risk information of workers in the worship places which can be applied for further studies and other occupations in other workplaces in Bangkok.

1.2 Objectives

This research aimed to study the exposure of BTEX and health risk assessment of the workers at worship places in Bangkok, Thailand. The specific objectives are as follows:

1) To determine ambient air concentration of BTEX in the worship places in Bangkok.
2) To evaluate potential occupational exposure to BTEX of the workers in worship places via inhalation pathway.
3) To estimate their health risk in their work places.

1.3 Hypotheses

1) The workers at worship places in Bangkok tend to have risks from exposure to BTEX in their workplace through inhalation.
2) The incense smoke tends to be an additional source of BTEX in worship places in the urban area.

1.4 Scope of the study

1.4.1. Study area

The sampling was held at two famous worship places, i.e. Tao Maha Brahma (TMB), next to Erawan hotel, and Kanlayanamit Woramahawiharn temple (KW). Tao Maha Brahma is an open air area where located on Ratchaprasong intersection, Ratchadamri Road, Pathum Wan district, Bangkok. There are four sampling positions of workers of TMB such as Thai folk dancers (TD), guard (G), janitors (J), and ambient position (AmB). Kanlayanamit Woramahawiharn temple is semi-open area where located at the Chao Phaya riverside, Thonburi district, Bangkok. Inside Kanlayanamit Woramahawiharn temple, there is a big statue of Buddha call “Laung Por To” which is very sacrosanctity to people for a long time. There are four sampling location. of workers of KW such as incense seller (IS), janitor (J), lottery seller (LS), and ambient position (AmB).

1.4.2 Sampling program

The sampling was performed on weekend (Sunday) and weekday (Wednesday) days during April (dry season), July (wet season) and December (cold season) 2012. These two days were supposed to represent the maximum and minimum of visiting people within a week. The workers at the position of sampling were interviewed to collect their general information including gender, body weight, age, health information and some information that used for calculating the inhalation exposure of BTEX.

1.4.3 Sampling technique for personal exposure

The sampling device in this study was a charcoal glass tubes connected to a personal air pump, and placed at 4 sampling points covering all area of worship place workers at 1.50 meter height above the ground. Each sampling will be performed for 8 hours (7.00am -3.00pm) during a working time.

1.4.4 Chamber test

The air samples of incense smoke were directly collected by active sampling from closed chamber at laboratory, and the ashes and incense weight were recorded. The incense samples from two study places were used to sampling in the chamber in order to confirm whether the BTEX profile obtained from the air sampling at the temples was similar to that of incense.

1.4.5 Analytical techniques

The activated chacoal were extracted by carbon disulfide as a extracting solvent, and analyzed by GC/FID.

1.5 Expected outcomes

1) The investigation of ambient air concentration of BTEX in the worship places in Bangkok.

2) The essential baseline of inhalation exposure to BTEX in the worship places in Bangkok.

3) The health risk information of the workers in the worship place which can help to prevent or reduce the risk from inhalation exposure to BTEX of the workers.

4) The background knowledge which can be applied for further studied and other occupation in other workplaces in Bangkok

CHAPTER II
LITERATURE REVIEWS

2.1 BTEX

BTEX is the abbreviation of four compounds; benzene, toluene, ethylbenzene and xylene. BTEX is classified as volatile organic compound and aromatic hydrocarbon group that have health effects to human and air pollution. Benzene and ethylbenzene are classified as carcinogenic compound (TOSC, 2003). The physical and chemical properties of BTEX as shown in Table 2.1.

Table 2.1 The physical and chemical properties of BTEX

Compound	Formula	Molecule weight (g/mole)	Solubility (mg/l)	Vapor Pressure (mm.Hg)	Henry's coefficient (m^3atm/mol)	Melting point (ºC)	Boiling point (ºC)
Benzene	C_6H_6	78.11	$1.75x10^3$	80.85	$4.84x10^{-3}$	5.5	80.1
Toluene	$C_6H_5CH_3$	92.14	535	21.86	$5.72x10^{-3}$	-93	110.6
Ethyl Benzene	$C_6H_5C_2H_5$	106.18	152	7.08	$7.04x10^{-3}$	-95	136
Xylene	$C_6H_4(CH_3)_2$	106.18	198	4.89	$6.38x10^{-3}$	-25	144

Source: Verchueren (1996); cited in Pimla Ratchadawannapong (2011)

2.1.1 Benzene

The characteristic of benzene is a colorless liquid compound with tang smell. It is easy to volatile in the air and flammable (PCD, 2002). Benzene is low solubility in water, and can be found in environment. In atmospheric condition, benzene can be chemically degraded in a few days. It is a component of petroleum and also used for making plastics, resin, rubbers, lubricants, dyes, detergents, drug, and pesticides. Many occupations may expose to benzene in industries that make benzene such as petrochemical, petroleum, refining, coke and coal chemical manufacturing (ATSDR, 1998).

50% of benzene in the air is rapidly absorbed into human lung and accumulate in fatty issues. Breathing a high exposure level of benzene can cause of death. Short-term with high concentration can effect central nervous system, cause paralysis, coma, convulsion, dizziness, rapid heart rate, tightness of the chest, tremors, and rapid breathing (National Institute of Health,US). Benzene is known as carcinogenic for human and associated to leukemia and the World Health Organization (WHO) has evaluated that a life time exposure of 1 $\mu g/m^3$ of benzene leads to about six cases of leukemia per million inhabitants and the life time risk of chronic leukemia is 4.4-$7.6x10^{-6}$ (WHO,2000).

2.1.2 Toluene

The characteristic of toluene is a by-product of coal and petrochemical industries and occurs naturally in crude oil. Toluene is a colorless liquid with a pungent odor, flammable and classified as moderately hazardous substance by United Nation. Toluene is used as solvent for aviation gasoline, spray, wall paint, dyes, explosive, detergent, component of gasoline to increase octane rating (PCD, 1998). Toluene is also in a production of benzene in a huge industry.

Breathing a high exposure level of toluene can cause unconscious or death and may effect to other organ such as kidneys, nervous system, brain, liver and heart. Long-term exposure can cause permanent brain damage or depression. Short-term with medium exposure can cause confusion, dizziness, headache, fatigue, weakness, memory loss, nausea, appetite loss, coughing, wheezing, and color vision loss (ATSDR, 1993).

2.1.3 Ethylbenzene

The characteristic of ethylbenzene is a colorless, flammable liquid with a pungent odor. Ethylbenzene is commonly used as a gasoline, aviation fuel additive, and consumer products such as paint, inks, plastic, pesticides and naturally occur in coal tar and petroleum (Ohio Department of Health, 2009). Ethylbenzene can be found in consumer products such as gasoline, paint, vanish, ink, pesticide, carpet glue, automotive product, and tobacco product.

Breathing a high exposure level of ethylbenzene can cause eyes and throat irritation, vertigo, and dizziness. In animal studies, ethylbenzene can affect auditory system, eyes and skin irritation from direct contract, oral exposure can be hepatotoxic (ATSDR, 2010).

2.1.4 Xylene

The characteristic of toluene is aromatic hydrocarbon and consist of o-xylene 30%, m-xylene 60-70% and p-xylene 5%. It is a colorless flammable liquid that cannot dissolve in water at 20 ºC but can dissolve in ethyl alcohol and ethyl ether. Xylenes can be found naturally in petroleum, used as industrial solvent, solvent in household product such as paint, coating, adhesive remover, paint thinner, and it is also used as mixture in gasoline (PCD, 1998,).

More than 50 % of xylene exposure absorb through human lung and lower than 50% inhalation exposure through the gastrointestinal tract. Dermal exposure can cause irritation, dryness and scaling of the skin, and vasodilatation. Breathing a xylene vapor can cause nose, eyes, throat irritating. In animal, high exposure of xylene can cause a development effect (ATRDR, 2007).

2.2 Emission sources of BTEX

Many people exposed to BTEX in much amount from the ambient (outdoor) air, workplace and home. The main sources of BTEX are emission of vehicle exhaust, fuel evaporative losses, industrial emission, petroleum refining, storage coating and using of solvent. The materials in incense that released BTEX when incense burning such as resin-glue (release benzene) and resin (release toluene) (Bureau of Environmental Health, 2009).

2.2.1 Vehicle exhaust source

The pollutants such as nitrogen oxides (NO_X), volatile organic compound (VOC), carbon monoxide (CO), carbon dioxide (CO_2), particulates, and sulphur dioxide (SO_2) emit from the vehicle exhaust. The factors of BTEX emission are engine usability, type of fuel and temperature of combustion. From Chang and Chen (2008) study, the concentration of main toxic VOC found from motorcycle exhaust is shown in Table 2.2. The result showed that BTEX were the main toxic compounds in motorcycle exhaust with concentration of 90.1, 76.8, 65.3, 56.0, 13.7 and 12.5 ppm,for benzene, toluene, ethylbenzene, p-Xylene, m-Xylene, and o-Xylene, respectively.The study in Taiwan (Wu *et. al* 2007), the commercial fuel 95-LFG was used to test the concentration of BTEX in vehicle exhaust and the effect of gasoline additive on BTEX emission. Gasoline additives were used for improving vehicle performance or solving specific problems. From Figure 2.1, the results showed that some gasoline additive had emitted 19.3% for benzene, 30.8% toluene, and 17.1 % for ethylbenzene more than fuel 95-LFG. In the fuel, 95-LFG emitted 2.69, 6.17, and 1.81 mg/km for benzene, toluene, and ethylbenzene, respectively. When add the gasoline additive to the fuel, 95-LFG emitted benzene, toluene and ethylbenzene in range of 0.63 to 3.21, 2.89 to 8.07, 1.29 to 2.23 mg/km, respectively.

Table 2.2 The concentration of main toxic VOC found from motorcycle exhaust

Compound	Mean tested gasoline concentration (ppm-v)
Methyl *tert*-butyl ether	14.1
Benzene	90.1
n-heptane	14.3
Toluene	76.8
Eyhylbenzene	65.3
p-Xylene	56.0
m-Xylene	13.7
o-Xylene	12.5
Isopropylbenzene	1.3
1,2,4 - Trimeethylbenzene	1.6

Source: Adapted from Chang and Chen (2008)

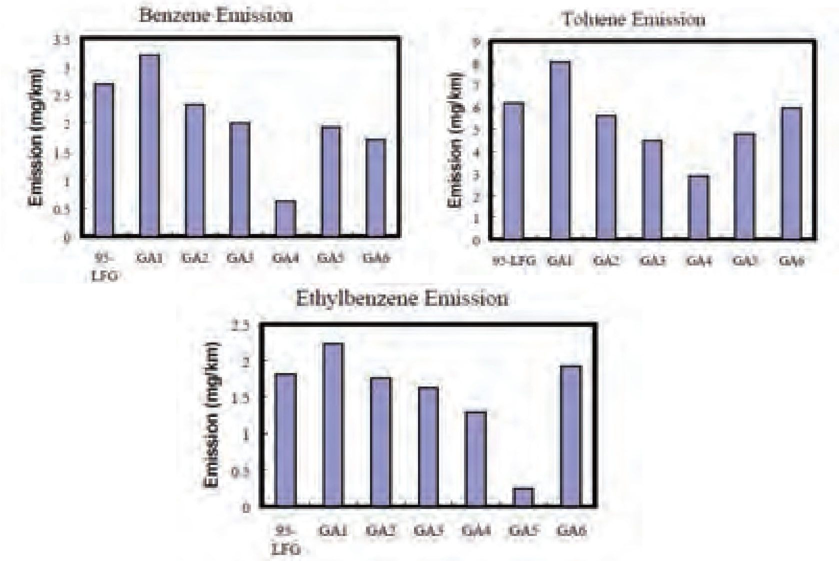


Figure 2.1 Benzene, toluene, and ethylbenzene emissions of the fuel and tested gasoline additives during FTP-75 testing (Wu *et. al* 2007)

2.2.2 Machinery source

In industry, the manufacturing process release many pollutants such as petroleum refinery and industry. In US, benzene is emitted from catalytic reforming, ethylene production, toluene dealkylation, coke oven light oil distillation, and xylene isomerization for 45%, 22%, 25%, 3%, and 2 %, respectively. The catalytic reforming process emitted benzene from process vent, equipment leak, storage vessels, wastewater collection and treatment system and product loading. Benzene might be emission in high rate from charge gas compressor and refrigeration compressor outages in ethylene production. The coke oven is the important source of benzene, and can be emitted from charging operation, leak oven door, top site port lids, and off take system of the topside of the battery (U.S. EPA, 1998).

Toluene production in US mostly come from petroleum fraction (Table 2.3) through processing system, crude oil can be converted to benzene, toluene, and xylene steams. Other source of toluene emission come from loading operation, storage and equipment leaks. Moreover, toluene can be emitted in the atmosphere from burning of fossil fuel and manufacturing process as by product such as coal combustion (U.S. EPA, 1994.)

Ethylbenzene can be emitted in catalytic reformate production, manufacturing, processing, and handling. The emission of ethylbenzene also found in the processing of crude oil and bulk emission. In the United Sates, ethylbenzene was ranked among the top 50 of chemical produced with the total production of 11 to 1 million pounds per year. (ATSDR, 2010)

Table 2.3 Emission factors for toluene production from petroleum fractions.

Emission Source	Emission Factor
Storage tank working losses, Toluene recovery	0.66 lb/1000 gallon (0.079 kg/1000 liter)
Storage tank breathing losses, Toluene recovery	3.6 lb/1000 gallon (0.43 kg/1000 liter)
Toluene recovery, General process emissions	1.7 x 10^{-4}lb/lb toluene produced
Toluene recovery, Storage	4.65 x 10^{-4}lb/lb toluene produced
Toluene recovery from catalytic formate, cracking unit	2.0 x 10^{-5}lb/lb toluene produced
Fugitives from petroleum refining with cracking and reforming	21 lb toluene/ton (10.5 g/kg) total hydrocarbon
Fugitives from petroleum refining without cracking and reformingb	21 lb toluene/ton (10.5 g/kg) total hydrocarbon

Source: U.S. EPA (1994)

Xylene is released into the air from industrial such as petroleum refinery and chemical plant, from vehicle exhaust, and from the use of solvent as a result of volatilization. In US, xylene also use in chemical manufacture, agriculture spray, adhesive, paint, and coating for 5.2 %, aviation fuel and gasoline 39.3%, chemical plastic and synthetic fiber industries for 55.5%. The production process emission factors for mixed xylene and xylene isomer for the treating tank in the production from coal-derived light oil are shown in Table 2.4. Other source emission of xylene may be come from loading operation, storage and equipment leaks.

Table 2.4 The production process emission factors for mixed xylene and xylene isomer

Production Process	Emission Source	Emission Factor kg/Mg (lbs/ton) Product	
Coal-Derived Mixed Xylene	Treating Tank	0.5	1.0
Mixed Xylene from Pyrolysis Gasoline	Ethylene Cracking Unit	0.07	0.14
p-Xylene Production	Overall	1.14	2.27
o-Xylene Production	Overall	2.09	4.16
m- Xylene Production	Overall	1.58	3.14

Source: Modified from USEPA (1994)

In the study of Pimpisut (2004) at Mab Ta Phut Industrial Estate, Thailand reviewed the air toxic release from petroleum refining shown in Table 2.5 and found that benzene, toluene, and xylene release higher than other pollutants but only lower than methyl ethyl ketone.

Table 2.5 Air toxic release from petroleum refining in U.S. EPA's annual toxic release inventory

Chemical name	Fugitive air	Point air	Total release air	Average per facilities
	lbs/year	lbs/year	lbs/year	lbs/year
Benzene	3,033,472	1,216,081	4,249,553	27,774.856
Toluene	6,447,238	2525,056	8,972,294	61,454.068
Ethylbenzene	945,272	418,264	1,363,896	9.812.2
Xylene (mixed isomer)	3,631,186	1,454,332	5,085,518	37,393.515
o-Xyene	224,674	98,181	322,855	20,178.438
p-Xylene	224,792	282,361	527,153	32,947.063
m-Xylene	297,605	55,255	352,860	25,204.286
Methyl Ethyl Ketone	4,349,330	250,384	4,599,714	69,692.636
Other	4,057,907	2,113,308	6,171,215	38,812.673

Source: Modified from Pimpisut (2004)

2.2.3 Indoor source

The indoor activities can be an important source of BTEX such as burning of incense, mosquito coil, and smoking of cigarette and some other by product such as construction material, furnishing, paint, vanishes, and solvent (Guo *et al.*, 2003). In Hong Kong, Guo *et al*. (2003) found that the indoor concentration of BTEX in shopping mall had the highest concentration when compare to office, home, and restaurant. In restaurant, benzene, toluene , and ethylbenzene had the second highest indoor concentration, except xylene concentration in office was higher than restaurant. In Table 2.6, the emission of aerosol particles and some gaseous pollutants for the investigated smoking, burning, and flying process showed that the incomplete combustion release high concentration of carbon monoxide (CO) and the incense stick had released the highest (Lofroth *et al*, 1991). In the study of Wang *et al*. (2007) about the air pollutant from incense burning show that the ratio of benzene and toluene (B:T) of temple (indoor) in Hong Kong (Figure 2.2) had the highest ratio compare to the ambient level of Cairo(Khoder, 2007), Taiwan (Hsieh *et al*., 2006) and India (Majumda *et al*., 2008) and the roadside in Vietnam (Truc and Oanh, 2007). Moreover, this ratio was higher level than the ratio of motorcycle exhaust.

Table 2.6 The emission of aerosol particles and some gaseous pollutants for the investigated smoking, burning, and flying process

Material	Emission in mg/g smoked burnt or fried material	
	Carbon monoxide (CO)	Benzene
Prince cigarette	80	0.44
Herbal cigarette	100	0.48
Incenses sticks	220	0.44
Incense cones	180	0.42
Mosquito coils	120	0.54
Lean, minced pork	<0.05	<0.0001

Source: Modified from Lofroth et al. (1991)

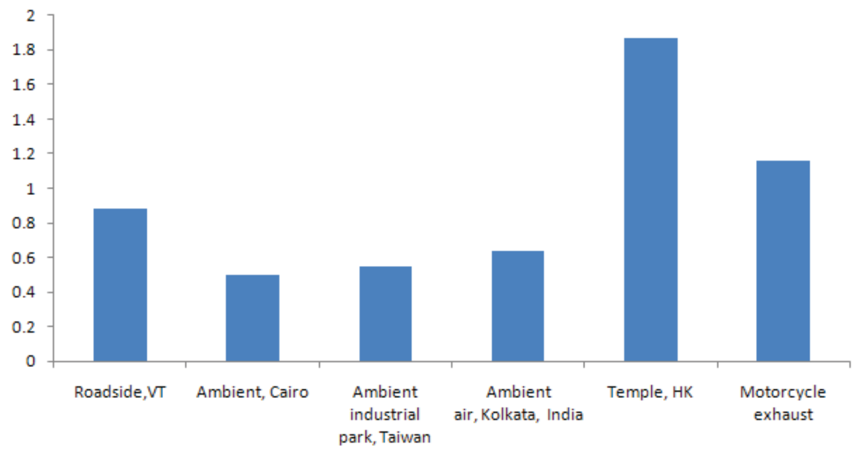


Figure 2.2 Comparison on the ratio of benzene and toluene at different areas and sources

2.3 Atmospheric chemistry of BTEX

When BTEX released in the air, it will disperse in the atmosphere as it property that easy to volatile. BTEX reacted with other air pollutants and are involved with the formation of petrochemical smog (Bhowmik, 2011). Aromatic hydrocarbons (i.e. BTEX) significantly contribute with photochemical reactions in the atmosphere. The reactions with NO_x in the presence of sunlight produce secondary pollutants and petrochemical smog such as OH radical and ozone (Atkinson, 2000). The ozone formation occurred by two major classes of nitrogen oxides (NO_x) and volatile organic compounds (VOC). In Figure 2.2, the ozone reaction started from VOC and OH radical or CO and OH radical. Then NO_2 is converted from NO through HO_2 or RO_3 radicals. Next, NO_2 is photolysis and produced oxygen atom with combined to O_2 to create ozone (O_3). There are some environmental factors that affect the level concentration of benzene in the atmosphere such as temperature, exposure time, humidity, and wind velocity (Cardinal *et al*. 2005).

$$VOC + OH \xrightarrow{[O_2]} RO_2 + H_2O$$

$$CO + OH \xrightarrow{[O_2]} HO_2 + CO_2$$

$$RO_2 + NO \xrightarrow{[O_2]} \text{secondary } VOC + HO_2 + NO_2$$

$$HO_2 + NO \rightarrow OH + NO_2$$

$$NO_2 + h\nu \rightarrow NO + O$$

$$O + O_2 + M \rightarrow O_3 + M$$

Figure 2.**3** Chemistry of the ozone cause by NO_x and VOC
(Source: Sillman (2003))

In figure 2.4, the degradation process of benzene was react with atmosphereric hydroxyl radical and also react with nitratrate radical and ozone in the atmosphere. The products from the reaction of benzene and nitrogen monoxide may have an adverse effect to human such as nitrobenzene, o- and p- nitrophenol, 2,4 and 2,6 dunitrophenol, formaldehyde, and glyoxal (ATSDR, 2007).

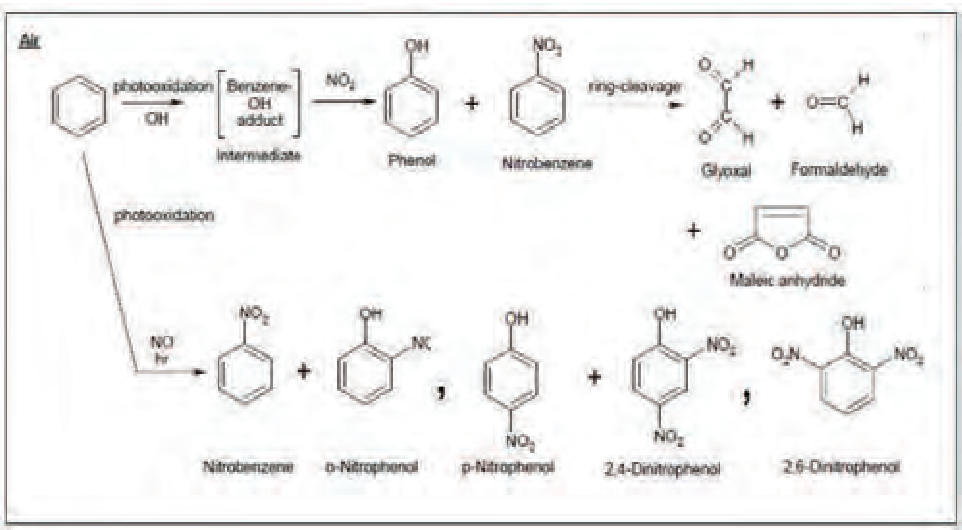


Figure 2.4 Environmental transformation products of benzene in atmosphere
(Source: Sillman (2003))

In the atmosphere, toluene is rapidly degraded by hydroxyl radical to creosol and benzaldehyde as shown in figure 2.5 and also oxidized by nitrogen dioxide, oxygen and ozone (ATSDR, 1993).

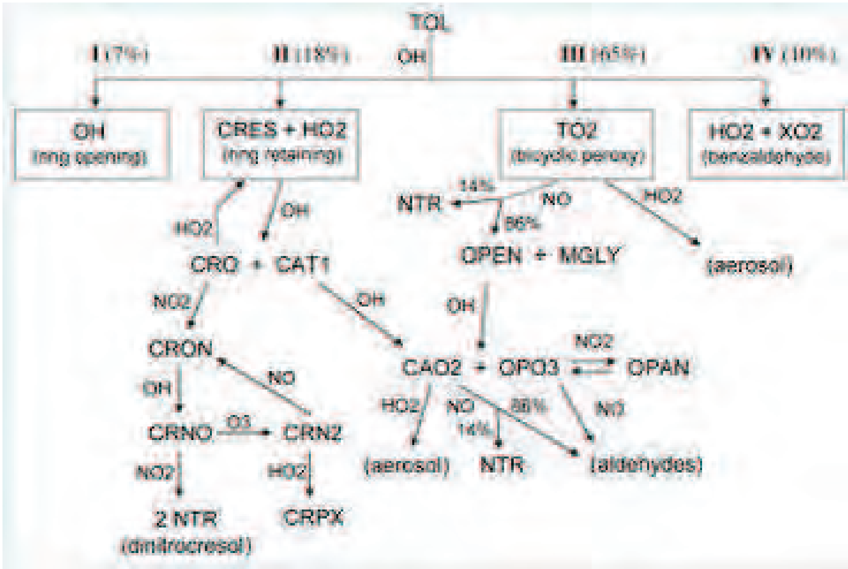


Figure 2.5 Reaction of toluene in atmosphere

(Source: Whitten *et al*., 2010)

2.4 Human health effect of BTEX through inhalation pathway

BTEX are able to get into human body via ingestion, inhalation and dermal adsorption. High concentration of BTEX can make skin and sensory irritation, central nervous system depression and effect on respiratory system. U.S. Environmental Protection Agency (U.S. EPA) believed from many studies of human and animals that benzene is a human carcinogen and the workers who exposure to benzene in high concentration was increased incident in leukemia (TOSC, 2003). It has been evaluated by World Health Organization (WHO) that a life exposure of 1 $\mu g/m^3$ of benzene has associated to 6 cases of leukemia per one million occupants (Zhang *et al*., 2012). Inhalation accounts for more than 95–99% of the benzene exposure of the general population, whereas intake from food and water consumption is minimal (WHO, 2010).

2.5 Distribution of BTEX in the ambient air in urban area

Nowadays, in mega cities of the world had been reported about the VOC or BTEX exposure in ambient atmosphere raise to their interested. Many activity of people was effected to increased the BTEX exposure, in the study in Australia found that vehicle repair, machinery use, refueling motor vehicle also include for this reason (Hinwood *et al.* 2007). Also in Thailand, the improper use and management, leakage, and illegal waste disposal by many industries had been raise concern of BTEX exposure. In Figure 2.6, Fernandes *et al.* (2002) study about atmospheric BTEX and hydrocarbon in Rio de Janeiro compared the atmospheric concentration of benzene among mega cities. They found that Calcutta (India) had the highest average benzene level (3,383 $\mu g/m^3$) follow by Rome (Italy), and Taipei. It had been found that benzene level in Asia (7-31 $\mu g/m^3$) the higher level than South America (5-24 $\mu g/m^3$), North America ($\leq$8 $\mu g/m^3$), and Europe (2-36 $\mu g/m^3$). Many studies had been reported about toluene and benzene ratio (T: B). Increasing of T: B ratio related to an increase of traffic volume, industrial emission, and other urban source in dense area. The average T: B ratio in the study of Laowagul *et al.* (2008) around Pathumwan junction, Bangkok found that the ratio in June was in range of 4.0 to 9.0 and the average for 5.7 which similar to Hong Kong as in range of 2 to 10 with the similar area setting (Lee *et al.*, 2002).

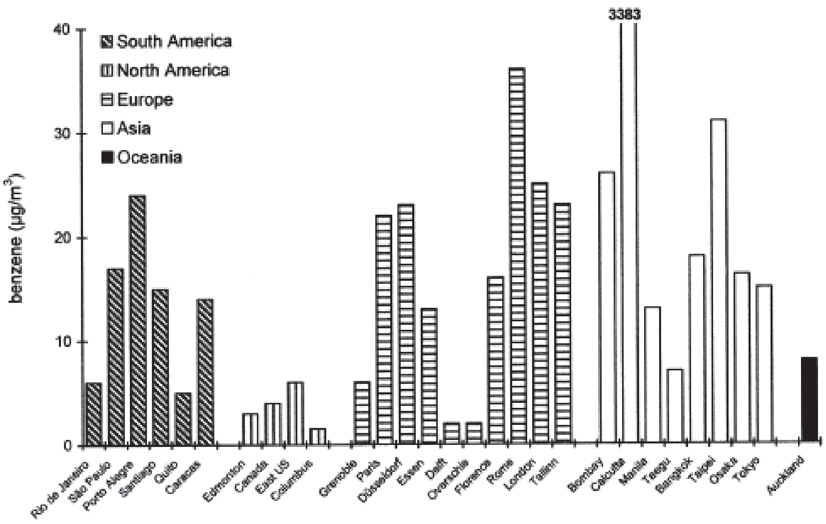


Figure 2.6 Average benzene level ($\mu g/m^3$) for Rio de Janeiro and other cities (Source: Fernandes *et al.* (2002))

2.6 Air quality standard of BTEX

There are many organizations in many countries established the standard of BTEX. Table 2.7 is a guideline standard for occupational exposure to BTEX mainly through inhalation established by three different agencies.

Table 2.7 Guideline Values for occupational exposure to BTEX

Agency / Substance	NIOSH (8hr)		OSHA (8hr)		ACGIH (8hr)	
	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
Benzene	0.1	0.32	10	30	10	30
Toluene	100	375	200	750	100	375
Ethylbenzene	100	435	100	435	100	435
Xylene	100	434	100	435	100	435

Source: Modified from Mingkwan Kitwatanavong (2010)

Remark: ACGIH = American Conference of Governmental Industrial Hygienists;
SHA = Occupational Health and Safety Administration;
NIOSH = National Institute for Occupational Safety and Health.

2.7 Human health risk assessment

EPA's Integrated Risk Information System (IRIS) is a human health assessment program that evaluated information on health effects that may result from exposure to environmental contaminants. The data base of IRIS contained information of substances more than 550 chemical substances and information of health effect. Risk assessment is used for evaluate effect to human health and environment for prevention and reduction the problems. The process of risk assessment composes of 4 steps as shown in Figure 2.7

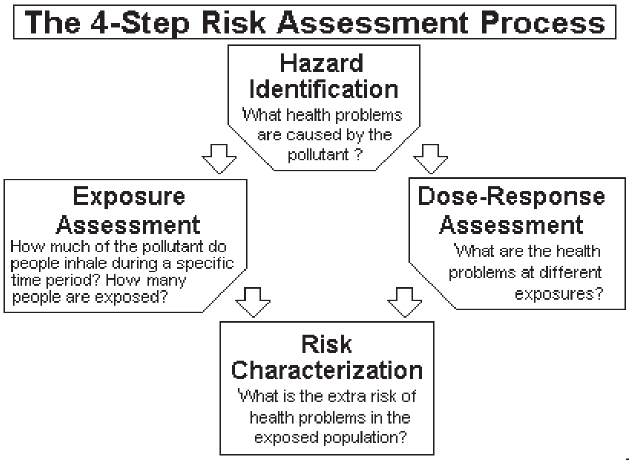


Figure 2.7 The process of health risk assessment
(Source: U.S. EPA (1991))

The first step of risk assessment is hazard identification. This process is to identify all possible situations that can make people injury, illness or disease. Exposure to BTEX workers may generate many different adverse effects in a human: diseases, formation of tumors, reproductive defects, death, or other effects. The second step of risk assessment is dose-response relationship that described how the possibility and acrimony of adverse health effects are related to the amount and condition of exposure to dose. The third step of risk assessment is exposure assessment; exposures can be estimated by measuring pollutant levels in various body tissues (such as hair, blood, urine, or nails) as biomarkers or by using various mathematical models with the data. In this process the extent, duration, frequency and magnitude of exposures to a pollutant are estimated via many way such as ingestion, inhalation and dermal. The final step, risk characterization, from the part that mention before the data are used to estimate the people who may be affected this pollutant. The data derived from the proceeding steps which are limited by uncertainty, assumptions, and scientific judgment. These will be a significant tool for conclusion the risk and for decision maker.

U.S. EPA guideline for risk assessment in Risk Assessment Guidance for Superfund (RAGS) Volume 1: Human Health Evaluation Manual used in this study for 2 parts. Part A, the baseline risk assessment (U.S. EPA, 1989) and part F, Supplement Guidance for Inhalation Risk Assessment (U.S. EPA, 2009) as shown in Table 2.8. From Table 2.8, first, the identification of which chemical is cancer or non cancer for human is an important step for selecting a specific value in step 2. The reference value from part A and part F for inhalation exposure will be prepared for calculating risk level in further step. The different between part A and part F is an exposure assessment step. In step 3, which is recommended process involves estimating the EC for the specific exposure scenario based on the decisions made in steps 1 and 2. RAGS Part A is estimated inhalation exposure in term of Chronic Daily Intake (CDI) for cancer and Average Daily Dose (ADD) for non-cancer. While part F used exposure concentration (EC) for each receptor exposed to contaminant via inhalation. The generic equation for estimating chemical intakes (calculating ADD or CDI) is shown in Equation 2.1.

Table 2.8 The four steps of risk assessment in RAGS part A and part F.

RAGS Volume I: Human Health Evaluation Manual	Part A The baseline Risk Assessment		Part F Supplement Guidance for Inhalation Risk Assessment	
Step 1: Hazard Identification	Cancer	Non-cancer	Cancer	Non-cancer
Step 2 : Dose respond Assessment	Inhalation Cancer Slope Factor (CSF_i)	Inhalation Reference Dose (RFD_i)	Inhalation Unit Risk (IUR)	Reference Concentration (RFC)
Step 3 : Exposure Assessment	Chronic Daily Intake (CDI)	Average Daily Dose (ADD)	Exposure Concentration (EC)	Exposure Concentration (EC)
Step 4 : Risk Characterization	CDI x CSF_i	ADD x RFD_i	EC x IUR	EC/RfC

Source: Mingkwan Kitwattanavong, 2010

$$I = CxCRxEFxED / BWxAT \qquad \text{(Eq. 2.1)}$$

where;

I (mg/kgBW-day)	= intake; the amount of chemical at the exchange boundry
CA (mg/m^3)	= Chemical concentration
CR (m^3/hr)	= Contract rate
BW (kg)	= Body weight
ET (hours/day)	= Exposure time
EF (days/year)	= Exposure frequency
ED (day)	= Exposure duration
AT (days)	= Averaging time

For calculating EC the term of Inhalation rate (IR) (or Contract Rate (CR) in equation 2.1) and Body Weight (BW) are not consist due to the amount of the chemical that reaches the target site is not a simple function of IR and BW. And the step of risk characterization, the risk level will be calculated by multiplying the data from step 2 and 3.

2.8 Related research articles

The study in Hong Kong, Lee *et al.* (2002) investigated spatial distribution of VOC in morning rush hours on winter (December and January) and summer (July and August) at five cities. The highest average concentration was found at the area of metal and printing industries as 15.07, 139.35, 24.68, 27.88, 13.39 μg/m^3 for benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene, respectively. However, the average benzene concentration (13 μg/m^3) in Hong Kong was found to be similar to Manila and Bangkok.

Lee and Wang (2004) studied air pollutants from burning of incense in a large environmental chamber in Hong Kong. The incenses are come from 10 different countries. The results after burning incense showed that benzene, toluene, methyl chloride and methylene chloride concentration is increasing. Some compound of VOCs concentrations at after burning time had a higher concentration more than during burning. From this result means the exposure period will more higher after incenses have already burnt. In addition, some incenses had a black smoke after burning which may contain a high VOCs concentration. The result also showed that benzene concentration of all incenses is over the standard of HKIAQO, however, toluene concentration of all incenses do not exceed the standard. From different type of incense, the result found that most VOCs concentration came from aromatic incense and follow by tradition incense and church incense, respectively.

Navasumrit *et al*. (2005) studied about environmental and occupational exposure to benzene in Thailand. They collected air samples from seven areas where have heavy traffic and cars in Bangkok, schools near the roadside and temples, school area in Chonburi compared with school in Bangkok and workplaces in gas station and factory. They found that the mean atmospheric BTEX concentration in Bangkok on main road was 33.71 ppb, so it was higher than three temples (12.39 ppb) which was a control area. Schools in Bangkok had a mean benzene level higher than schools in Chonburi (8.25:2.71 ppb). And the result from gas station and factory were 64.78 and 66.24 ppb, respectively. Also the result about DNA damage and repair were significant increase in all benzene exposure groups.

Khoder (2006) collected the ambient volatile organic compounds (VOCs) in urban area, Cairo and one rural area for background. The BTEX ratio in two urban areas was similar as 2.01:4.94:1:4.95 and 2.03:4.91:1:4.87 which higher than in the rural area as2.31:2.98:1:2.59. The high concentration of toluene in both areas was indicated that both areas might be effected from the same sources. The proportional of toluene and benzene (T:B) in ambient urban area (2.45) was lower than the ratio of automotive exhaust (2.70) and 2-fold higher than ambient rural area (1.29).

Truc and Oanh (2007) monitored roadside BTEX concentration during dry season in Vietnam. They selected 3 streets with high, low traffic volume and high traffic in industrial estate. The highest geometric mean was form sampling in industrial with a concentration of 123, 87, 24, 56, 30 $\mu g/m^3$ and follow by high traffic street and low traffic street as 65, 62, 15, 43, 22 $\mu g/m^3$, and 30, 38, 9, 26, 13 $\mu g/m^3$, for for benzene, toluene, ethybenzene, m,p-xylene and o-xylene, respectively. They also found that the geometric mean of BTEX of peak hour in morning (7.00-9.00) and afternoon (16.00-19.00) on weekday were higher than a weekend. For weekday, peak-hour BTEX concentration was 110, 112, 30, 88, and 45 $\mu g/m^3$ and weekend was 47, 71, 17, 51, and 25 $\mu g/m^3$, for benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene, respectively. The monitoring daily data showed that the amount of vehicle in weekday was 6,500 for motorcycles, and 120 for trucks which higher than weekend. The effect from traffic jam and the vehicle speed in peak hour on weekday might be an important for the high BTEX concentration.

Wang *et al*. (2007) investigated about characteristic of emissions of air pollutants from burning of incense in two famous temples in Hong Kong. They determined peak and non-peak period as sampling duration. Temple 1 has a big area about 16,700 m^2 and temple 2's area is 32 m x 34 m. The sampling point collected in temple 1 is the main altar room where is the semi-open site which has only the door and ceiling can open to outside. Temple 2, the sample was collected in worship room (20x20 m and 12 m high) and temple yard. VOC is collected for 8 hrs from 9 am to 5 pm, and they found methyl chloride, benzene and toluene are the most frequency detected. The total VOC concentration during peak period in temple 1 is 870±63 $\mu g\ m^{-3}$, temple 2 indoor is 260±17 $\mu g\ m^{-3}$, and outdoor is 39±4.9 $\mu g\ m^{-3}$. For non-peak period the total VOC concentration in temple 1 is 52±7.1 $\mu g\ m^{-3}$, temple 2 indoor is 23±2.1 $\mu g\ m^{-3}$, and temple 2 outdoor is 9.8±1.0 $\mu g\ m^{-3}$. For BTEX compound, benzene was detected over standard for both two temples (146±14 $\mu g\ m^{-3}$ for temple 1 and 84±7.4 $\mu g\ m^{-3}$ for temple 2 indoor). Hong Kong Indoor Air Quality Objectives for Office Buildings and Public Places (HKIAQO) recommend benzene and toluene concentration as 16.1 $\mu g\ m^{-3}$ and 1092 $\mu g\ m^{-3}$ respectively; however, toluene concentration is not over the standard.

Another study from Navasumrit *et al*. (2008) studied about potential health effects of exposure to carcinogenic compounds in incense smoke in temple workers. This study was undertaken to evaluate the incense smoke which contain carcinogenic substances; benzene, 1,3 butadiene and PAH. The area of this study is in three provinces near Bangkok (Ayutthaya, Chachensao and Samautprakan). The result of ambient air concentration showed that all three substances have higher level inside the temple than a control work place (4 times higher for benzene, 261 times for 1,3 butadiene and 12.5 times for PAH). They also studied about biomarker of exposure of three substances and found the same answers like their study before that have a significant higher. The last result to ensure the increasing of cancer risk is DNA damage and DNA repair.

Tawanwong and Lorjitsieng (2010) also studied about VOCs emitted from incense burning in environmental chamber. Two types of incense; smoked incense and smokeless incense were selected for the experiment. The result showed the average concentration of benzene, toluene, ethylbenzene, m,p-xylene and total-BTEX emitted from smoked incense were 8.777, 2.408, 0.082, 0.053, 0.086 and 11.407 mg/m^3, respectively. For smokeless incense the average concentration were 5.748, 1.233, 0.037, 0.020, 0.027 and 7.059 mg/m^3. Moreover, the emission rate of BTEX of the smoked incense was still higher than smokeless incense. The ashes from smoked incense were 0.15±0.11 g/g incense and 0.14±0.03 g/g incense for smokeless incense. There was no correlation between the amounts of ash per gram incense and concentration of BTEX (mg/m^3) in both incense types.

The study of Health risk assessment of toll way station worker and gas station workers exposed to BTEX in Thailand had been investigated by Ruangtrakul (2013) and Kitwattanavong (2010), respectively. The sampling of 8 hour working time from two tollway stations in wet and dry season. The results of both stations showed that on weekday (Friday) was higher than weekend (Sunday). Benzene and toluene on weekday had the highest concentration of 127.85 and 206.41 $\mu g/m^3$, respecrively. For the lifetime cancer risk of the workers show that 95% confidental interval of benzene and ethylbenzene was in range of 6.93×10^{-5}-1.41×10^{-4} and 2.15×10^{-6} - 4.52×10^{-6}, respectively, which higher than the acceptable risk. For the gas station workers, personal and ambient concentration of toluene had the highest level at all stations at 297.03 and 302.64 $\mu g/m^3$. Moreover, the average BTEX concentration was not exceed the occupational limits of Thailand. For benzene, the lifetime cancer risk was in range of $4.14x10^{-5}$ – $4.99x10^{-4}$ and 100 % over acceptable risk of 10^{-6}.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Study area

3.1.1 Sampling Location

a.) Tao Maha Brahma (TMB) shrine

Tao Maha Brahma (TMB) shrine is situated in the open air and is located at the intersection of two main roads (Ratchaprasong intersection, Ratchadamri and Sukhomwit Roads) next to the Erawan hotel in the Pathum Wan district, Bangkok (Figure 3.1), and so has a high car exhaust fume background as shown in Figure 3.2. TMB was one of the famous worship places of this area which many Thais and foreigners came to worship and benedicts the gilded statue of the four-faced Hindu god of creation named Phra-Phrom in Thai. The Tao Maha Brahma foundation Erawan hotel established from Thais and foreigners for administration the money donated from people for the maintenance of the Brahma. The job description of the workers at TMB is summarized in Table 3.1 and a record of people who came to visit the Brahma on the sampling day is shown in Table 3.2

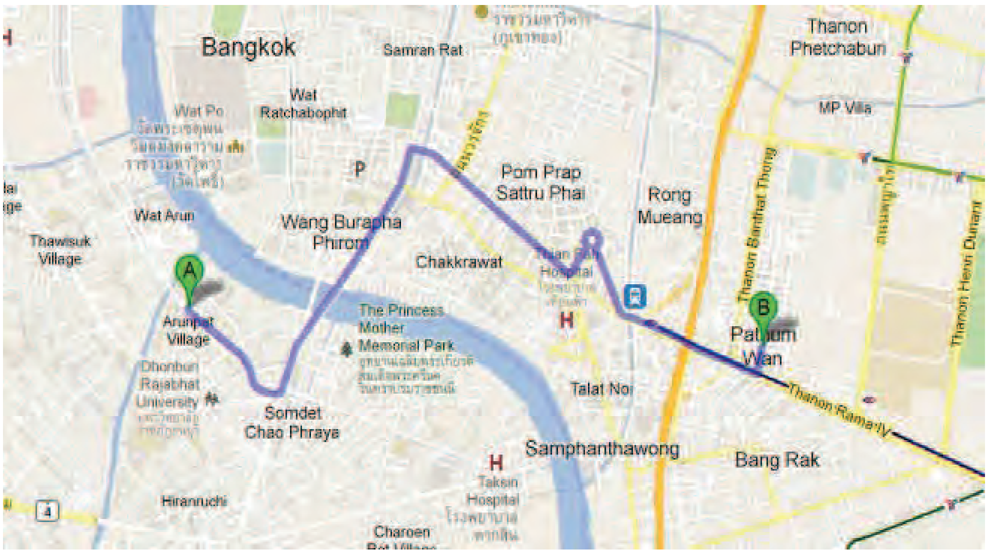


Figure 3.1 the location of the Kanlayanamit Woramahawiharn temple (A) and Maha Brahma shrine (B).

Figure 3.2 The sampling location of TMB

Table 3.1 Job description for the workers at TMB

Occupation	Working position	Description
Thai folk dancer	Inside the pavillion	Dance for visitor who want to benedict to the Brahma with different type of song (5 minute per song) by two dance groups (8 people per group) of Thai folk dancer and they work there from 8 a.m. to 10 p.m every day
Janitor	Near the Brahma statue and all area	Collect incenses (4-5 janitors take turn to collect the incense) and clean all area
Guard	Near roadside	Take care security of the Brahma statue and visitor

Table 3.2 Amount of visitors at TMB on weekend (Sunday) and weekday (Wednesday) on a sampling period (7.00 am- 3.00 pm) .

Sampling period	Sampling Date	Amount of visitor (people/day)		Approximation amount of incenses*	
		Weekend	Weekday	Weekend	Weekday
Dry season (March to April)	14th and 18th March	5185	4340	62,220	52,080
	28th March and 1st April	2045	2007	24,540	24,084
	25th and 29th April	3353	4160	40,236	49,920
Wet season (July)	1st and 4th July	6535	2798	78,420	33,576
	15th and 18th July	3530	3973	42,360	47,676
Cold season (November to December)	21th and 25th November	4979	3671	59,712	44,052
	12th and 16th December	3111	5931	37,322	71,172

Source: Unofficial report from Tao Maha Brahma foundation

* the amount of burnt incenses was calculated from the amount of incense in one package of 12 incenses per one person

b) Kanlayanamit Woramahawiharn temple

The Kanlayanamit Woramahawiharn (KW) temple is located in a semi-open area aside the Chao Phaya River in the Thonburi district, Bangkok (Figure 3.1 and 3.3), and not closed to a main road which should has a much lower car exhaust background than TMB. The KW temple was built since the King Rama III by Chao Phaya Nikornbordin who had strongly faith in Buddhism. He also sacrificed his own property to built KW temple and became the first abbot. Inside Kanlayanamit Woramahawiharn temple there is a big statue of Buddha call “Laung Por To” and very sacrosanctity of people nearby for a long time. The job description of workers at KW temple is summarized in Table 3.3 and the amount of incenses which collected from this temple and counted by the author is shown in Table 3.4. Due to no record of the visitors for this temple, the number of visitors was approximately calculated by the burnt incenses amount, as for nine incenses per one person.

Figure 3.3 The sampling location of KW temple

Table 3.3 Job description for the workers at KW temple

Occupation	Working position	Description
Janitor	All area of temple	Collect the incenses (collect when the incense stick pot was full) and clean all area
Incense seller	Inside the temple area	Sell an incense, candle and beverage
Lottery seller	The entrance door of the temple	Sell the lottery in front of the temple (with the permission from the abbot).

Table 3.4 Amount of incenses at KW temple on weekend (Sunday) and weekday (Wednesday) on sampling period

Sampling period	Sampling date	Amount of visitor* (people/ day)		Amount of incenses					
		Peak day	Non-peak day	Weekend			Weekday		
				S	M	L	S	M	L
Dry season (March to April)	21th and 25th Mar	1639	238	14752	280	120	2149	64	14
	4th and 8th Apr	2137	335	19238	320	80	3019	116	12
Wet season (July)	8th and 11th July	1,274	300	11466	196	33	2692	69	21
	22th and 25th July	1,261	55	11348	409	118	500	30	12
Cold season (Nov to Dec)	28th Nov to 2nd Dec	733	480	6599	182	69	4320	132	45
	19th and 23th Dec	762	235	6859	250	61	2117	46	24

* The number of visitors was approximately calculated from nine incenses (small) per one person

**S mean small size of incense, M mean medium size of incense, and L mean large size of incense

3.1.2 Sampling position

The four sampling positions at TMB represent Thai folk dancer, janitor, guard and ambient position was shown in Figure 3.4**.** There was four incense stick pot at TMB and the position of janitor was near the Tao Maha Brahma statue and in the center of the four incense stick pots. The position of the Thai folk dancer and guard was near the janitor’s position but guard was near the roadside. The ambient position was outside of the shrine area and closed to Sukumwit Rd. For KW temple, The four sampling positions were covered janitor, incense seller, lottery seller, and ambient position as shown in Figure 3.2. There was eight incense stick pot at KW temple and the position of janitor was not in the center of the incense stick pot as the janitor at TMB as we could not install sampling equipment at the center of the KW temple. The incense seller position was on the left and the lottery seller was near the entrance. The background area for ambient position was the parking lot area and beside also has the school on the right of the temple.

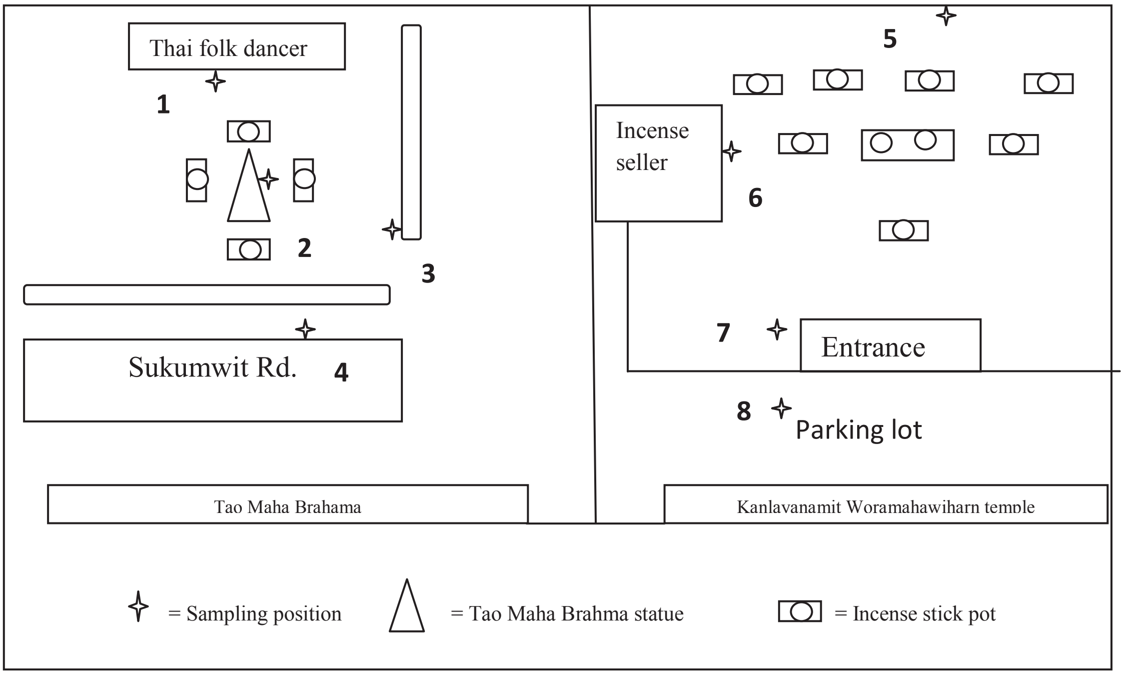


Figure 3.4 The sampling position at two worship places. (1= Thai folk dancer position, 2= janitor position (TMB), 3= Guard position, 4 = Ambient background (TMB), 5 = janitor position (KW temple), 6= Incense seller position, 7= Lottery seller position, 8= Ambient background (KW temple))

3.2 Sampling program

3.2.1 Sampling duration

The sampling was performed in April (dry season), July (wet season) and December (cold season) 2012. All samples in each worship places were collected twice within two weeks. In April, there was the highest temperature of the year more than July and December. The difference in temperature of each month were supposed to represent the high and the low BTEX exposure level from incense burning, respectively.

3.2.2 Sampling date and time

Sampling was performed for 8 h during work time (7 am to 3 pm) on four weekends (Sunday) and four weekdays (Wednesday) in April (dry season), July, and December of 2012, respectively. The sampling date at TMB and KW temple were presented in Table 3.2 and 3.4, respectively.

3.3 Experiment preparation and quality control of laboratory

3.3.1 Analysis instrument

For analysis of BTEX, Gas Chromatography, model HP 6890N, connected with Flame Ionization Detector (GC/FID) at the 11th floor Petrochemical Building, Chulalongkorn University were used. GC/FID installed with the capillary column HP-5 size 30mx0.32 mm x 0.25µm (19091J-413) produced by Agilent was used for separating BTEX. The carrier gases are nitrogen (N_2), helium (He), hydrogen (H_2) and air zero. Ramp 1 was set an initial temperature at 35 ºC, and was increased until 120 ºC at an increase rate of 5ºC/min. Ramp 2 was set to increase the temperature from 120 ºC to 230ºC at an increase rate of 20 ºC/min and held at this temperature for 5 minutes. The temperature of FID at 300 ºC was the best condition for analysis BTEX. The condition of GC/FID for analyzing BTEX is shown in Table 3.5.

Table 3.5 The condition of GC/FID

Capillary Column	HP-5 size 30mx0.32 mm x 0.25µm (19091J-413)
Carrier Gases	Nitrogen (N_2), Helium (He), Hydrogen (H_2) and air zero
Flow rate of He	1.5 ml/min
Type of injection	Splitless
Injection volume	1 µL
Injection Temperature	300 ºC
Detector	Flame Ionization Detector (FID)
Detector temperature	300 ºC

Oven Ramp	ºC/min	Next (ºC)	Hold (min)	Run time (min)
Initial		35	0.00	0.00
Ramp 1	5.00	120	0.00	17.00
Ramp 2	20.00	230	5.00	27.50

Source: Kitwattanavong, 2010

3.3.2 Standard curves

The calibration curves of BTEX were prepared by using the mix standard of BTEX concentration of 125, 250,500, 1,000, 2,000, 4,000, and 8,000 ng/ml, respectively. Toluene-d8 concentration of 8,115 ng/ml was mixed as intenal standard in every standard BTEX concentration. The coefficients of determination or R^2 values of the calibration curves were $\geq$0.99.

3.3.3 Limits of instrument

Limits of Detection (LOD) and Limit of Quantification (LOQ) of GC/FID were calculated by measuring the lowest concentration of mix standard BTEX as shown in equation 3.1 and 3.2. Comparison the signal and noise ratio of 3:1 for LOD and 10:1 for LOQ

$$\text{LOD} = \frac{3\text{x the lowest concentration used x } \delta}{\bar{x}} \qquad \text{(Eq.3.1)}$$

$$LOQ = \frac{10x \text{ the lowest concentration used x } \delta}{\bar{x}} \qquad \text{(Eq.3.2)}$$

where;

δ = standard deviation

$\bar{x}$ = average peak area of the observation

3.4 Air sampling at the work place

a) Air sample

Sampling was performed using a activated charcoal glass tube. A glass tube containing 400 and 200 mg of 20-40 mesh activated charcoal as shown in Figure 3.5 in the upper and lower portion, respectively, to physically absorb the BTEX, was connected to a personal air pump (Figure 3.6) operated at 100 ml/min. These devices were placed one on each of four different sampling points per place (Figure 3.4) at 1.50 m above the ground. The charcoal tubes have to be closed with the caps immediately after sampling to prevent volatilization of BTEX. The charcoal tube will be kept in cold condition and preserved in refrigerator at low temperature (<4 ºC) until the further analysis step.

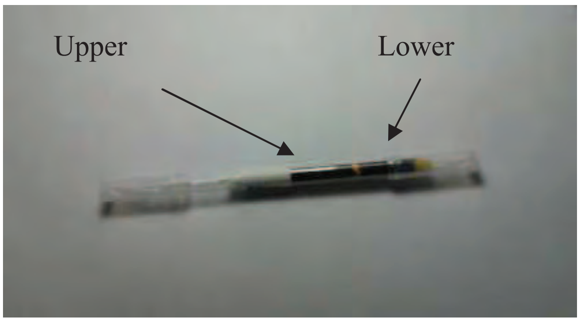


Figure 3.5 Activated charcoal tubes

Figure 3.6 Personal air pump

b) Additional data

Due to limitation on amount of workers in this study area, only eight workers at each sampling site (Figure 3.4) were asked to collect their general information, including gender, body weight, age, health information, by face to face interview technique. This information was gathered as the same group as the ongoing study "Inhalation exposure to particle-bound polycyclic aromatic hydrocarbons and health risk assessment of workers at the worship place in Bangkok" by Vachirawon Nonthakanok which was approved by the Ethical Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University, COA No. 104/2555 (3 July 2011).

3.5 Air sampling of incense burning in the chamber

The air samples of incense smoke were directly collected by active sampling from a closed chamber in the laboratory, and the ashes and incense weight were also recorded. The incense samples from two study places were used for sampling in the chamber in order to confirm whether the BTEX profile obtained from the air sampling at the temples was similar to that of incense. There are four different types of incense that used in two worship places as shown in Figure 3.7. From TMB, there was only one type of incense; whereas three different types were normally used in the KW temple.

Figure 3.7 Example incense from TMB (left) and 3 types of incense (small, medium, and large) from KW temple (right).

The chamber size of 36cmx29cmx45cm drilled a hole on the top for filter cassette was used to collect the air sample as shown in Figure 3.8. The filter cassette was connected to personal pump and the charcoal tube for collecting BTEX from incense smoke.

Figure 3.8 The chamber test of incense smoke

In the chamber, an incense of 4 types was burnt in 45 minutes separately and was repeated for 3 times for each type. The filter cassette was put on the top of the chamber, and the air stream was drawn through the sampling train. BTEX was then absorbed on charcoal in a glass tube. The charcoal tube was preserved until the further analysis step as mentioned above.

3.6 Sample extraction and preparation

To analyze the BTEX, the upper part of the tube was represented the actual amount of the sampling and the lower part was used for breakthrough checking. The internal standard of Toluene-d8 was spiked into each sample, and carbon disulfide was added for extracting the samples. The diagram of BTEX extraction is shown in Figure 3.9.

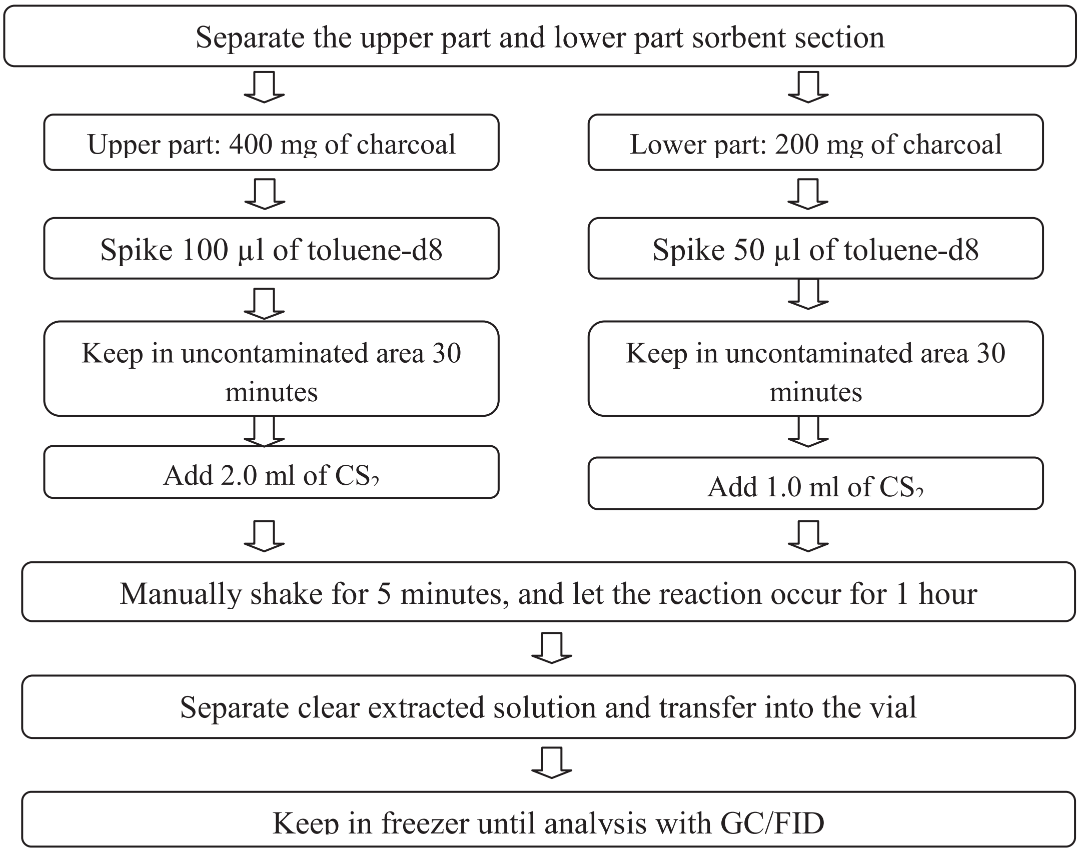


Figure 3.9 Extraction procedure of BTEX for charcoal tube
(Source: Kitwattanavong, 2010)

3.7 Sample analysis and quantification of BTEX

BTEX concentration was calculated by comparing with the mixed standard solution which contained an internal standard Toluene-d8 at known concentration and calculated by the Equation 3.3 and 3.4 (Mingkwan Kitwatanavong, 2010)

$$M_s = (P_A - P_B)/P_S \times C_S \times V_S/V_1 \qquad \text{(Eq.3.3)}$$

where;

M_S (µg/sample)	= Mass of BTEX
Cs (µg/ml)	= Concentration of the mixed standard solution
P_A (unitless)	= Peak area of BTEX per peak area of Toluene d-8 in sample
P_B (unitless)	= Peak area of BTEX per peak area of Toluene d-8 in blank
P_S (unitless)	= Peak area of BTEX per peak area of Toluene d-8 in mixed standard solution
V_S (µl)	= Sample volume 2 ml
V_1 (µl)	= Injection volume 1 µl

$$\text{Concentration of BTEX } (\mu g/m^3) = \frac{\text{Mass of BTEX } (\mu g)}{\text{Volume of Air } (m^3)} \qquad \text{(Eq.3.4)}$$

3.8 Health risk assessment of worship place workers

The risk assessment process generally consisting of 4 steps as described in Chapter 2: hazard identification, exposure assessment, dose-response assessment and risk characterization. Each step applied in this study following to RAGS part A and part F recommended by US EPA (1989 and 2010) which can be explained as follows.

3.8.1 Hazard identification

The first step of risk assessment will give the information of the target organ and critical effects of the chemical. BTEX is classified as the toxic compounds in worship places. Available toxicity data and critical effects for BTEX are summarized in Table 3.6

Table 3.6 The critical health effects of the chemicals

Compounds	EPA cancer classification	Target Organ	Precursor effect/ Tumor type	Critical Effects
Benzene	A	Blood	Leukemia	Decreased lymphocyte
Toluene	D	-	-	Neurological effects in occupationally-exposed workers
Ethly benzene	B2	Kidney	Tumor	Developmental toxicity
Xylene	D	-	-	Impaired motor coordination (decreased rotarod performance)

Remark: A=Human carcinogen, B_2 = Probable Human Carcinogen, C= Possible Human Carcinogen, D = No classifiable as to Human Carcinogenicity, E=Evidence of Non-Carcinogenicity to Humans (U.S. EPA, 1986)

3.8.2 Dose response assessment

The second step is dose-response assessment that qualifies the relationship between adverse effects and the amount of the dose. The inhalation Cancer Slope Factor (CSF_i) of carcinogenic compounds could be found for benzene and ethylbenzene by Risk Assessment Information System (RAIS, 2010). The inhalation Reference concentration (R_fC) of non-carcinogenic compounds could be found for toluene and xylene by Integrated Risk Information System (IRIS) (U.S. EPA, 2003; U.S. EPA, 2005) as shown in Table 3.7.

Table 3.7 Toxicity values for carcinogenic compounds

Toxicity values	Cancer		Non-cancer	
	Benzene	Ethylbenzene	Toluene	Xylene
RAIS'$sCSF_i$ $(mg/kg\text{-}day)^{-1}$	2.73×10^{-2}	3.85×10^{-3}	-	-
IRIS's R_fC (mg/m^3)	-	-	5	0.1

3.8.3 Exposure assessment

As mention before, the mean exposure concentration of contaminant with exposed population variables are used for estimation contaminant intake. The calculation of Chronic daily intake (CDI) for carcinogenic substance and exposure concentration (ECs) for non carcinogenic substance are shown as Equation 3.5 and 3.6. For estimating chemical intake, the functions of concentration of the chemical in the air and inhalation rate were used for inhalation exposure of the workers in the generic equation as shown in Table 3.8.

$$CDI = (CA \times IR \times ET \times EF \times ED)/ (BW \times AT) \qquad \text{(Eq.3.5)}$$

$$EC = (CA \times ET \times EF \times ED)/AT \qquad \text{(Eq.3.6)}$$

where CA is the chemical concentration ($\mu g/m^3$) and was calculated in this study, IR is the contract rate (0.875 m^3/hr) (USEPA, 1989), BW is the body weight (kg), ET is the exposure time (8 h/day) (from the questionnaire), EF is the exposure frequency (350 days/year) (USEPA, 1989), ED is the exposure duration (30 year) (USEPA, 1989),, and AT is the averaging time (25,500 days for CDI and 262,800 h for EC) (USEPA, 1989),. 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.

Table 3.8 Parameters for estimating chemical intake for inhalation exposure

	CA ($\mu g/m^{3)}$	IR (m^3/hr)	ET (hours/day)	EF (days/year)	ED (day)	BW (Kg)	AT (days)
Chronic Daily Intake (CDI)	BTEX concentration (from equation 3.5	0.875 (assumed for adult)	8	350	30	Derived from the questionnaire	25,500
Exposure concentration (EC)	BTEX concentration (from equation 3.6)	-	8	350	30	-	262,800

3.8.4 Risk characterization

The CDI of each chemical was calculated from the exposure assessment step and the CSF_i, reference from the United State Environmental Protection Agency' database RAGS Part A for carcinogenic compounds, were then used to determine the lifetime cancer risk level . A lifetime cancer risk was calculated by multiplying CDI and the inhalation slope factor as shown in Equation 3.7. A lifetime 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.

$$\text{Lifetime cancer risk} = CDI \times CSF_i \qquad \text{(Eq.3.7)}$$

For the non-cancer risk, the hazard quotients (HQs) were calculated under the RAGS part F for non- carcinogenic compounds, where Exposure Concentration came from the calculation of exposure assessment step and Reference Concentration (R_fC) by IRIS at dose response assessment step. The hazard quotients (HQ) for the inhalation pathway was calculated by EC divided R_fC as shown in Equation 3.8. The hazard quotients (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.

$$HQ = EC / (R_fC \times 1000\ \mu g/mg) \qquad \text{(Eq.3.8)}$$

3.9 Statistical Data Analysis

The difference of the pollutants in the worship places was statistically analyzed by the following method;

1) ANOVA using SPSS 17.0 for Windows for the comparison of BTEX exposure levels among workers and among three seasons.

2) T-Test using SPSS 17.0 for Windows for the comparison of BTEX concentration between weekend and weekday, TMB and KW temple

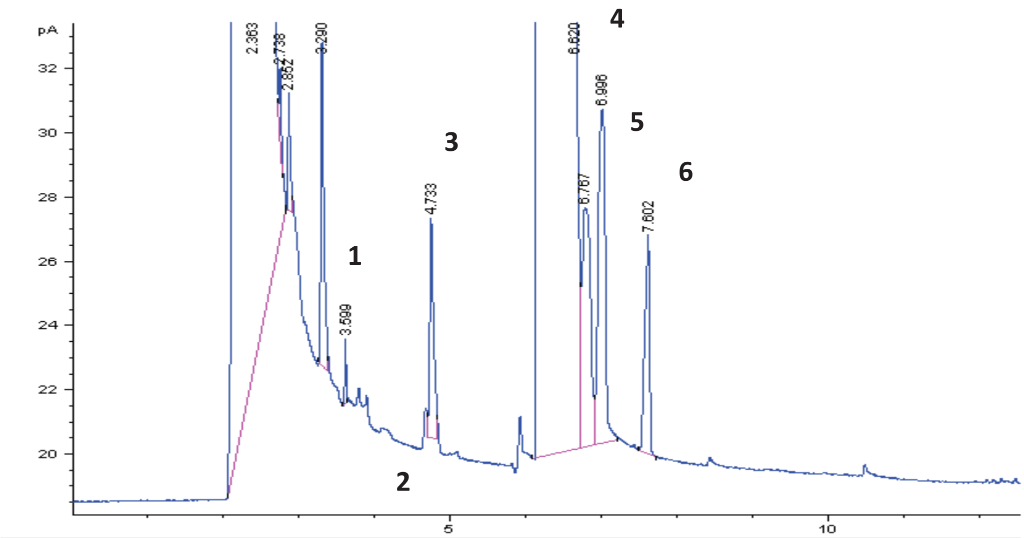
CHAPTER IV

RESULTS AND DISCUSSION

4.1 Preliminary study

4.1.1 Calibration curves

Qualitative and quantitative analysis of BTEX in the samples was determined by using the BTEX standard. Chromatogram of standard BTEX at the concentration of 8000 ng/ml with Toluene d-8 as the internal standard is shown in Figure 4.1. The calibration curve consisted of six concentrations including 250, 500, 1000, 2000, 4000, and 8000 ng/ml, each concentration added with internal standard Toluene-d8 at the concentration of 8,115 ng/ml. The coefficients of determination or R^2 values of the standard curves were in the range of 0.992-0.995, see standard curves in Appendix B.



1. Benzene (3.51)   2. Toluene-d8 (4.6)   3. Toluene (4.7)

4. Ethylbenzene (6.7)   5. m,pXylene (6.9)   6. O-Xylene (7.5)

Figure 4.1 Chromatogram of standard BTEX at the concentration of 8000 ng/ml with Toluene d-8 as the internal standard.

4.1.2 Quality control

4.1.2.1 LOD and LOQ of Gas Chromatography/FID

The Limit of Detection (LOD) and Limit of Quantification (LOQ) were determined by the lowest concentration of mix standard BTEX which was detectable with GC/FID. Mean and standard deviation (SD) of the mix standard BTEX was calculated resulting from three times injection. The LOD and LOQ were defined by the signal to noise ratio of 3:1 and 10:1, respectively, and calculated by equation 3.1 and 3.2 in Chapter 3. The reference values of LOD and LOQ (unit of µg/ml), as shown in Table 4.1, were then used in this study, 5.01 and 16.7 ng/ml for benzene, 3.06 and 10.2 ng/ml for toluene, 1.02 and 5.00 for ethylbenzene, 0.86 and 13.88 ng/ml for m,p-xylene, and 0.87 and 14.01 for o-xylene, respectively. The LOD and LOQ in the unit of mass per air volume (calculated by the air flow rate of 100 ml/ min from personal pump in the total of working time 8 hrs), $\mu g/m^3$, were then applied in this study as shown in Table 4.1.

Table 4.1 LOD and LOQ for BTEX analysis

Compound	LOD		LOQ	
	ng/ml	$\mu g/m^3$	ng/ml	$\mu g/m^3$
Benzene	5.01	0.063	16.70	0.21
Toluene	3.06	0.021	10.20	0.10
Ethylbenzene	1.02	0.018	5.00	0.29
m,p-Xylene	0.86	0.018	13.88	0.29
o-Xylene	0.87	0.018	14.01	0.29

4.1.2.2 Accuracy and precision

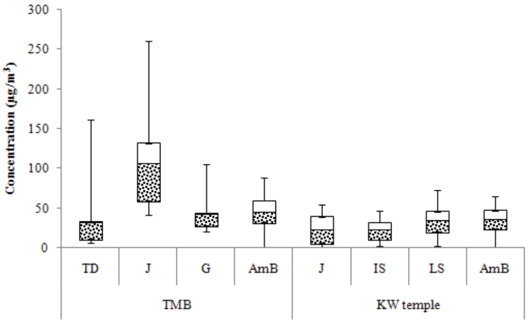
For the accuracy of sample analysis, recovery test was performed . The mixed standard of BTEX at 4,000 ng/ml was injected into the activated charcoal glass tube and extracted by CS_2 as explained in Fig. 3.?. The result of recovery test was found

110.5±1.5, 106.6±12.6, 95.75±9.25, 93.04±9.96, and 94.10±9.76 % for benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene, respectively. For the precision of instrument analysis, The percent of Relative Standard Deviation (RSD) was used for compare uncertainity between different measurement. %RSD of benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene standard was found at 2.36, 5.67, 4.73, 4.93 and 6.86%for, respectively.

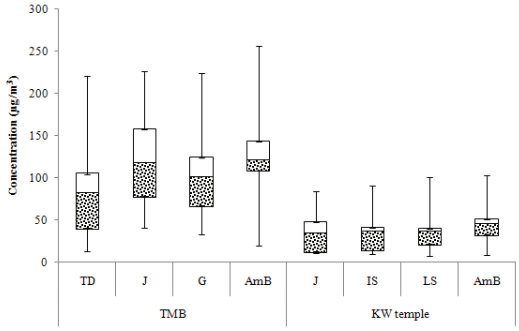
4.2 Comparison of BTEX exposure levels among workers in the worship places

At each worship place, 4 sampling positions were selected to represent the possible ambient air that the workers exposed , and one of four positions was set as the background ambient air in the area, i.e Amb, as shown in Figure 3.2 (Chapter III). The sampling was carried out on Wednesday (weekday) and Sunday (weekend) during March to April (dry season), July (wet season), and November to December (cold season) 2012. The BTEX concentrations (n= 14) at each sampling point of two worship places was shown in Figure 4.2.

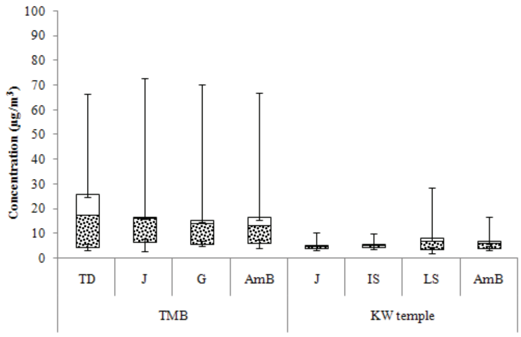
The 8-h average BTEX concentration of Thai folk dancer at TMB was 32.94 (5.94-161.37), 82.77 (13.37-220.98), 17.65 (3.23-66.52), 22.91 (5.51-49.20), 9.03 (3.15-26.03), and 165.31 (31.20-524.10) μg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of janitor at TMB was 107.14 (41.09-261.30), 118.55 (41.04-226.74), 16.52 (2.71-72.31), 20.44 (0.83-41.90), 16.59 (0.82-43.79), and 279.25 (102.86-606.08) μg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of guard at TMB was 43.40 (21.30-105.41), 101.60 (32.67-224.51), 14.15 (5.0-67.58), 16.88 (6.70-31.15), 9.12 (3.17-20.21), and 184.49 (106.75-360.09) μg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of ambient position at TMB was 45.63 (0.64-88.13), 121.26 (19.19-256.76), 13.19 (4.13-60.20), 27.52 (2.35-72.61), 10.69 (2.35-30.83), and 205.95 (0.64-412.80) μg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively.



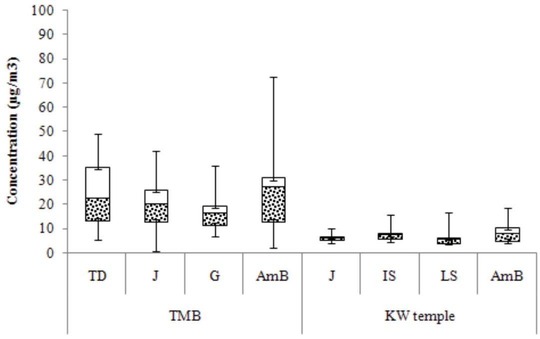
(a) Benzene



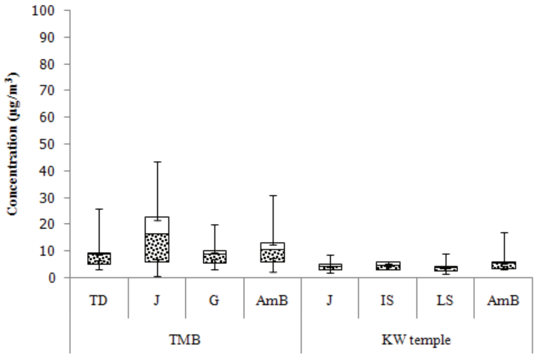
(b) Toluene



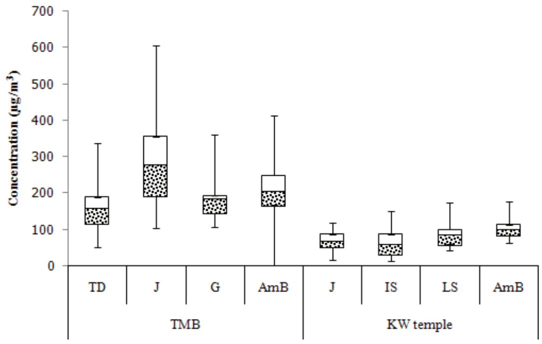
(c) Ethylbenzene



(d) m,p-Xylene



(e) o-Xylene



(f) Total BTEX

Figure 4.2 The BTEX concentration at the working area of the workers at TMB and KW temple. (TD= Thai folk dancer, J= janitor, G= guard, AmB= Ambient position, IS=Incense seller, LS = Lottery seller)

The 8-h average concentration (n=14) of BTEX measured at the four sites in the working area of each place is shown in Figure 4.3. From Figure 4.3 and Table 4.2.

The janitor at the TMB had the highest average exposure level to benzene and o-xylene as 107.14 and 16.59 μg/m^3, respectively. The ratio of benzene and o-xylene compare to the ambient background was 2.35:1 and 1.55:1 which meant the exposure level was higher than the background concentration of the area. While there was a significant difference in the benzene exposure levels between janitor, Thai folk dancer, guard and ambient position, and for the o-xylene exposure between janitor, Thai folk dancer ,and guard at the TMB ($p < 0.05$) using compare mean one way ANOVA, SPSS 17.0 for Window, and the detail of statistical analysis were shown in Appendix F. For toluene exposure level, the janitor at the TMB was also exposed to high concentrations (118.55 μg/m^3), but not as high as the ambient concentration (121.26 μg/m^3) and follow by guard and Thai folk dancer as 101.60 and 82.77 μg/m^3, respectively. The ratio of toluene for ambient position to Thai folk dancer, janitor and guard was 1:0.98:0.84:0.68. For ethylbenzene exposure level, Thai folk dancer was exposed the highest concentration of 17.65 μg/m^3, however; janitor and guard had exposed a little lower than Thai folk dancer in 16.52 and 14.15 μg/m^3, respectively and the same level as ambient background (13.18 μg/m^3).

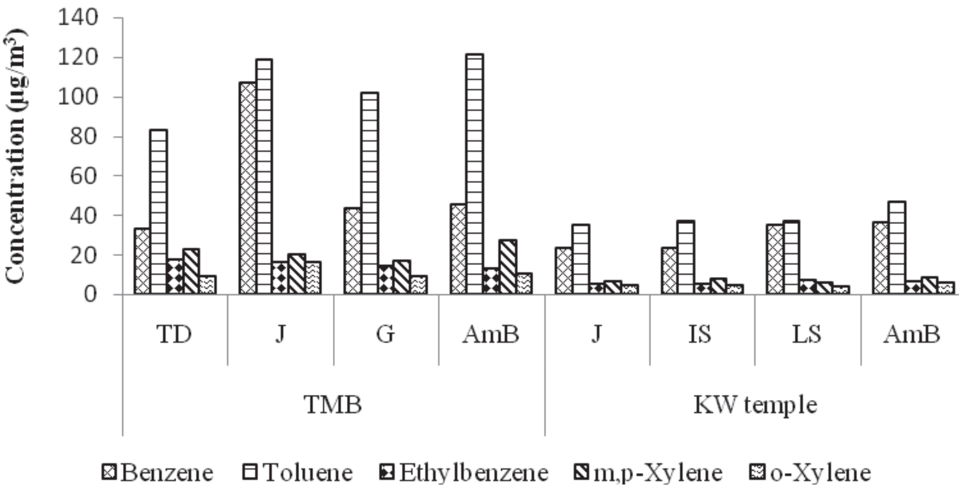


Figure 4.3 The 8-h average concentration of BTEX measured at the four sites in the working area of TMB and KW temple. (TD= Thai folk dancer, J= janitor, G= guard, AmB= Ambient position, IS=Incense seller, LS = Lottery selle

Table 4.2 Comparison of BTEX concentration at TMB

Compound	Average concentration ±SD (µg/m^3)	Concentration range (µg/m^3)	Concentration ranking (High to Low)
Benzene			
-TD	32.94±39.37	5.94-161.37	J^a >AmB^b>G^b >TD^b (2.35:1:0.95:0.72)
-J	107.14±59.69	41.09-261.30	
-G	43.40±23.41	21.30-105.41	
-AmB	45.63±25.46	0.64-88.13	
Toluene			
-TD	82.77±60.71	13.37-220.98	AmB^a>J^a>G^a>TD^a (1:0.98:0.84:0.68)
-J	118.55±55.82	41.04-226.74	
-G	101.60±49.31	32.67-224.51	
-AmB	121.26±58.63	19.19-256.76	
Ethylbenzene			
-TD	17.65±19.47	3.23-66.52	TD^a>J^a> G^a >AmB^a (1.34:1.25:1.07:1)
-J	16.52±17.74	2.71-72.31	
-G	14.15±16.52	5.0-67.58	
-AmB	13.19±14.84	4.13-60.20	
m,p-Xylene			
-TD	22.91±15.73	5.51-49.20	AmB^a>TD^a>J^a>G^a (1:0.83:0.74:0.61)
-J	20.44±11.14	0.83-41.90	
-G	16.88±7.40	6.70-31.15	
-AmB	27.52±19.91	2.35-72.61	
o-Xylene			
-TD	9.03±6.74	3.15-26.03	J^a> AmB^{ac} > G^{bc}> TD^{bc} (1.55:1:0.85:0.84)
-J	16.59±12.18	0.82-43.79	
-G	9.12±4.56	3.17-20.21	
-AmB	10.69±7.57	2.35-30.83	
Total-BTEX			
-TD	165.31±85.27	31.20-524.10	J^a> AmB^{ac} >G^{bc}>TD^{bc} (1.36:1:0.90:0.80)
-J	279.25±132.96	102.86-606.08	
-G	184.49±64.21	106.75-360.09	
-AmB	205.95±100.38	0.64-412.80	

Remark: The character on the right of the workplace name show the comparable mean different among workers and (TD= Thai folk dancer (n=14), J= janitor (n=14), G= guard(n=14), AmB= Ambient position (n=14)).

From Figure 4.2, the 8-h average BTEX concentration of janitor at KW temple was 23.64 (1.86-54.34), 35.28 (10.36-84.44), 5.01 (3.42-10.15), 6.55 (4.03-1.06), 4.57 (2.03-8.78), 69.67 (16.33-118.93) µg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average

BTEX concentration of incense seller at KW temple was 23.34 (2.35-46.83), 36.82 (10.00-90.70), 5.54 (3.83-9.76), 8.00 (4.74-15.98), 4.84 (3.27-6.33), 70.00 (13.56-150.54) $\mu g/m^3$, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of lottery seller at KW temple was 34.90 (1.92-72.82), 37.13 (7.15-101.12), 7.18 (1.94-25.56), 6.17 (3.43-16.59), 3.92 (1.72-8.98), 87.21 (41.65-175.06) $\mu g/m^3$, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of ambient position at KW temple was 36.23 (19.16-60.16), 57.73 (33.21-102.82), 5.06 (3.33-6.15), 10.82 (7.3-18.53), 3.67 (3.34-3.98), 114.30 (64.50-177.91) $\mu g/m^3$, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively.

With respect to the KW temple (as shown in Figure 4.3 and Table 4.3), the ambient position had the highest average concentration of benzene, toluene, m,p-xylene, and o-xylene at 36.23, 46.67, 8.48 and 5.83 $\mu g/m^3$, respectively, with the ratio of 1:0.96:0.64:0.96, 1:0.80:0.79:0.78, and 1:0.94:0.77:0.73 respectively . The lottery seller was exposed the highest concentration of ethylbenzene at 7.18 $\mu g/m^3$ and also exposed in high concentration of benzene at 34.90 $\mu g/m^3$. Janitor and incense seller were exposed to the same level of benzene as 23.64 and 23.34 $\mu g/m^3$, respectively. The incense seller was exposed the highest average concentration of o-xylene as 4.88 $\mu g/m^3$. However, there was no significant difference between the BTEX concentrations among the four different sampling sites at the KW temple ($p < 0.05$). This indicates that more widespread BTEX at KW temple caused the same levels found at all sites.

Table 4.3 Comparison of BTEX concentration at KW temple

Compound	Average concentration ±SD (µg/m^3)	Concentration range (µg/m^3)	Concentration ranking (High to Low)
Benzene (n=)			
-J	23.64±20.36	1.86-54.34	AmB^a> LS^a >J^a>IS^a (1:0.96:0.64:0.96)
-IS	23.34±16.20	2.85-46.83	
-LS	34.90±22.15	1.92-72.82	
-AmB	36.23±18.80	1.24-65.29	
Toluene (n=)			
-J	35.28±22.87	10.36-84.44	AmB^a>LS^a >IS^a>J^a (1:0.80:0.79:0.78)
-IS	36.82±27.26	10.00-90.70	
-LS	37.13±30.16	7.15-101.12	
-AmB	46.67±28.99	8.78-102.82	
Ethylbenzene (n=)			
-J	5.01±2.15	3.42-10.15	LS^a >AmB^a >IS^a >J^a (1.12:1:0.87:0.78)
-IS	5.54±1.97	3.83-9.76	
-LS	7.18±7.07	1.94-26.56	
-AmB	6.39±4.00	3.33-16.90	
m,p-Xylene (n=)			
-J	6.55±2.07	4.03-10.06	AmB^a >IS^a>J^a>>LS^a (1:0.94:0.77:0.73)
-IS	8.00±4.12	4.74-15.98	
-LS	6.17±3.67	3.43-16.59	
-AmB	8.48±4.49	4.33-18.53	
o-Xylene (n=)			
-J	4.57±2.19	2.03-8.78	LS^a>AmB^a> J^a >LS^a (0.67:1:0.78:0.67)
-IS	4.84±1.68	3.27-6.33	
-LS	3.92±2.24	1.72-8.98	
-AmB	5.83±4.01	3.06-15.92	
Total-BTEX (n=)			
-J	69.67±32.62	16.63-118.93	AmB^a>LS^a> IS^a> J^a (1:0.86:0.69:0.69)
-IS	70.00±41.09	13.56-150.54	
-LS	87.21±39.96	41.65-175.06	
-AmB	100.91±35.04	63.50-177.91	

Remark: The character on the right of the workplace name show the comparable mean different among workers and J= janitor (n=12), IS=Incense seller (n=12), LS = Lottery seller (n=12), AmB= Ambient position (n=12)

Comparing worker exposure to BTEX from TMB and KW temple, all of 8-h average BTEX concentration at TMB was totally higher than KW temple. The janitor at TMB was exposed the highest concentration of benzene and 3.25-, 2.47-, 2.35-fold higher than Thai folk dancer, guard and ambient position, respectively. Comparing with the KW temple, ambient position was exposed the highest concentration of benzene as 36.23 $\mu g/m^3$ which 2.96-fold lower than the janitor at TMB. On the other hand, janitor at KW temple was exposed benzene concentration 4.53-, and 1.53-fold lower than janitor at TMB and ambient position at KW temple. The difference in the benzene concentration exposed to the janitors at the two places might arise from the different configuration of the sampling position (Figure 3.2 in chapter III) as we could not install sampling equipment at the center of the KW temple.

The Thai folk dancer was exposed the highest concentration of ethylbenzene and 2.45-fold higher than the highest concentration at KW temple. Guard at TMB also exposed in high concentration of toluene but 1.16-,1.19 -fold lower than janitor and the ambient position at TMB. The incense seller at TMB was exposed to the lowest concentration of benzene of both places at 23.34 $\mu g/m^3$. The janitor at KW temple was exposed to the lowest concentration of toluene, ethylbenzene, and o-xylene as 35.27, 5.01, and 4.57 $\mu g/m^3$, respectively. For m,p-xylene exposure, the lottery seller at KW temple was exposed the lowest concentration of both places at 6.17 $\mu g/m^3$. The ambient position of both places was exposed the highest concentration of toluene and m,p-xylene as 121.25 and 27.52 $\mu g/m^3$, for TMB and 46.67 and 8.48 $\mu g/m^3$ for KW temple, respectively.

The ambient background position of these worship places were compared with the previous study which performed in an urban atmosphere in Hong Kong (Lee *et al.*, 2002), in Vietnam (Truc and Oanh, 2007). The ambient position at TMB and KW temple was exposed to benzene higher than the heavy traffic area in Hong Kong which the average concentration of 45.63 $\mu g/m^3$ and 15.11 $\mu g/m^3$, respectively. For toluene, the average concentration of TMB and KW temple was 1.13- and 2.94-fold lower than Hong Kong (137.15 $\mu g/m^3$). For toluene exposure, toluene exposure level of janitor and ambient position at TMB (118.55 and 121.26 $\mu g/m^3$) was 1.06- and 1.08-fold higher than the average concentration of peak-hour roadside in Vietnam (112 $\mu g/m^3$) but lower than in Hong Kong (137.15 and 139.35 $\mu g/m^3$). For ethylbenzene exposure, the exposure level of TMB and KW temple was lower than Hong Kong and Vietnam at 24.68 and 30 $\mu g/m^3$, respectively.

4.3 Comparison of the BTEX concentrations between weekend and weekday

The 8-h average BTEX concentrations on weekend and weekday of TMB (n=14) and the KW temple (n=12) are shown in Figure 4.4 and Table 4.4. The 8-h average BTEX concentration on weekend at TMB was 64.04 (10.13-162.10), 91.53 (19.19-172.70), 10.29 (2.71-36.70), 15.78 (5.78-43.16), 10.65 (3.17-29.88), and 189.85 (83.55-379.42) µg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration in weekday at TMB was 52.36 (5.94-261.20), 102.53 (13.37-256.76), 20.19 (3.23-72.31), 27.85 (0.83-72.61), 12.29 (0.82-43.79), and 233.22 (50.54-606.08) µg/m^3 for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively.

At the TMB, counter to expectations, the 8-h average concentration of toluene, ethylbenzene, m,p-xylene, and o-xylene on the weekdays were 120.53, 20.19, 7.85, and 12.29 µg/m^3 and 1.32, 1.96, 1.76, and 1.15 fold higher, respectively, than those on the weekend. There were statistically significantly different ($p < 0.05$) for toluene, m,p-xylene and ethylbenzene using compare mean Paired-sample T test and 2-related sample, SPSS 17.0 for Window (for comparing the mean different between two sample groups). Thus, only benzene was slightly (1.22-fold) but not significantly higher on the weekend than the weekdays.

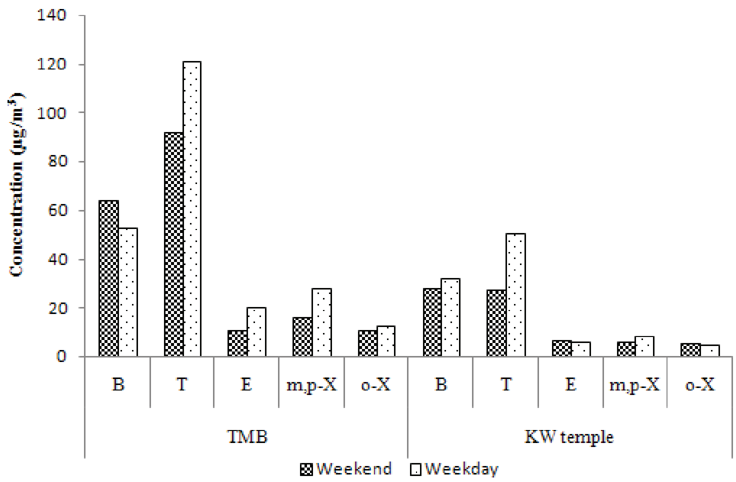


Figure 4.4 The 8-h average BTEX concentrations on the weekend and weekdays at the Tao Maha Brahma (TMB) and Kanlayanamit Woramahawiharn (KW) temples.

The 8-h average BTEX concentration on weekend at KW temple was 27.61 (2.02-51.03), 27.33 (7.35-51.15), 6.55 (1.94-26.56), 5.98 (3.43-11.74), 5.42 (1.72-15.93), and 189.85 (83.55-379.42) μg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration in weekday at KW temple was 31.80 (1.24-72.82), 50.39 (7.15-102.82), 5.88 (3.42-12.98), 8.19 (4.06-18.53), 4.37 (2.03-7.48), and 95.67 (31.62-177.91) μg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX , respectively.

In contrast, all of the 8-h average concentration of benzene, toluene, and m,p-xylene on the weekdays at the KW temple were 31.80, 50.39 and 8.19 μg/m^3 and 1.15-, 1.84-, and 1.37-fold higher than those on the weekend for benzene, toluene, m,p-xylene, respectively. Only the 8-h average concentration of ethylbenzene and o-xylene (6.55 and 5.42 μg/m^3) on weekend that 1.12- and 1.24-fold higher than weekday. There was no significantly different ($p < 0.05$) between the 8-h average BTEX concentration of weekend and weekday using compare mean Paired-sample T test, SPSS 17.0 for Window. The mean difference between BTEX concentration of TMB and KW temple was summarized in Table 4.4 and the detail of statistical analysis was shown in Appendix F.

Comparing the 8-h average concentration of weekend and weekday at TMB and KW temple, most of BTEX concentration of weekday of both places was higher than weekend. The 8-h average concentration of toluene, and m,p-xylene on weekday at TMB was 2.39-and 3.40-fold higher than weekday at KW temple. The 8-h average concentration on weekend at TMB of benzene was exposed 1.22-, 2.01-fold higher than the 8-h average concentration on weekday at TMB (52.36 μg/m^3) and KW temple (31.80 μg/m^3), respectively. The 8-h average concentration on weekday at TMB of ethylbenzene was exposed the highest concentration as 20.19 μg/m^3 and 3.08-fold higher than the 8-h average concentration on weekend at KW temple (6.55 μg/m^3). For o-xylene exposure, the 8-h average concentration on weekday was the highest concentration as 12.29 μg/m^3 and 2.27-fold higher than the 8-h average concentration on weekend at KW temple (5.42 μg/m^3). The higher average BTEX concentrations on the weekdays 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. 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 weekdays but removed every hour on weekend.

Table 4.4 The average BTEX concentration during weekend and weekday at TMB and KW temple

Compound	Average concentration ±SD(μg/m^3)		Concentration range (μg/m^3)	
	Weekend	Weekday	Weekend	Weekday
Benzene				
-TMB	64.04±47.00	52.36±49.98	10.13-162.10	5.94-261.20
-KW temple	27.61±16.35	31.80±22.91	2.02-51.03	1.24-72.82
Toluene				
-TMB	91.53±45.43*	120.53±64.17*	19.19-172.70	13.37-256.76
-KW temple	27.33±13.10	50.39±31.85	7.35-51.15	7.15-102.82
Ethylbenzene				
-TMB	10.29±7.95**	20.19±21.25**	2.71-36.70	3.23-72.31
-KW temple	6.55±6.42	5.88±2.44	1.94-26.56	3.42-12.98
m,p-Xylene				
-TMB	15.78±8.19*	27.85±16.58*	5.78-43.16	0.83-72.61
-KW temple	5.98±2.21	8.19±4.34	3.43-11.74	4.06-18.53
o-Xylene				
-TMB	10.65±7.65	12.29±9.70	3.17-29.88	0.82-43.79
-KW temple	5.42±4.01	4.37±1.59	1.72-15.93	2.03-7.48
Total BTEX				
-TMB	189.85±82.85*	233.22±118.56*	83.55-379.42	50.54-606.08
-KW temple	63.83±26.60*	95.67±43.39*	13.56-109.16	31.62-177.91

Remark: * significantly different ($p < 0.05$) using compare mean Paired-sample T test, SPSS 17.0 for Window, ** significantly different ($p < 0.05$) using compare mean 2-related sample (for non-parametric), SPSS 17.0 for Window. n_{TMB}= 14, n_{KW} = 12

Comparing the 8-h average BTEX concentrations of the weekend and weekdays of this study with the result of two temples in Hong Kong (Wang *et al.*, 2007) revealed that the average benzene concentration on the weekend at the TMB (64.04 μg/m^3) was 1.34-fold lower than at the corresponding indoor temple in a semi-urban area in Hong Kong (85.8 μg/m^3). While the average weekend benzene concentration at the KW temple (31.80 μg/m^3) was 2.68-fold lower than the semi-open area but the larger temple in Hong Kong. However, the average toluene concentrations in the TMB and KW temples (91.53 and 27.33 μg/m^3)

were 1.05- and 5.0-fold higher than those in the two temples in Hong Kong (87 and 5.46 μg/m^3).

4.4 Comparison of the BTEX concentrations between TMB and KW temple

The 8-h average BTEX concentration of TMB (n=38) and KW temple (n=34) was shown in Figure 4.5 and Table 4.5. The 8-h average concentration at TMB was 57.28 (0.64-261.30), 105.77 (13.37-256.77), 15.33 (2.71-72.31), 21.82 (0.83-72.61), 11.50 (0.82-73.79), and 207.39 (0.64-606.38) μg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX respectively. The 8-h average concentration at KW temple was 29.80 (1.24-72.82), 39.12 (7.15-102.83), 6.17 (1.94-26.56), 7.27 (3.43-18.53), 4.80 (1.72-15.93), and 80.10 (13.56-177.91) μg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX respectively.

At TMB, toluene was found the highest concentration as 105.77 μg/m^3 follow by benzene (57.28 μg/m^3), m,p-xylene (21.82 μg/m^3), ethylbenzene (15.33 μg/m^3), and o-xylene (11.50 μg/m^3). For KW temple, toluene was also found the highest concentration as 39.12 μg/m^3 but lower than the highest exposed of toluene at TMB (2.70 fold). Benzene also presented in high concentration next to toluene at the KW temple as 29.80 μg/m^3 and 1.92-fold lower than TMB. For ethylbenzene, m,p-xylene, o-xylene, the 8-h average concentration was 6.17, 7.27, and 4.80 μg/m^3, respectively, and 2.48-, 3.0-, 2.40-fold lower than TMB. There was a significantly different ($p < 0.05$) for all average BTEX concentration between TMB and KW temple using compare mean independent-sample T test, SPSS 17.0 for Window

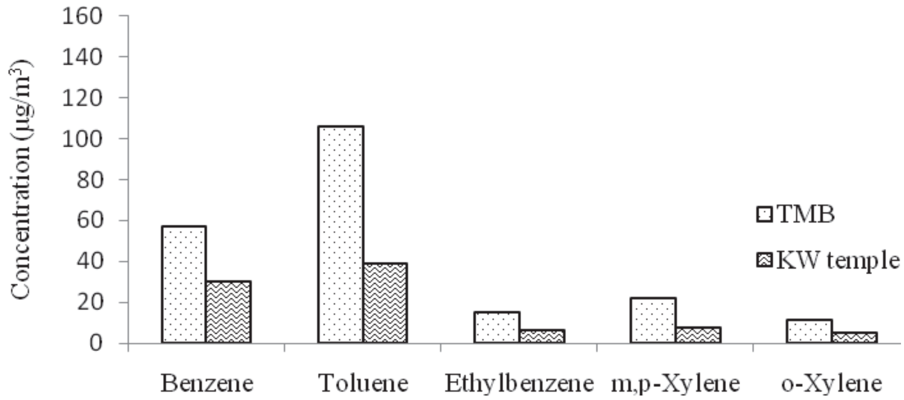


Figure 4.5 The 8-h average BTEX concentrations at the Tao Maha Brahma (TMB) and Kanlayanamit Woramahawiharn (KW) temples.

Table 4.5 The 8-h average BTEX concentrations and concentration range at the Tao Maha Brahma (TMB) and KW temple

Compound	Average concentration ±SD ($\mu g/m^3$)	Concentration range ($\mu g/m^3$)
Benzene		
- TMB	57.28±48.56*	0.64-261.30
- KW temple	29.8±19.94*	1.24-72.82
Toluene		
- TMB	105.77±56.82*	13.37-256.77
- KW temple	39.12±26.93*	7.15-102.83
Ethylbenzene		
- TMB	15.33±16.77*	2.71-72.31
- KW temple	6.17±4.54*	1.94-26.56
m,p-Xylene		
- TMB	21.82±14.31*	0.83-72.61
- KW temple	7.27±3.73*	3.43-18.53
o-Xylene		
- TMB	11.5±8.73*	0.82-73.79
- KW temple	4.8±2.80*	1.72-15.93
Total-BTEX		
- TMB	207.39±106.19*	0.64-606.38
- KW temple	80.1±39.23*	13.56-177.91

Remark: * significantly different ($p < 0.05$) using compare mean Independent sample T-test, SPSS 17.0 for Window, ** significantly different ($p < 0.05$) using compare mean 2-related sample (for non-parametric), SPSS 17.0 for Window. n_{TMB}= 38, n_{KW} = 34

4.5 Comparison of the BTEX concentrations among three seasons

The 8-h average BTEX concentration among three seasons (dry season, wet season, and cold season) at TMB was shown in Figure 4.6 and Table 4.6. The 8-h average BTEX concentration of dry season was 52.02 (7.80-162.11), 113.72 (45.70-256.76), 18.98 (2.71-72.31), 25.22 (10.34-72.61), 9.69 (3.41-29.88), and 219.62 (83.55-412.80) µg/m^3 for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of wet season was 58.10 (10.78-261.30), 138.45 (142.34-226.74), 17.79 (9.09-35.32), 23.70 (7.62-49.20), 14.17 (3.17-43.79), and 233.71 (160.74-606.08) µg/m^3 for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of cold season was 64.35 (11.64-135.86), 63.20 (13.37-139.24), 7.87 (3.23-22.83), 15.07 (0.83-46.54), 12.22 (0.82-30.83), and 162.71 (50.54-268.57) µg/m^3, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. While there was a significant difference in the toluene, ethylbenzene, m,p-xylene, and total BTEX average concentration among three seasons ($p < 0.05$) using compare mean one way ANOVA, SPSS 17.0 for Window and the detail of statistical analysis was shown in Appendix F.

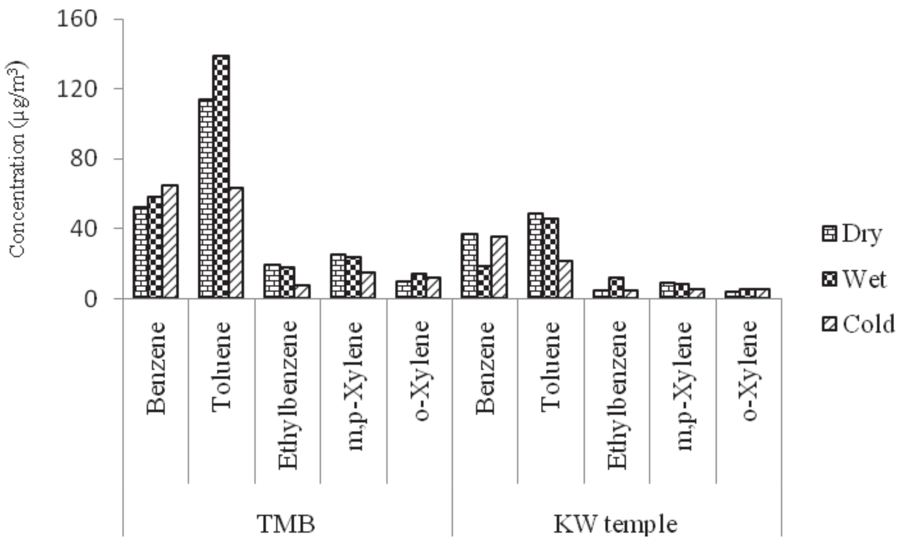


Figure 4.6 Comparison of the BTEX concentrations among three seasons

At TMB, toluene, and o-xylene was found the highest concentration in wet season at 138.45 (142.34-226.74) and 14.17 (3.17-43.79) µg/m^3, respectively, and

1.22- and 2.19-fold, 1.46- and 1.16-fold higher than dry season and cold season, respectively. For benzene, cold season had the highest concentration of 64.35 (11.64-135.86) μg/m^3 which 1.24- and 1.11-fold higher than dry season and wet season, respectively. The dry season had the highest concentration of ethylbenzene and m,p-xylene at 18.97 (2.71-72.31) and 25.22 (10.34-72.61) μg/m^3 which 1.08- and 1.87-fold higher and 1.07- and 2.41-fold higher than wet season and cold season, respectively.

Table 4.6 Comparison of the BTEX concentrations at TMB among three seasons

Compound	Average concentration ± SD (μg/m^3)	Concentration range (μg/m^3)	Concentration ranking (High to Low)
Benzene			
-Dry season	52.02±40.76	7.80-162.11	Cold^a > Wet^a > Dry^a
-Wet season	58.10±68.48	10.78-261.30	
-Cold season	64.35±36.23	11.64-135.86	
Toluene			
-Dry season	113.72±61.93	45.70-256.76	Wet^a >Dry^b > Cold^b
-Wet season	138.45±32.99	142.34-226.74	
-Cold season	63.20±40.30	13.37-139.24	
Ethylbenzene			
-Dry season	18.98±22.87	2.71-72.31	Dry^a >Wet^{ab} > Cold^b
-Wet season	17.79±8.82	9.09-35.32	
-Cold season	7.87±4.97	3.23-22.83	
m,p-Xylene			
-Dry season	25.22±15.21	10.34-72.61	Dry^a >Wet^{ab} > Cold^b
-Wet season	23.70±13.37	7.62-49.20	
-Cold season	15.07±12.00	0.83-46.54	
o-Xylene			
-Dry season	9.69±6.91	3.41-29.88	Wet^a > Cold^a >Dry^a
-Wet season	14.17±11.48	3.17-43.79	
-Cold season	12.22±8.80	0.82-30.83	
Total-BTEX			
-Dry season	219.62±105.56	83.55-412.80	
-Wet season	233.71±129.28	160.74-606.08	Wet^a > Dry^a > Cold^a
-Cold season	162.71±66.63	50.54-268.57	

Remark: The character on the right of the workplace name show the comparable mean different among worker (n= 14)

The 8-h average BTEX concentration among three seasons (dry season, wet season, and cold season) at KW temple was shown in Figure 4.6 and Table 4.7. The 8-

h average BTEX concentration of dry season was 36.73 (4.81-72.82), 48.66 (10.36-102.82), 4.38 (1.94-6.33), 8.81 (3.43-18.53), 3.67 (2.03-6.25), and 93.53 (13.56-177.91) $\mu g/m^3$ for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of wet season was 18.22 (1.24-51.03), 45.45 (11.24-100.56), 11.69 (5.22-26.56), 8.16 (4.06-13.44), 5.35 (2.38-7.47), and 75.66 (16.63-151.64) $\mu g/m^3$ for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. The 8-h average BTEX concentration of cold season was 35.22 (2.02-65.29), 21.66 (7.15-49.61), 4.40 (3.17-5.33), 5.44 (3.92-6.60), 5.59 (1.72-15.92), and 70.49 (26.95-93.79) $\mu g/m^3$, for benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, and total BTEX, respectively. While there was a significant difference in the toluene, ethylbenzene, m,p-xylene, and total BTEX average concentration among three seasons ($p < 0.05$) using compare mean one way ANOVA, SPSS 17.0 for Window and the detail of statistical analysis were shown in Appendix F.

At Kw temple, benzene, toluene , and m,p-xylene in dry season was found the highest concentration of 36.73 (4.81-72.82), 48.66 (10.36-102.82), and 8.81 (3.43-18.53) $\mu g/m^3$, respectively, which 2.02-and 1.04- , 1.07- and 2.25-, and 1.08– and 1.62-fold higher than wet season and cold season, respectively. The wet season had the highest concentration of ethylbenzene at 11.69 $\mu g/m^3$ which 2.67- and 2.66-fold higher than dry season and cold season. The cold season had the highest concentration of o-xylene at 5.59 $\mu g/m^3$ which 1.52- and 1.04-fold higher than dry season and wet season.

For TMB, the highest concentration in wet season might come from the amount of visitor which was the highest at peak day in wet season and for KW temple might be come from the amount of small size incense which ewas the highest in dry season. Morove, the different in traffic on each area might affect to BTEX concentration in both worship places. So the parameter of meteology such as wind direction, wind speed and humidity should be measure on the area for the futher study. From the study of Majumdar *et al*. (2011) also study about the seasonal level of BTEX in India, the results showed the toluene level of post monsoon season at industry and residential area had the highest concentration of 74 $\mu g/m^3$ which higher than summer and winter season. For benzene level, the post monsoon season also had the high level (68 µg/m^3) nearly to summer season (71 µg/m^3)which was the highest concentration.

Table 4.7 Comparison of the BTEX concentrations at KW temple among three seasons

Compound	Average concentration ± SD (µg/m^3)	Concentration range (µg/m^3)	Concentration ranking (High to Low)
Benzene			
-Dry season	36.73±19.11	4.81-72.82	Dry^a > Cold^a > Wet^b
-Wet season	18.22±18.17	1.24-51.03	
-Cold season	35.22±17.95	2.02-65.29	
Toluene			
-Dry season	48.66±28.83	10.36-102.82	Dry^a > Wet^a > Cold^b
-Wet season	45.45±27.58	11.24-100.56	
-Cold season	21.66±14.09	7.15-49.61	
Ethylbenzene			
-Dry season	4.38±1.40	1.94-6.33	Wet^a > Cold^b >Dry^b
-Wet season	11.69±6.60	5.22-26.56	
-Cold season	4.40±0.68	3.17-5.33	
m,p-Xylene			
-Dry season	8.81±5.06	3.43-18.53	Dry^a >Wet^{ab} > Cold^b
-Wet season	8.16±3.44	4.06-13.44	
-Cold season	5.44±0.84	3.92-6.60	
o-Xylene			
-Dry season	3.67±1.19	2.03-6.25	Cold^a > Wet^a >Dry^a
-Wet season	5.35±2.22	2.38-7.47	
-Cold season	5.59±3.64	1.72-15.92	
Total-BTEX			
-Dry season	93.53±52.12	13.56-177.91	Dry^a >Wet^a > Cold^a
-Wet season	75.66±36.17	16.63-151.64	
-Cold season	70.49±20.40	26.95-93.79	

Remark: The character on the right of the workplace name show the comparable mean different among worker (n= 12)

4.6 BTEX emission from incense burning in the chamber test

4.6.1 BTEX concentration from incense burning in the chamber test

The average BTEX concentration in an environmental chamber of incense burning which of the incense samples taken from TMB and KW temple was shown in Figure 4.7 and Table 4.8. The large incense from KW temple had the highest concentration of benzene at 12.87 mg/m^3 which 1.42-fold, 21.81-, and 6.47-fold higher than small incense (KWS) (0.59 mg/m^3), medium incense (KWM) (1.99 mg/m^3) from KW temple and TMB incense (9.08 mg/m^3), respectively. For toluene, large incense from KW temple had the highest concentration of 5.18 mg/m^3 and 1.72-, 6.16-, 7.4-fold higher than TMB incense (3.02 mg/m^3), small incense (0.84 mg/m^3) and medium incense (0.7 mg/m^3) of KW temple. The large incense from KW temple also had the highest concentration of ethylbenzene, m,p-xylene, and o- xylene at 0.23, 0.33, and 0.12 mg/m^3 and 10-, 3.15-fold higher for ethylbenzene, 1.65-, 4.23-fold higher for m,p-xylene, and 120-, and 3.53-fold higher than small incense and medium incense. However, there was no detected in ethylbenzene, m,p-xylene, and o- xylene from the incense from TMB.

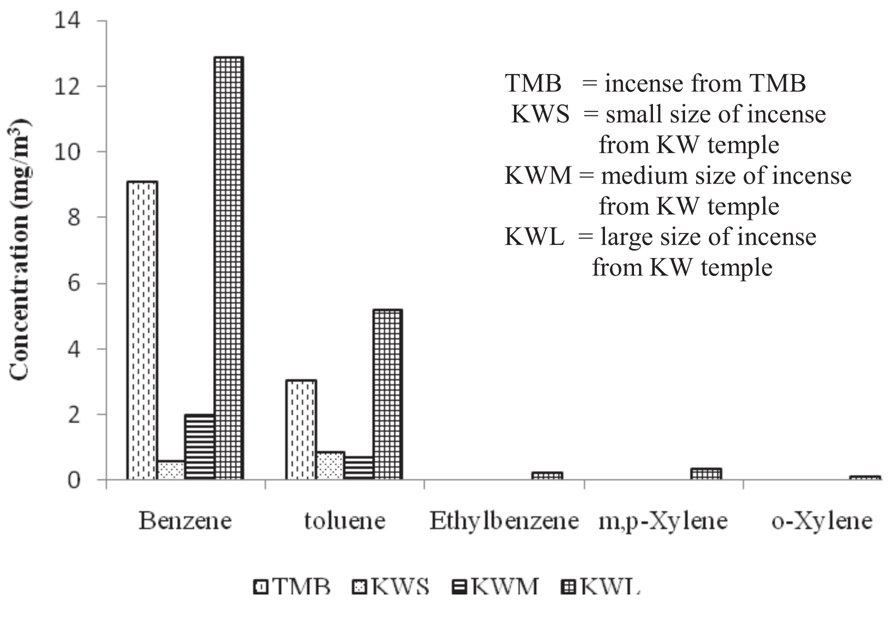


Figure 4.7 The average BTEX concentration from incense smoke in an environmental chamber from TMB and KW temple (mg/m^3).

Table 4.8 The average BTEX concentration from incense smoke in an environmental chamber (mg/m^3)

BTEX	TMB (n=3)	KWS (n=3)	KWM (n=3)	KWL (n=3)	Mean±SD
Benzene	9.09±0.75	0.59±0.21	1.99±0.63	12.87±1.92	6.13±5.83
Toluene	3.02±1.91	0.84±1.02	0.70±1.22	5.18±0.83	4.28±2.11
Ethylbenzene	nd	0.023±0.035	0.073±0.12	0.23±0.10	1.50±0.11
m,p-Xylene	nd	0.020±0.035	0.078±0.13	0.33±0.16	0.13±0.16
o-Xylene	nd	0.0011±0.0018	0.034±0.052	0.12±0.057	0.097±0.06
Total-BTEX	12.11	1.47	2.88	18.73	12.07±8.13

Remark: nd = not detected, TMB = incense from TMB, KWS = small size of incense from KW temple, KWM = medium size of incense from KW temple, KWL = large size of incense from KW temple.

For all types of incense, The average BTEX concentration as shown in Figure 4.8 was in range of 0.097-6.13 mg/m^3 and the highest average concentration was benzene (6.13 mg/m^3) follow by toluene (4.29 mg/m^3), ethylbenzene (1.44 mg/m^3), m,p-xylene (0.12 mg/m^3) , and o-xylene (0.097 mg/m^3).

Comparing the average BTEX concentration of incense burning from the environmental chamber in this study with the previous study which performed in the same chamber with some incenses sold in Thailand by Tawanwong and Lorjitsieng (2010) and the study in Hong Kong (Lee and Wang, 2004). The average concentration of benzene was 1.43-fold lower than the study of some incenses in Thailand and 52.35-fold higher than the study in Hong Kong. The average concentration of toluene, ethylbenzene, m,p-xylene, and o-xylene was1.78-, 1.74-, 2.45- and1.13-fold higher than those of the previous study in Thailand. Moreover, all of average BTEX concentration from this study was higher than the study in Hong Kong. This might be explained by the chamber test condition. Due to the chamber used in this study was the same chamber as studied by Tawanwong and Lorjitsieng (2010) and the type of incense was similar which made by Thai manufacturing, the concentration was then found in the same range with this study (0.053-8.777 mg/m^3). For the study in Hong

Kong, the environmental chamber was bigger (18.26 m^3) and there was an air exchange in the chamber which could make the BTEX concentration lower than the average concentration in this study.

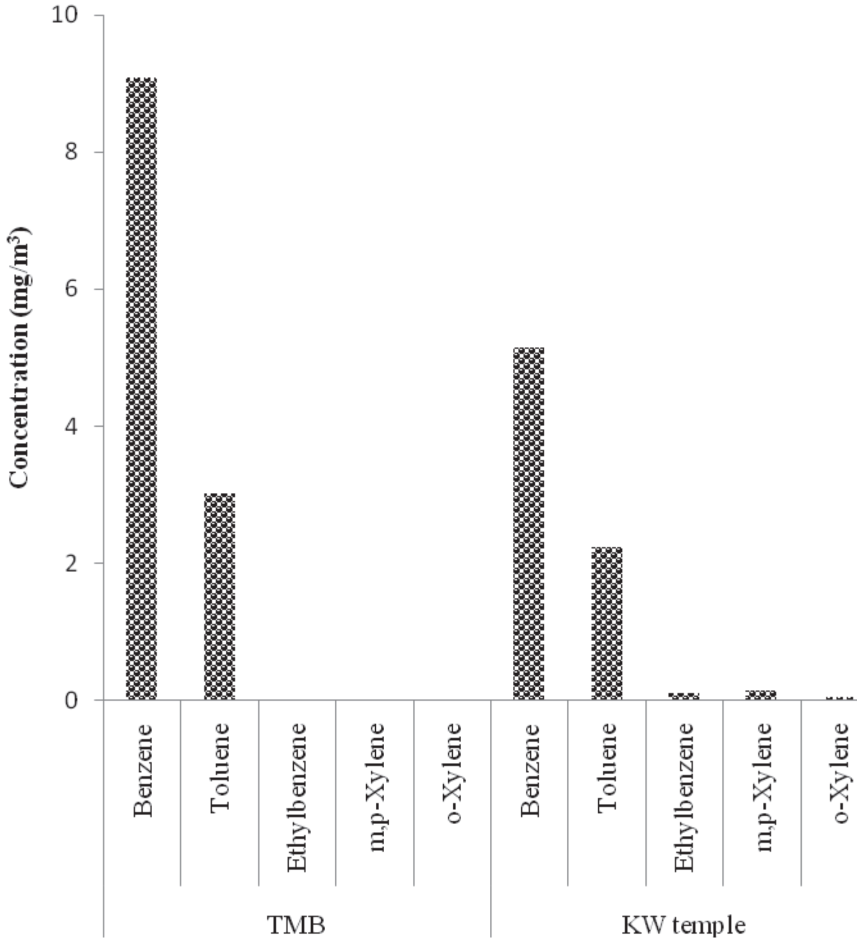


Figure 4.8 The average BTEX concentration of all type of incense buring from TMB and KW temple

4.6.2 Emission rate of BTEX from incense burning

The emission rate of BTEX from 1 g of burnt incense is shown in Figure 4.9 and Table 4.9. The emission rate of benzene of TMB incense had the highest level of 57.4 µg/g, and 5.74-, 1.15-, 1.41- fold higher than small incense, medium incense, and large incense of KW temple, respectively. For toluene, TMB incense was also had the highest emission rate at 24.26 µg/g, which 1.70-, 13.7-, and 1.48-fold higher than those incenses of KW temple, respectively. For ethylbenzene, m,p-xylene, and o-xylene, small incense at KW temple had the highest emission rate of 4.13, 2.40, and 2.05 µg/g, respectively, which 3.72- and 5.66-fold higher for ethylbenzene, 2.58- and 2.29-fold higher for m,p-xylene, and 2.53- and 5.54-fold highe for o-xylene, than medium and large incense from KW temple, respectively.

Comparing the average BTEX concentration of incense burning from the environmental chamber with the previous studies which performed in Thailand by Tawanwong and Lorjitsieng (2010) and in Hong Kong (Lee and Wang, 2004). The emission rate of benzene in this study was lower than the previous study in Thailand (73.93-114.70 µg/g) and Hong Kong (175-1252 µg/g). For toluene, ethylbenzene, m,p-xylene, and o-xylene, the emission rate was in the same range with the study in Thailand as 19.01-37.37, 0.63-1.06, 0.36-0.72, 0.65-1.04 µg/g, for toluene, ethylbenzene, m,p-xylene, o-xylene, respectively. However, the BTEX emission rate in this study was totally lower than in Hong Kong as 175-1252, 39-661, nd-2048, nd-58, nd -1764 µg/g, for benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene, respectively.

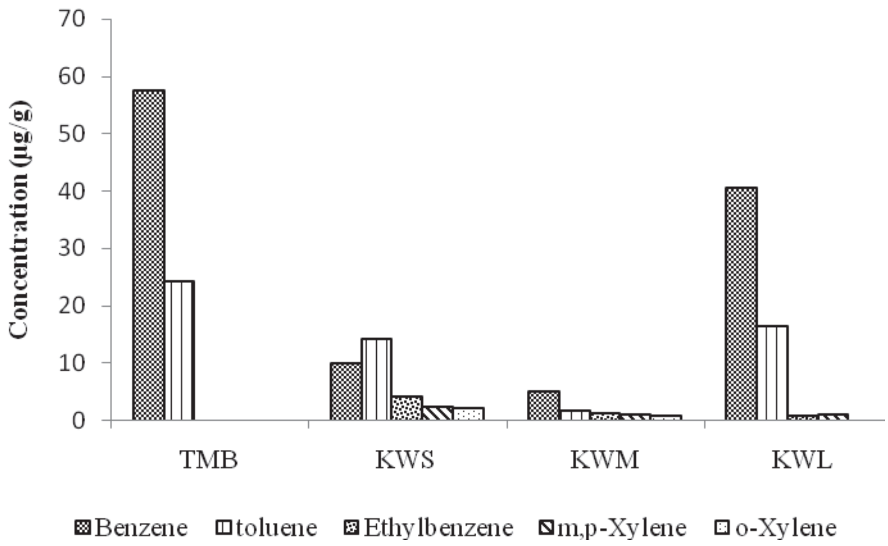


Figure 4.9 The BTEX emission rate of incense from TMB and KW temple in the chamber test. TMB = incense from TMB, KWS = small size of incense from KW temple, KWM = medium size of incense from KW temple, KWL = large size of incense from KW temple.

Table 4.9 The BTEX emission rate of incense (μg/g) from TMB and KW temple in the chamber test

BTEX	TMB (n=3)	KWS (n=3)	KWM (n=3)	KWL (n=3)	Means±SD
Benzene	57.40	9.95	5.01	40.54	28.23±25.00
Toluene	24.26	14.23	1.77	16.36	21.18±9.31
Ethylbenzene	nd	4.13	1.11	0.73	7.82±1.81
m,p-Xylene	nd	2.40	0.93	1.05	1.30±0.99
o-Xylene	nd	2.05	0.81	0.37	0.95±0.89
Total-BTEX	81.66	32.76	9.63	59.04	23.29±31.30

Remark: nd = not detected, TMB = incense from TMB, KWS = small size of incense from KW temple, KWM = medium size of incense from KW temple, KWL = large size of incense from KW temple.

4.7 Benzene and toluene concentration ratio (B:T) of TMB and KW temple

The main BTEX components found (from incense burning) in the two worship places 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 as in Table 4.10 between each other as well as with the data obtained by another study at two temples in Hong Kong (Wang et al., 2007) and from the direct burning of this study and the previous study in Thailand or Hong Kong incense in an environmental chamber (Lee and Wang, 2004, Tawanwong and Lorjitsieng, 2010). 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 (0.40-1.35). Thai folk dancer and ambient position were in similar range of (0.054-1.51) and (0.16-1.15) respectively and guard had the range of ratio of 0.18-1.29. In contrast, for all B:T ratios at the KW temple were in the same broad range of about 0.04-3.98, although this covered the highest range found at the TMB. The highest B:T ratio at KW temple was lottery seller at 0.16-3.98 follow by ambient position at 0.20-3.26, janitor at 0.04-2.73, and incense seller at 0.11-1.38.

Table 4.10 Comparison of benzene and toluene ratio (B:T) of workers of the TMB and KW temple

Sampling/Location	City/Country	Range of B:T ratio	Reference
Tao Maha Brahma	TD	0.054-1.51	This study
	J	0.40-1.35	
	G	0.18-1.29	
	AmB	0.16-1.15	
KW temple	J	0.04-2.73	This study
	IS	0.11-1.38	
	LS	0.16-3.98	
	AmB	0.20-3.26	
Temple	Hong Kong	0.71-3.17	Wang *et al*., 2007
Environmental chamber	Incense from TMB	1.90-4.89	This study
	Incense from KW temple (3 types)	0.99-2.58	
	Thailand	3.07-5.58	Tawanwong and Lorjitsieng, 2010
	Hong Kong	0.77-5.64	Lee and Wang ,2004

Remark: TD= Thai folk dancer (n=14), J= janitor (n=14), G= guard (n=14), IS=Incense seller (n=12), LS = Lottery seller (n=12), AmB= Ambient position (n=12)

The B:T ratio of worker was compared to B:T ratio of the ambient as shown in Table 4.11. At TMB, the position of janitor had the highest average ratio of 2.39 follow by Thai folk dancer (1.76) and guard (1.20). At KW temple, the position of incense seller had the highest average ratio of 3.26 follow by lottery seller (1.88) and janitor (0.88). All the average of B:T ratio of worker compared to B:T of ambient was higher than 1 which meant the B:T ratio of workers was higher than the ratio in ambient background in any position.

Table 4.11 The ratio of $B:T_{workers}$ compare to $B:T_{AmB}$ at TMB and KW temple on sampling day.

Sampling date	TMB			KW temple		
	TD	J	G	J	IS	LS
Dry season	0.22	2.55	0.61	0.97	1.16	1.24
	5.65	1.97	1.58	0.34	0.58	0.30
	2.54	3.38	1.47	1.77	0.45	0.99
	1.98	4.27	1.61	3.64	0.60	1.99
	1.27	1.92	1.55	-	-	-
Wet season	0.28	3.25	0.74	1.01	0.48	2.01
	0.16	1.55	0.53	0.97	1.31	1.54
Cold season	0.5	2.9	1.35	0.17	0.20	0.82
	1.24	1.28	0.96	0.54	1.30	3.07
	4.16	2.03	0.9	0.04	0.97	0.88
	1.32	1.18	1.85	0.84	3.26	1.88
mean±SD	1.76±1.75	2.39±0.97	1.20±0.46	1.03±1.04	1.03±0.87	1.47±0.80

Remark: TD= Thai folk dancer (n=11), J= janitor (n=11), G= guard (n=11), IS=Incense seller (n=10), LS = Lottery seller (n=10), AmB= Ambient position (n=10)

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 in the temples in Hong Kong (0.71-3.17) (Table 4.10). However, the B: T ratios rise up to 4.89, 5.58 and 5.64 for this study, 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).

4.8 General information of the workers at worship places

The general information of the worker at worship places is shown in Table 4.12. In the worship places ,the majority age of all workers was in the range of 41-50 years old. The weight of male and female were over 70 kilogram. The working period of the workers was over 8 hours and the exposure duration was 5-15 years. The majority work of participant was cleaning area and collected the incense the worship place. Most of worker in the worship place never received the annually medical examination. The symptom of irritate nose and eyes and headache were mostly found in the workers. Most of workers in the worship places did not wear personal protection equipment.

Table 4.12 The general information of worker at the worship place

Characteristis	Worship places workers											
	J (n=10)		G (n=2)		TD (n=2)		IS (n=1)		LS (n=2)		Other (n=7)	
	n	%	n	%	n	%	n	%	n	%	n	%
age												
31-40	3	30	-		2	100	-		-		2	28.57
41-50	5	50	1	50	-		-		1	50	2	28.57
51-60	2	20	1	50	-		-		1	50	3	42.86
>60							1	100	-		-	
Body weight (Kg)												
>50	1	10	-		1	50	-		-		-	
51-60	1	10	1	50	1	50	-		1	50	3	42.86
61-70	1	10	-		-		1	100	1	50	1	14.29
>70	7	70	1	50	-		-		-		3	42.86
Working period (hr)												
≤8 hr	5	50	-		2	100	1	100	-		2	28.57
>8 hr	5	50	2	100	-		-		2	100	5	71.43
Exposure duration (year)												
<5	5	50	2	100	-		-		-		1	14.29
5-15	2	20	-		2	100	1	100	2	100	2	28.57
15-30	2	20	-		-		-		-		3	42.86
>30	1	10	-		-		-		-		1	14.29
Responsibility												
Collecting incense	7	70	-		-		-		-		1	14.29
Trading	-		-		-		1	100	2	100	3	42.86
Security and parrking lot	-		2	100	-		-		-		2	28.57
Thai Dancing	-		-		2	100	-		-		-	
Cleaning area	10	100	-		-		-		-		3	42.86

Table 4.12 (cont.)

Characteristis	Worship places workers											
	J (n=10)		G (n=2)		TD (n=2)		IS (n=1)		LS (n=2)		Other (n=7)	
	n	%	n	%	n	%	n	%	n	%	n	%
Annually medical examination												
never	4	40	2	100	-		-		2	100	5	71.43
>3 month	2	20	-		2	100	1	100	-		-	
3-6 month	-		-		-		-		-		-	
6-1 year	1	10	-		-		-		-		1	14.29
> 1 year	3	30	-		-		-		-		1	14.29
Symtom												
Headache	8	80	1	50	-		1	100	-		5	71.43
Vomit	-		-		-		-		-		-	
Irritating	8	80	1	50	2	100	1	100	2	100	5	71.43
Nose bleed	-		-		-		-		-		-	
Fatigue	3	30	-		-		-		-		1	14.29
Having tight chest	5	50	1		-		1	100	-		-	
Faint	-		-		-		-		-		-	
Protection												
No protection	6	60	2	100	2	100	1	100	2	100	-	
Face mask	3	30	-		-		-		-		7	100

Remark: TD= Thai folk dancer, J= janitor, G= guard, IS=Incense seller , LS = Lottery seller , AmB= Ambient position.

4.9 Potential health risk assessment of the workers at two worship places

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 were summarized in Tables 4.13, 4.14, 4.16 and 4.17, respectively. The average chronic daily intake (CDI) levels of workers at the TMB for benzene, ethylbenzene was in the range of 1.4-3.8 and 0.063-2.72, 2.0-130 and 0.13-2.22, and 1.53-7.58 and 0.065-3.29 µg/kg.day, for Thai folk dancer , janitor, and guard, respectively. The total chronic daily intake (CDI) levels of workers at TMB was 1.27, 6.57, and 4.34 µg/kg.day, for Thai folk dancer , janitor, and guard, respectively. For KW temple, the average chronic daily intake (CDI) levels of workers for benzene and ethylbenzene was in the range of 0.076-1.55 and 1.1-3.43, 0.13-3.49 and 1.82-4.32, and 0.036-4.86 and 0.066-8.99 µg/kg.day, for janitor, incense seller, and lottery seller, respectively. The total chronic daily intake (CDI) levels of workers at KW temple was 1.24, 1.52, and 1.57 µg/kg.day, for janitor, incense seller, and lottery seller, respectively.

Table 4.13 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

Carcinogenic compounds	TMB		Carcinogenic compounds	KW temple	
	CDI (µg/kg.day)	95% CI of LCR (x 10^{-6})		CDI (µg/kg.day)	95% CI of LCR (x 10^{-6})
Benzene			Benzene		
TD	1.4-3.8	3.79-103	J	0.076-1.55	1.72-74.3
J	2.0-130	54.2-345	IS	0.13-3.49	3.44-60.7
G	0.0015-0.0076	41.8-207	LS	0.036-4.86	1.77-89.9
Ethylbenzene			Ethylbenzene		
TD	0.063-2.72	0.29-5.99	J	1.1-3.43	0.45-1.32
J	0.13-2.22	0.50-0.13	IS	1.82-4.32	0.85-5.71
G	0.065-3.29	1.38-18.7	LS	0.066-8.99	0.32-3.46
Total	0.0075-0.016	2.00-428	Total	0.00021-0.0071	0.80-194

Remark: TD= Thai folk dancer (n=24), J= janitor (n=24), G= guard (n=24), IS=Incense seller (n=24) , LS = Lottery seller (n=24).

The 95 % confidential interval (CI) of lifetime cancer risk of benzene and ethylbenzene of the worker at the TMB was in the range of 3.79x10^{-6}-103 x10^{-6} and 0.29x10^{-6}-5.99 x10^{-6}, 54.2x x10^{-6}-345 x10^{-6} and 0.50x10^{-6} -0.13 x10^{-6}, and 41.8 x10^{-6} - 207 x10^{-6} and 1.38 x10^{-6} -18.7x10^{-6}, for Thai folk dancer, janitor, guard, respectively. The total risk of the worker at TMB was 3.11, 13.24, and 7.93 x10^{-6} for Thai folk dancer, janitor, guard, respectively (Table 4.14). The 95 % confidential interval (CI) of lifetime cancer risk of benzene and ethylbenzene of the worker at the KW temple was in the range of 0.29-5.99 and 0.45-1.32, 0.50-0.13 and 0.85-5.71, and 1.38-18.7 and 0.066 x10^{-6}-8.99 x10^{-6}, for janitor, incense seller, and lottery seller, respectively. For benzene, the janitor at TMB had the highest lifetime cancer risk of all workers from both places which 4.41 and 1.7-fold higher than guard and Thai folk dancer, respectively. The lifetime cancer risk of workers at TMB was totally higher than those of KW temple. For etylbenzene, guard had the highest lifetime cancer risk at TMB which 1.86 and 1.10 –fold higher than Thai folk dancer and janitor. The highest lifetime cancer risk at KW temple was found for the incense seller ($0.85x10^{-6}$-$5.71x10^{-6}$) which 4.32- and 1.65-fold higher than janitor and lottery seller and also in the same level of Thai folk dancer at TMB (0.29-5.99). The total CDI and 95% of LCR of the worker at TMB was 2.25-and 2.21- fold higher than that of KW temple.

Table 4.14 Total 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

Worker	TMB		Worker	KW temple	
	CDI (µg/kg.day)	LCR (x 10^{-6})		CDI (µg/kg.day)	LCR (x 10^{-6})
TD	1.27	3.11	J	1.24	2.87
J	6.57	13.24	IS	1.52	3.52
G	4.34	7.93	LS	1.57	3.69

Remark: TD= Thai folk dancer (n=24), J= janitor (n=24), G= guard (n=24), IS=Incense seller (n=24) , LS = Lottery seller (n=24).

Correspondingly, the lifetime cancer risks (LCR) of exposure to benzene and ethylbenzene of total workers was calculated in percentage of higher and lower than 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) (USEPA, 1989) as shown in Figure 4.10. The workers amount at the risk higher than acceptable criteria of 10^{-6} was found at 100 % ($1.25x10^{-6}$-3.45×10^{-4}) and 83.82 % ($2.91x10^{-7}$-$1.87x10^{-5}$), for TMB, and 100% ($1.30x10^{-6}$-$8.99x10^{-5}$) and 42% ($3.29x10^{-7}$-$5.71x10^{-6}$), for KW temple. Eventhough, the KW temple was located in outer city and less traffic than TMB, the lifetime cancer risk of benzene was still over acceptable criteria of 10^{-6}, as well as for ethylbenzene, the lifetime cancer risk of the workers at KW temple was 1.9-fold lower than the TMB which of 83.82 % higher than acceptable criteria.

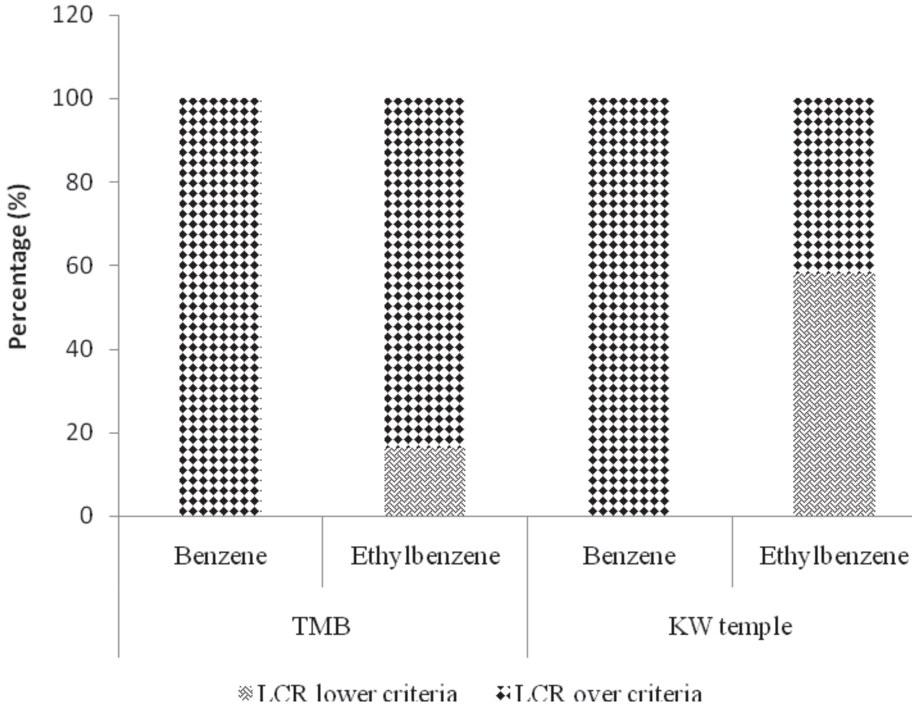


Figure 4.10 Percent distribution of total lifetime cancer risk of the worker at TMB and KW temple

The risk estimating from the actual exposure duration of the worker as collected from questionnaire (i.e. 5 years and 15 years) at TMB and KW temple as shown in Table 4.15. The cancer risk of the workers exposure to benzene and ethylbenzene for 5 years at the TMB was in the range of 0.63x10^{-6}-17.17 x10^{-6} and 0.074x10^{-6}-0.99 x10^{-6}, 4.88x10^{-6} -57.40 x10^{-6} and 0.084x x10^{-6}-2.24 x10^{-6}, and 4.88x10^{-6}-34.50 x10^{-6} and 0.14 x10^{-6}-3.12 x10^{-6}, for Thai folk dancer, janitor, and guard, respectively. The cancer risk of the workers exposure benzene and ethylbenzene at the TMB was in the range of 1.90 x10^{-6}-51.50 x10^{-6} and 0.15 x10^{-6}-2.99 x10^{-6}, 14.6 x10^{-6}-172 x10^{-6} and 0.25 x10^{-6}-6.72 x10^{-6}, and 14.6 x10^{-6}-103 x10^{-6} and 0.43 x10^{-6}-9.36 x10^{-6}, for Thai folk dancer, janitor, and guard, respectively. The 5 years exposure to benzene and ethylbenzene of the worker at KW temple would have the cancer risk in the range of 0.86 x10^{-6}-50.3 x$10^{-6}$and 0.29 x10^{-6}-1.15 x10^{-6}, 1.72 x10^{-6}-30.3 x$10^{-6}$and 0.22 x10^{-6}-0.83 x10^{-6}, and 0.88 x10^{-6}-44.9 x10^{-6} and 0.13 x10^{-6}-1.73 x10^{-6}, for janitor, incense seller, and lottery seller, respectively. Regarding to 5 years exposure to benzene and ethylbenzene the workers amount at the cancer risk higher than acceptable criteria of 10^{-6} was decreased to 94.74 % ($6.31x10^{-7}$-$5.74 x 10^{-5}$) and 3.63 % ($4.85x10^{-8}$-$3.12x10^{-6}$), respectively, for TMB, and 84.21% ($1.51x10^{-7}$-$1.49x10^{-5}$) and 0% ($4.21x10^{-8}$-$5.77x10^{-7}$), repectively, for KW temple. As for 15 years exposure, the workers amount at the cancer risk higher than acceptable criteria of 10^{-6} was still found at 100 % ($1.46x10^{-6}$-$1.72 x 10^{-4}$) and decreased to 36.84 % ($1.46x10^{-7}$-$9.35x10^{-6}$), respectively, for TMB, and became to 96.49% ($8.59x10^{-7}$-$5.02x10^{-5}$) and 3.03% ($1.26x10^{-7}$-$1.73x10^{-6}$),respectively, for KW temple. From the risk estimation scenarios of 5 and 15 years exposure, the results show that the number of workers at the risk higher than an acceptable level (10^{-6}) was decreased especially for ethylbenzene. Therefore, the standard value of exposure duration as 30 years might cause an overestimation of the cancer risk for the workers.

Table 4.15 Cancer risk (LCR) of workers' exposure to BTEX at the Tao Maha Brahma (TMB) and Kanlayanamit Woramahawiharn (KW) temples in Bangkok, Thailand in 5 years and 15 years.

Carcinogenic compounds	TMB		Carcinogenic compounds	KW temple	
	$CR_{5\ year}$ (x 10^{-6})	CR_{15year} (x 10^{-6})		$CR_{5\ year}$ (x 10^{-6})	CR_{15year} (x 10^{-6})
Benzene			Benzene		
TD	0.63-17.17	1.90-51.50	J	0.15-12.39	0.86-50.3
J	4.88-57.40	14.6-172	IS	0.21-9.43	1.72-30.3
G	4.88-34.50	14.6-103	LS	0.17-15.0	0.88-44.9
Ethylbenzene			Ethylbenzene		
TD	0.074-0.99	0.15-2.99	J	0.074-0.22	0.29-1.15
J	0.084-2.24	0.25-6.72	IS	0.12-0.27	0.22-0.83
G	0.14-3.12	0.43-9.36	LS	0.042-0.57	0.13-1.73

Remark: TD= Thai folk dancer (n=24), J= janitor (n=24), G= guard (n=24), IS=Incense seller (n=24) , LS = Lottery seller (n=24).

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 (Table 4.16). The exposure concentration of the Thai folk dancer at TMB was in range of 4.27-70.63, 1.76-15.72, and 1.01-8.32 µg/m^3 for tolene, m,p-xylene, and o-xylene, respectively. The exposure concentration of the janitor at TMB was in range of 13.11-

72.48, 0.26-13.41, and 0.26-14.00 μg/m^3 for tolene, m,p-xylene, and o-xylene, respectively. The exposure concentration of the guard at TMB was in range of 10.44-71.76, 2.14-11.57, and 1.01-6.46 μg/m^3 for tolene, m,p-xylene, and o-xylene, respectively. The total exposure concentration of the workers at the TMB was 36.67, 49.73, and 40.78 μg/m^3, for Thai folk dancer, janitor, and guard, respectively.

Table 4.16 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

Non-carcinogenic compound	TMB		Non-carcinogenic compound	KW temple	
	EC (μg/m3)	95% CI of HQ		EC (μg/m^3)	95% CI of HQ
Toluene			Toluene		
TD	4.27-70.63	0.0038-0.014	J	3.31-26.99	0.00066-0.0054
J	13.11-72.48	0.0030-0.14	IS	3.20-28.99	0.00087-0.0058
G	10.44-71.76	0.0036-0.014	LS	2.28-32.99	0.0014-0.0065
m,p-Xylene			m,p-Xylene		
TD	1.76-15.72	0.024-0.16	J	1.29-3.24	0.013-0.32
J	0.26-13.41	0.033-0.13	IS	1.52-5.11	0.017-0.051
G	2.14-11.57	0.021-0.12	LS	1.09-5.20	0.01-0.053
o-Xylene			o-Xylene	\	
TD	1.01-8.32	0.014-0.083	J	0.65-3.22	0.0065-0.032
J	0.26-14.00	0.011-0.14	IS	1.04-2.78	0.011-0.028
G	1.01-6.46	0.01-0.034	LS	0.55-2.87	0.0087-0.024
Total	4.50-194.51	0.011-0.057		1.30-79.37	0.011-0.13

Remark: TD= Thai folk dancer (n=24), J= janitor (n=24), G= guard (n=24), IS=Incense seller (n=24) , LS = Lottery seller (n=24).

For KW temple, the exposure concentration of the janitor was in range of 3.31-26.99, 1.29-3.24, and 0.65-3.22 μg/m^3 for tolene, m,p-xylene, and o-xylene, respectively. The exposure concentration of the incense seller was in range of 3.20-28.99, 1.52-5.11, and 1.04-2.78 μg/m^3 for tolene, m,p-xylene, and o-xylene, respectively. The exposure concentration of the lottery seller was in range of 2.28-32.99, 1.09-5.20, and 0.55-2.87 μg/m^3 for tolene, m,p-xylene, and o-xylene, respectively. The total exposure concentration of the workers at the KW temple was 14.98, 15.93, 15.23 μg/m^3 for janitor, incense seller, and lottery seller.At TMB, Thai folk dancer, janitor, and guard were in the same range of toluene at 4.27-72.48 μg/m^3 which higher than those of KW temple in range of 2.28-32.99 μg/m^3. For m,p-xylene and o-xylene, the exposure concentration of workers at TMB were 2.26- and1.42-fold higher than those of KW temple .

The hazard quotient (HQs) of Thai folk dancer was in range of 0.0038-0.014, 0.024-0.16, and 0.014-0.083, for tolene, m,p-xylene, and o-xylene, respectively. The hazard quotient (HQs) of janitor at TMB was in range of 0.0030-0.14, 0.033-0.13, and 0.011-0.14, for tolene, m,p-xylene, and o-xylene, respectively. The hazard quotient (HQs) of guard was in range of 0.0036-0.014, 0.021-0.12, and 0.01-0.034, for tolene, m,p-xylene, and o-xylene, respectively. For KW temple, the hazard quotient (HQs) of janitor was in range of 0.00066-0.0054, 0.013-0.32, and 0.0065-0.032 for tolene, m,p-xylene, and o-xylene, respectively.

The janitor at TMB had the highest HQs of toluene and o-xylene at the range of 0.011-0.14 which 10- and 1.69-fold, respectively higher than Thai folk dancer and guard. For m,p-xylene at TMB, Thai folk dancer had the highest HQs of 0.024-0.16 which 1.23- and 1.33-fold higher than janitor and guard. At KW temple , the lottery seller had the highest HQs of toluene in the range of 0.0014-0.065 which 1.2-, 1.12- and higher than janitor and incense seller, respectively. For m,p-xylene and o-xylene, the janitor had the highest HQs at the range of 0.013-0.032 and 0.0065-0.032 which 6.27- and 6-fold higher, for m,p-xylene and 1.14- and 1.33-fold higher than incense seller and lottery seller, respectively.

Moreover, The total EC and HQs (or hazard index, HI) at TMB was 2.45- and 2.46-fold higher than KW temple, respectively. However, all the 95% CIs of the HI 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.

Table 4.17 The hazard index for non-cancer risk of workers exposure from BTEX at the Tao Maha Brahma (TMB) and Kanlayanamit Woramahawiharn (KW) temples in Bangkok, Thailand

Worker	TMB		Worker	KW temple	
	EC ($\mu g/m^3$)	95% CI of HI		EC ($\mu g/m^3$)	95% CI of HI
TD	36.67	0.12	J	14.98	0.041
J	49.73	0.14	IS	15.93	0.051
G	40.78	0.087	LS	15.23	0.038

Remark: TD= Thai folk dancer (n=24), J= janitor (n=24), G= guard (n=24), IS=Incense seller (n=24) , LS = Lottery seller (n=24).

The average lifetime cancer risk in this study was comparable as those previously reported as shown in Table 4.18. For carcinogenic compound (benzene and ethylbenzene), lifetime cancer risk was lower than Kitwattanavong (2010)'s reported for the gas station workers exposure to BTEX in Thailand in the range of 4.14×10^{-5} to 4.99×10^{-4} and 1.47×10^{-6} to 1.26×10^{-5}; a landfill workers in Turkey in the range of 9.53×10^{-6} to 3.73×10^{-4} (Durmusoglu *et al*., 2010) and in the same range with the metropolitan city, Kolkata, India in the range of 8.3×10^{-6} to 2.8×10^{-5} and 1.2×10^{-6} to 1.3×10^{-6}, for benzene and ethylbenzene, respectively (Majumdar *et al*., 2008); a smoker's home in Hong Kong in the range of 1.41×10^{-6} to 8.35×10^{-5} for benzene (Guo *et al*., 2004).

Table 4.18 Comparison of risk levels studied at TMB and KW temple with other studies

Location	Cancer substance	Cancer risk	HQ	Reference
Bangkok, Thailand	Benzene	4.14×10^{-5} to 4.99×10^{-4}		Kitwattanavong, 2010
	Toluene		0.0044 to 0.0313	
	Ethylbenzene	1.47×10^{-6} to 1.26×10^{-5}		
	m,p-xylene		0.0714 to 0.4927	
	o-xylene		0.0169 to 0.1595	
Turkey	Benzene	9.53×10^{-6} to 3.73×10^{-4}		Durmusoglu *et al*., 2010
	Toluene		0.0014 to0.093	
	xylene		0.0081 to 2.33	
Hong Kong	benzene	1.41×10^{-6} to 8.35×10^{-5}	-	Guo *et al*., 2004
Kolkata, India	Benzene	8.3×10^{-6} to 2.8×10^{-5}		Majumdar *et al*., 2008
	Toluene		0.0201 to 0.7741	
	Ethylbenzene	1.2×10^{-6} to 1.3×10^{-6}		
	xylene		0.12 to 0.2	

For non carcinogenic risk, the average hazard quotient of toluene was also lower than the gas station workers in Thailand and the metropolitan city, Kolkata, India, in the range of 0.0044 to 0.0313 and 0.0201 to 0.7741, respectively (Kitwattanavong, 2010; Majumdar *et al*., 2008). However, the average hazard quotient of toluene was in the same range with a landfill worker in Turkey in the range of 0.0014 to 0.093 (Durmusoglu *et al*., 2010). For m,p-xylene and o-xylene, the average hazard quotient in this study also lower than the pervious studies in the range of 0.0714 to 0.4927 and 0.0169 to 0.1595, for m,p-xylene and o-xylene, respectively (Kitwattanavong, 2010); 0.0081 to 2.33 and 0.12 to 0.2 for xylene (summation of m,p-xylene and o-xylene) (Durmusoglu *et al*., 2010)).

According to the guideline method used for calculating LCR which was recommended by USEPA, some factors, i.e. inhalation rate, would be represented by the people in the US. This factor might not be appropriate for 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 any 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.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

This study aimed to determine BTEX (benzene, toluene, ethylbenzene, and xylene) concentration, to evaluate the potential health risk and estimate workers health risk for the workers at worship places. The sampling was performed at weekend (Sunday) and non peak (Wednesday) days in April (dry season), July (wet season) and December (cold season) 2012 at Tao Maha Bhrama (TMB) shrine and Kanlayanamit Woramahawiharn (KW) temple. All results can be concluded as follows:

1) From the proximity of their workplace 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, The janitor at the TMB had the highest average exposure level to benzene and o-xylene as 107.14 and 16.59 $\mu g/m^3$, 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 36.23, 46.67, 8.48 and 5.83 $\mu g/m^3$, respectively.

2) For the 8-h average concentration on weekend and weekday, only the level of benzene on weekend at the TMB was higher than that on the weekday, the 8-h average concentration of toluene, ethylbenzene, m,p-xylene, and o-xylene on the weekday were 120.53, 20.19, 7.85, and 12.29 $\mu g/m^3$ and 1.32, 1.96, 1.76, and 1.15 fold higher, respectively, than those on the weekend. While all BTEX concentrations on the weekday at the KW temple were higher than on the weekend. All of the 8-h average concentration of benzene, toluene, and m,p-xylene on the weekday at the KW temple were 31.80, 50.39 and 8.19 $\mu g/m^3$ and 1.15-, 1.84-, and 1.37-fold higher than those on the weekend for benzene, toluene, m,p-xylene, respectively.

3) At TMB, toluene was found the highest concentration as 105.77 μg/m^3 followed by benzene (57.28 μg/m^3), m,p-xylene (21.82 μg/m^3), ethylbenzene (15.33 μg/m^3), and o-xylene (11.50 μg/m^3). At KW temple, toluene was also found the highest concentration as 39.12 μg/m^3 but lower than the highest exposed of toluene at TMB (2.70 fold).

4) Toluene, ethylbenzene, and o-xylene was found the highest concentration in wet season at 88.7 (10.36-256.76), 13.85 (1.94-72.31), and 7.68 (2.03-29.88) μg/m^3, respectively, and 1.02- and 2.06-fold , 1.10- and 2.47-fold, and 1.56- and 1.31-fold higher than dry season and cold season, respectively. For benzene, cold season had the highest concentration of 50.25 (2.02-135.86) μg/m^3 which 1.09- and 1.32-fold higher than dry season and the wet season, respectively. The dry season had the highest concentration of m,p-xylene and total BTEX at 19.45 (3.43-72.61) and 169.18 (1.56-412.79) μg/m^3 which 1.08- and 1.87-fold higher and 1.09- and 1.43-fold higher than wet season and cold season, respectively.

5) For the chamber test, the average BTEX concentration was in the range of 0.097-6.13 mg/m^3, and the highest average concentration was benzene (6.13 mg/m^3), followed by toluene (4.29 mg/m^3), ethylbenzene (1.44 mg/m^3), m,p-xylene (0.12 mg/m^3), and o-xylene (0.097 mg/m^3) and the large incense from KW temple had the highest concentration of all four incense types.

6) 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 (0.4-2.45). In contrast, for all B:T ratios at the KW temple were in the same broad range of about 0.03-4.53, although this covered the highest range found at the TMB. The highest B:T ratio at KW temple was lottery seller at 1.81 (0.07-4.29).

7) The workers amount at the risk higher than acceptable criteria of 10^{-6} was found at 100 % (3.79×10^{-6}-3.45×10^{-4}) and 83.82 % (2.91×10^{-7}-1.87×10^{-5}), for TMB, and 100% (1.72×10^{-6}-8.99×10^{-5}) and 42% (3.29×10^{-7}-5.71×10^{-6}), for KW temple. Eventhough, the KW temple was located in outer city and less traffic than TMB, the lifetime cancer risk of benzene was still over acceptable criteria of 10^{-6}, as well as for ethylbenzene, the lifetime cancer risk of the workers at KW temple was 1.9-fold lower than the TMB which of 83.82 % higher than acceptable criteria.

8) All the 95% CI of the HQs of the workers exposed to non-carcinogenic compounds (toluene, m,p-xylene, o-xylene 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.

5.2 Recommendation

1. The workers in such areas should have warning information on health effects, and should be recommended to wear personal protection equipment such as a standard respirator mask and eyeglasses to avoid exposure of BTEX and some chemicals from breathing incense smoke.

2. Onside data such as wind direction and wind speed should be observed and order to investigate how these factors would affect to distribution of BTEX in such area.

3. The other worship places with different in the area should be selected for further study.

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APPENDICES

APPENDIX A

Quastionnaires

A.1 Questionnaire for workers (Thai version)

แบบสอลถามข้อมูลผู้ปฏิบัติงานในสถานประกอบพิธีกรรมในกรุงเทพมหานคร

วัน......./........./.........

ชื่อสถานที่ประกอบพิธีกรรม..

เพศ ❑ชาย ❑หญิง

อายุ.........................ปี

น้ำหนัก...................กิโลกรัม

ระยะเวลาที่ทำงานในสถานประกอบพิธีกรรม...ปี

งานที่รับผิดชอบ..

จำนวนวันที่ทำงานต่อสัปดาห์..วัน/สัปดาห์

ระยะเวลาในการทำงาน..ชั่วโมง/วัน

ช่วงเวลาทำงาน.................................น. ถึง..................................น.

ช่วงเลาพัก.................................น. ถึง..................................น.

สถานที่พักในเวลาพักคือ ....

การตรวจสุขภาพประจำปี ❑เคย ❑ไม่เคย

การตรวจสุขภาพครั้งล่าสุด ❑ต่ำกว่า 3 เดืน ❑3 เดือน – 6 เดือน

❑6 เดือน – 1 ปี ❑มากกว่า 1 ปี

ในระหว่างการทำงานท่างมีอาการง่วนอนหรือไม่ ❑ไม่มี ❑มี

ในระหว่างการทำงานท่านมีอาการปวดศรีษะ/มึนงงหรือไม่ ❑ไม่มี ❑มี

ในระหว่างการทำงานท่านมีอาการ คลื่นไส้/อาเจียนหรือไม่ ❑ไม่มี ❑มี

ในระหว่างการทำงานท่านมีอาการระคายเคืองตา/จมูก/คอ/ผิวหนัง หรือไม่ ❑ไม่มี ❑มี

ในระหว่างการทำงานท่านมีอาการเลือดกำเดาไหลหรือไม่ ❑ไม่มี ❑มี

ในระหว่างการทำงานท่านมีอาการอ่อนเพลียเมื่อยล้าหรือไม่ ❑ไม่มี ❑มี

ในระหว่างการทำงานท่านมีอาการเจ็บหน้าอก/ หายใจติดขัดหรือไม่ ❑ไม่มี ❑มี

ในระหว่างการทำงานท่านมีอาการเป็นลม/ หมดสติหรือไม่ ❑ไม่มี ❑มี

ในระหว่างการทำงานท่านมีการป้องกันการสัมผัสกับควันธูปหรือไม่

❑ไม่มี ❑มี ใส่ผ้าปิดจมูก/ หน้ากากป้องกัน ❑มี ใส่เสื้อผ้ามิดชิด ❑มี ใส่ถุงมือ

สภาพอากาศระหว่างเวลาทำงาน...

ท่านคาดว่าจะทำงานในสถานประกอบพิธีกรรมอีก............................ปี

APPENDIX B

Preliminary Study

B.1 Calibration curves

Table B.1 Concentration (ppm) of standard BTEX of calibration curves

Compounds	Peak area Ratio							
	250 ng/ml	500 ng/ml	1,000 ng/ml	2,000 ng/ml	4,000 ng/ml	8,000 ng/ml	Average	SD
Benzene	14	28	55	160	320	752	1.4	4.23
Toluene	3.1	7.7	16.9	37.1	77.1	179.5	4.23	4.56
Ethylbenzene	5.6	12.7	21.6	44.9	90.5	218	7.2	9.3
m,p-Xylene	4.6	10.6	15.2	29.8	58.6	135.5	7.7	9.3
o-Xylene	4.2	10.4	15.6	30.2	59.2	134.4	3.9	4.4

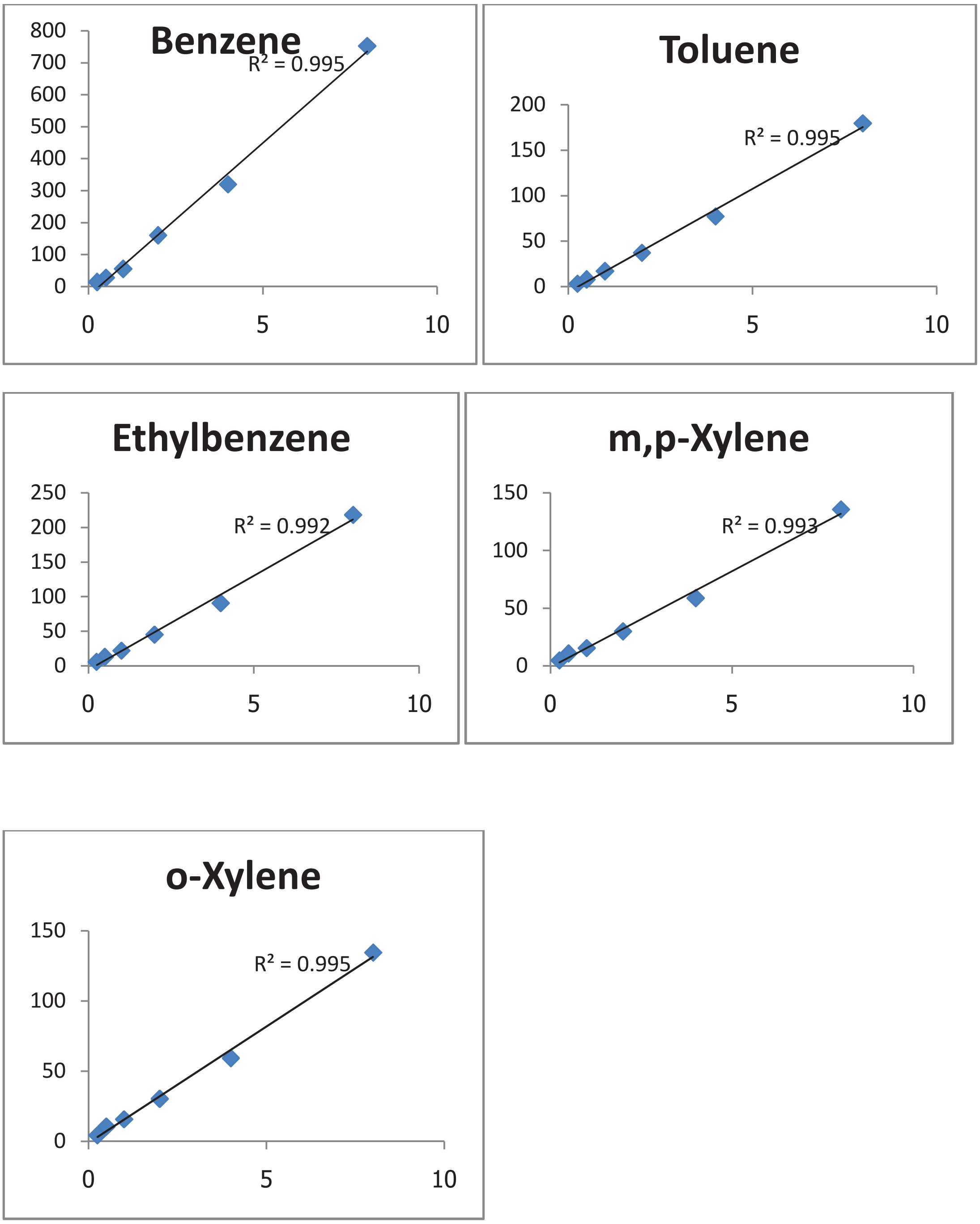

Figure B.1 Calibration Curve of standard BTEX

APPENDIX C

BTEX concentration in dry season (March to April) at Tao Maha Brahma and Kanlayanamit Woramahawiharn temple

C.1 BTEX concentration at Tao Maha Brahma

Table C.1 BTEX concentration on weekday day (March 1st week) at TMB

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	TD	J	G	AmB	
Benzene	7.79	65.12	21.29	21.79	29.00±24.94
Toluene	220.98	163.03	224.51	139.23	186.94±42.49
Ethylbenzene	66.52	72.31	67.58	60.2	66.66±4.98
m,p-Xylene	35.58	30.31	36.15	30.24	33.07±3.23
o-Xylene	7.95	8.33	10.54	7.189	8.51±1.44
Total BTEX	338.82	339.1	360.07	258.649	324.18±44.79

Table C.2 BTEX concentration on weekend day (March 1st week) at TMB

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	TD	J	G	AmB	
Benzene	161.37	41.09	45.60	51.19	74.81±57.85
Toluene	62.44	45.70	63.06	111.92	70.78±28.58
Ethylbenzene	36.70	2.71	7.91	8.33	13.91±15.40
m,p-Xylene	43.16	10.34	10.82	27.94	23.06±15.70
o-Xylene	26.03	3.41	4.82	8.05	10.57±10.48
Total BTEX	329.71	103.25	132.21	207.43	193.15±101.07

Table C.3 BTEX concentration on weekday day (March 2nd week) at TMB

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	TD	J	G	AmB	
Benzene	34.08	113.38	39.16	48.09	58.68±36.93
Toluene	71.59	179.50	142.07	256.76	162.48±77.15
Ethylbenzene	9.16	15.36	8.50	17.40	12.61±4.45
m,p-Xylene	27.50	36.07	17.20	72.61	38.34±24.11
o-Xylene	7.23	18.98	10.06	17.92	13.55±5.80
Total BTEX	149.55	363.30	216.97	412.79	285.65±123.06

Table C.4 BTEX concentration on weekend day (April 2nd week) at TMB

Compound	Personal exposure concentration ($\mu g/m^3$)				Average ±SD ($\mu g/m^3$)
	TD	J	G	AmB	
Benzene	33.93	162.10	35.22	29.34	65.15±64.69
Toluene	64.26	142.46	82.29	110.07	99.77±34.13
Ethylbenzene	4.54	12.05	5.84	6.41	7.21±3.32
m,p-Xylene	13.57	26.43	16.75	23.80	20.14±5.99
o-Xylene	5.66	29.88	5.91	8.97	12.61±11.61
Total BTEX	121.96	372.92	146.02	178.58	204.87±114.41

Table C.5 BTEX concentration on weekday day (April 3rd week) at TMB

Compound	Personal exposure concentration ($\mu g/m^3$)				Average ±SD ($\mu g/m^3$)
	TD	J	G	AmB	
Benzene	31.01	55.79	41.22	63.70	47.93±14.63
Toluene	68.43	81.30	74.55	178.11	100.60±51.94
Ethylbenzene	4.76	6.50	5.63	9.79	6.67±2.20
m,p-Xylene	13.60	14.63	17.96	51.07	24.31±17.93
o-Xylene	4.25	5.42	4.42	13.43	6.88±4.39
Total BTEX	122.06	163.63	143.77	316.10	186.39±88.12

Table C.6 BTEX concentration on weekend day (April 3rd week) at TMB

Compound	Personal exposure concentration ($\mu g/m^3$)				Average ±SD ($\mu g/m^3$)
	TD	J	G	AmB	
Benzene	29.80	81.69	24.51	10.13	36.53±31.23
Toluene	60.17	76.55	56.52	53.81	61.76±10.19
Ethylbenzene	10.09	7.76	5.22	4.13	6.80±2.67
m,p-Xylene	14.86	12.57	11.64	10.39	12.36±1.89
o-Xylene	5.87	4.25	8.86	5.09	6.02±2.01
Total BTEX	120.79	182.82	106.75	83.55	123.48±42.44

C.2 BTEX concentration at Kanlayanamit Woramahawiharn temple

Table C.7 BTEX concentration on weekday day (March 1st week) at KW temple

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	J	IS	LS	AmB	
Benzene	54.34	31.62	72.82	60.16	54.73±17.23
Toluene	48.32	n.d.	50.71	51.78	50.26±1.77
Ethylbenzene	3.42	n.d.	4.55	5.91	4.62±1.25
m,p-Xylene	6.36	n.d.	5.07	8.02	6.48±1.48
o-Xylene	2.03	n.d.	4.05	3.34	3.14±1.03
Total BTEX	114.47	31.62	137.20	129.21	103.12±48.59

Table C.8 BTEX concentration on weekend day (March 1st week) at KW temple

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	TD	J	G	AmB	
Benzene	6.89	n.g.	4.81	19.16	10.29±7.75
Toluene	35.11	13.56	28.15	33.21	27.51±9.75
Ethylbenzene	3.63	nd	2.48	4.84	3.65± 1.18
m,p-Xylene	4.03	nd	3.43	7.30	4.92±2.09
o-Xylene	3.23	nd	2.78	nd	3.01±0.32
Total BTEX	52.88	13.56	41.65	64.50	43.15±21.82

Table C.9 BTEX concentration on weekday day (April 2nd week) at KW temple

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	J	IS	LS	AmB	
Benzene	45.56	31.91	45.62	46.70	42.45±7.05
Toluene	56.60	90.70	101.02	102.82	87.79±21.47
Ethylbenzene	4.58	5.69	6.33	6.16	5.69±0.79
m,p-Xylene	9.23	15.99	16.59	18.53	15.09±4.05
o-Xylene	2.96	6.25	5.50	3.69	4.60±1.53
Total BTEX	118.93	150.54	175.06	177.91	155.61±27.37

Table C.10 BTEX concentration on weekend day (April 2nd week) at KW temple

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	TD	J	G	AmB	
Benzene	22.44	46.83	36.35	25.69	32.83±11.06
Toluene	10.36	33.89	30.59	43.12	29.49±13.81
Ethylbenzene	nd	4.12	1.94	3.33	3.13±1.10
m,p-Xylene	nd	6.01	4.60	9.44	6.68±2.49
o-Xylene	nd	3.50	2.72	3.98	3.40±0.64
Total BTEX	32.80	94.35	76.20	85.57	72.23±27.31

APPENDIX D

BTEX concentration in wet season (July) at Tao Maha Brahma and Kanlayanamit Woramahawiharn temple

D.1 BTEX concentration at Tao Maha Brahma

Table D.1 BTEX concentration on weekday day (July 1st week) at TMB

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	TD	J	G	AmB	
Benzene	5.94	72.07	22.67	51.00	37.92±29.40
Toluene	108.47	137.00	126.74	150.59	130.70±17.75
Ethylbenzene	35.32	16.42	16.20	19.73	21.92±9.08
m,p-Xylene	49.20	19.90	20.16	48.56	34.45±16.66
o-Xylene	14.75	19.18	8.39	15.02	14.34±4.45
Total BTEX	213.67	264.57	194.16	284.90	239.32±42.48

Table D.2 BTEX concentration on weekend day (July 1st week) at TMB

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	TD	J	G	AmB	
Benzene	10.77	122.56	24.31	38.72	49.09±50.29
Toluene	142.34	140.42	121.71	144.13	137.15±10.41
Ethylbenzene	nd	14.45	27.68	9.09	17.07±9.57
m,p-Xylene	7.62	18.76	18.11	20.67	16.29±5.88
o-Xylene	nd	23.43	3.17	4.37	10.32±11.37
Total BTEX	160.74	319.63	194.97	216.99	223.08±68.40

Table D.3 BTEX concentration on weekday day (July 2nd week) at TMB

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	TD	J	G	AmB	
Benzene	8.70	261.30	39.48	0.64	77.53±123.65
Toluene	97.24	226.74	101.31	nd	141.76±73.62
Ethylbenzene	9.34	32.35	13.67	nd	18.45±12.23
m,p-Xylene	17.60	41.90	24.73	nd	28.07±12.49
o-Xylene	5.57	43.79	6.81	nd	18.72±21.71
Total BTEX	138.44	606.08	186.00	0.64	232.79±260.72

Table D.4 BTEX concentration on weekend day (July 2nd week) at TMB

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	TD	J	G	AmB	
Benzene	27.48	155.33	50.08	38.54	67.86±59.04
Toluene	172.70	168.84	116.87	121.61	145.00±29.85
Ethylbenzene	nd	17.79	10.02	9.20	12.34±4.74
m,p-Xylene	nd	18.40	6.69	19.50	14.86±7.10
o-Xylene	nd	19.06	nd	6.50	12.78±8.88
Total BTEX	200.17	379.42	183.67	195.35	239.65±.93.43

D.2 BTEX concentration at Kanlayanamit Woramahawiharn temple

Table D.5 BTEX concentration on weekday day (July 1st week) at KW temple

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	J	IS	LS	AmB	
Benzene	1.86	2.85	1.92	1.24	1.97±0.66
Toluene	45.55	42.06	29.18	49.14	41.48±8.70
Ethylbenzene	nd	nd	12.98	7.69	10.33±3.74
m,p-Xylene	nd	nd	4.06	5.42	4.74±0.96
o-Xylene	nd	nd	nd	nd	-
Total BTEX	47.41	44.90	48.13	63.49	50.99±8.45

Table D.6 BTEX concentration on weekend day (July 1st week) at KW temple

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	J	IS	LS	AmB	
Benzene	5.39	3.54	21.56	24.33	13.71±10.76
Toluene	11.24	13.65	22.59	51.15	24.66±18.32
Ethylbenzene	nd	9.76	26.56	16.90	17.74±8.43
m,p-Xylene	nd	nd	4.53	11.74	8.13±5.09
o-Xylene	nd	nd	nd	5.03	5.03
Total BTEX	16.63	26.95	75.25	109.16	57.00±43.15

Table D.7 BTEX concentration on weekday day (July 2nd week) at KW temple

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	J	IS	LS	AmB	
Benzene	2.98	7.90	15.11	20.40	11.60
Toluene	84.44	68.95	91.20	100.56	86.29
Ethylbenzene	10.15	5.22	6.12	9.77	7.82
m,p-Xylene	10.06	8.68	7.37	13.44	9.89
o-Xylene	6.51	nd	2.38	7.47	5.46
Total BTEX	114.16	90.75	122.19	151.64	119.68

Table D.8 BTEX concentration on weekend day (July 2nd week) at KW temple

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	J	IS	LS	AmB	
Benzene	37.80	43.46	50.11	51.03	45.60±6.19
Toluene	29.84	23.68	24.93	39.03	29.37±6.97
Ethylbenzene	nd	nd	nd	nd	-
m,p-Xylene	nd	nd	nd	nd	-
o-Xylene	nd	nd	nd	nd	-
Total BTEX	67.64	67.14	75.04	90.06	74.97

APPENDIX E

BTEX concentration in cold season (November - December) at Tao Maha Brahma and Kanlayanamit Woramahawiharn temple

Table E.1 BTEX concentration on weekday (November 1st week) at TMB

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	TD	J	G	AmB	
Benzene	11.64	56.35	35.35	43.70	36.76±18.84
Toluene	23.28	108.41	91.26	107.98	82.73±40.44
Ethylbenzene	4.67	14.33	10.33	5.66	8.75±4.47
m,p-Xylene	5.51	26.19	20.42	2.35	13.62±11.51
o-Xylene	5.45	25.93	20.21	2.35	13.48±11.38
Total BTEX	50.54	231.21	177.57	162.03	155.34±86.31

Table E.2 BTEX concentration on weekend (November 2nd week) at TMB

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	TD	J	G	AmB	
Benzene	54.68	121.84	81.09	71.94	82.39±24.49
Toluene	20.42	93.30	139.24	111.68	91.16±50.80
Ethylbenzene	4.67	10.33	5.00	7.33	6.83±2.62
m,p-Xylene	5.78	21.66	9.49	12.99	12.48±6.79
o-Xylene	5.72	21.44	9.39	12.86	12.35±6.72
Total BTEX	91.26	268.57	244.21	216.81	205.21±95.42

Table E.3 BTEX concentration on weekday (November 1st week) at KW temple

Compound	Personal exposure concentration (µg/m^3)				Average ±SD (µg/m^3)
	J	IS	LS	AmB	
Benzene	20.58	33.47	28.48	37.43	30.00±7.26
Toluene	29.40	34.91	7.15	28.79	25.06±12.26
Ethylbenzene	4.67	5.00	5.32	4.17	4.79±0.49
m,p-Xylene	5.78	6.19	6.58	5.16	5.92±0.61
o-Xylene	5.10	6.33	2.65	5.31	4.85±1.56
Total BTEX	65.53	85.90	50.18	80.84	70.61±22.18

Table E.4 BTEX concentration on weekend (December 1st week) at KW temple

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	J	IS	LS	AmB	
Benzene	2.02	15.39	32.23	36.18	21.45±15.78
Toluene	49.61	nd	37.57	37.16	41.45±7.08
Ethylbenzene	5.17	5.17	5.33	4.00	4.92±0.62
m,p-Xylene	6.39	6.39	6.60	4.95	6.08±0.76
o-Xylene	8.78	nd	8.98	4.70	7.49±2.42
Total BTEX	71.97	26.95	90.71	86.98	81.38±26.66

Table E.5 BTEX concentration on weekday (December 1st week) at TMB

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	TD	J	G	AmB	
Benzene	20.23	55.51	105.41	81.92	65.77±36.57
Toluene	13.37	41.04	49.61	71.25	43.82±23.95
Ethylbenzene	3.23	4.67	6.17	9.33	5.85±2.61
m,p-Xylene	46.54	0.83	14.03	31.14	23.13±19.94
o-Xylene	3.15	0.82	13.88	30.83	12.17±13.68
Total BTEX	86.53	102.86	189.10	224.48	150.74±96.75

Table E.6 BTEX concentration on weekdend (December 2nd week) at TMB

Compound	Personal exposure concentration (µg/m³)				Average ±SD (µg/m³)
	TD	J	G	AmB	
Benzene	23.77	135.86	42.15	88.13	40.75±9.25
Toluene	33.08	55.47	32.67	19.19	10.96±3.57
Ethylbenzene	22.83	4.27	8.33	4.83	3.83±0.60
m,p-Xylene	57.34	8.17	12.17	6.46	4.74±0.74
o-Xylene	56.76	8.33	12.05	6.39	7.11±7.70
Total BTEX	193.77	212.10	107.36	125.00	67.39±21.87

Table E.7 BTEX concentration on weekday (December 3rd week) at KW temple

Compound	Personal exposure concentration (μg/m^3)				Average ±SD (μg/m^3)
	J	IS	LS	AmB	
Benzene	53.64	16.43	64.87	65.29	50.06±23.06
Toluene	11.84	10.00	15.11	8.78	11.43±2.75
Ethylbenzene	4.17	3.83	4.17	3.50	3.92±0.32
m,p-Xylene	5.16	4.74	5.16	4.33	4.85±0.39
o-Xylene	4.29	3.27	4.49	3.06	3.78±0.72
Total BTEX	79.09	38.27	93.79	84.96	74.03±27.25

Table E.8 BTEX concentration on weekend (December 4th week) at KW temple

Compound	Personal exposure concentration (μg/m^3)				Average ±SD (μg/m^3)
	J	IS	LS	AmB	
Benzene	30.15	nd	44.91	47.20	40.75
Toluene	11.03	nd	7.35	14.50	10.96
Ethylbenzene	4.33	nd	3.17	4.00	3.83
m,p-Xylene	5.36	nd	3.92	4.95	4.74
o-Xylene	3.68	nd	1.72	15.93	7.11
Total BTEX	54.54	-	61.06	86.57	67.39

APPENDIX F

Example of statistical analysis

Table F.1 One way ANOVA of BTEX concentration among workers at TMB

Tests of Normality

	Worker	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Benzene	Thaiflok	.444	6	.000	.649	6	.002
	janitor	.210	6	.200*	.918	6	.490
	guard	.197	6	.200*	.919	6	.497
	Ambient	.202	6	.200*	.960	6	.822

ANOVA

Benzene

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10307.226	3	3435.742	2.463	.092
Within Groups	27901.730	20	1395.087		
Total	38208.957	23			

Post Hoc Tests

Multiple Comparisons

Benzene
LSD

(I) Worker	(J) Worker	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Thaiflok	janitor	-36.86455	21.56453	.103	-81.8474	8.1183
	guard	15.16451	21.56453	.490	-29.8183	60.1473
	Ambient	12.29022	21.56453	.575	-32.6926	57.2730
janitor	Thaiflok	36.86455	21.56453	.103	-8.1183	81.8474
	guard	52.02907*	21.56453	.026	7.0463	97.0119
	Ambient	49.15477*	21.56453	.034	4.1720	94.1376
guard	Thaiflok	-15.16451	21.56453	.490	-60.1473	29.8183
	janitor	-52.02907*	21.56453	.026	-97.0119	-7.0463
	Ambient	-2.87430	21.56453	.895	-47.8571	42.1085
Ambient	Thaiflok	-12.29022	21.56453	.575	-57.2730	32.6926
	janitor	-49.15477*	21.56453	.034	-94.1376	-4.1720
	guard	2.87430	21.56453	.895	-42.1085	47.8571

Table F.2 Paired sample T-test of workers exposure concentration of toluene and ethylbenzenet between weekend and weekday.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Toluene-peak	.257	12	.028	.855	12	.042
Toluene-nonpeak	.186	12	.200*	.918	12	.266
Ethylbenzene-peak	.299	12	.004	.606	12	.000
Ethylbenzene-nonpeak	.320	12	.001	.735	12	.002

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Toluene-peak	77.4371	12	29.25216	8.44437
	Toluene-nonpeak	150.0059	12	65.51379	18.91220

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Toluene-peak & Toluene-nonpeak	12	.278	.382

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Toluene-peak - Toluene-nonpeak	-72.56883	63.89335	18.44442	-113.16473	-31.97294	-3.934	11	.002

Ranks

		N	Mean Rank	Sum of Ranks
Ethylbenzene-nonpeak - Ethylbenzene-peak	Negative Ranks	2[a]	4.00	8.00
	Positive Ranks	10[b]	7.00	70.00
	Ties	0[c]		
	Total	12		

a. Ethylbenzene-nonpeak < Ethylbenzene-peak

b. Ethylbenzene-nonpeak > Ethylbenzene-peak

c. Ethylbenzene-nonpeak = Ethylbenzene-peak

Test Statistics[b]

	Ethylbenzene-nonpeak - Ethylbenzene-peak
Z	-2.432[a]
Asymp. Sig. (2-tailed)	.015

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Table F.3 Independent sample T-test of the benzene concentrations between TMB and KW temple

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Benzene	Equal variances assumed	12.092	.001	3.595	100	.001	27.4815886	7.6449799	12.3141661	42.6490110
	Equal variances not assumed			3.857	75.974	.000	27.4815886	7.1243795	13.2920778	41.6710994

Table F.4 One way ANOVA of toluene concentration at among seasons

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	46525.613	2	23262.807	9.464	.000
Within Groups	127820.297	52	2458.083		
Total	174345.910	54			

Post Hoc Tests

Multiple Comparisons

T
LSD

(I) season	(J) season	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Dry season	Wet season	-24.72567	16.31846	.136	-57.4711	8.0197
	Cold season	50.51852*	16.00157	.003	18.4090	82.6280
Wet season	Dry season	24.72567	16.31846	.136	-8.0197	57.4711
	Cold season	75.24419*	17.81860	.000	39.4886	110.9998
Cold season	Dry season	-50.51852*	16.00157	.003	-82.6280	-18.4090
	Wet season	-75.24419*	17.81860	.000	-110.9998	-39.4886

*. The mean difference is significant at the 0.05 level.

APPENDIX G

Risk Assessment

G.1 Risk assessment in dry season of workers at the worship places

Table G.1 Cancer risk of workers at TMB exposed to benzene

Occupation	TMB					
	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	1.10E-04	1.10E-05	2.21E-05	2.26E-05	1.99E-05	2.02E-05
Janitor	5.47E-05	9.93E-05	2.20E-04	1.50E-04	1.10E-04	7.48E-05
Guard	9.17E-05	6.05E-05	7.08E-05	7.92E-05	4.96E-05	8.25E-05

Table G.2 Cancer risk of workers at KW temple exposed to benzene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	6.84E-06	5.07E-05	2.20E-04	4.54E-04
Incense seller	3.21E-04	3.82E-05	5.94E-06	4.65E-04
Lottery seller	4.77E-06	6.79E-05	3.60E-04	4.57E-07

Table G.3 Cancer risk of workers at TMB exposed to ethylbenzene

Occupation	TMB					
	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	3.30E-06	6.0E-06	4.09E-07	8.25E-07	9.08E-07	4.28E-07
Janitor	5.04E-07	1.34E-05	2.24E-06	2.86E-06	1.44E-06	1.21E-06
Guard	2.19E-06	1.87E-05	1.62E-06	2.35E-06	1.45E-06	1.56E-06

Table G.4 Cancer risk of workers at KW temple exposed to ethylbenzene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	4.72E-07	4.46E-07	nd	5.96E-07
Incense seller	-	-	5.71E-06	9.69E-07
Lottery seller	3.23E-07	5.92E-07	2.69E-06	8.25E-07

Table G.5 Hazard quotient of workers at TMB exposure to toluene

Occupation	TMB					
	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	4.00E-03	1.41E-02	4.10E-03	4.58E-03	3.84E-03	4.40E-03
Janitor	3.00E-03	1.00E-02	9.11E-03	1.15E-02	4.90E-03	5.20E-03
Guard	4.00E-03	1.43E-02	5.26E-03	9.10E-03	3.61E-03	4.77E-03

Table G.6 Hazard quotient of workers at KW temple exposure to toluene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	2.24E-03	3.10E-03	6.62E-04	3.62E-03
Incense seller	8.67E-04	-	2.17E-03	5.80E-03
Lottery seller	1.80E-03	3.24E-03	1.96E-03	6.46E-03

Table G.7 Hazard quotient of workers at TMB exposure to m,p-xylene

Occupation	TMB					
	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	1.38E-01	1.14E-01	4.34E-02	8.79E-02	4.75E-02	4.35E-02
Janitor	3.30E-02	9.69E-02	8.45E-02	1.15E-01	4.02E-02	4.68E-02
Guard	3.46E-02	1.16E-01	5.35E-02	5.50E-02	3.72E-02	5.74E-02

Table G.8 Hazard quotient of workers at KW temple exposure to m,p-xylene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	1.29E-02	2.03E-02	-	2.95E-02
Incense seller	-	-	1.92E-02	5.11E-02
Lottery seller	1.09E-02	1.62E-02	1.47E-02	5.30E-02

Table G.9 Hazard quotient of workers at TMB exposure to o-xylene

Occupation	TMB					
	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	8.32E-02	2.54E-02	1.81E-02	2.31E-02	1.88E-02	1.36E-02
Janitor	1.09E-02	2.66E-02	9.55E-02	6.07E-02	1.36E-02	1.73E-02
Guard	1.54E-02	3.37E-02	1.89E-02	3.21E-02	2.83E-02	1.41E-02

Table G.10 Hazard quotient of workers at KW temple exposure to o-xylene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	1.03E-02	6.48E-03	0.00E+00	9.47E-03
Incense seller	-	--	1.12E-02	2.00E-02
Lottery seller	8.89E-03	1.30E-02	8.70E-03	1.76E-02

G.2 Risk assessment in wet season of workers at the worship places

Table G.11 Cancer risk of workers at TMB exposed to benzene

Occupation	TMB			
	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	6.88E-06	6.97E-06	1.75E-05	6.40E-06
Janitor	1.64E-04	9.81E-05	2.08E-04	3.51E-04
Guard	5.54E-05	4.90E-05	1.01E-04	8.13E-05

Table G.12 Cancer risk of workers at KW temple exposed to benzene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	6.88E-06	6.97E-06	1.75E-05	6.40E-06
Incense seller	1.64R-04	9.81E-05	2.08E-04	3.51E-04
Lottery seller	5.54E-05	4.90E-05	1.01E-04	8.13E-05

Table G.13 Cancer risk of workers at TMB exposed to ethylbenzene

Occupation	TMB			
	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	-	3.18E-06	-	8.41E-07
Janitor	2.69E-06	3.05E-06	3.31E-06	6.02E-06
Guard	7.66E-06	4.48E-06	2.77E-06	3.79E-06

Table G.14 Cancer risk of workers at KW temple exposed to ethylbenzene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	-	-	-	1.32E-06
Incense seller	1.66E-06	-	-	8.90E-07
Lottery seller	3.46E-06	1.69E-06	-	7.98E-07

Table G.15 Hazard quotient of workers at TMB exposure to toluene

Occupation	TMB			
	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	9.91E-03	8.98E-03	7.78E-03	9.21E-03
Janitor	6.93E-03	8.76E-03	8.1E-03	9.63E-03
Guard	1.10E-02	1.08E-02	7.47E-03	7.77E-03

Table G.16 Hazard quotient of workers at KW temple exposure to toluene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	7.18E-04	2.91E-03	1.91E-03	5.40E-03
Incense seller	8.73E-04	2.69E-03	1.51E-03	4.41E-03
Lottery seller	1.44E-03	1.86E-03	1.59E-03	5.83E-03

Table G.17 Hazard quotient of workers at TMB exposure to m,p-xylene

Occupation	TMB			
	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	0.024	0.157	-	0.056
Janitor	0.060	0.064	0.059	0.133
Guard	0.058	0.064	0.021	0.079

Table G.18 Hazard quotient of workers at KW temple exposure to m,p-xylene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	-	-	-	0.032
Incense seller	-	-	-	0.016
Lottery seller	0.014	0.012	-	0.019

Table G.19 Hazard quotient of workers at TMB exposure to o-xylene

Occupation	TMB			
	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	-	0.0471597	-	0.01779068
Janitor	0.0748987	0.0612953	0.0609064	0.13996074
Guard	0.0101223	0.0268267	-	0.02176592

Table G.20 Hazard quotient of workers at KW temple exposure to o-xylene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	-	-	-	0.032
Incense seller	-	-	-	0.027
Lottery seller	-	-	-	0.023

G.3 Risk assessment in cold season of workers at the worship places

Table G.21 Cancer risk of workers at TMB exposed to benzene

	TMB			
Occupation	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	3.49E-05	7.43E-06	1.52E-05	1.29E-05
Janitor	1.61E-04	7.43E-05	1.79E-04	7.32E-05
Guard	1.59E-04	6.94E-05	8.28E-05	2.07E-04

Table G.22 Cancer risk of workers at KW temple exposed to benzene

	KW temple			
Occupation	Weekend	Weekday	Weekend	Weekday
Janitor	2.79E-06	2.85E-05	4.18E-05	7.43E-05
Incense seller	2.79E-05	6.07E-05	-	2.98E-05
Lottery seller	4.47E-05	3.95E-05	6.22E-05	8.99E-05

Table G.23 Cancer risk of workers at TMB exposed to ethylbenzene

	TMB			
Occupation	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	4.20E-07	4.20E-07	2.06E-06	2.91E-07
Janitor	1.92E-06	2.67E-06	7.94E-07	8.68E-07
Guard	1.38E-06	2.86E-06	2.31E-06	1.71E-06

Table G.24 Cancer risk of workers at KW temple exposed to ethylbenzene

	KW temple			
Occupation	Weekend	Weekday	Weekend	Weekday
Janitor	1.01E-06	9.12E-07	8.47E-07	8.14E-07
Incense seller	1.32E-06	1.28E-06	0.00E+00	9.79E-07
Lottery seller	1.04E-06	1.04E-06	6.19E-07	8.14E-07

Table G.25 Hazard quotient of workers at TMB exposure to toluene

Occupation	TMB			
	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	0.0013	0.00148	0.0021	0.00085
Janitor	0.0059	0.00693	0.0035	0.0026
Guard	0.0089	0.0058	0.0021	0.0032

Table G.26 Hazard quotient of workers at KW temple exposure to toluene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	0.0032	0.0019	0.0007	0.00076
Incense seller	-	0.0022	-	0.0006395
Lottery seller	0.0024	0.00046	0.0004699	0.00097

Table G.27 Hazard quotient of workers at TMB exposure to m,p-xylene

Occupation	TMB			
	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	0.018	0.018	0.055	0.15
Janitor	0.069	0.084	0.026	0.0026
Guard	0.03	0.065	0.039	0.045

Table G.28 Hazard quotient of workers at KW temple exposure to m,p-xylene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	0.02	0.018	0.017	0.016
Incense seller	0.02	0.02	-	0.015
Lottery seller	0.021	0.021	0.012	0.016

Table G.29 Hazard quotient of workers at TMB exposure to o-xylene

Occupation	TMB			
	Weekend	Weekday	Weekend	Weekday
Thai folk dancer	0.018	0.017	0.054	0.01
Janitor	0.068	0.083	0.027	0.0026
Guard	0.03	0.065	0.039	0.044

Table G.30 Hazard quotient of workers at KW temple exposure to o-xylene

Occupation	KW temple			
	Weekend	Weekday	Weekend	Weekday
Janitor	0.028	0.016	0.012	0.014
Incense seller	-	0.02	-	0.01
Lottery seller	0.028	0.0085	0.0055	0.014

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