HEALTH RISK ASSESSMENT OF BTEX EXPOSURE TO PARKING WORKERS AT ONE OF PARKING STRUCTURE IN BANGKOK THAILAND

Miss Wassana Loonsamrong

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การประเมินความเสี่ยงต่อสุขภาพจากการรับสัมผัสสารอินทรีย์ระเหยกลุ่ม BTEX ของพนักงานในลานจอดรถแห่งหนึ่งในกรุงเทพมหานคร ประเทศไทย

นางสาววาสนา ลุนสำโรง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาสาธารณสุขศาสตรมหาบัณฑิต
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Thesis Title	HEALTH RISK ASSESSMENT OF BTEX EXPOSURE TO PARKING WORKERS AT ONE OF PARKING STRUCTURE IN BANGKOK THAILAND
By	Miss Wassana Loonsamrong
Field of Study	Public Health
Thesis Advisor	Nutta Taneepanichskul, Ph.D.
Thesis Co-Advisor	Sitthichok Puangthongthub, Ph.D.

Accepted by the Faculty of College of Public Health Sciences, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.....Dean of the College of Public Health Sciences

(Professor Surasak Taneepanichskul, M.D.)

THESIS COMMITTEE

.....Chairman

(Assistant Professor Wattasit Siriwong, Ph.D.)

.....Thesis Advisor

(Nutta Taneepanichskul, Ph.D.)

.....Thesis Co-Advisor

(Sitthichok Puangthongthub, Ph.D.)

.....External Examiner

(Benjawan Tawatsupa, Ph.D.)

วาสนา ลุนสำโรง : การประเมินความเสี่ยงต่อสุขภาพจากการรับสัมผัสสารอินทรีย์ระเหยกลุ่ม BTEX ของพนักงาน ในลานจอดรถแห่งหนึ่งในกรุงเทพมหานคร ประเทศไทย. (HEALTH RISK ASSESSMENT OF BTEX EXPOSURE TO PARKING WORKERS AT ONE OF PARKING STRUCTURE IN BANGKOK THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: อ. ดร.ณัฏฐา ฐานีพานิชสกุล, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: อ. ดร.สิทธิโชค พวงทองทับ, , หน้า.

การศึกษานี้มีวัตถุประสงค์เพื่อวัดปริมาณการรับสัมผัสสารอินทรีย์ระเหยกลุ่ม BTEX (ได้แก่ เบนซีน โทลูอีน เอธิลเบนซีน และไซลีน) ผ่านทางการหายใจของพนักงานในลานจอดรถ พร้อมทั้งนำค่าที่ตรวจวัดได้มาประเมินความเสี่ยงต่อสุขภาพที่พนักงานได้รับสัมผัส ซึ่งวัดปริมาณการรับสัมผัส BTEX โดยใช้หลอดเก็บตัวอย่างอากาศแบบแพร่ชนิดแอคทีฟ (active diffusion) แล้ววิเคราะห์ด้วยเทคนิคแก๊สโครมาโทกราฟีชนิดเฟรมไอออนไนซ์เซชั่นดีเทคเตอร์ (Gas Chromatography with Flame Ionization Detector, GC-FID) และวัดระดับการรับสัมผัสผ่านการบ่งชี้ด้วยสารเมตาโบไลท์ทางปัสสาวะ (Urinary Metabolite) โดยการเก็บตัวอย่างปัสสาวะหลังเลิกงานมาวิเคราะห์ด้วยเทคนิคโครมาโทกราฟีของเหลวสมรรถนะสูง (High Performance Liquid Chromatography - Ultraviolet Detection, HPLC-UV) ผลการศึกษาพบค่าความเข้มข้นเฉลี่ย (±ส่วนเบี่ยงเบนมาตรฐาน) ของเบนซีน โทลูอีน เอธิลเบนซีน และไซลีนคือ 11.282 (±5.033), 56.129 (±73.963), 7.166 (±9.198), and 10.587 (±6.324) ไมโครกรัม/ลูกบาศก์เมตร ตามลำดับ เมื่อคำนวณค่าความเสี่ยงต่อการเป็นมะเร็งจากการรับสัมผัสสารเบนซีน พบว่าความเสี่ยงอยู่ที่ระดับ 4.37×10^{-6} (มีโอกาสเป็นมะเร็งประมาณ 5 คนในล้านคน) ซึ่งถือว่าเป็นค่าความเสี่ยงที่ไม่สามารถยอมรับได้ (มีโอกาสเป็นมะเร็งมากกว่า 1 คนในล้านคน) สำหรับค่าความเสี่ยงในกรณีไม่ใช่มะเร็ง (Hazard Quotients; HQ) จากการรับสัมผัสสาร BTEX นั้นอยู่ในระดับที่สามารถยอมรับได้ โดยปริมาณความเข้มข้นของสาร BTEX ที่คนงานรับสัมผัสมีค่าไม่เกินค่าความเข้มข้นอ้างอิงของสารแต่ละตัว (HQ < 1) โดยมีค่า 0.36, 0.01, 0.006, และ 0.105 ตามลำดับ และสำหรับความเข้มข้นของสารเมตาโบไลท์ของสารเบนซีน โทลูอีน และไซลีน ที่วัดได้คือ กรดทรานส์,ทรานส์-มิวโคนิคมีค่าความเข้นข้นเฉลี่ย 177.07 ไมโครกรัม/กรัมครีอะตินีน, กรดฮิบพรูริกมีค่าความเข้นข้นเฉลี่ย 0.390 กรัม/กรัมครีอะตินีน, และกรดเมทธิลฮิบพรูริกแอซิดมีความเข้นข้นเฉลี่ย 0.11 กรัม/กรัมครีอะตินีน ซึ่งไม่พบความสัมพันธ์ระหว่างปริมาณการรับสัมผัสสารในอากาศกับความเข้มข้นสารเมตาโบไลท์ทางปัสสาวะของสารแต่ละตัว สำหรับอาการตอบสนองที่เกี่ยวข้องกับการรับสัมผัสสาร BTEX พบการรับสัมผัสสารเอธิลเบนซีนในอากาศในปริมาณที่เพิ่มขึ้นทำให้มีโอกาสเสี่ยงต่อการเกิดอาการคลื่นไส้มากขึ้น (OR = 1.14; 95% CI, 1.008 - 1.288) และการรับสัมผัสสารไซลีนในอากาศในปริมาณที่เพิ่มขึ้นทำให้มีโอกาสเสี่ยงต่อการเกิดอาการไอเพิ่มขึ้น (OR = 1.137; 95% CI, 1.012 - 1.278)

สาขาวิชา สาธารณสุขศาสตร์ ลายมือชื่อนิสิต .....

ปีการศึกษา 2556 ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก .....

ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม .....

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WASSANA LOONSAMRONG: HEALTH RISK ASSESSMENT OF BTEX EXPOSURE TO PARKING WORKERS AT ONE OF PARKING STRUCTURE IN BANGKOK THAILAND. ADVISOR: NUTTA TANEEPANICHSKUL, Ph.D., CO-ADVISOR: SITTHICHOK PUANGTHONGTHUB, Ph.D., pp.

This study aimed to estimate the level of Benzene, Toluene, Ethylbenzene and Xylene (BTEX) exposure and identified a health risk assessment related to BTEX exposure via inhalation for workers at a car parking. Measured personal exposure, air samples were collected by using active diffusion sampling tubes and analyzed by Gas Chromatography, with Flame Ionization Detector (GC-FID). Urine samples were collected from workers at post-shift and analyzed by High Performance Liquid Chromatography with Ultraviolet Detection (HPLC-UV). The mean concentrations (±SD) of benzene, toluene, ethylbenzene, and xylenes (m,p,o-xylene) were 11.282 (±5.033), 56.129 (±73.963), 7.166 (±9.198), and 10.587 (±6.324) μg/m^3 respectively. Then, a risk assessment methodology was employed to evaluate the potential adverse health effects of the individual BTEX compounds according to their carcinogenic and non-carcinogenic effects. Cancer risk for benzene was estimated to be 4.37×10^{-6}, indicated developing cancer over lifetime exceeding 5 people in a million which considered an unacceptable level (acceptable level, cancer risk < 10^{-6}). Non-carcinogenic risks (Hazard Quotients; HQ), were considered an acceptable level (HQ < 1), which the results were 0.360, 0.010, 0.006, and 0.105 for benzene, toluene, ethylbenzene, and xylenes respectively. The mean concentration of t,t-Muconic acid, Hippuric acid, and Methylhippuric acid in urine were 177.07 μg/g creatinine, 0.39 g/g creatinine, and 0.11 g/g creatinine, respectively. Analysis of correlation between air benzene, toluene, and xylene concentrations and their urinary metabolites concentrations was found no correlation. Increasing ethylbenzene exposure was associated with increased likelihood of exhibiting nausea (OR = 1.14; 95% CI, 1.008 - 1.288), and increasing xylene exposure was associated with increased likelihood of exhibiting cough (OR = 1.137; 95% CI, 1.012 - 1.278).

Field of Study: Public Health
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Student's Signature .....
Advisor's Signature .....
Co-Advisor's Signature .....

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LIST OF ABBRAVIATIONS

ACGIH	American Conference of Governmental and Industrial Hygienist
AT	Averaging Time
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
EC	Exposure Concentration
ED	Exposure Duration
EF	Exposure Frequency
U.S.EPA	U.S. Environmental Protection Agency
GC-FID	Gas Chromatography with Flame Ionization Detector
HPLC	High Performance Liquid Chromatography
HI	Hazard Index
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
RAGS	Risk Assessment Guidance for Superfund
RfC	Inhalation Reference Concentration
STEL	Short-Term Exposure Limit
TLV	Threshold Limit Value
TWA	Time-Weight Average
VOCs	Volatile Organic Compounds

CHAPTER I
INTRODUCTION

1.1 Background and Rational

Benzene, Toluene, Ethylbenzene and Xylenes known as the BTEX group of Volatile Organic Compounds (VOCs) which are common air pollutants in urban area including workplace. BTEX sources include cigarette smoke, building materials and industrial paints. As well traffic is considered important source (Han & Naeher, 2006; Kim et al., 2001) and BTEX can released from vehicle that migrate from the garages (Wheeler et al., 2013). Since indoor VOCs exposures can be 2 to 100 times higher than outside (Zhu et al., 2005) enclosed parking is one of workplaces which need more attention as parking workers are at risk of exposure to BTEX compounds.

Health effects from BTEX exposure depend on chronic or acute exposure. Chronic exposures to low concentrations may cause adverse effect, especially Benzene. Benzene has been widely recognized as a human carcinogen which classified by the International Agency for Research on Cancer (IARC, 2014) and the United States Environmental Protection Agency (U.S.EPA, 2012a). In case of chronic expose, BTEX might be psychological and also toxic or damaging the liver, kidneys, eyes and central nervous system, For acute effect with higher concentrations over a short period of time, is respiratory system causing throat irritation and eyes irritation, central nervous system causing headache, dizziness, vomiting and confusion (ATSDR, 2004).

Bangkok, the capital city of Thailand, has been increasing car parking and its trend to be enclosed or located on the underground of buildings, especially department store, shopping malls, and hotels. This study aims to assess the health risk through inhalation pathway, a major route of BTEX exposure, among parking workers in Bangkok, Thailand. Moreover, assessing the association between acute effect (BTEX exposure symptoms) and exposure dose among these workers are analyzed. The investigation association between the BTEX concentrations and BTEX urinary metabolite concentrations are analyzed as well.

1.2 Research Question

1) Are parking workers at risk from BTEX exposure via inhalation pathway?

2) Are there associations between BTEX concentrations and urinary metabolites concentrations among parking workers?

3) Are there associations between BTEX concentrations and BTEX exposure symptoms among parking workers?

1.3 Hypothesis

1) Parking workers are at risk from BTEX exposure via inhalation pathway.

2) There are associations between BTEX concentrations and urinary metabolites concentrations among parking workers.

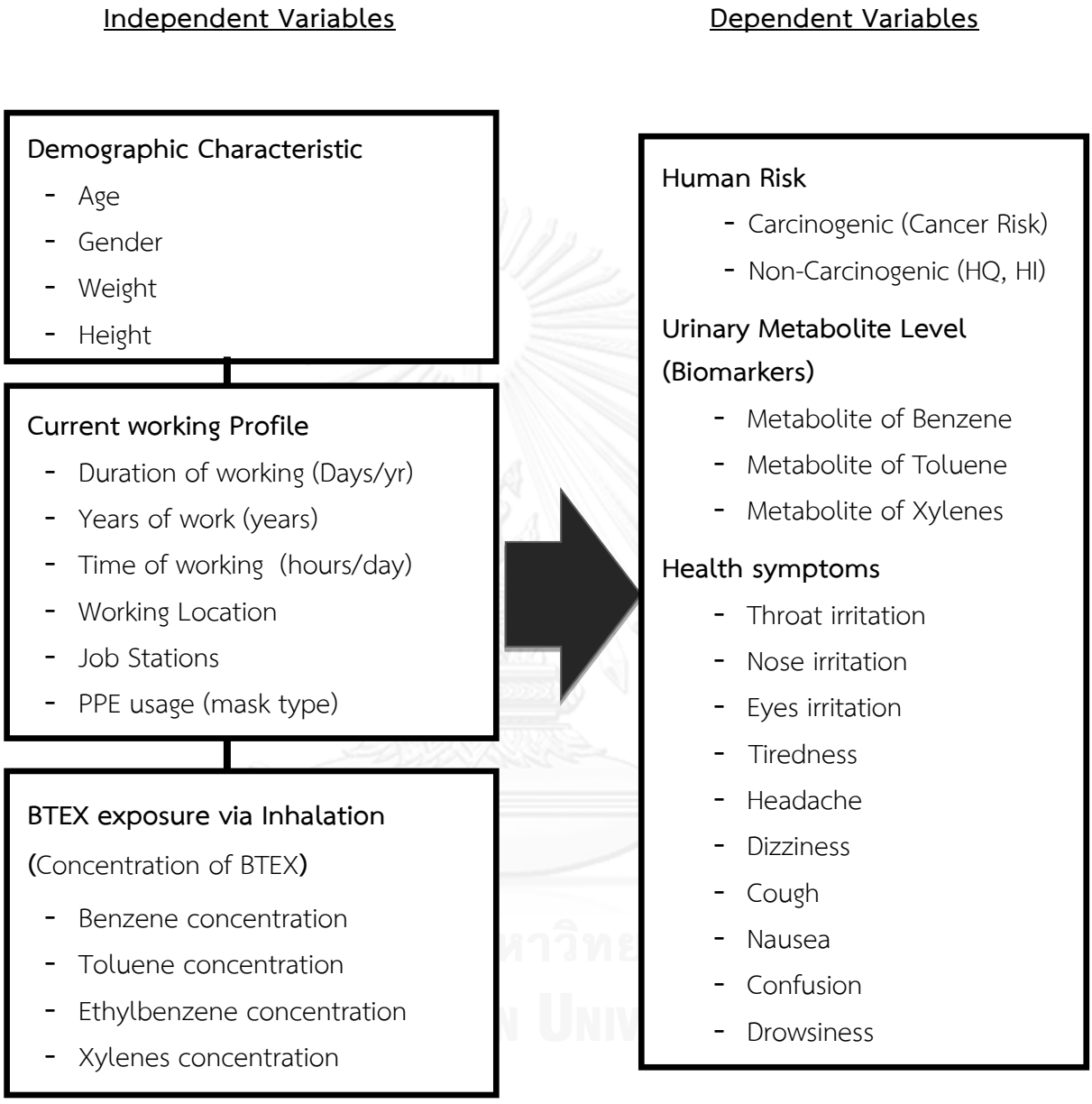
3) There are relationships between BTEX concentrations and BTEX exposure symptoms among parking workers.

1.4 Objectives

Main objective is to estimate the concentrations of BTEX exposure among parking workers, the specific objectives are:

1) To evaluate human health risk through inhalation exposure to BTEX in parking worker.
2) To investigate association between the BTEX concentrations and Urinary Metabolites in parking workers.
3) To investigate association between the BTEX concentrations and BTEX exposure symptoms occurrence in parking workers.

1.5 Conceptual Framework



Source: ATSDR, 2004; U.S.EPA, 2009

Figure 1 Conceptual Framework

1.6 Operation Definitions

BTEX refer to Benzene, Toluene, Ethylbenzen and Xylenes

BTEX exposure via Inhalation refer to average daily dose of benzene, toluene, ethylbenzen and xylenes, which human expose by breathing air that contains the benzene, toluene, ethylbenzen and xylenes

Parking workers refer to workers who make convenient to customer when they drive in and park or stop car in parking.

Exposure assessment refer to process of measuring or estimating the magnitude, frequency, and duration of human exposure to an agent in the environment, or estimating future exposures for an agent that has not yet been released (U.S.EPA, 1989).

Exposure factors refer to concentration of BTEX, conversion factor, inhalation Rate, Exposure Frequency, Exposure Duration, Averaging Time and Body Weight.

Human risk refers to outcome of risk characterization including both carcinogenic effects and non-carcinogenic effect.

HQ refers the ratio between the BTEX exposure and a reference concentration (RfC). This is the present of non-cancer risk from BTEX inhalation exposure. HQ greater than one can be described as indicating that a potential may exist for adverse health effects (U.S.EPA, 1989).

HI refers to sum of HQ for benzene, toluene, ethylbenzen and xylenes exposure.

Smoking behavior refers to active smoking, that is, the intentional inhalation of tobacco smoke.

Passive smoking behavior refers to breathing in someone else's cigarette smoke.

Reference Concentration (RfC) refer to an estimate of a continuous inhalation exposure concentration to people that is likely to be without risk of deleterious effects during a lifetime. An RfC is reported in milligrams of pollutant per cubic meter of air (mg/m^3) (U.S.EPA, 1989).

Inhalation Units Risk (IUR) refer to an upper bound estimated of an individual probability to get cancer over a lifetime of exposure to a concentration of 1 microgram (µg) of chemical or pollutant per cubic meter (m^3) of air. (U.S.EPA, 1989).

Urinary Metabolites refers to measurable benzene, toluene, ethylbenzen and xylenes in the human body by measured in urine. This measurement can be used to monitor the presence of these chemical in the body, including the presence of biological responses and adverse health effect. In this study urinary metabolite (sometimes call biomarker) will be t,t- muconic acids (benzene urinary metabolite), hippuric acid (toluene urinary metabolite), and methylhippuric acid (xylenes urinary metabolite). However mandelic acid (ethylbenzene urinary metabolite) will not include in this study due to laboratory limitation.

BTEX exposure symptoms refer to health symptoms that related to BTEX exposure including to throat irritation, nose irritation, eyes irritation, tiredness, headache, dizziness, cough, nausea, confusion, drowsiness.

CHAPTER II

LITERATURE REVIEW

2.1 Situation of VOCs in Thailand

The demand-supply analysis data of each VOCs from 2001-2005 (PCD, 2009) indicates that major VOCs utilization in Thailand is increasing. Some VOCs are consumed in a small amount or discontinued for the import and usage whereas some of them are major chemicals with significant demand for several applications. Examples of demand-supply analysis by PCD were given for benzene, toluene and p-xylene as illustrated in Figure 2– 4

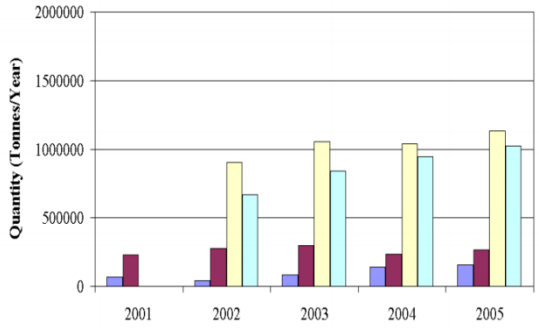


Figure 2 Demand-supply of p-xylene

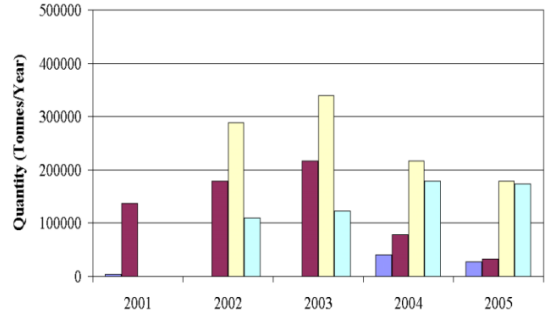


Figure 3 Demand-supply of Toluene

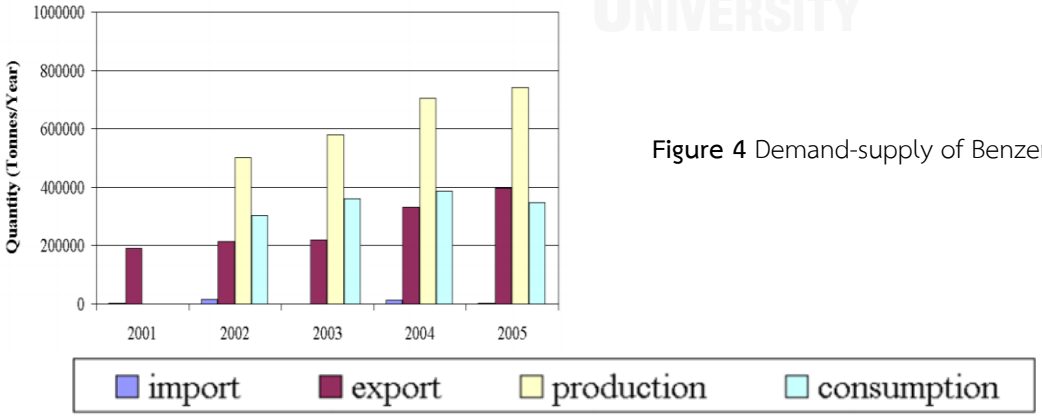
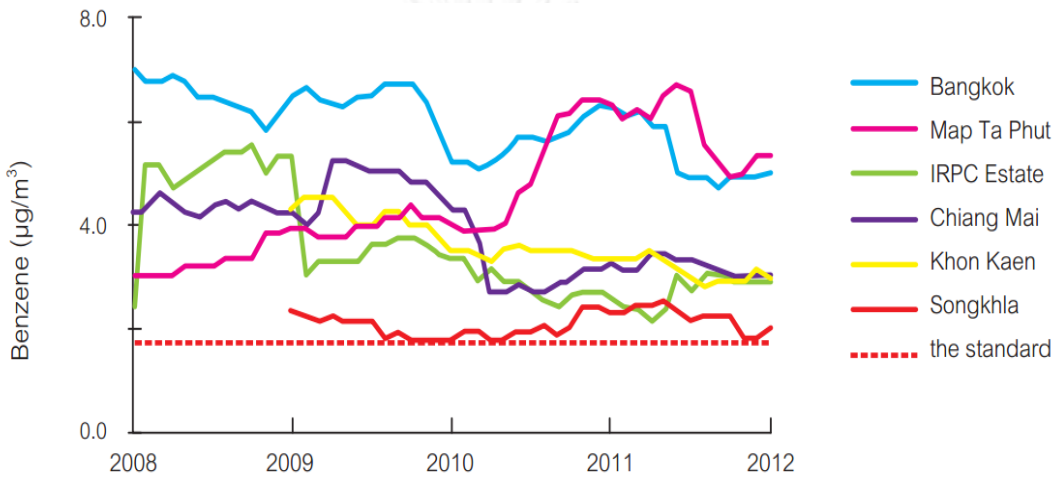


Figure 4 Demand-supply of Benzene

Source: The Development of Environmental and Emission Standards of Volatile Organic Compounds (VOCs) in Thailand (PCD, 2009)

In 2012, the measurement result of volatile organic compounds (VOCs) in ambient air in Thailand that monitored by Pollution Control Department (PCD) shown concentration of VOCs in Bangkok were over the standard (National Environmental Board, 2007). Especially benzene concentration in ambient air were higher than the standard (benzene standard is 1.7 microgram/cubic meter) since 2008 – 2012 (PCD, 2012).



Source: Thailand State of Pollution Report 2012 (PCD, 2012)

Figure 5 Highest 12-Month average ambient air Benzene (moving averages) in Thailand from 2008 to 2012

At that same time traffic-related sources of air pollution are drawing increasing concerns and were interested by researchers. Evaluation factors of particular activities related to VOCs production, consumption and emission by Thailand Environmental Institute (2007) showed some of result, for example the major source of benzene emission is “vehicles” which accounts for more than 75% of total emission (PCD, 2009).

Number of car in Bangkok is Increasing (Department of Land Transport, 2014) which influence increasing car park. Regarding to the high cost of city center land, may car park are underground or enclosed. This rise concern on workers who spent time working there everyday. Without any PPE can increase the severity of BTEX exposure.

Studies in other countries found those ground-level traffic vehicles in urban areas are typically natural gas fueled, gasoline fueled or diesel-fueled (Han & Naeher, 2006). The physical characteristics and chemical compositions of natural gas, gasoline and diesel are mainly volatile aromatic compounds such as benzene, toluene, ethylbenzene and xylene, a group of compounds known as BTEX (ATSDR, 1999). Traffic is considered one of important source of BTEX for both indoor and outdoor exposure. There has been increased attention on community exposure a potentially large number of sources with varying concentrations.

2.2 BTEX Related to Car Parking

Thailand is a developing country and Bangkok is the capital city with high energy consumption for both industrial sector and transportation. Leading to continuously increasing gasoline consumption and rapid increased number of gasoline stations. A few studies in the literature have evaluated the concentration and Health Risk Assessment of BTEX in gasoline station wokers in thailand (Tunsaringkarn et al., 2012) found BTEX concentration in gas stations was slightly high and benzene were often unacceptable level for carcinogenic concern. However there is limited study and information about BTEX in car parking at underground structure or enclose location where people and workers being in those areas that may increase their personal exposure to environmental concentrations of BTEX.

Some studies found mean BTEX levels in homes with an attached garage (regardless of a connecting door) were approximately double those in homes without an attached garage. As well, benzene and toluene concentrations were significantly higher (Wheeler et al., 2013). However few studies interested BTEX in enclose car parking, a study in Athens, Greece (Soldatos et al., 2002) found benzene concentrations at gas station and enclose car parking were higher than air quality limits, another one study (Hinwood et al., 2007) found that risk factors for increased BTEX exposure in four Australian cities were included vehicle repair and machinery use, refueling of motor vehicles, and being in an enclosed car park.

2.3 Background Information of BTEX

Benzene, toluene, ethylbenzene and xylenes known as the BTEX group of Volatile Organic Compounds (VOCs), with Carbon component. The detail of 'Background information of BTEX' summarizes information on the chemical and physical information, toxicokinetics, and health effects. The summaries are mainly based on ATSDR - Toxicological Profile (ATSDR, 2000, 2007a, 2007b, 2010).

2.3.1 Benzene

2.3.1.1 Chemical and Physical Information

Benzene is a natural part of crude oil, gasoline, cigarette smoke. Benzene is made from petroleum source and also widely used in chemicals production which used to synthetic other chemical substances, makes rubber products, plastics and are also component of drugs and pesticides (ATSDR, 1999). Benzene also found in emission from burning oil and gasoline in motor vehicle exhaust, as well as evaporates from gasoline stations (ATSDR, 2007a; PCD, 2009). Benzene is a colorless substance, sweet odor and highly flammable. Other physical information of benzene has shown in table below.

Table 1 Chemicals and Physical Information of Benzene

Property	Information
Formula	C_6H_6
Chemical Structure	
CAS Number	71-43-2
Molecular weight	78.11
Melting point	5.5 °C
Boiling point	80.1°C
Density at 15 °C	0.8787 g/cm^3
Vapor density	2.77
Vapor pressure at 20 °C	75 mmHg

Property	Information
Water solubility at 25 °C	w/w: 0.188% (0.188g/100 mL)
Log K_{ow} (octanol-water partitioning coefficient)	2.13
Log K_{oc} (soil adsorption coefficient)	1.8 – 1.9
Auto-ignition temperature	498 °C
Flashpoint	-11 °C (closed cup)

Source: adapted from the Toxicological Profile for Benzene (ATSDR, 2007a)

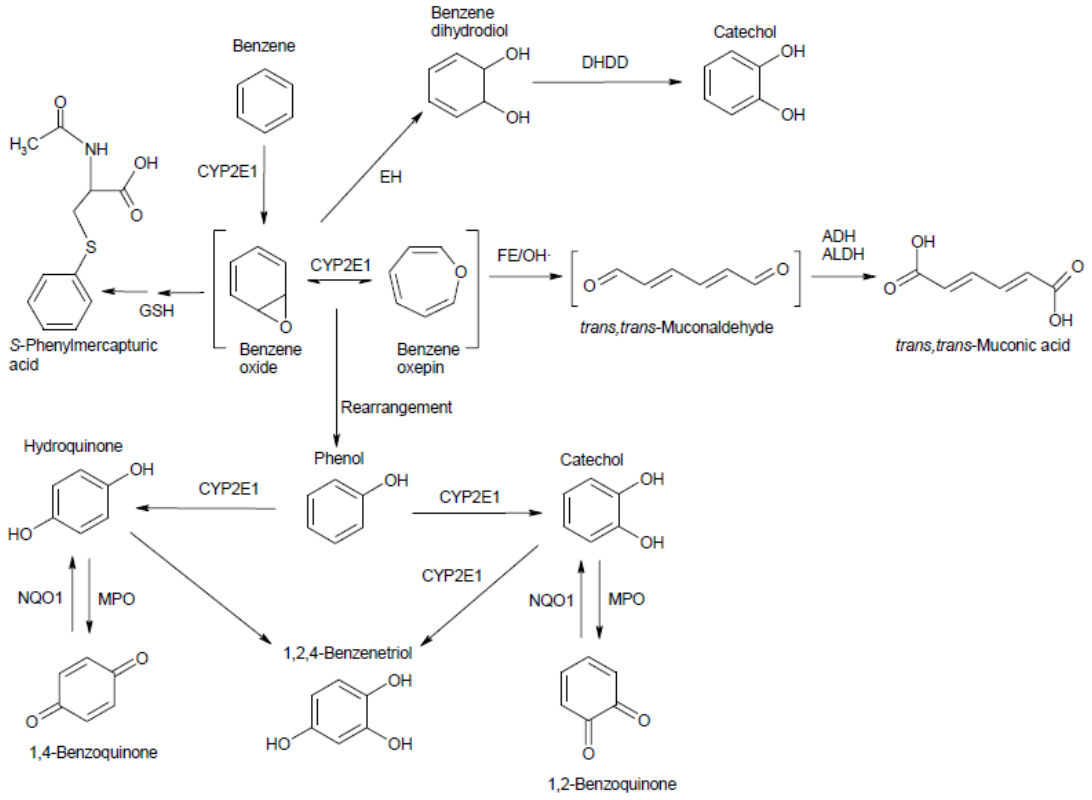
2.3.1.2 Toxicokinetics

Metabolism

Inhalation exposure is probably the major route of human exposure to benzene, although oral and dermal exposure are also important. Absorbed benzene is rapidly distributed throughout the body and tends to accumulate in fatty tissues. The liver serves an important function in benzene metabolism, which results in the production of several reactive metabolites. Benzene is distributed throughout the body following absorption into blood. Since benzene is lipophilic, a high distribution to fatty tissue might be expected.

The metabolic scheme of benzene, the first step is the cytochrome P-450 2E1 (CYP2E1) catalyzed oxidation of benzene to form benzene oxide, which is in equilibrium with its oxepin. Several pathways are involved in the metabolism of benzene oxide. The predominant pathway involves non-enzymatic rearrangement to form phenol, the major initial product of benzene metabolism. Phenol is oxidized in the presence of CYP2E1 to catechol or hydroquinone, which are oxidized via myeloperoxidase (MPO) to the reactive metabolites 1,2- and 1,4-benzoquinone, respectively. The reverse reaction (reduction of 1,2- and 1,4-benzoquinone to catechol and hydroquinone, respectively) is catalyzed by NAD(P)H:quinone oxidoreductase (NQ01). Both catechol and hydroquinone may be converted to the reactive metabolite 1,2,4-benzenetriol via CYP2E1 catalysis. Alternatively, benzene oxide may undergo epoxide hydrolase-catalyzed conversion to benzene dihydrodiol and subsequent dihydrodiol dehydrogenase-catalyzed conversion to catechol. Each of the phenolic metabolites of benzene (phenol, catechol, hydro-quinone, and 1,2,4-benzenetriol) can undergo sulfonic or glucuronic conjugation; the conjugates of phenol and hydroquinone are major

urinary metabolites of benzene. Other pathways of benzene oxide metabolism include: (1) reaction with glutathione (GSH) to form S-phenylmercapturic acid, and (2) iron-catalyzed ring-opening conversion to trans,trans-muconic acid, presumably via the reactive trans,transmuconaldehyde intermediate (ATSDR, 2007a).



Source: Toxicological Profile for Benzene (ATSDR, 2007a)

Figure 6 Metabolic pathways of Benzene

Eliminations, Excretion and Biomarker

Exhalation is the main route for elimination of unmetabolized benzene, metabolites are excreted predominantly in the urine, and only a small amount of the absorbed amount is eliminated in feces.

The primary benzene metabolites are phenol, catechol, hydroquinone, 1,2,4-benzenetriol, and to a lesser extent, trans,trans-muconic acid, which are eliminated in urine as glucuronide and sulfate conjugates. Urinary S-phenylmercapturic and t,t- muconic acids are used for monitoring workplace exposure (ATSDR, 2007a; CDC, 2013). Monitoring by excretion of these metabolite in urine, urine specimen have to collect end of shift. S-Phenylmercapturic acid

and t,t-Muconic acid shouldn't more than 25 ug/g Creatinine and 500 ug/g Creatinine, respectively (ACGIH, 2007; Ministry of Labour, 2007).

2.3.1.3 Health Effects

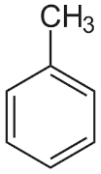
The primary target organs for acute exposure are the hematopoietic system, nervous system, and immune system. Following low-level chronic exposure, the primary target for adverse systemic effects is the hematological system as well. Benzene is a known human carcinogen and is associated with leukemia, classified as carcinogen group 1 by IARC (IARC, 2014) and classified as group A by EPA) (U.S.EPA, 2012a). Benzene exposure may also be associated with reproductive and developmental**.** Acute inhalation or oral exposure to high levels of benzene has caused symptoms and signs of central nervous system toxicity, effects such as tremors, dizziness, narcosis, vertigo, and cardiac arrhythmias have been observed for both acute nonlethal and lethal exposures (ATSDR, 2007a).

2.3.2 Toluene

2.3.2.1 Chemical and Physical Information

Toluene is a clear, colorless liquid with a distinctive smell. Toluene occurs naturally in crude oil and in the tolu tree. It is also produced in the process of making gasoline and other fuels from crude oil and making coke from coal. Toluene is used in making paints, paint thinners, fingernail polish, lacquers, adhesives, and rubber and in some printing and leather tanning processes (ATSDR, 1999).

Table 2 Chemicals and Physical Information of Toluene

Property	Information
Formula	C_7H_8, $C_6H_5CH_3$
Chemical Structure	
CAS Number	108-88-3
Molecular weight	92.14

Property	Information
Melting point	-95 ℃
Boiling point	110.6 ℃
Density at 20 ℃	0.8669 g/mL
Vapor density	3.2
Vapor pressure at 25 ℃	28.4 mmHg
Water solubility at 25 ℃	534.8 mg/L
Log K_{ow} (octanol-water partitioning coefficient)	2.72
Log K_{oc} (soil adsorption coefficient)	1.57 – 2.25
Auto-ignition temperature	480 ℃
Flashpoint	4 ℃

Source: adapted from the Toxicological Profile for Toluene (ATSDR, 2000)

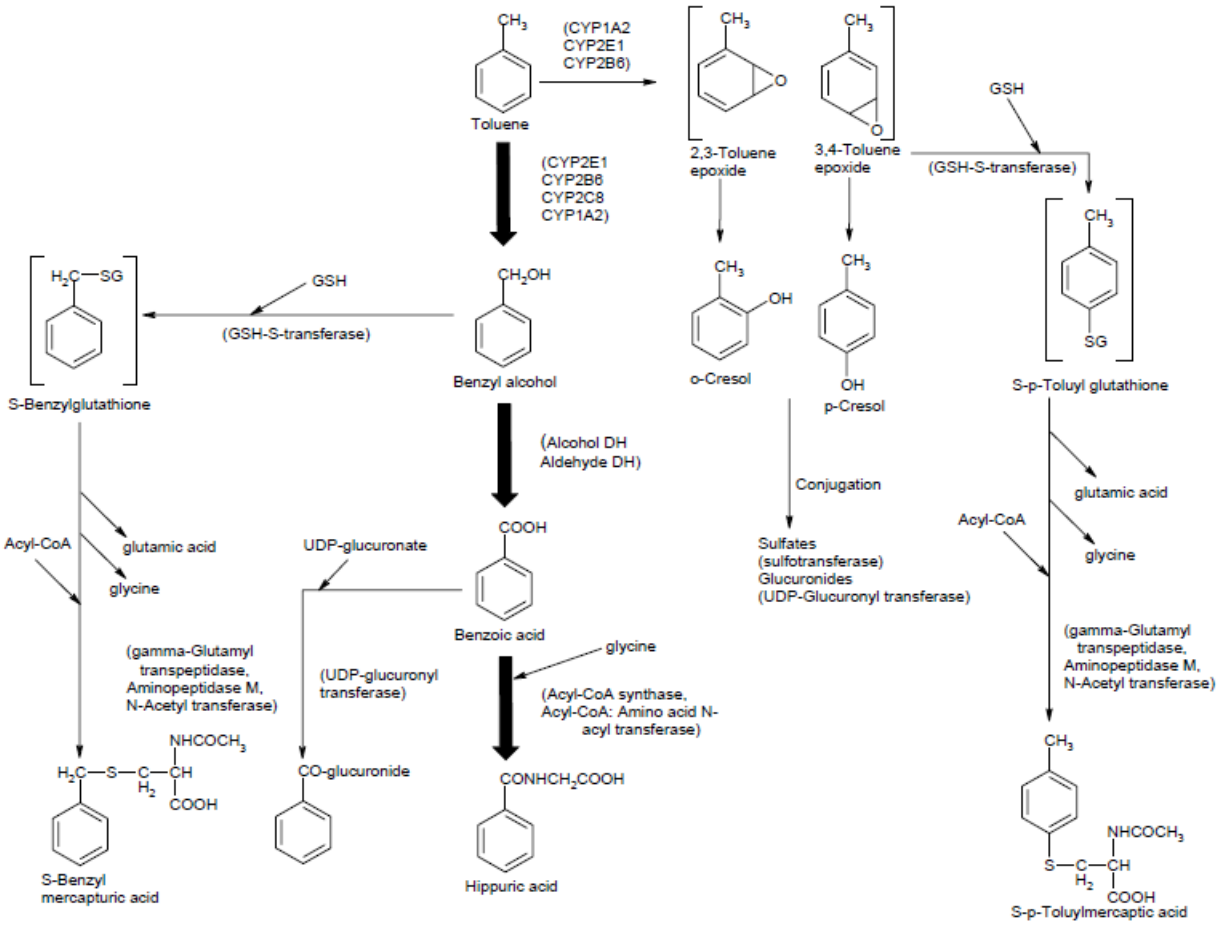
2.3.2.2 Toxicokinetics

Metabolism

Toluene is rapidly absorbed by inhalation exposure. Animal studies have shown that toluene is absorbed less rapidly by the oral route, while toluene is absorbed slowly through human skin. Toluene has been identified in brain, liver, lung, and blood in humans following toluene exposure. Within the human brain, toluene has a greater affinity for areas of the brain that contain lipid-rich white matter, such as the brain stem, rather than the areas with larger amounts of grey matter. The human data are supported by animal studies where distribution of toluene was found to be characterized by uptake in lipid tissues (brain and fat) immediately following inhalation exposure.

The primary initial steps in toluene metabolism in humans and laboratory animals are side-chain hydroxylation (to form benzyl alcohol) catalyzed predominately by the cytochrome P450 (CYP) isozyme, CYP2E1 followed by oxidation to benzoic acid. Most of the benzoic acid is then conjugated with glycine to form hippuric acid, but a small portion can be conjugated with UDP-glucuronate to form the acyl-glucuronide. Studies with volunteers and human liver microsomes indicate that a very small portion (<1–5%) of absorbed toluene

can be converted by CYP1A2, CYP2B2, or CYP2E1 to ortho- or para-cresol, which are excreted in the urine as sulfate or glucuronate conjugates. In both humans and rats, up to about 75–80% of inhaled toluene that is absorbed can be accounted for as hippuric acid in the urine. Much of the remaining toluene is exhaled unchanged. In humans exposed by inhalation, rates of urinary excretion of orthocresol were about 1,000-fold lower than excretion rates for hippuric acid. The excretion of toluene and its metabolites is rapid, with the major portion occurring within 12 hours of exposure. A scheme for toluene metabolism in humans and animals is presented in **Figure 7**.



Source: Toxicological Profile for Toluene (ATSDR, 2000)

Figure 7 Metabolic pathways of Toluene

Eliminations, Excretion and Biomarker

Following acute inhalation exposure to toluene, absorbed toluene is excreted predominately in the urine as metabolites and, to a lesser extent, as non-metabolized toluene in exhaled air. That most absorbed toluene is rapidly eliminated from the body and that a smaller portion is slowly eliminated. Urinary metabolites in toluene-exposed humans have identified hippuric acid (the glycine conjugate of benzoic acid) as the major urinary metabolite of toluene. Minor urinary metabolites (in approximate order of decreasing abundance) include: the glucuronyl conjugate of benzoic acid; sulfate and glucuronide conjugates of ortho- and para-cresol; S-benzylmercapturic acid; and S-p-toluylmercapturic acid. Monitoring by excretion hippuric acid in urine, urine specimen have to collect end of shift and hippuric acid shouldn't more than 1.6 g/g Creatinine (ACGIH, 2007; Ministry of Labour, 2007)

2.3.2.3 Health Effects

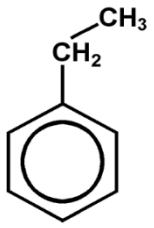
Toluene inhalation exposer in animals showing changes in behavior, hearing loss, and subtle changes in brain structure, electrophysiology, and levels of neurotransmitters. In human toluene has caused respiratory tract irritation following acute inhalation exposure. For chronic inhalation exposure have provided little evidence for serious liver damage (ATSDR, 2000).

2.3.3 Ethylbenzene

2.3.3.1 Chemical and Physical Information

Ethylbenzene is a colorless substance with an aromatic odor, and flammable, naturally found in crude oil, It use as solvent and primarily to produce another chemical especially styrene (ATSDR, 1999) This chemical easily distributed in the environment. Products containing ethylbenzene such as gasoline, varnishes, inks, pesticides and tobacco products (ATSDR, 2010). Other physical information of benzene has shown in table below.

Table 3 Chemicals and Physical Information of Ethylbenzene

Property	Information
Formula	C_8H_{10}, $C_6H_5CH_2CH_3$
Chemical Structure	
CAS Number	100-41-4
Molecular weight	106.17
Melting point	-94.975 ℃
Boiling point	136.19 ℃
Density at 20 ℃	0.8670
Vapor pressure at 25 ℃	9.53 mmHg
Water solubility at 25 ℃	160 mg/L
Log K_{ow} (octanol-water partitioning coefficient)	2.38
Log K_{oc} (soil adsorption coefficient)	1.57 – 2.25
Auto-ignition temperature	432 ℃
Flashpoint	15 ℃

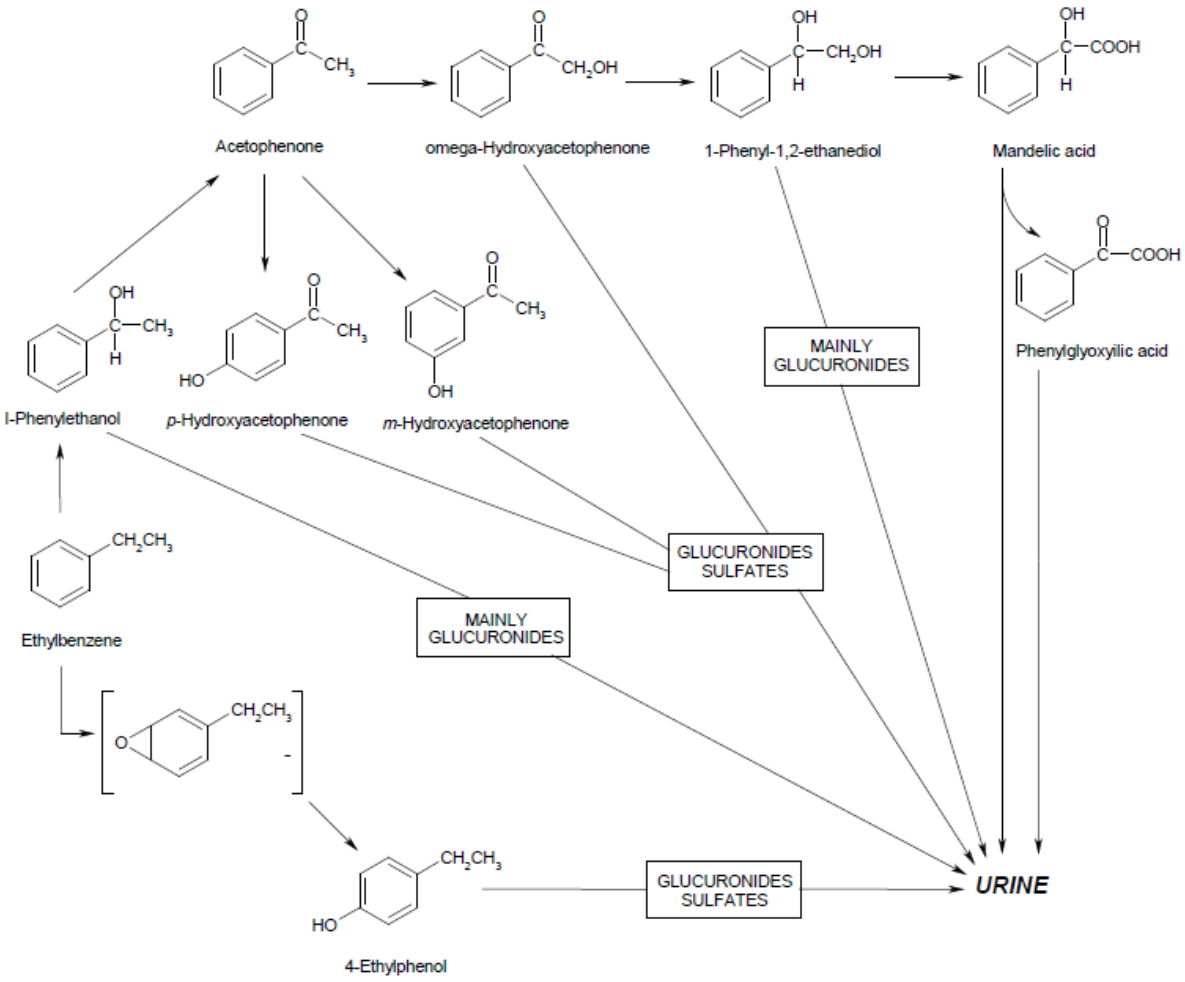
Source: adapted from the Toxicological Profile for Ethylbenzene (ATSDR, 2010)

2.3.3.2 Toxicokinetics

Metabolism

Ethylbenzene is well absorbed in humans via the inhalation and dermal routes of exposure, although oral absorption data in humans are lacking. Ethylbenzene rapidly distribution to adipose tissues throughout the body and accumulated primarily in the liver, kidney, and fat. Ethylbenzene is metabolized mainly through hepatic cytochrome P-450-mediated side chain oxidation (hydroxylation) to initially form 1-phenylethanol, from which several metabolites are

produced that are excreted in the urine. Isozymes involved in the initial oxidation include CYP2E1 and CYP1A2. The major urinary metabolites of ethylbenzene in humans exposed via inhalation are mandelic acid (approximately 64–71%) and phenylglyoxylic acid (approximately 19–25%). Minor pathways in humans yield hydroxylated derivatives that are conjugated with glucuronide or sulfate (ATSDR, 2010).



Source: Toxicological Profile for Ethylbenzene (ATSDR, 2010)

Figure 8 Metabolic pathways of Ethylbenzene

Elimination, Excretion and Biomarkers

The elimination ethylbenzene with inhalation exposure, major metabolite mandelic acid was rapid and biphasic, with half-lives of 3.1 hours for the rapid phase and 25 hours for the slow phase. The highest excretion rate of urinary metabolites in humans exposed to ethylbenzene by inhalation occurred 6–10 hours after the beginning of exposure and metabolic efficiency was of the exposure dose. Ethylbenzene can be measured in blood, subcutaneous fat, and in expired air. Mandelic and phenylglyoxylic acids are the predominant urinary metabolites and have been used to monitor workplace exposure (CDC, 2013: online; ATSDR, 2010). Monitoring by excretion mandelic acid in urine, urine specimen have to collect end of shift and level shouldn't more than 1.5 g/g Creatinine (ACGIH, 2007; Ministry of Labour, 2007).

2.3.3.3 Health Effect

Exposure to high levels of ethylbenzene can cause eye and throat irritation, vertigo, and dizziness. Direct contact with liquid ethylbenzene caused eye and skin irritation in animals. Developmental effects (decreases in growth and increased skeletal variations) have been observed in animals following inhalation exposure to high levels of ethylbenzene (ATSDR, 2010). IARC has classified ethylbenzene in group 2B as possibly carcinogenic to humans (IARC, 2014).

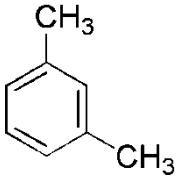
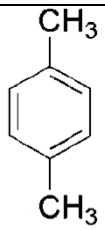
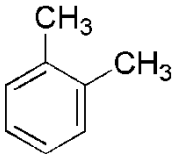
2.3.4 Xylene

2.3.4.1 Chemical and Physical Information

Xylene is sweet smell, colorless that catches easily on fire, found naturally in petroleum and coal. Industries also produce them for used as solvent, printing and rubber process (ATSDR, 1999). Xylenes are three forms (the methyl group refer to isomers) as meta-xylene, ortho-xylene and para-xylene. Physical information of benzene has shown in table below.

Table 4 Chemicals and Physical Information of Xylenes

Property	m-Xylene	p-Xylene	o-Xylene
Synonyms names	1,3-Dimethyl-benzene	1,4-Dimethyl-benzene	1,2-Dimethyl-benzene

Property	m-Xylene	p-Xylene	o-Xylene
	meta-xylene	para-xylene	ortho-xylene
Formula	C_8H_{10}	C_8H_{10}	C_8H_{10}
Chemical Structure			
CAS Number	108-38-3	106-42-3	95-47-6
Molecular weight	106.16	106.16	106.16
Melting point	-47.8 °C	13.2 °C	-25.2 °C
Boiling point	139.1 °C	138.4 °C	144.5 °C
Density at 20 °C	0.864 g/cm^3	0.8611 g/cm^3	0.880 g/cm^3
Vapor pressure at 25°C	8.29 mmHg	8.84 mmHg	6.61 mmHg
Water solubility at 25°C	161 mg/L	162 mg/L	178 mg/L
Log K_{ow} (octanol-water partitioning coefficient)	3.2	3.15	3.12
Log K_{oc} (soil adsorption coefficient)	2.22	2.31	2.11
Auto-ignition temperature	527 °C	528 °C	463 °C
Flashpoint	27 °C	27 °C	32 °C

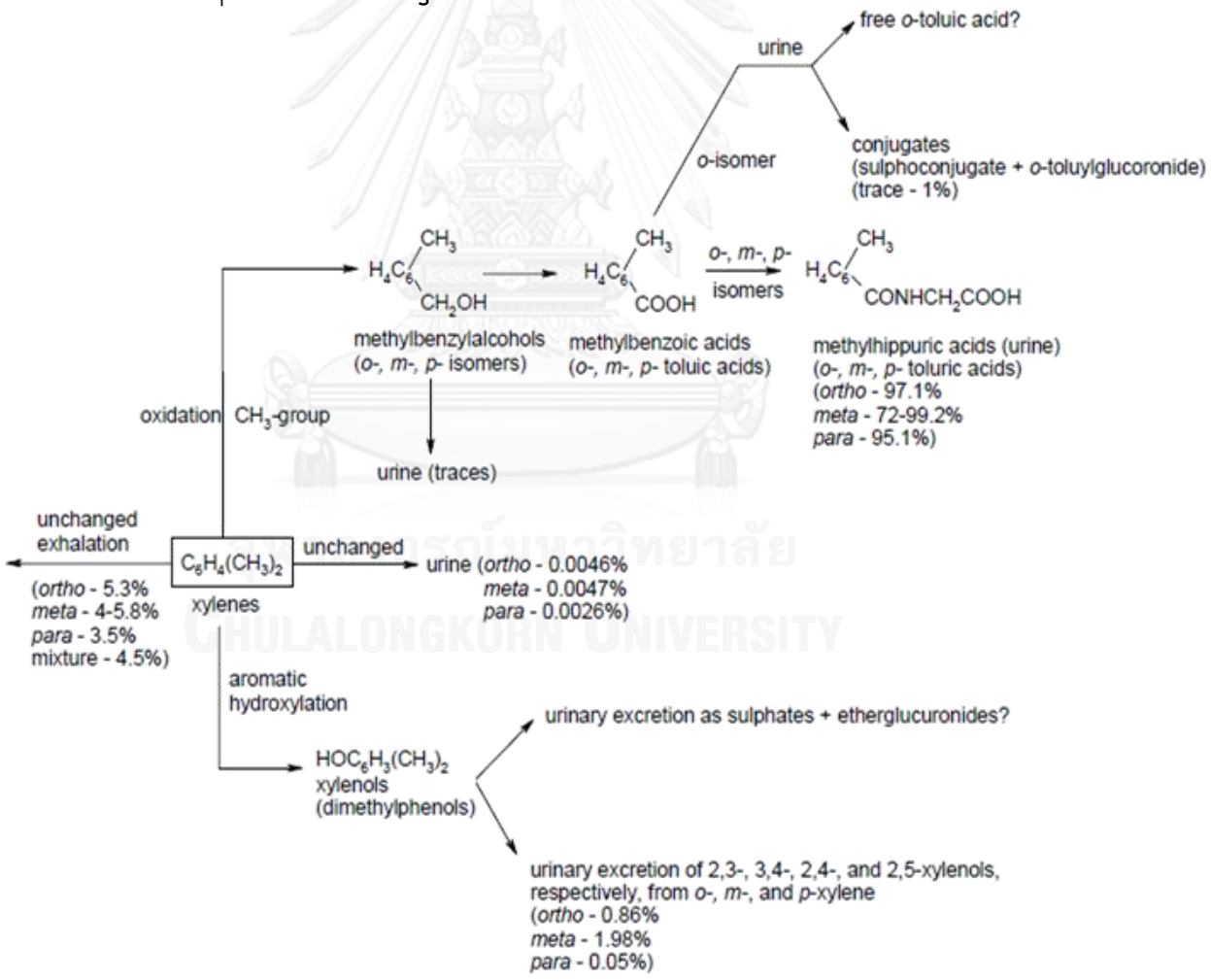
Source: adapted from the Toxicological Profile for Xylene (ATSDR, 2007b)

2.3.4.2 Toxicokinetics

Metabolism

Xylenes are well absorbed by inhalation and oral routes, and mainly distribute to lipid-rich tissues especially adipose and brain. If high uptake will occurs in well-perfused organs like kidneys and liver. Metabolism of xylenes in humans occurs primarily by hepatic cytochrome P-450-catalyzed oxidation of a side-chain methyl group to yield methylbenzoic acids (o-, m-, or p-toluic acids),

which are conjugated with glycine to form methylhippuric acids. Important CYP isozymes involved in the methylhydroxylation include CYP2E1 and CYP2B1, and metabolism to methylhippuric acids accounts for almost all (>90%) of the absorbed dose in humans, regardless of the isomer, route of administration, or dose or duration of exposure. Minor metabolic pathways that account for <10% of the absorbed dose in humans include unchanged xylene in the exhaled breath, and methylbenzyl alcohols, o-toluic acid glucuronide, xylene mercapturic acid, and xylenols (dimethylphenols) in the urine. CYP1A2 appears to be involved in the formation of the minor phenolic metabolites. The metabolism of xylenes in rats and other laboratory animals is qualitatively similar to that of humans, although glucuronide conjugates make up a larger proportion of the urinary excretion products (ATSDR, 2007b). A scheme for xylenes metabolism in humans and animals is presented in **Figure 9.**



Source: Toxicological Profile for Xylenes (ATSDR, 2007b)

Figure 9 Metabolic pathways of Xylenes

Elimination, Excretion and Biomarkers

In humans, 95% of absorbed xylene isomers is excreted as urinary metabolites, almost exclusively as methylhippuric acids, with the most of the remaining amount eliminated unchanged in the exhaled air. Less than 2% of the absorbed dose is excreted in the urine unchanged and as xylenols. There appear to be at least two distinct phases of elimination, a relatively rapid one (1-hour half-life) and a slower one (20-hour half-life, corresponding to elimination from the muscles and adipose tissue). Humans exposed to 100 or 200 ppm m-xylene for 7 hours excreted 54 and 61%, respectively, of the administered dose by 18 hours after exposure ended. Following intermittent acute exposure to 23, 69, or 138 ppm m-xylene, excretion of m-methylhippuric acid peaked 6–8 hours after exposure began and subsequently decreased rapidly so that almost no xylene or methyhippuric acid was detected 24 hours later. A fraction of an absorbed xylene dose is excreted unchanged in exhaled air, and about 90% of a dose is metabolized by the liver and then eliminated in urine over several days. Methylhippuric acids are the predominant urinary metabolites and have been used to monitor workplace exposures (CDC, 2013: online; ATSDR, 2007b). Monitoring by excretion methylhippuric acid in urine, urine specimen have to collect end of shift and methylhippuric acid shouldn't more than 1.5 g/g Creatinine (ACGIH, 2007; Ministry of Labour, 2007)

2.3.4.3 Health Effects

The primary effects of xylene exposure involve the nervous system by all routes of exposure, the respiratory tract by inhalation exposure, and, at higher oral exposure levels, hepatic, renal, and body weight effects. The nervous system effects include subjective symptoms of intoxication at higher concentrations and impaired performance on tests of short-term memory, reaction time, and equilibrium at lower concentrations. Humans have reported signs of nose, eye, and throat irritation during exposure to xylene vapors (ATSDR, 2007b).

Table 5 Summary of BTEX Information and Standard

	Benzene	Toluene	Ethylbenzene	Xylene
How might be exposed	- Tobacco smoke - Exhaust from motor vehicles / Gas stations and automobile service stations - Working in industries that use benzene (petroleum, petrochemicals) - Printers, shoe makers, steel workers, gas station workers (ATSDR, 2007a)	- Automobile exhaust. - Working with gasoline, kerosene, heating oil, paints, and lacquers. - Contact with containing toluene products (ATSDR, 2000)	- Working in petroleum industry, industries using solvents. - Contact with gasoline, automobile emissions, solvents, printing inks, varnishes and paints - Cigarette smoke (ATSDR, 2010)	- Work or live near petroleum industry or industries using xylene. - Painters, laboratory workers, gas station, automobile garage and metal workers. - Contact to products (paint, varnish, shellac, etc) and Cigarette smoke (ATSDR, 2007b)
Health Effect				
Acute effect	Drowsiness, dizziness, headaches, nausea, irritation skin, eyes, and nose, rapid heart rate, confusion, unconsciousness (ATSDR, 2007a)	Light-headed, dizzy or sleepy, Tiredness, weakness, confusion, nausea, loss of appetite (ATSDR, 2000)	Dizziness, throat and eyes irritation (ATSDR, 2010)	Headache, Dizziness, confusion, irritation of skin, eyes, throat and nose (ATSDR, 2007b)

	Benzene	Toluene	Ethylbenzene	Xylene
Chronic effect	Effect to bone marrow, decrease red blood cells (anemia), leukemia (ATSDR, 2007a)	Paranoid psychosis, loss of hearing and color vision, Effect to children with birth defects, growth and retard mental abilities (ATSDR, 2000)	Kidney damage in animal, Hearing loss, possible human carcinogen (ATSDR, 2010)	Problem with the lungs (possible liver and kidneys), memory difficulties (ATSDR, 2007b)
Carcinogenic Classification				
IARC (IARC, 2014)	Group 1 (Carcinogenic to humans)	Group 3 (Not classifiable as to its carcinogenicity to humans)	Group 2B (Possibly carcinogenic to humans)	Group 3 (Not classifiable as to its carcinogenicity to humans)
ACGIH (OSHA, 2012)	A1: Confirmed human carcinogen	A4: Not classifiable as a human carcinogen	A3: Confirmed animal carcinogen with unknown relevance to humans	A4: Not classifiable as a human carcinogen
USEPA (OSHA, 2012)	Know/likely human carcinogen	Inadequate information to assess carcinogenic potential	Not classifiable as to human carcinogenicity	Inadequate information to assess carcinogenic potential

	Benzene	Toluene	Ethylbenzene	Xylene
Ambient Air Standard				
Thailand Ambient Air Quality Standard (National Environmental Board, 2007)	Annual average: 1.7 µg/m^3	–	–	–
Exposure Limits				
ACGIH Threshold Limit Value; TLV (OSHA, 2012)	Time-weighted Average; TWA : 1 ppm	TWA: 20 ppm	TWA: 100 ppm	TWA: 100 ppm
NIOSH Recommended Exposure Limit; REL (OSHA, 2012)	Time-weighted Average; TWA : 0.1 ppm Short-term Exposure Limit; STEL: 1 ppm	TWA: 100 ppm STEL: 150 ppm	TWA: 100 ppm STEL: 125 ppm	TWA: 100 ppm STEL: 150 ppm
OSHA Permissible Exposure Limit; PEL General workplace (OSHA, 2012)	- TWA: 0.5 ppm - STEL: 5 ppm	TWA: 200 ppm	TWA: 20 ppm	- TWA: 100 ppm - STEL: 150 ppm

	Benzene	Toluene	Ethylbenzene	Xylene
Thailand, Labour Laws (Ministry of Interior, 1979)	TWA: 10 ppm	TWA: 200 ppm		TWA: 100 ppm
Biological Exposure Indicator				
ACGIH Biological Exposure Indices; BEIs (ACGIH, 2007)	TT-Muconic acid in urine (End of Shift: EOS) - 500 µg/g Cr. S-phenylmercapturic acid in urine(EOS) - 25 µg/g Cr.	Hippuric acid in urine (EOS) - 1.6 g/g Cr. o-Cresol in urine (EOS) - 0.5 mg/L	-	Methylhippuric acid in urine (EOS) – 1.5 g/g Cr.
Ministry of Labor, Thailand. Diagnostic Criteria of Occupational Disease (Ministry of Labour, 2007)	TT-Muconic acid in urine (End of Shift: EOS) - 500 µg/g Cr, And S-phenyl-mercapturic acid in urine(EOS) - 25 µg/g Cr.	Hippuric acid in urine (EOS) - 1.6 g/g Cr. o-Cresol in urine (EOS) - 0.5 mg/L	Mandelic acid in urine (End of workweek) - 1.5 g/g Cr.	Methylhippuric acid in urine (EOS) – 1.5 g/g Cr.
USEPA Toxicity Values (IRIS, 2014)				
Inhalation Reference Concentration (RfC) for Noncarcinogenic Effect	3×10^{-2} mg/m^3 (critical effect: decreased lymphocyte count)	5 mg/m^3 (critical effect: Neurological effects in	1 mg/m^3 (critical effect: developmental toxicity)	0.1 mg/m^3 (critical effect: decreased rotarod performance;

	Benzene	Toluene	Ethylbenzene	Xylene
		occupationally-exposed workers)		balance and coordination)
Inhalation Unit Risk (IUR) for Carcinogenic Effect	2.2 x 10^{-6} per µg/m^3 to 7.8 10^{-6} per µg/m^3	-	-	-
ATSDR Inhalation Minimal Risk Level (MRL) (ATSDR, 2004)	0.009 ppm (acute) 0.006 ppm (intermediate) 0.003 ppm (chronic)	1 ppm (acute) 0.08 ppm (chronic)	5 ppm (acute) 2 ppm (intermediate) 0.06 ppm (chronic)	2 ppm (acute) 0.6 ppm (intermediate) 0.05 ppm (chronic)

2.4 Route of BTEX Exposure

People are exposed to a number of chemicals in home, at work, and in the general environment. Exposure to toxic substances occurs through the three major routes (ATSDR, 2004) listed below.

(1) Inhalation is the main route of BTEX exposure, because BTEX substances are the volatile organic compounds which easily enter to human body. They often contaminate in the air and they are readily absorbed in the respiratory tract. The lining of the respiratory tract is not effective in preventing absorption of toxic substances into the body. The respiratory tract consists of the nasal passages, trachea (windpipe), larynx (voice box) and the lungs. The following factors affect inhalation of toxic substances.

(2) Dermal Absorption people can contact BTEX with the skin. BTEX are solvents, they are easily absorbed through the epidermis.

(3) Ingestion usually occurs accidentally or unknowingly. The digestive tract consists of the mouth, the esophagus (food canal), stomach, and intestine (large and small).

2.5 Concept of Health Risk Assessment

At the beginning of Human Health Risk Assessment Development, Many Organization made an effort to created their own principle, process or tools for predicted the difference health hazard, Organization such as US Environmental Protection Agency (USEPA) introduced 4 step of health risk assessment which focus on Chemicals, WHO coordinated with the Food and Agriculture Organization of the United Nations (FAO) introduced 4 step (similar to EPA's) which focus on Microbial risk assessment. Besides are other Organization (World Organization for Animal Health, Australia, New Zealand), they also produce principles with difference step or process but similar in substance.

For this study choose the principle of the Environmental Protection Agency that appropriated to assess health risk of pesticide exposure. In the very early step would scope issue and direction of the assessment, process will be done under the scenario and assumption that have to defined before starting step 1. USEPA defined health risk assessment is the process, can estimate the presumption of adverse health effect in people who exposure to chemicals from

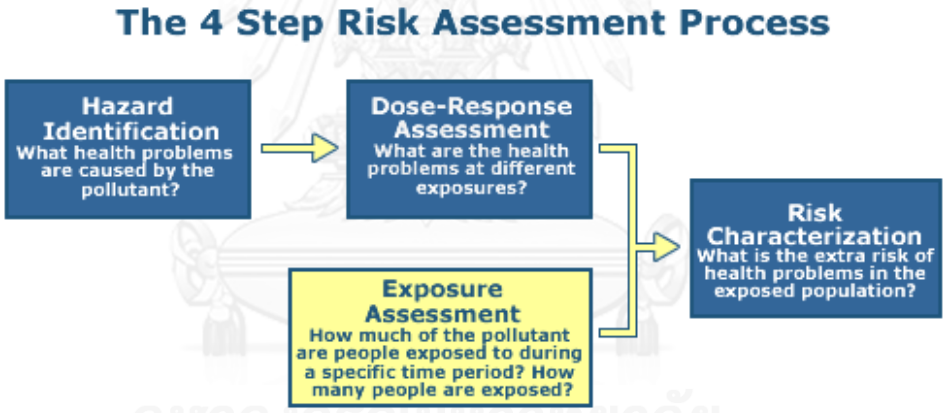
contaminate environmental, both of now and in the future. Explaining for understand better, process should address essential issue such as:

Identifying the important question such as: What are problem? What is the cause? Which people or groups of people were affected? What is opportunity of people will get health problem, when they expose those chemical in different levels? Are some people have more possibility to expose or more risk when expose environment stressor. (Considering factors such as genetics, age, gender, ethnic practices etc.)

Identifying list of hazard or list of chemical may affect to human health.

Reviewing previous evidence or information, including necessary data which have to use for assess risk. (e.g. RfD, RfC, people life expectancy, skin absorb rate)

The information supporting of these issues can helps for decision making, understanding the possible cause of environmental that lead to rise human health risk.



Source: USEPA.Integrated Risk Information System (U.S.EPA, 2012b)

Figure 10 Step of Health Risk Assessment

2.5.1 Hazard Identification

To identified kind of adverse effects that can cause by exposure to some agent. This step have to show “What is/are hazard(s)?” Hazard means events or substances that occur both of nature creating and man-made, can be potential cause to make problem on health, injury disability including death. Classify hazard as nature hazard (e.g. earth quacks, flooding, forest fire, Tsunami) and man-made hazard (e.g. chemicals hazard, industrial pollution, radiation). Another way to classify by

hazard characteristic, show hazard in three types as biological hazard, chemical hazard and physical hazard.

In case of pesticide, Hazard identification can determine cause an increasing of incidence of adverse effects (e.g. pesticide exposure can cause the delay of nervous system). The process of exist for scientific information for a chemical and develop a number of evidence linkage between chemicals and the effects that people didn't expect.

2.5.2 Dose – Response Assessment

To verify the association between dose and chemical effect, is the two-step process. First step is assessment all data that were available or could be gather through analysis, in condition to verify the dose-response relationships by rang of doses that we observe (i.e. doses that reported in data collecting system). The second step composed of extrapolation to determine the risk (probably of adverse effect) over the lover rang of exist observation data in condition to make intervention about the critical region where the level of dose began to be cause of adverse effect in the human population.

Generally, the evidence information is analyzed for a better biological or natural understanding of each type of toxicity or adverse effect (response) occurring; the understanding of toxicity were caused can call the "mode of action" (which is defined by processes and key events, beginning with interaction of chemical substance with a cell, proceeding through anatomical changes and body system, and the result of effect, for example, mutation formation). Have to use concept of a no observed adverse effect level (NOAEL), lowest observed adverse effect level (LOAEL), reference dose (RfD) or reference concentration (RfC) for determine human risk. In term of apply theses value /dose to assess risk in human population, usually review information from organization of international level (such as ATSDR, IRIS)

2.5.3 Exposure Assessment

To calculate a numeric estimate of exposure or dose. Exposure assessment considered both the exposure pathway (agent taken from source to human be contacting) as well as the route of exposure (means entry of agent into human body). The route exposure be generally additional describe as intake (through an opening of body, e.g. inhaling, drinking, eating) or uptake (absorb through body

tissues, such as through the skin and eye). The apply dose is the total of agent at the absorption barrier that is available for absorption. The potential dose is the amount of agent that is ingested, inhaled, or applied to the skin. The applied dose may be less than the potential dose if the agent is only partly bioavailable. For the internal dose or absorb dose is the total of a chemical that had been absorbed and was exist for interaction with significant receptor in the human body. Finally, delivery dose was the total of chemical existing for interaction of specific cell or specific organ.

2.5.4 Risk Characterization

This steps aims to summarized information, including integrate information from the proceed steps of health risk assessment to synthesis all conclusion about risk and use this output information for decision makers, thus risk characterization is not only about science but also about making clear those science doesn't tell us surely thing and making clear that policy choice must be made.

A risk characterization bring the risk assessor's judgment as to the character and present or absence of risk, according with information about how risk can assessed, where assumptions and uncertainty still available , and where alternative policy will want to be created. Risk characterization taken put in both human health risk assessment and ecological risk assessment.

2.6 Analysis of BTEX

2.6.1 BTEX in Air Samples

There are several suggestion a method for analysis of VOCs and BTEX such as USEPA suggested using the sensitive and specificity analytical method; procedure that requires elaborate sampling and double stage thermal desorption with gas chromatography and a mass detector (GC/MS) (U.S.EPA, 1996). The Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) suggested using method for simple requiring sampling with charcoal, extraction in carbon disulfide and inject into the gas chromatography flame ionization detector (GC-FID) (NIOSH, 2003a; OSHA, 2002)

Gas chromatography is separating a mixture of analyzes of their partitioning between stationary phase and mobile phase. The volatile organic liquid mixture will inject into the GC through the septum to a heated injection port. The temperature of

the injector is selected so as to vaporize the sample upon injection. The sample vapour is then carried through the column by the carrier gas. The detector temperature is chosen to be at least 20°C higher than the highest boiling point, in order to ensure all analyzes are detected as gases.

2.6.2 BTEX in Urinary Samples

Following NIOSH Manual of Analytical Methods, the collection of sampling and analysis methods. All of air, urine and blood of workers who expose occupationally contaminants. NIOSH suggested HPLC-UV detection for analyze urinary metabolites of toluene and xylene (biomarkers are hippuric acid, and methylhippuric acid, respectively) (NIOSH, 2003b)

2.7 Related Research

The several studies related to BTEX exposure had been reported. Summation of some study related to this study was reviewed and presented in **Table 6**

Table 6 Summary of Studies Related to BTEX

Location /References	Study locations/ study subjects	Sample collection	Concentrated Chemicals	Results
Bangkok, Thailand (Tunsaringkarn et al., 2012)	6 gasoline stations /49 workers	- ambient air samplers (both working area and the roadside)	Benzene, Toluene, Ethylbenzene, Xylene	BTEX concentration in gas stations was slightly higher than the roadside, benzene were in the unacceptable level for carcinogenic concern (1.75×10^{-4}) and exposure to benzene and toluene may cause fatigue.
Bangkok, Thailand (Thaveevongs et al., 2010)	10 gas station 20 workers	- Ambient air samples at the roadsides. - Personal air samples	MTBE, benzene, toluene, xylene, ethylbenzene, isooctane, n-heptane, stylene	MTBE and benzene were in the unacceptable level for carcinogenic effect of concern as 2.41×10^{-5} - 1.18×10^{-4} and 3.42×10^{-4} - 1.23×10^{-3},respectively, exposure level of ethylbenzene, 1.55×10^{-6} -5.83×10^{-6} was within an acceptable criteria.
Bangkok, Thailand (Kitwattanavong, 2010)	Gas station in Bangkok	- Station ambient air samples - Personal air samples	Carbonyl Compounds and BTEX	Concentration of benzene 220.29 µg/m^3, toluene 297.03 µg/m^3, etylbenzene 34.96 µg/m^3, xylene 139.89 µg/m^3. Found cancer risk for benzene was 4.14×10^{-5} – 4.99×10^{-4} but found an acceptable level for non-carcinogenic risk.
Bangkok, Thailand (Arayasiri et al., 2010)	13 roadside locations and 9	- Ambient air samples at the roadsides.	benzene, 1,3-butadiene	Ambient air concentrations at the roadsides were significantly higher than in police offices. Traffic

Location /References	Study locations/ study subjects	Sample collection	Concentrated Chemicals	Results
	police offices in central Bangkok/ 24 traffic policemen and 24 office policemen	- Personal air samples - Urine samples both pre-shift and post-shift		policemen had a significantly higher exposure to benzene and 1,3-butadiene than office policemen. Biomarkers of benzene exposure urinary metabolite, trans, trans-muconic acid were significantly higher in traffic policemen than office policemen.
Thailand (Navasumrit et al., 2005)	main road, schools, gasoline stations, petrochemical factories, street venders	- Ambient Air - Personal air - Urine and blood (DNA)	Benzene, trans,trans-muconic acid, blood benzene, DNA damage	Results showed benzene concentration on main road (33.71 ppb), schools (8.25 ppb), gasoline stations (64.78 ppb), petrochemical factories (66.24 ppb), found that increased benzene exposure were significantly increased trans,trans-muconic acid in all benzene-expossed groups.
Athens, Greece (Soldatos et al., 2002)	Enclosed parking and gasoline station workers	- Personal air samples	BTEX	BTEX concentrations in car parking recorded the highest mean is toluene concentrations (374 µg/m^3) and the lowest is ethybenzene concentrations (102 µg/m^3). Concentrations of BTEX in the first and second underground floor higher than the third floor, Concentrations were related to the number of cars.

CHAPTER III
REEARCH METHODOLOGY

3.1 Research Design

The research design of this study is a cross-sectional study to find relationship between BTEX exposure, urinary metabolite and health symptoms, while Health Risk Assessment process was use for estimate human health risk or the presumption of adverse health effect.

3.2 Study Area

Car parking in the urban area at central of Bangkok with parking spaces for thousands of vehicles and employ workers in position parking attendants, were purposive selected.

Figure 11 Sampling Site Locations

(a), (b) parking in building, and **(c)** parking in basement open air area

3.3 Study Population

The occupationally exposed group consisted of 26 day-shift workers at selected parking. With jobs description as to make traffic convenient for customer. The concentrations of BTEX would monitor continuously during working time with personal samplers at the breathing zone by attached to clothing of the workers. Urine was collected at the ending of shift day and interviewing by using questionnaire was done at that time.

3.4 Data Collection

The data collections have done to collect samples both weekday and weekend (under comparable car density condition). Collection consisted of personal air sampling, urine sampling and interviewing by using questionnaire. All performance has done together for 4 days (2 days for weekday and 2 days for weekend).

Table 7 Summary of Data Collection

Participants code	Weekday	Weekend	Total Samples
01	Air + urine + Questionnaire (Daily symptoms)	Air + urine + Questionnaire (Daily symptoms)	Air = 2 Urine = 2 Daily symptoms = 2
02	same as above	same as above	same as above
03	same as above	same as above	same as above
...	same as above	same as above	same as above
26	same as above	same as above	same as above
Total	Air = 26 Urine = 26 Daily symptoms = 26	Air = 26 Urine = 26 Daily symptoms = 26	Air = 52 Urine = 52 Daily symptoms = 52
	Average weekday – weekend concentrations (26 records)		52 records

The average concentrations of BTEX and urinary metabolites concentrations of weekday and weekend would be used to calculated exposure concentration in the health risk assessment step 3rd - exposure assessment and then calculate risk level in the final step – risk characterization. Investigation of associations for BTEX

concentrations, urinary metabolite concentrations, and BTEX exposure symptoms were used another data set (52 records)

3.4.1 Air Sampling

Personal BTEX exposure monitored continuously 8 hours. The method of sample collection was followed NIOSH Manual of Analytical Method No.1501: Hydrocarbon, Aromatic (NIOSH, 2003a). Using active diffusion sampling tubes, sample tubes attached to participant's clothing and monitored continuously over working times. After that collected sample tubes and cover both tip by stopples and Aluminium foil, then keep in box (at 4 °C) before carry to *Laboratory of College of Public Health Science, Chulalongkorn University.* (kept at about 4 °C and have to analyze within 30 days)

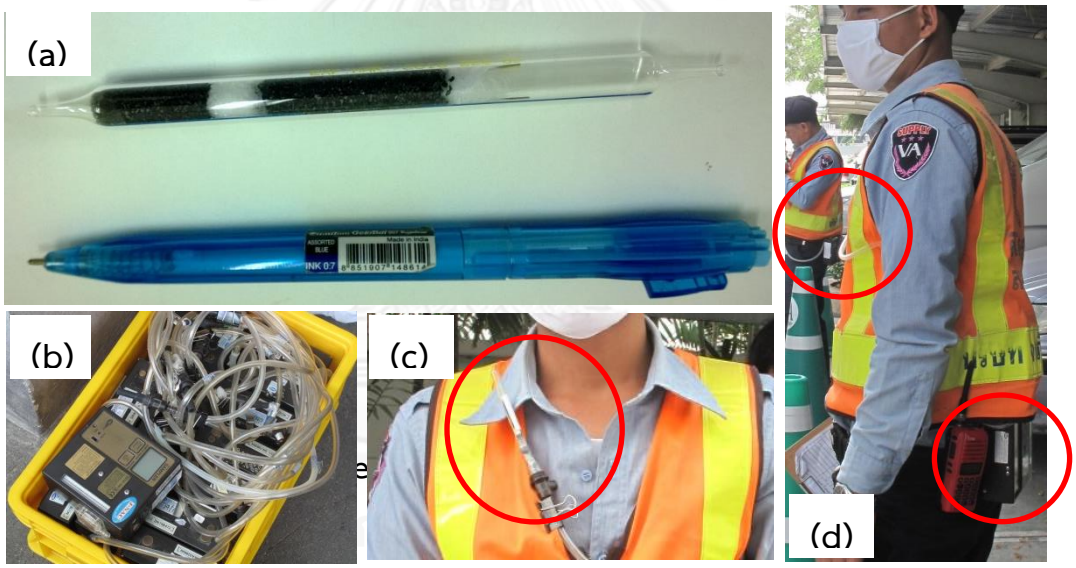


Figure 12 Air Sampling Instruments

(a) Charcoal sorbent sample tubes**, (b)** personal pump connected via a length of tubing, **(c)** Sample tubes attached to participant's clothing, and **(d)** show position of personal pump

3.4.2 Urine Sampling

After interviewing and collected the questionnaire, participant's urine was collected for measure the urinary metabolite level. The method of urine sample collection followed the method 8301 (NIOSH, 2003b) for evaluate hippuric acid and methyl hippuric (biomarkers of toluene and xylenes, respectively). Evaluation trans,trans-muconic acid or t,t-MA (biomarker of benzene) by in house method. In this study haven't analyzed urinary metabolite of ethylbenzene (mandelic acid) because the laboratory limitation. Urine samples collected 50 - 100 ml. into plastic bottle bottles at the end of the work shift and for preservative kept at about 4 °C before carry to *Private-Laboratory (Special-Lab Center Co.,Ltd. Sathorn Bangkok).* Analyzed by High-performance liquid chromatography (HPLC). Creatinine was used to adjust the urine metabolite concentration.

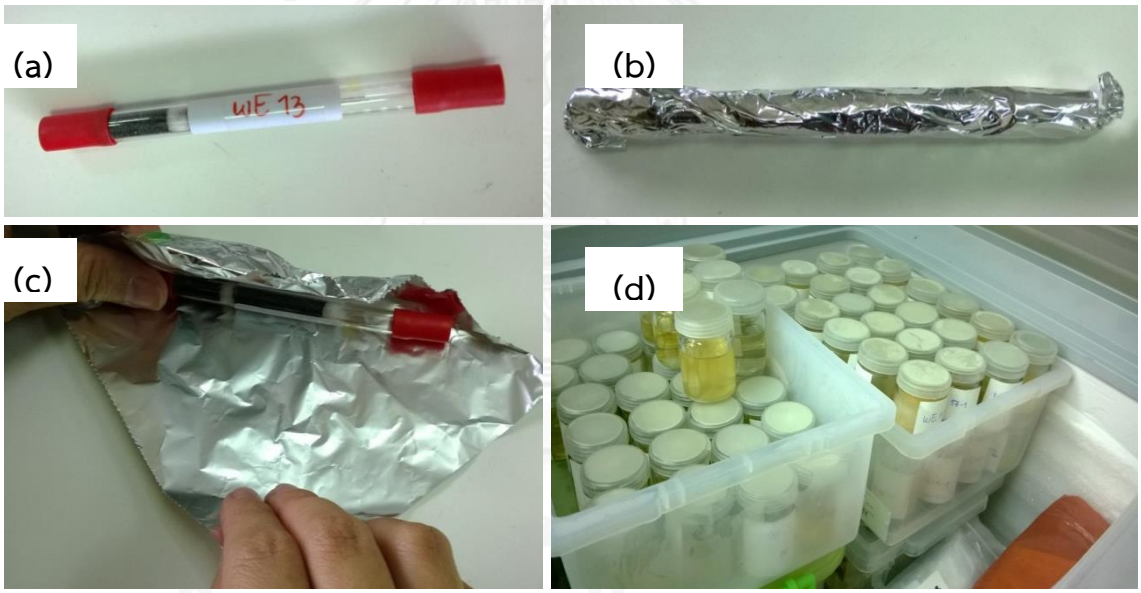


Figure 13 Samples Preservation

(a) Charcoal sorbent sample tubes cover by both tip by stopples, **(b)** and **(c)** Charcoal sorbent sample tubes cover by Aluminium foil, and **(d)** urine preservative kept in freeze

3.4.3 Questionnaire

Interview administer questionnaires was used to investigate demographic information, as well as risk factors and BTEX exposure symptoms. The questionnaire include specific question on current health profile that concentrate on BTEX exposure.

The questionnaire separated into 3 parts ***(Appendix A and B)*** as following;

Part 1: General Characteristic - asked about demographic information, environmental factors and personal behaviours which may influence participant exposure to BTEX.

Part 2: Current Working Information - The questions included specific questions on the exposure to BTEX in the air in their workplace (exposure factors), where necessary for calculate exposure concentration (EC).

Part 3: BTEX Exposure Symptoms - The questions about health symptoms related BTEX exposure via inhalation.

An evaluation using the Item Objective Congruence Index or IOC was process by three experts as Assist.Prof.Dr.Wattasit Siriwong, Dr.Nutta Taneepanichskul and Dr.Benjawan Tawatsupa. They were rated individual items on the degree to which they do or do not measure specific objectives. A content expert evaluated each item by giving the item a rating of 1 (for clearly measuring), -1 (clearly not measuring), or 0 (degree to which it measures the content area is unclear) for each objectives. After revised wording in some items of questionnaire, An index of item objective congruence (IOC) of the questionnaire was 0.85

Reliability established using a pilot test by collecting data from 30 subjects not included in the sample. Reliability was analyzed on a questionnaire in which the items are dichotomous by Kuder-Richardson-20 (KR-20), Cronbach's alpha was 0.73

3.5 Data Analysis

Data analysis separated for 4 sections including an air samples analytical method, urinary analytical methods, exposure assessment and risk calculation, and statistical analysis

3.5.1 Air Samples Analytical Method

3.5.1.1 Sample Preparation

Analysis BTEX used carbon disulfide (CS2) for extraction then inject standard solvent (Internal standard) leave for 30 minute, separated clear extracted solution and transfer to 2 mL glass vials injected into Gas Chromatography with flame ionization detector (GC-FID). The flow of sample preparation is shown in **Figure 14**

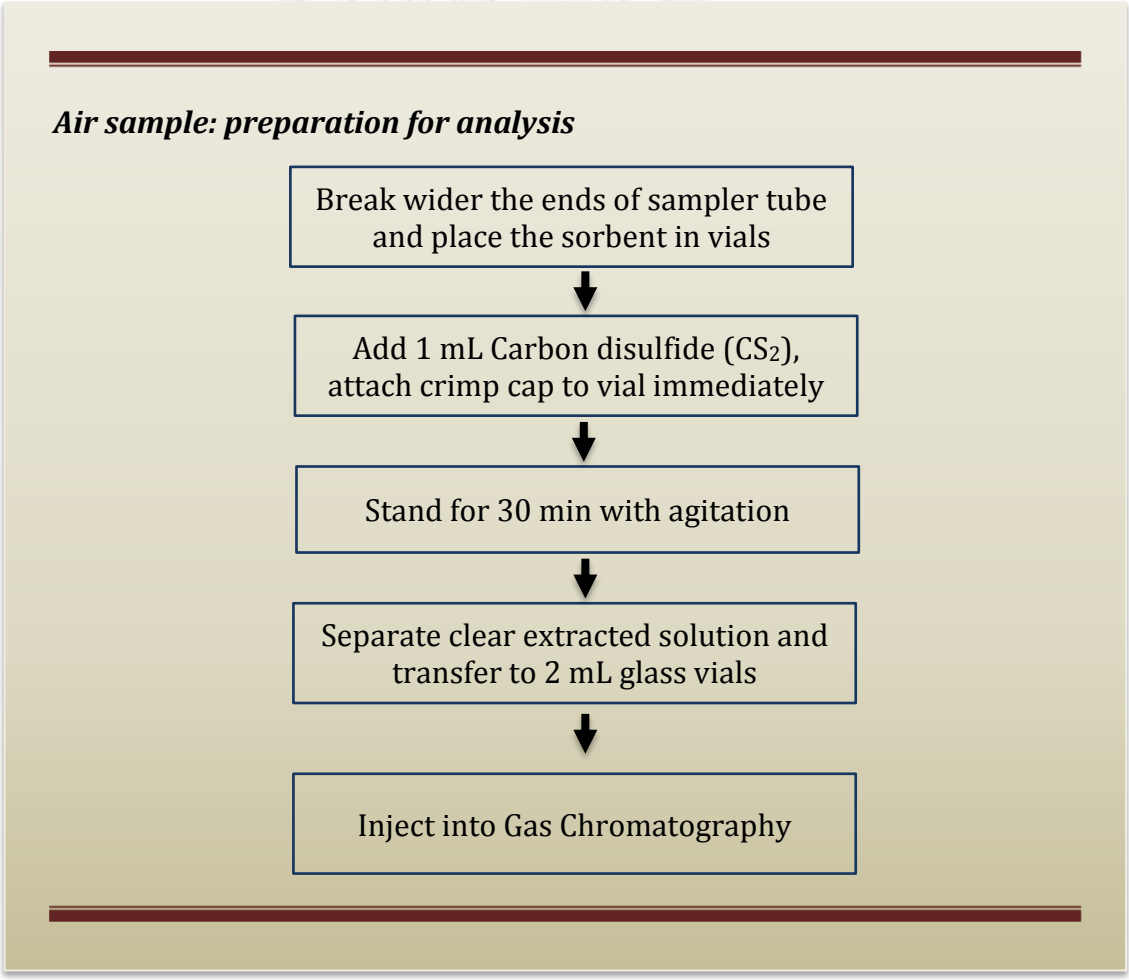


Figure 14 Air Sample Preparations

3.5.1.2 Sample Analysis

Analytical Technique

The samples analysis procedure of BTEX was based on the NIOSH Manual of Analytical Method No.1501 (NIOSH, 2003a). Gas chromatography with flame ionization detector (GC-FID) was used to be analysis technique. The GC condition for analysis is shown in **Table 8**

Table 8 The Condition for BTEX Analysis

Capillary Column	CP-Sil 24 CB 30m, 0.32mm, 0.25µm, #CP7831
Carrier Gas	Helium (He)
	make up Helium (He) – 28 ml/min make up Hydrogen (H_2) – 30 ml/min make up Air, Oxygen (O_2) – 300 ml/min
Flow rate of He	1 ml/min
Type of Injection	Spiltless
Injection Volume	2 µL
Injector Temperature	150°C
Detector	Flame Ionization Detector (FID)
Detector Temperature	150°C
Oven	Temp 40°C, Hold 2 min to 100°C, Rate 10°C/min

Quality Control

The Limit of Detection (LOD) was determined by preparing the lowest concentration of mix standard. The concentration of sample lower than LOQ was reported as not detected. The calculation of LOD follows equations 3.1

$$\mathrm{LOD} = \frac{3 \times \text{the lowest concentration used} \times \text{standard deviation}}{X_{bar}} \quad \textbf{Equation 3.1}$$

$$\text{Standard deviation} = \sqrt{\sum_{i=1} \frac{(X_i - X_{bar})^2}{(n-1)}} \qquad \textbf{Equation 3.2}$$

Where;

Xi = Peak area of target compound observed

Xbar = Average area of these observations

Mix standard were injected into GC-FID for 3 times, the average was calculated. The limit of detection (LOD) of benzene, toluene, ethylbenzene, and xylene were set to 0.2, 0.3, 0.2, and 0.03 µg/m^3 respectively. Percent of recovery of BTEX were in range of 80 – 120 %. All of chemicals usage was analytical and chromatographic grade. Carbon disulfide and sorbent in the sampler tube (field blanks) was analyzed as to check contamination of BTEX species. Concentrations of BTEX measured in duplicate samples were in good agreement.

Calibration Curve

Using mix standard solution (Mix of Aromatic Hydrocarbon), five difference concentrations as 0.5, 1, 5, 10 and 15 ppm were prepared. In each standard BTEX concentration, alpha, alpha, alpha-Trifluorotoluene (Ehrenstorfer, Germany) with concentration 2,000 ng/µl in Methanol was added as the internal standard. The calibration curve of benzene, toluene, ethylbenzene, m,p-xylene and o-xylene have $R^2 \geq 0.99$ ***(Appendix C).***

Calculation of Concentration Values

According to Calibration curve and their linear equation, the mass of BTEX and concentrations of BTEX could be calculated.

$$Ms = \frac{(P_A - P_B)}{P_S} \times C_S \times \frac{V_s}{V_1} \qquad \text{Equation 3.3}$$

Where:

MS (µg) = Mass of contaminants (BTEX)

C_S (µg/ml) = Concentration of the mixed standard solution

P_A = Peak area of contaminants per peak area of Internal standard in sample

P_B = Peak area of contaminants per peak area of Internal standard in blank

P_S = Peak area of contaminants per peak area of Internal standard in mixed standard

V_S (µg) = Sample volume (2 ml)

V_1 (µg) = Injection volume (1 µg)

$$\text{concentration of Contaminant} = \frac{\text{Mass of contaminants (µg)}}{\text{Volume of Air } (m^3)}$$ Equation 3.4

3.5.2 Urinary Analytical Method

Analytical Technique

The samples analysis procedure of BTEX was based on the *NIOSH Manual of Analytical Method No.8301* (NIOSH, 2003b) to analyzed hippuric acid and methylhippuric acid. *In house method* was used for analyzed t,t-muconic acid. High Performance Liquid Chromatography with Ultraviolet Detection method (HPLC-UV) was used to be analysis technique.

Calibration Curve and Calculation of Concentration Values

Stock solution for t,t-muconic acid was prepared in methanol. Urine samples were spike with t,t-MA (working solutions) to reach final concentration 0.20, 0.50, 1.00, 2.50, and 5.00 ug/ml. The solution of vanillic acid at the concentration of 100 µg/mL was prepared as internal standard. These solutions were used to prepare the calibration curves and for quality control. Determination was carried out based on internal standardization. The calibration curves were drawn by plotting peak area ratio of the analyte to the internal standard against the concentration. For Hippuric acid and Methyl hippuric acid, The working solutions at concentrations 0.06, 0.125, 0.25, 0.50, and 1.00 g/L. ***(Appendix C)***.

3.5.3 Exposure Assessment and Risk Calculation

According to literature reviewing in chapter II, four steps were conduct to obtain the risk level. Inhalation Risk Assessment in this study hold to USEPA's principles, Risk Assessment Guidance for Superfund (RAGS) Volume I: Human Health Evaluation Manual (Part F: Supplemental Guidance for Inhalation Risk Assessment) (U.S.EPA, 2009)

3.5.3.1 Hazard Identification

This step provides the hazard chemicals and serious health effects. Since benzene, toluene, ethylbenzene, and xylene were identified as hazard chemicals that known to cause adverse acute and chronic human health effects (literature show in **Chapter II – Table 5**) at concentrations that are frequently releases from combustion in vehicle. These chemicals could effect to parking workers via inhalation partway.

3.5.3.2 Dose-Respond Assessment

This step focuses on the potential risk of development toxicity associated with exposure to BTEX. Following IRIS, the EPA's electronic database containing scientific information of chemicals about potential adverse health effects, health benchmarks for non-carcinogenic health effects including RfD and RfC as well as health benchmarks for carcinogenic effects as oral Slop Factor, and IUR. The BTEX information was evaluated and available from USEPA.IRIS website. This step used information from the summary in **Table 5.**

3.5.3.3 Exposure Assessment

Direct measurement of individual exposure via the air medium. Calculated by using information of laboratory analysis in a previously subtopic of data analysis. According to a main document as RAGS, Part A (U.S.EPA, 1989) was described the intake equation below;

$$\text{Intake (mg/kg-day)} = \frac{\text{CA x IR x ET x EF x ED}}{\text{BW x AT}} \qquad \textbf{Equation 3.5}$$

Where; CA (mg/m^3) = Contaminants concentration in air

IR (m^3/hour) = Inhalation Rate

ET (hours/day)	=	Exposure time
EF (days/year)	=	Exposure Frequency
ED (years)	=	Exposure Duration
BW (kg)	=	Body Weight
AT (days)	=	Averaging Time

USEPA developed RAGS Part F (U.S.EPA, 2009), updated and recommended the estimation of exposure concentrations (EC) for each BTEX via inhalation were estimated by equations below. This document also recommends that when assess risk via inhalation, should use the concentration of chemicals in air as exposure metric (such as mg/m$^{3)}$ rather than inhalation intake of contaminant in air (such as mg/kg-day which base on IR and BW) because the chemical that reaches the target site through the inhalation pathway is not simple function of the IR and BW.

For obtaining duration of contact information (i.e. ET, EF, ED), in this study can be obtained from interview administer questionnaires.

1) Estimating Exposure Concentrations for Assessing Cancer Risks

$$EC = \frac{CA \times ET \times EF \times ED}{AT} \qquad \textbf{Equation 3.6}$$

Where;

EC (μg/m^3)	=	Exposure concentration
CA (μg/m^3)	=	B, T, E, X concentration in air
ET (hours/day)	=	Exposure time
EF (days/year)	=	Exposure Frequency
ED (year)	=	Exposure Duration
AT (hours)	=	Averaging Time
		(Lifetime in years x days/year x hours/day)

2) Estimating Exposure Concentrations for Calculating Hazard Quotients

$$EC = \frac{CA \times ET \times EF \times ED}{AT} \qquad \text{Equation 3.7}$$

Where; EC ($\mu g/m^3$) = Exposure concentration

CA ($\mu g/m^3$) = B, T, E, X concentration in air

ET (hours/day) = Exposure time

EF (days/year) = Exposure Frequency

ED (year) = Exposure Duration

AT (hours) = Averaging Time
(ED in years x 336 days/year x 8 hours/day)

3.5.3.4 Risk Characterization

In RAGS part F, risk level for carcinogenic and non-carcinogenic health effect can be calculated with the following equations.

1) Carcinogenic Risk Characterization

$$\text{Cancer Risk} = \text{EC x IUR} \qquad \text{Equation 3.8}$$

Where; EC ($\mu g/m^3$) = Exposure concentration

IUR (per $\mu g/m^3$) = Inhalation Unit Risk

2) Non-Carcinogenic Risk Characterization

$$HQ = \frac{EC}{RfC \times 1000\ \mu g/mg} \qquad \textbf{Equation 3.6}$$

Where; EC ($\mu g/m^3$) = Exposure concentration

RfC (mg/m^3) = Inhalation Reference Concentration

Interpret that Cancer risk of more than 10^{-6} will consider an unacceptable level for carcinogenic effect of concern. HQ and HI of more than 1 will consider an unacceptable level for non-carcinogenic effect of concern

3.5.4 Statistical Analysis

The licensed SPSS version 17 for windows was used. All study parameters were tested for normality by the one-sample Kolmogorov–Smirnov test. Mann-

whitney U test and post-hoc test were used for comparing BTEX concentration means differences. The correlation between air BTEX concentrations and urinary metabolite concentrations were computed by spearman rank correlation test. The relationship between air BTEX concentrations and BTEX exposure symptoms was evaluated by logistic regression analysis, it was performed to assess the relative contribution of individual exposure, biomarkers of exposure and confounding factors including environmental factors and personal habits.

3.6 Ethical Consideration

This study was review and approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University. COA No. 053/2014

CHAPTER IV
RESULT

4.1 Participants Characterizations

A total of 26 workers were participated in this study (13 men and 13 women). All of them were interviewed face to face by author following questionnaire using. The results show that the age of male and female ranged 20 to 63 years old, the mean and Standard Deviation (mean ± SD) of these participants is 35.85 ± 12.09 years old. Body weight of them ranged 44 to 80 kilograms and the mean ± SD is 59.88 ± 9.08 kilograms. Height ranged 150 to 170 centimeters and the mean ± SD of their height is 160.92 ± 4.95 centimeters.

For present about working location, workers were rotated day by day. For example they work at underground parking today, tomorrow they were moved to other locations. Considering jobs station, there are 14 workers are taking care and make convenient at parking, and 12 workers are handle at entrance/exit and give a parking pass to customer. They are 8 – 12 hours of work per day, 336 days of working per year, and 3.61 ± 2.78 years for working duration at this working site.

For present other risk factor for increased exposure to BTEX, there are 9 smoking workers and 17 non-smoking workers. The results also present passive smoking exposure, there are 11 workers that have passive smoking behavior, and 15 workers are not. For living near pollution source for increased exposure to BTEX, there are only a few numbers of workers that living near those pollution sources as show in table below.

Table 9 Basic Characteristic of Parking Workers

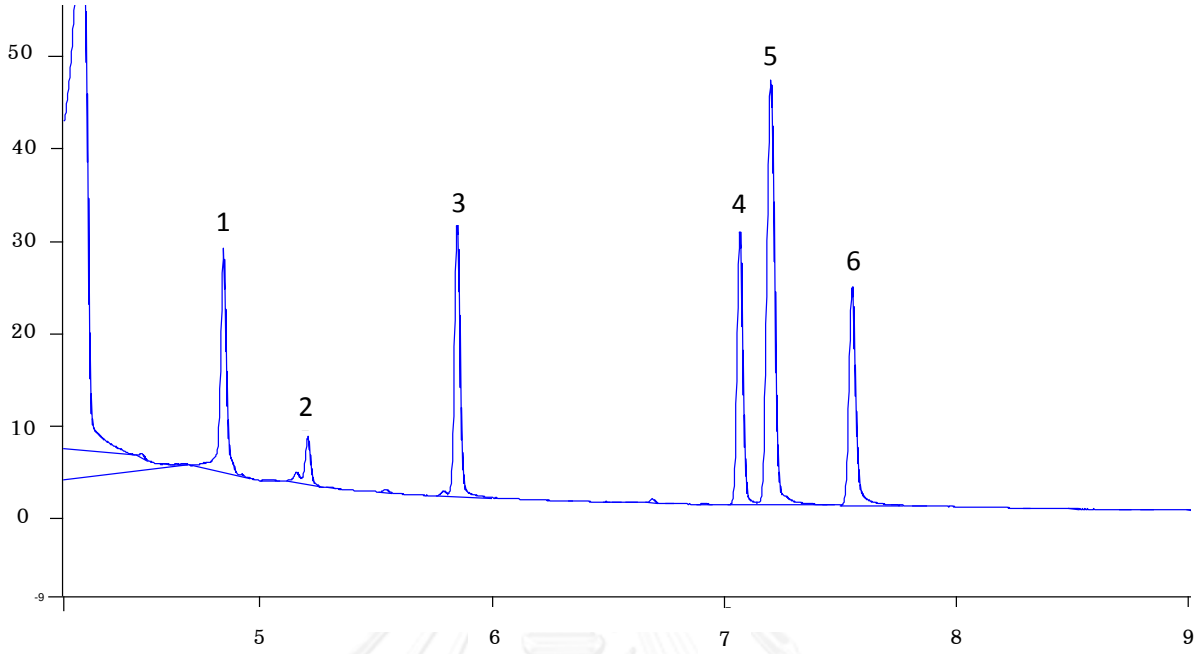
Characteristic	Mean (±SD)
Numbers (n = 26) Male (n= 13), Female (n= 13)	
Age (yrs)	35.85 ± 12.09
Weight (kg)	59.88 ± 9.08
Height (cm)	160.92 ± 4.95
Hours of work per day (hour)	8.00 – 12.00
Days of work per year (day)	336.00
Working Duration (year)	3.61 ± 2.78

Characteristic	Frequency (Percent)
Jobs description	
Making convenient at parking	14 (53.8%)
Sitting at Entrance/Exit	12 (46.2%)
Smoking	
Non-Smoker	17 (65.4%)
Smoker	9 (34.6%)
Passive smoking exposure	
No	15 (57.7%)
Yes	11 (42.3%)
Living near high traffic	
No	22 (84.6%)
Yes	4 (15.4%)
Living near gas station (<500m.)	
No	21 (80.8%)
Yes	5 (19.2%)
Living near automotive service station/garage (<500 m.)	
No	23 (88.5%)
Yes	3 (11.5%)
Living near petrochemical/rubber/paint factory (<1000 m.)	
No	26 (100%)
Yes	0 (0%)
PPE using (Mask type)	
No	22 (84.3%)
Yes	4 (15.4%)

4.2 Optimum Condition of Instruments for Determining BTEX

4.2.1 Optimum Condition for Determining BTEX

The optimum condition for determining personal BTEX exposure of Gas Chromatography with flame ionization detector or GC-FID was set up by using standard solution of BTEX (Mix of Aromatic Hydrocarbon) and alpha, alpha, alpha-Trifluorotoluene as an internal standard. The chromatogram of BTEX from GC-FID showed in **Figure 15**



1. Benzene (4.86) 2. Internal standard (5.39) 3. Toluene (5.76)

4. Etylbenzene (7.18) 5. m,p-Xylene (7.32) 6. o-Xylene (7.68)

Figure 15 Chromatogram of Standard BTEX

At the Concentration of Standard Solution 10 ppm. (The number in bracket represented retention time)

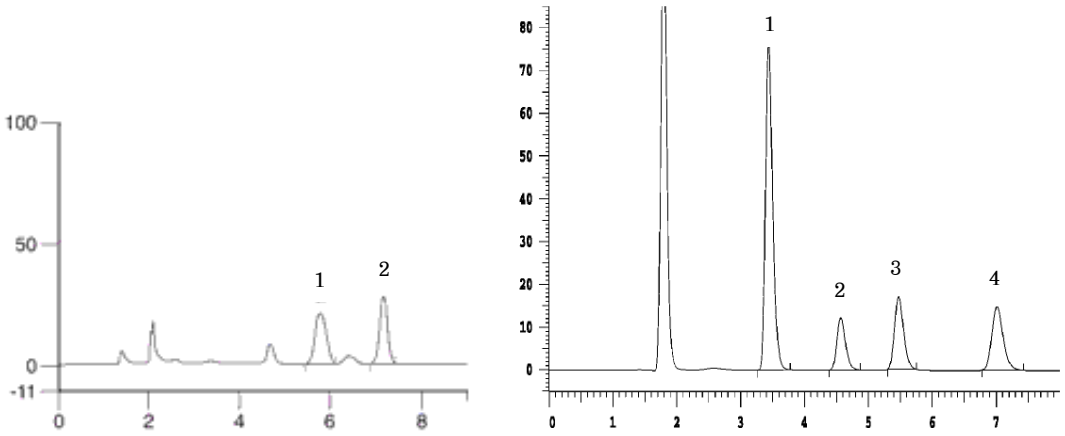
4.2.2 Optimum Condition for Determining Urinary Metabolite

The optimum condition for determining urinary metabolite level (Biomarker) of High Performance Liquid Chromatography with Ultraviolet Detection method (HPLC-UV) was set up by using

- ***Determining t,t-Muconic acid*** by using Vanillic acid as an internal standard. Measurable values were divided by the concentration of urinary creatinine, to give t,t-MA/creatinine ratio for each sample which is biomarker of benzene. The example of chromatogram from HPLC-UV showed in F**igure 16**.

- ***Determining Hippuric acid/creatinine, and Methylhippuric acid*** Measurable values were divided by the concentration of urinary creatinine, to give Hippuric acid/creatinine ratio (toluene's biomarker), and Methylhippuric acid

(xylene's biomarker) for each sample. The example of chromatogram from HPLC-UV showed in **Figure 16**.



1. t,t-Muconic acid
2. Internal standard

1. Hippuric acid
2. 2-Methylhippuric acid
3. Internal Standard
4. 3-Methylhippuric acid

Figure 16 Examples of Chromatograms of t,t-Muconic acid, Hippuric acid and Methylhippuric acid.(The number in bracket represented retention time)

4.3 Concentrations of BTEX in Air Samples

4.3.1 Descriptive of BTEX Concentrations

The mean and other descriptive statistics of personal exposure to BTEX are shown in **Table 10.** The mean concentrations of benzene, toluene, ethylbenzene, and xylenes (m, p, o-xylene) were 11.282 (±5.033), 56.129 (±73.963), 7.166 (±9.198), and 10.587 (±6.324) μg/m^3 respectively. The results show that toluene had the highest mean concentrations. All of BTEX concentrations were widely range and standard deviation were high especially toluene and ethylbenzene are showed standard deviation higher than the average.

Table 10 Descriptive of BTEX Concentrations (µg/m^3, n=52)

Statistic	LOD	Mean	SD	Min	Percentile25	Percentile50	Percentile75	Max
Benzene	0.2	11.282	5.033	1.293	8.515	9.881	13.515	25.837
Toluene	0.3	56.129	73.963	3.278	14.494	28.803	57.489	354.901
Ethylbenzene	0.2	7.166	9.198	2.157	3.038	3.996	6.267	46.108
Xylenes	0.03	10.587	6.324	1.595	5.316	9.495	13.540	30.330
BTEX	-	82.297	87.901	3.799	36.659	54.186	90.567	439.671

4.3.2 Comparisons for BTEX Concentrations

Personal exposure of BTEX were comparable between weekday and weekend, which might be due to number of cars that came into parking and increased BTEX concentrations through car exhaust. This study also compared personal exposure of BTEX in difference working location as defined for 4 location of parking were motorcycle parking, parking at underground, basement area, and up in the building zone. For BTEX concentrations difference according to job stations which defined in two groups as 1) Making convenient at parking, refer to worker who have duty to look after the traffic in parking, and 2) Sitting at Entrance/Exit, refer to worker who have to sit at the entrance or exit and give a parking pass to visitor. All of results summarized below.

4.3.2.1 Concentration of BTEX Difference between Weekday and Weekend

Summary statistic for personal exposure of BTEX were comparable between weekday and weekend also reported, which might be due to number of cars that came into parking and increased BTEX concentrations through car exhaust. The results show in **Table 11.** The table shows that toluene, ethylbenzene, and xylene concentrations in weekday were statistically significantly higher than in weekend (p-value 0.023, 0.022, and 0.001 respectively). Weekday benzene concentration was also higher than weekends but difference was not significant, probably the highly standard deviation has an influence in the comparison of mean difference. However the total BTEX concentration in weekday was statistically significantly higher than in weekend (p-value 0.022). Assuming that because of the number of car in weekday difference from weekend, in weekend especially Sunday appears lower density of cars than the weekday period.

Table 11 Concentration (μg/m^3) of BTEX Difference in Weekday and Weekend (n=52)

	Weekday		Weekend		p-value
	Mean ± SD	Mean Rank	Mean ± SD	Mean Rank	
Benzene	12.580 ± 5.188	29.04	10.083 ± 5.033	22.23	.099
Toluene	65.551 ± 63.852	30.38	47.433 ± 73.963	21.00	.023*
Ethylbenzene	7.257 ± 6.350	30.42	7.081 ± 9.198	20.96	.022*
Xylene	13.347 ± 6.523	33.54	7.827 ± 6.324	19.46	.001*
BTEX	92.168 ± 74.402	31.31	72.426 ± 87.901	21.69	.022*

Test difference using Mann-Whitney U Test, the level of significant was set at 0.05

**Statistic significant between weekday and weekend*

4.3.2.2 Concentration of BTEX Difference of Working Location

Summary statistic for personal exposure of BTEX in working location as defined for 4 location of parking were motorcycle parking, parking at underground, basement area, and up in the building zone. Concentrations for each location are shown in **Table 12**, the motorcycle parking recorded the highest concentration for benzene (mean value 13.369 ± 3.258 μg/m^3), toluene (mean value 114.160 ± 1.768 μg/m^3), Ethylbenxene (21.904 ± 2.135 μg/m^3) and xylene (21.904 ± 2.135μg/m^3). For the total BTEX concentration, motorcycle parking also recorded the highest concentration with mean value 160.482 ± 6.206 μg/m^3 and the lowest values were found in samplers taken from the parking up in the building zone with mean value 48.613 ± 64.892 μg/m^3. The statistic test concentrations in different locations of parking were related to motor type and fuel, and also density of cars in and out of those locations. Comparison mean rank between locations appear the highest mean rank of every chemical in motorcycle parking followed by parking at underground, basement area and building zone respectively, and p-value 0.005, 0.001, <0.003, and <0.001 respectively).

Post-hoc pairwise comparisons were made sure which pairs of working locations are significantly different from each other. The results from post-hoc test showed in **Table 13**, benzene concentration in underground parking was statistically significantly higher than building zone parking (6.156 μg/m^3, p-value 0.004) and also higher than basement area (5.353 μg/m^3, p-value 0.009). For concentration of toluene found that underground parking was statistically significantly higher than building zone parking (73.039 μg/m^3, p-value 0.028) and also higher than basement area (78.632 μg/m^3, p-value 0.01). In the same way, ethylbenzene concentration in underground parking was statistically significantly higher than building zone parking (10.493 μg/m^3, p-value 0.007) and also higher than basement area (10.571 μg/m^3, p-value 0.004). For xylene concentration also found that underground parking was statistically significantly higher than building zone parking (73.039 μg/m^3, p-value 0.028). Moreover xylene concentration in motorcycle parking was higher than building zone parking (15.338 μg/m^3, p-value < 0.001) and basement area (11.850 μg/m^3, p-value 0.002).

Table 12 Concentrations (μg/m^3) of BTEX Difference in Each Working Location

Number of Samples = 52	Benzene		Toluene		Ethylbenzene		Xylene		BTEX	
	Mean ± SD	Mean Rank	Mean ± SD	Mean Rank	Mean ± SD	Mean Rank	Mean ± SD	Mean Rank	Mean ± SD	Mean Rank
Motorcycle parking (n=5)	13.369 ± 3.258	36.00	114.160 ± 1.768	44.00	21.904 ± 2.135	43.00	21.904 ± 2.135	49.33	160.482 ± 6.206	46.00
Parking at Underground (n=13)	15.278 ± 6.264	36.38	107.524 ± 108.924	35.54	14.014 ± 5.620	34.54	14.014 ± 5.620	36.08	151.356 ± 128.544	38.69
Basement (n=18)	9.924 ± 3.877	20.47	28.891 ± 21.481	21.74	10.054 ± 6.249	22.37	10.054 ± 6.249	25.32	52.839 ± 26.039	24.00
Building zone (n=16)	9.121 ± 3.302	20.33	34.484 ± 60.833	17.87	6.568 ± 2.868	18.13	6.568 ± 2.868	16.47	48.613 ± 64.892	16.53
p-value		0.005		0.001		0.003		0.000		0.000

**Test for concentrations difference between working location, using Kruskal Wallis Test, the level of significant was set at 0.05*

Table 13 Concentrations (µg/m^3) of BTEX: Pairwise Comparisons

Pollutant	Location (A)	Location (B)	Mean Difference (A - B), (µg/m^3)	p-value
Benzene	Underground parking	Building zone parking	6.156	0.004
	Underground parking	Basement area	5.353	0.009
Toluene	Underground parking	Building zone parking	73.039	0.028
	Underground parking	Basement area	78.632	0.010
Ethylbenzene	Underground parking	Building zone parking	10.493	0.007
	Underground parking	Basement area	10.571	0.004
Xylene	Underground parking	Building zone parking	7.448	0.001
	Motorcycle parking	Basement area	11.850	0.002
	Motorcycle parking	Building zone parking	15.338	0.000

Test for concentrations difference of working locations by using Post-hoc Test, the level of significant was set at 0.05

Table 13 showed pairs with significantly difference concentrations. The results can confirm that air samples which taken from underground parking were found BTEX concentration higher than other locations (except motorcycle parking). For xylene concentration, not only in underground parking higher than parking in building zone but also found motorcycle parking was record the highest concentration of xylene (Table 4.4) as well as xylene concentration higher than basement area and building zone with statistically significant. This can be explained that BTEX concentrations related to ventilation difference and pollutants that emitted from vehicles driving in and out (only physical ventilation in all of location).

4.3.2.3 Concentration of BTEX according to Job Stations

Summary statistic for personal exposure of BTEX also reported according to jobs stations, which might be due to changing or similarity of BTEX concentrations in the parking. The results shown in **Table 14**, BTEX concentrations according to job stations which defined in two groups as 1) Making convenient at parking, refer to worker who have duty to look after the traffic in parking, and 2) Sitting at Entrance/Exit, refer to worker who have to sit at the entrance or exit and give a parking pass to visitor. There are demonstrated that statistic were not significant for all of individual chemicals and total BTEX concentrations between workers who making convenient at parking and workers who sitting at entrance/exit.

Table 14 Concentration (µg/m^3) of BTEX according to Job Stations

n = 52	Jobs Stations				
	Making convenient at parking		Sitting at Entrance/Exit		
	Mean ± SD	Mean Rank	Mean ± SD	Mean Rank	p-value*
Benzene	11.986 ± 5.731	26.36	10.577 ± 4.222	24.64	0.677
Toluene	67.682 ± 88.259	28.48	44.577 ± 55.691	22.52	0.148
Ethylbenzene	9.418 ± 12.331	28.12	4.914 ± 3.182	22.88	0.204
Xylene	11.263 ± 6.956	27.81	9.857 ± 5.812	25.08	0.516
BTEX	93.751 ± 105.032	28.70	69.927 ± 64.504	24.12	0.276

**Test difference using Mann-Whitney U Test, the level of significant was set at 0.05*

4.4 Urinary Metabolite of BTEX

The values of urinary t,t-Muconic acid, Hippuric acid, and Methylhippuric acid/creatinine were shown in **Table 15.** The mean values of t,t-Muconic acid, Hippuric acid, and Methylhippuric acid in urine were 177.07 (±170.41) µg/g creatinine, 0.390 (±0.31) µg/g creatinine, and 0.11 (±0.12) µg/g creatinine, respectively. The range of concentrations were 1.15 - 775.76 µg/g creatinine, 0.03 - 1.32 µg/g creatinine,, and 0.007 - 0.59 µg/g creatinine respectively.

Concentrations of three metabolites were not statistically significantly difference in smoker and nonsmoker but only hippuric acid, the metabolite substance of toluene was statistically significantly higher in passive smoking exposure group than non-passive smoking group (p-value 0.017). There was also found difference of methylhippuric acid, the metabolite substance of xylene was higher in female than male (p 0.042). Number of samples that found metabolite concentration higher than the Biological Exposure Indices: BEI (ACGIH, 2007) are 2 urinary samples which measured t,t-Muconic acid higher than 500 µg/g creatinine.

Table 15 Descriptive of BTEX Urinary Metabolite (End of Shift)

Environmental factors and personal habits	t,t-Muconic acid (µg/g Cr.) (BEI 500 µg/g Cr.)	Hippuric acid (g/g Cr.) (BEI 1.6 g/g Cr.)	Methylhippuric acid (g/g Cr.) (BEI 1.5 g/g Cr.)
Range	1.15 - 775.76	0.03 – 1.32	0.007 - 0.59
Mean ± SD			
Total	177.07 ± 170.41	0.390 ± 0.31	0.11 ± 0.12
Sex			
Male	142.06 ± 128.58	0.36 ± 0.28	0.08 ± 0.11
Female	205.98 ± 196.62	0.42 ± 0.33	0.13 ± 0.13*[a]
Smoking behavior			
Smoker	161.33 ± 136.39	0.39 ± 0.29	0.08 ± 0.10
Nonsmoker	184.93 ± 186.95	0.39 ± 0.32	0.11 ± 0.13
Passive smoking exposure			
Yes	212.99 ± 198.55	0.49 ± 0.30	0.11 ± 0.09
No	144.40 ± 136.68	0.32 ± 0.29*[b]	0.11 ± 0.14
PPE using (mask type)			
Yes	218.83 ± 185.69	0.35 ± 0.38	0.14 ± 0.10
No	171.42 ± 170.20	0.39 ± 0.29	0.09 ± 0.12
Number of samples that higher than BEI	2	0	0

Test difference by using Mann-Whitney U Test, the level of significant was set at 0.05

[a] Methylhippuric acid level in female was statistically significantly higher than male (p .042)

[b] Hippuric acid level in passive smoking exposure group was statistically significantly higher than non- passive smoking group (p .017)

4.5 Correlations between BTEX Concentrations and Urinary Metabolites

The non-parametric, Spearman's correlation was used to test association between BTEX concentrations and urinary metabolites concentrations. Results shown in **Table 16**, correlations coefficient (r_s) was not strong and that were not statistically significant (p-value > 0.05). There was no correlation between air BTEX concentrations and their urinary metabolites.

Table 16 Correlations between BTEX Concentrations and Urinary Metabolites

Correlations	r_s	p-value
Benzene & t,t-MA	0.032	0.843
Toluene & Hippuric acid	-0.175	0.224
Xylenes & Methylhippuric acid	0.032	0.841

**Spearman's correlation, significant at the 0.05 level*

4.6 Health Risk Assessment

In the health risk assessment, exposure assessment was a process determining of BTEX exposure as Exposure Concentrations (EC) like above mention in chapter 3. After getting EC for each chemical, Characterization of the cancer risk and non-cancer risk of this population was done.

Estimating Exposure Concentrations according;

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

Calculated cancer risk according;

$$\text{Cancer risk} = EC \times IUR$$

And calculated non-carcinogenic risk according;

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

For CA, come from direct assessment measuring personal exposure to BTEX in this study, is the time-weighted of BTEX concentrations over the duration of exposure (8 hours), then brought to calculate EC. Exposure factors (i.e. Exposure time, Exposure Frequency, Exposure Duration, and Averaging Time) could get from

questionnaire, the exposure frequency (EF) of this population is 336 days/year because they have day off for 2 day per month. Considering the exposure time (ET) for 8 hours/day to made comply with the daily mean BTEX concentrations that monitored. In addition considered the exposure duration (ED) as 3.61 years that got from questionnaire.

The HQ of each chemical was able to combine as the sum of more than one HQ for multiple substances, defined as Hazard Index (HI). According to equations above, detail and information reference in Chapter 2 and 3, the associated toxicity values and necessary factors was used in the risk estimation illustrated in **Table 17.**

In **Table 18**, benzene presented the cancer risk at 4.37×10^{-6} which considered an unacceptable level for carcinogenic effect of concern (higher than 10^{-6}), meaning the risk will have been developing cancer over lifetime of 70 years exceeding 5 people in a million.

Table 19 show the non-carcinogenic risk estimated Hazard Quotients, According to BTEX exposure concentrations, there were presented HQ at 0.361 for benzene, 0.010 for toluene, 0.006 for ethylbenzene, and 0.105 for xylene, which considered in an acceptable level (lower than 1). Total non-carcinogenic risk on BTEX exposure in this study presented HI at 0.485, meaning the average exposure concentration wasn't exceeded the reference concentration for BTEX compounds. In addition the highest HI was 0.821 thus none of workers participated in this study was exposure to BTEX with exceeded the reference concentrations.

Table 17 BTEX Concentration and Exposure Factors for Risk Assessment

N = 26	Concentration CA ($\mu g/m^3$)	Exposure time ET (hours/day)	Exposure Frequency EF (days/year)	Exposure Duration: ED (year)	Averaging Time: AT* (hours)	EC: Exposure Concentration ($\mu g/m^3$)
Exposure Concentrations for Assessing Cancer Risks						
Benzene	10.848	8.00	336.00	3.61	188,160.00	0.560
Exposure Concentrations for Calculating Hazard Quotients						
Benzene	10.848	8.00	336.00	3.61	9,718.15	10.848
Toluene	53.971	8.00	336.00	3.61	9,718.15	53.971
Eethylbenzene	6.890	8.00	336.00	3.61	9,718.15	6.890
Xylene	10.587	8.00	336.00	3.61	9,718.15	10.587

* Averaging Time (hours) for *Assessing Cancer Risks* calculated according to (Lifetime in years x days/year x hours/day), decided 70 years as lifetime (EPA, 2003)

* Averaging Time (hours) for *Calculating Hazard Quotients* calculated according to (ED in years x working days/year x Working hours/day = 3.61 years x 366 days/year x 12 hours/day)

Table 18 The Cancer Risk of Workers Exposed to BTEX

N = 26	Concentration CA (μg/m^3)	EC: Exposure Concentration (μg/m^3)	Inhalation Unit Risk: IUR (per μg/m^3)	Cancer Risk* (EC x IUR)			Number of workers at unacceptable risk
				Average	Min	Max	
Benzene	10.848	0.560	7.8×10^{-6}	4.37×10^{-6}	4.83×10^{-7}	1.94×10^{-5}	22 (84.61%)

Cancer risk of more than 10^{-6} will consider an unacceptable level for carcinogenic effect of concern.

Table 19 The Hazard Quotient of Workers Exposed to BTEX

N = 26	Concentration CA (μg/m^3)	Exposure Concentrations EC (μg/m^3)	Inhalation Reference Concentration RfC (mg/m^3)	Hazard Quotient EC / (RfC x 1000 μg/mg)			Number of workers at unacceptable risk
				Average	Min	Max	
Benzene	10.848	10.848	0.03	0.361	0.144	0.612	0
Toluene	53.971	53.971	5	0.010	0.0003	0.036	0
Eethylbenzene	6.890	6.890	1	0.006	0.001	0.024	0
Xylene	10.587	10.587	0.1	0.105	0.026	0.253	0
			Hazard Index	0.485	0.172	0.821	0

HQ and HI of more than 1 will consider an unacceptable level for non-carcinogenic effect of concern

4.7 Association between BTEX Exposure and BTEX Exposure Symptoms.

Association between 10 symptoms occurrences of parking workers and their risk factors were calculated by Chi-squared test. The factors list was sex, underlying disease, smoking behavior, passive smoking exposure and using mask. According to result Participants characterizations, there are only a few numbers of workers that living near those pollution sources as show in **Table 9.** Analysis association in this part was excluded living near petrochemical/rubber/paint factory because no workers living in radius 1000 meters nearing by those factories. The Environmental factors and personal habits were analyzed. Chi-square test showed results only three out of ten symptoms (result of all variables were not showed in text) as eyes irritation (X^2 7.63; p-value 0.010), headache (X^2 5.52; p-value 0.031), and drowsiness (X^2 7.48; p-value 0.020) that statistically significant associated with living near automotive service station or garages. Almost environmental factors and personal habits were not statistically significant associated with symptoms. Even if used mask during working was still not associated with a reduction for any symptoms.

According to association between environmental factors & personal habits and health symptoms were not appeared as mentioned above, However unsured association between some factors (i.e. age, smoking behavior, passive smoking exposure) because several studies have shown significantly increasing risk of respiratory symptoms, thus logistic regression analysis was entered age, smoking behavior, passive smoking exposure, and living near automotive service station (only one environmental factor which showed significant association with eyes irritation, headache, and drowsiness) into logistic regression analysis as confounders. Therefore the assessing model used 52 cases for 5 independent variables that were fit to basic assumption for logistic regression model. The results are presented increasing most of BTEX exposure was not associated with the likelihood of health symptoms occurrence that observed in this study excepted increasing ethylbenzene exposure was associated with increased likelihood of exhibiting nausea (OR = 1.14; 95% CI, 1.008 - 1.288), and increasing xylene exposure was associated with increased likelihood of exhibiting cough (OR = 1.137; 95% CI, 1.012 - 1.278). Show detail in **Table 20.**

Table 20 Adjusted ORs for Association between BTEX Exposure and Symptoms
(adjusted for age, smoking behavior, passive smoking, and living near automotive service station)

Health Symptoms	Adjusted ORs	95% CI	p-value
Benzene			
Throat Irritation	1.012	0.898 - 1.140	0.847
Nose Irritation	1.012	0.898 - 1.140	0.847
Eyes Irritation	1.021	0.897 - 1.163	0.753
Tiredness	1.161	0.911 - 1.161	0.648
Headache	1.097	0.963 - 1.249	0.165
Dizziness	1.135	0.894 - 1.007	0.903
Cough	1.064	0.935 - 1.210	0.348
Nausea	1.144	0.949 - 1.380	0.158
Confusion	1.017	0.884 - 1.171	0.810
Drowsiness	1.082	0.938 - 1.247	0.278
Toluene			
Throat Irritation	0.998	0.990 - 1.006	0.637
Nose Irritation	0.993	0.983 - 1.003	0.181
Eyes Irritation	0.999	0.990 - 1.008	0.868
Tiredness	0.998	0.990 - 1.007	0.717
Headache	1.002	0.994 - 1.01	0.574
Dizziness	0.997	0.987 - 1.006	0.475
Cough	1.005	0.997 - 1.014	0.206
Nausea	1.010	0.999 - 1.021	0.073
Confusion	1.003	0.994 - 1.012	0.458
Drowsiness	1.000	0.989 - 1.011	0.991
Ethylbenzene			
Throat Irritation	1.005	0.941 - 1.073	0.886
Nose Irritation	0.970	0.899 - 1.046	0.425
Eyes Irritation	1.022	0.953 - 1.096	0.543
Tiredness	1.004	0.940 - 1.073	0.898
Headache	1.039	0.970 - 1.113	0.275
Dizziness	1.000	0.935 - 1.070	0.990
Cough	1.061	0.986 - 1.143	0.115
Nausea	1.140	1.008 - 1.288	0.036*
Confusion	1.054	0.982 - 1.132	0.146
Drowsiness	1.023	0.948 - 1.105	0.556
Xylene			
Throat Irritation	0.959	0.867 - 1.061	0.421
Nose Irritation	0.871	0.771 - 0.985	0.027
Eyes Irritation	1.022	0.921 - 1.135	0.676

Health Symptoms	Adjusted ORs	95% CI	p-value
Tiredness	0.970	0.877 - 1.072	0.549
Headache	1.058	0.950 - 1.179	0.305
Dizziness	0.952	0.856 - 1.060	0.371
Cough	1.137	1.012 - 1.278	0.031*
Nausea	1.162	0.966 - 1.396	0.110
Confusion	1.036	0.917 - 1.170	0.574
Drowsiness	1.012	0.887 - 1.154	0.860

** Statistically significant (p <0.05)*

The ORs of increasing benzene exposure were seem associated with exhibiting all of symptoms because presented OR more than 1. But the 95% CI of all models were covered 1, that means there were not significant associations. In case of toluene exposure, there were not any significant associations while ORs either less than 1 or very close to 1.

The significant association found in increasing ***ethylbenzene*** exposure that associated with exhibiting ***nausea*** (OR = 1.14; 95% CI, 1.008 - 1.288 also confirmed this association was significance). While ORs of another 7 symptoms were higher than 1 but there seem so small ORs and also 95% CI included 1, indicated there were not significant associations.

In case of xylene exposure, the significant association found in one more model as increasing ***xylene*** exposure was associated with exhibiting ***cough,*** the OR was 1.137 with 95% CI of 1.012 to 1.278. While ORs of another 5 symptoms were higher than 1 but 95% CI included 1, indicated there were not significant associations.

CHAPTER V
DISSCUSSION

5.1 Socio-Demographic of Participants

Participants in this study are the traffic supporting workers, service for all of customer visited to that place. Interviewing also found they had to change working location every day. According to the result, number of male was equal to number of female participants. Average working duration was only 3.61 years, ranged 1 – 10 years, while age ranged 20 – 63 year old. Some of them were young that might move to other jobs and change their risk factor to BTEX exposure.

According to the environmental factors and personal habits, participants were mainly non-smoker (65.4%) and difference not much for number of passive smoking exposure (42.3%) and non- passive smoking exposure (57.7%). For other risk factors related to increased or decreased BTEX exposure, the results demonstrated just a few workers living near high traffic (15.4%), gas station (19.2%), automotive service station or garage (11.5%), and none of participant living near factory that normally emit BTEX such as chemical, rubber and paint factories. For protecting BTEX exposure like personal protective equipment usage as mask type, results presented most of them (84.3%) were not used mask with reason as not comfortable and be trouble in communication. Nevertheless these factors weren't made change the concentration of BTEX that measure in air because this study monitoring only working period, thus statistic was not significant when test difference of BTEX among these factors but might effected to changing urinary metabolite level and their BTEX exposure symptoms. However the environmental factors and personal habits normally increased risk of BTEX exposure, design of study measured exposure concentrations of BTEX only in the working time and the cancer and non-cancer risk were estimated regard as only risk at workplace but didn't followed them and monitored BTEX in air at their house. That mean risk level might higher than risk demonstrated in the result.

5.2 BTEX Concentrations in Personal Air Samples

BTEX concentrations measured in this study were lower than those Time-weighted Average (TWA) of that defined by NIOSH and OSHA. The concentration of benzene, toluene and benzene were also comparable with permissible exposure limit which noticed in Thailand labour law, Notification of Ministry of Interior regarding working safety in respect to environmental condition (chemicals) B.E.2522 (Ministry of Interior, 1979) however results also show concentrations lower than Thailand exposure limits.

Table 21 Comparison of BTEX Concentration with the Occupational Limits

Chemical	Average personal exposure (µg/m^3)	NIOSH:TWA (µg/m^3)	OSHA: TWA (µg/m^3)	Thailand Labor Law: TWA (µg/m^3)
Benzene	10.848 (0.003 ppm)	320 (0.1 ppm)	1,597 (0.5 ppm)	31,947 (10 ppm)
Toluene	53.971 (0.014 ppm)	376,850 (100 ppm)	753,700 (200 ppm)	753,700 (200 ppm)
Ethylbenzene	6.890 (0.001 ppm)	434,233 (100 ppm)	86,846 (20 ppm)	-
Xylene	10.587 (0.002 ppm)	434,192 (100 ppm)	434,192 (100 ppm)	434,192 (100 ppm)

In addition this study also compared with BTEX concentration has reported in similar studies show in **Table 22**, like mentioned above that the BTEX concentrations measured in this study were lower than those measured in some previous studies in same city as Bangkok Thailand (Kitwattanavong, 2010; Ruangtrakula et al., 2013; Thaveevongs et al., 2010). The most similarity study is the one which located in Greece (Soldatos et al., 2002) they taken personal air samples from enclosed parking and found concentrations of BTEX higher than this study, they reported concentrations of BTEX in the first and second underground floor higher than the third floor. This is consistent with finding of this study. Patterns of BTEX concentration were obtained by previous studies often demonstrated toluene present the highest concentration followed by benzene and xylene while ethylbenzene have showed the lowest concentrations (Jo & Song, 2001; Kitwattanavong, 2010; Kuntasal et al., 2005; Manini et al., 2006; Ruangtrakula et al., 2013).

Table 22 Comparison of BTEX Concentration with Other Studies in Literature

Location	**Study area/ Study population**	**Benzene ($\mu g/m^3$)**	**Toluene ($\mu g/m^3$)**	**Ethylben-zene ($\mu g/m^3$)**	**Xylene ($\mu g/m^3$)**
This Study	Car Parking/ workers	10.848	53.971	6.890	10.587
Athens, Greece (Soldatos et al., 2002)	Underground (enclosed)parking / stationary and personal air samples	366	374	102	403
Bangkok, Thailand (Kitwattanavong, 2010)	Gas Station/ workers	220.29	297.03	34.96	139.89
Bangkok, Thailand (Thaveevongs et al., 2010)	Gas station in Bangkok/ workers	518.70	498.46	10 - 27	41.03
Bangkok, Thailand (Ruangtrakula et al., 2013)	Tollway stations workers	99.29	146.06	29.92	48.75
Ankara, Turkey (Kuntasal et al., 2005)	Gas station	27.52	52.28	11.47	48.54
Italy (Bono et al., 2003)	Gas station attendant (summer)	502.7	711.6	-	379.4
Italy (Carrieri et al., 2006)	Gas station	44	-	-	-
Spain (Periago & Prado, 2005)	Refuelling stations/ personal air samples	163	753	-	316
Korea (Jo & Song, 2001)	Non-smoker gas station attendant	72.1	126	12.1	50.7
Italy (Manini et al., 2006)	Taxi drivers and Taxicab	7.7	35.2	6.2	27.7
Turkey (Pekey & Yılmaz, 2011)	Ambient air near industrial city	2.26	35.51	9.72	49.33
China (Wang et al., 2002)	Urban Roadside	51.5	77.3	17.8	81.6

5.3 BTEX Urinary Metabolites

Almost of personal habitats and environmental factors was not association with urinary metabolites concentrations in this study. Only two pairs were significantly association i.e. methylhippuric acid level in female was statistically significantly higher than male (p-value 0.042), and hippuric acid level in passive smoking exposure group was statistically significantly higher than non- passive smoking group (p-value 0.017). The result showed that urinary metabolites concentration for parking workers was low when compared with the Biological Exposure Index (BEI) which defined by the American Conference of Governmental Industrial Hygienists (ACGIH, 2007). But interesting in t,t-Muconic acid the two highest concentrations were 538.35 and 775.76 µg/g creatinine, that higher than BEI (BEI for t,t-MA is 500 µg/g creatinine) although their personal benzene exposure those measured from air samples were very low.

Analysis correlation in this study found no correlation was apparent between air BTEX concentrations and urinary metabolites concentrations. Previous studies revealing correlation between environmental exposure and biomarkers. For example a study in Thailand on biomonitoring of benzene in traffic policemen (Arayasiri et al., 2010) reported urinary t,t-muconic acid was correlated significantly with benzene exposure. A Study on another occupational exposure (school children, factory workers, gas station workers) to benzene in Thailand (Navasumrit et al., 2005) found urinary t,t-muconic acid were significantly increased in all benzene-exposed groups. One more example case is a study in China (Qu et al., 2005) reported urinary t,t-muconic acid were significantly correlated with exposure levels of benzene.

However urinary t,t-muconic acid and hippuric acid may not a specific marker of exposure to benzene and toluene respectively, since ingestion of unknown amounts of dietary may influence variability in urinary metabolites concentration (Lauwerys & Hoet, 2001). Smoking behavior also effect to excretion of benzene, toluene and xylene metabolites and shortly half-life of each pollutants should be concerned (ATSDR, 2004). The low power correlation in this study might effected by confounding factors as mentioned before, lack of adjustment these factors may explain this finding which consistent with finding from previous studies (Carrieri et al., 2006; Lagorio et al., 2013; Manini et al., 2006; Negri et al., 2005; Protano et al., 2010).

5.4 Carcinogenic and Non-carcinogenic Risk Characterizations

This study showed a potentially increased health risk for underground workers compared to workers who work in the higher floor of parking. The average cancer risk for benzene was 4.37×10^{-6}, ranged 4.83×10^{-7} to 1.94×10^{-5}, rather smaller when compared with the results obtained by previous studies that assessed human risk in gas station workers in Bangkok (Thaveevongs et al., 2010; Tunsaringkarn et al., 2012). Comparing with studies assessed risk for another outdoor workers in Bangkok, this study demonstrated cancer risk lower than the finding of cancer risk in tollway station workers (Ruangtrakula et al., 2013) and motorcycle-taxi & street vender (Tunsaringkarn et al., 2014). The more density of car passing in those studies might explain why finding in this study was lower. For non-carcinogenic risk of benzene, toluene, ethylbenzene, and xylene were considered an unacceptable level, look like results from several previous studies (Kitwattanavong, 2010; Ruangtrakula et al., 2013; Thaveevongs et al., 2010; Tunsaringkarn et al., 2014; Tunsaringkarn et al., 2012).

Regarding to results in **Table 21**, average personal exposure of benzene, toluene, ethylbenzene, and xylene although were lower than occupational limit of that defined by NIOSH, OSHA, and Thailand state agency but participant become to be at risk. However workers who work over 8 hours-shifts (for example in case of swing shift) may get the higher risk.

5.5 BTEX Concentration and BTEX Exposure Symptoms

The results from logistic regression model are presented increasing most of BTEX exposure was not associated with the likelihood of health symptoms occurrence that observed in this study, excepted increasing ethylbenzene exposure was associated with increased likelihood of exhibiting nausea (OR = 1.14; 95% CI, 1.008 - 1.288), and increasing xylene exposure was associated with increased likelihood of exhibiting cough (OR = 1.137; 95% CI, 1.012 - 1.278). There was not consistent results, a study estimated association between BTEX exposure and symptoms among gas station workers (Tunsaringkarn et al., 2012) reported exposure to benzene and toluene was significantly associated with fatigue. Also not consistent with a study estimated association between BTEX exposure and symptoms among outdoor workers as motorcycle-taxi, street vender and security guard (Tunsaringkarn et al., 2014) that reported benzene was significantly associated to headache and fatigue, while toluene was associated to headache, dizziness and throat irritation.

CHAPTER VI
CONCLUSION

6.1 Conclusion

Concentrations of BTEX in air measured in this study were rather lower than earlier studies. This is because BTEX concentrations in the air may be depends on density of car that passed in difference study area. Comparisons of BTEX concentrations in difference working location found that parking at underground structure was presented concentration higher than the higher floor (parking in building zone). Indicated BTEX concentrations not depend on only density of car but also ventilation in that parking. Average 8 hours of BTEX concentrations in this study lower than occupational limit of that defined by international organization. Human health risk through inhalation exposure to BTEX found workers were at risk of cancer from benzene exposure via inhalation pathway, risk communication should be introduced to the participants to protect themselves from BTEX exposure such as using mask.

Investigated correlation between BTEX concentrations in the air and urinary metabolites concentrations also done but the results didn't appearance significantly correlation. This is because urinary metabolite might be influenced by many confounding factors.

Investigated association between BTEX exposure and symptoms occurrence, found that Increasing exposure of some ethylbenzene and xylene were associated with increased likelihood of exhibiting nausea and cough, However the association found in this part seem to be not strong enough to confirm because of a very small number of case in logistic model and collected data for very short period.

6.2 Limitation of this study

This study was determined benzene, toluene and xylene urinary metabolites but urinary metabolite of ethylbenzene (mandelic acid) was not determined because of laboratory limitation. Although using biomarkers can confirms absorption into human body but measures integrated exposure from all routes and all sources. Thus biomarker does not define sources or pathways of exposure because it is a snap-shot and an integrated measured. BTEX concentrations were obtained by measuring in this

study might not representative for the truth average concentrations that workers exposed because this study designed data collection for 4 day (2 days for weekday, 2 days for weekend). Since concentrations of BTEX difference between weekday and weekend thus the average might be higher.

Small sample size resulted finding in this study might not be generalized to the broader parking and small number of case in logistic models and collected data for very short period resulted to weakly associations. Moreover workers answered the questions about their health symptoms might be subjective error.

6.3 Recommendation

Suggested recommendation in term of risk communication would be introduced to the participants to protect themselves from BTEX exposure such as using mask. Recommendation for further study, the urinary metabolite measured in this study was not shown to be sensitive enough at these exposure levels, Further studies are need to determine the factors that may modified the urinary metabolite levels such as half-life of pollutants, lifestyles and restrictive dietary type. However environmental monitoring seems to be better method of evaluated individual exposure but further studies are need to carefully define study area and study population, especially sample size which very influence data distribution.

In addition, according to limitation mentioned about the truth average concentrations of BTEX, further studies are should to carefully designed data collection to getting the good representative data for make more reliability and strength of the study.

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APPENDIX

APPENDIX A

Questionnaire English Version

Participant code_____

Thesis topic: Health Risk Assessment of BTEX exposure to underground parking workers in Bangkok, Thailand

This questionnaire is a part of Master Degree Curriculum (M.P.H) College of Public Health Science, Chulalongkorn University. The results which give in this questionnaire will be used for education only.

Part I General Information

1. Gender

☐ Male ☐ Female

2. Age.....years

3. Body weight.....Kg

4. Height.....Centimeters

5. You ever been told by a doctor that you have health condition?

☐ No

☐ Yes, give the name.....

6. Have you ever smoked?

☐ Never

☐ Used to, but quite right now.

☐ Yes, how many cigarettes .....number/day

7. In your house, have other one smoke?

☐ No ☐ Yes

8. Does any part around your house have the sources of air pollution?

☐ .0 No

☐ 1. Main Road/Traffic jam far from house.....meter

☐ 2. Factories give the type..... far from house.....meter

☐ 3. Gas station far from house.....meter

☐ 4. Garage far from house.....meter

☐ 5. Other..... far from house.....meter

Part II Current Working Information

9. Have you ever done other jobs before you work this job?

☐ .0 No

☐ 1. Factories give the type..... How long? .....years

☐ 2. Repairman give the type..... How long? .....years

☐ 3. Gas station give the type..... How long? .....years

☐ 4. Other..... How long? .....years

10. Job Descriptions

☐ .1 Guards

☐ .2 Office workers

☐ .3 Other.....

11. How many year that you have working here?..... years

12. How many day that you normally work in a week?.....days/week

13. How many hour that you normally work in a day?.....hours/day

14. While you work, do you use mask?

☐ Never (if your answer is NEVER, go to item 18)

☐ Yes, sometimes

☐ Yes, Every time

15. What kind of mask?

☐ Handkerchief (if your answer is Handkerchief, go to item 18)

☐ Mask like doctor use

☐ Other.....

16. How do you cover the mask?

- ☐ Cover my mouth
- ☐ Cover my Nose
- ☐ Both Mouth and Nose

17. How long you use mask?

- ☐ Along working time
- ☐ More than haft of working time
- ☐ Less than haft of working time

Part III Health Symptoms

In the working time, Have you ever got symptom which show in table below?

	Symptoms	Yes	No
18	ThroatIrritation		
19	NoseIrritation		
20	EyesIrritation		
21	Tiredness		
22	Headache		
23	Dizziness		
24	Cough		
25	Nausea or Vomiting		
26	Confusion		
27	Drowsiness		

APPENDIX B

Questionnaire Thai Version

หมายเลขแบบสอบถาม.....

หัวข้อวิจัย : การประเมินความเสี่ยงต่อสุขภาพของคนงานในลานจอดรถใต้ดินใน กรุงเทพมหานคร ประเทศไทย

คำชี้แจง: แบบสอบถามชุดนี้ เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรสาธารณสุขศาสตร์มหาบัณฑิต (ปริญญาโท) วิทยาลัยวิทยาศาสตร์สาธารณสุข จุฬาลงกรณ์มหาวิทยาลัย โดยผลที่ได้จะนำไปใช้เพื่อวัตถุประสงค์ทางการศึกษาเท่านั้น

เลขที่โครงการวิจัย 012.1/57

วันที่รับรอง - 2 เม.ย. 2557

วันหมดอายุ - 1 เม.ย. 2558

ส่วนที่ 1 ข้อมูลทั่วไป

1. เพศ ☐ 1.ชาย ☐ 2.หญิง
2. อายุ.....ปี
3. น้ำหนัก.....กิโลกรัม
4. ส่วนสูง.....เซนติเมตร
5. ท่านมีโรคประจำตัวหรือไม่
   - ☐ 0.ไม่มี
   - ☐ 1. มี ระบุ.....
6. ท่านสูบบุหรี่มากน้อยเพียงใด
   - ☐ 0. ไม่เคย
   - ☐ 1. เคยสูบ แต่เลิกแล้ว
   - ☐ 2. ยังสูบอยู่ ระบุ.....มวน/วัน
7. ในบ้านของท่านมีผู้อื่นที่สูบบุหรี่หรือไม่
   - ☐ 0. ไม่มี
   - ☐ 1. มี
8. *สภาพแวดล้อมรอบบริเวณบ้านของท่าน มีแหล่งกำเนิดมลพิษทางอากาศหรือไม่*
   - ☐ *0. ไม่มี*
   - ☐ *1. ถนนที่มักจะมีการจราจรหนาแน่น* *ห่างจากบ้าน.....เมตร*
   - ☐ *2. โรงงานอุตสาหกรรม ประเภท.....* *ห่างจากบ้าน.....เมตร*
   - ☐ *3. ปั๊มน้ำมัน/แก๊สรถยนต์* *ห่างจากบ้าน.....เมตร*
   - ☐ *4. อู่ซ่อม เคาะ พ่นสีรถยนต์* *ห่างจากบ้าน.....เมตร*
   - ☐ *5. อื่นๆ ระบุ.....* *ห่างจากบ้าน.....เมตร*

ส่วนที่ 2 ข้อมูลเกี่ยวกับการทำงาน

9. *ก่อนมาทำงานที่นี่ ท่านเคยทำงานอย่างอื่นหรือไม่*

- ☐ *0.ไม่เคย*
- ☐ *1. งานโรงงาน ระบุลักษณะงาน..... ทำเป็นเวลา.....ปี*
- ☐ *2. งานช่าง ระบุลักษณะงาน..... ทำเป็นเวลา.....ปี*
- ☐ *3. งานในปั๊มน้ำมัน/ปั๊มแก๊ส ระบุลักษณะงาน..... ทำเป็นเวลา.....ปี*
- ☐ *4. อื่นๆ ระบุลักษณะงาน..... ทำเป็นเวลา.....ปี*

10. ลักษณะงานที่ทำในปัจจุบัน

- ☐ 1. ยาม (ตรวจตราและอำนวยความสะดวกให้รถยนต์ที่เข้าออก)
- ☐ 2. ทำงานในออฟฟิศ
- ☐ 3. อื่นๆ ระบุ.....

11. ท่านทำงานในลานจอดรถแห่งนี้มานานกี่ปี.....ปี (ระบุปีที่เริ่มทำงาน พ.ศ.....)

12. ปกติท่านทำงานดังกล่าวสัปดาห์ละกี่วัน.....วัน

13. ปกติท่านทำงานดังกล่าววันละกี่ชั่วโมง.....ชั่วโมง

14. ขณะทำงานท่านใส่ผ้าปิดจมูกหรือไม่

- ☐ 1. ไม่เคยใส่ (ข้ามไปตอบข้อ 18)
- ☐ 2. ใส่บางครั้ง
- ☐ 3. ใส่ทุกครั้ง

15. ประเภทของผ้าปิดจมูกที่ใช้ส่วนมาก

- ☐ 1. ผ้าเช็ดหน้า (ข้ามไปตอบข้อ 18)
- ☐ 2. ผ้าปิดจมูกแบบหมอ
- ☐ 3. อื่นๆ ระบุ.....

16. ส่วนใหญ่ท่านคาดผ้าปิดจมูกอย่างไร

- ☐ 1. ปิดเฉพาะปาก
- ☐ 2. ปิดเฉพาะจมูก
- ☐ 3. ปิดทั้งปากและจมูก

17. ส่วนใหญ่ท่านคาดผ้าปิดจมูกนานเพียงใด

☐ 1. ตลอดเวลาการทำงาน

☐ 2. มากกว่าครึ่งหนึ่งของระยะเวลาการทำงาน

☐ 3. น้อยกว่าครึ่งหนึ่งของระยะเวลาการทำงาน

ส่วนที่ 3 การเกิดอาการผิดปกติทางสุขภาพ

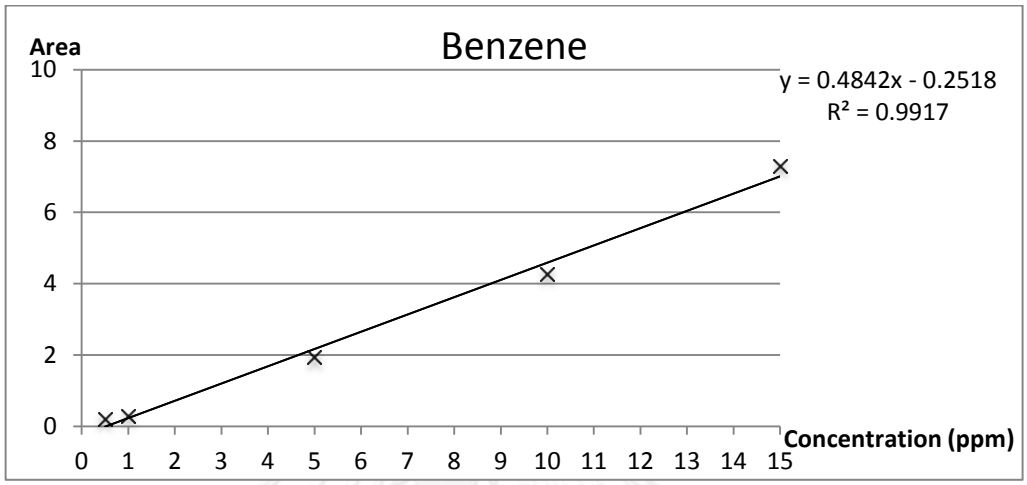
ในระหว่างเวลาทำงาน ท่านมีอาการเหล่านี้หรือไม่

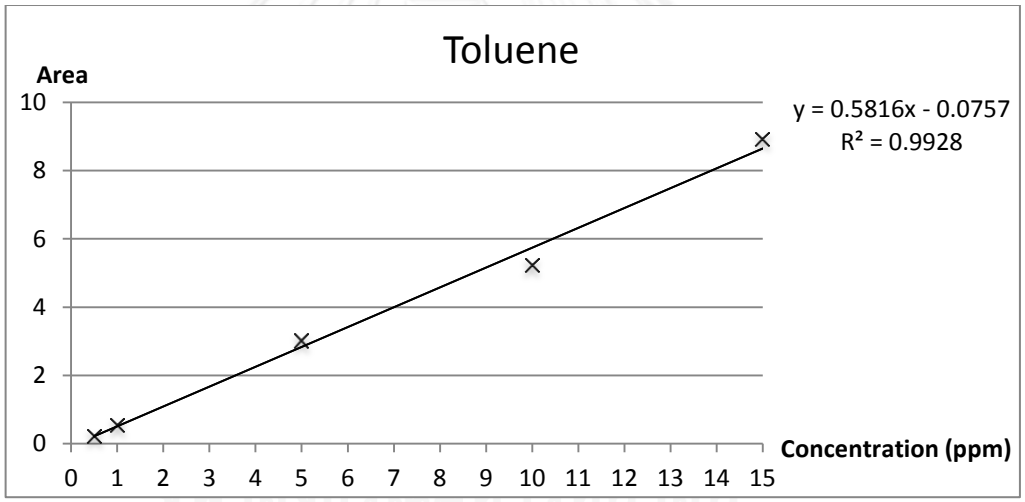
	อาการ	มีอาการ	ไม่มีอาการ
18	ระคายเคืองคอ		
19	ระคายเคืองจมูก		
20	ระคายเคืองตา		
21	อ่อนเพลีย เมื่อยล้า		
22	ปวดศีรษะ		
23	เวียนศีรษะ		
24	ไอ		
25	คลื่นไส้ อาเจียน		
26	สับสน		
27	เซื่องซึม		

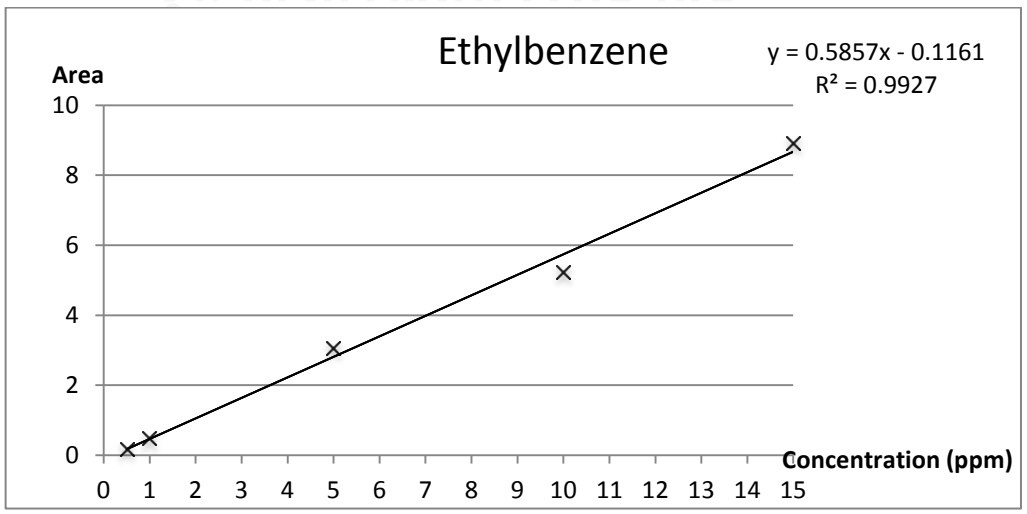
APPEXDIX C

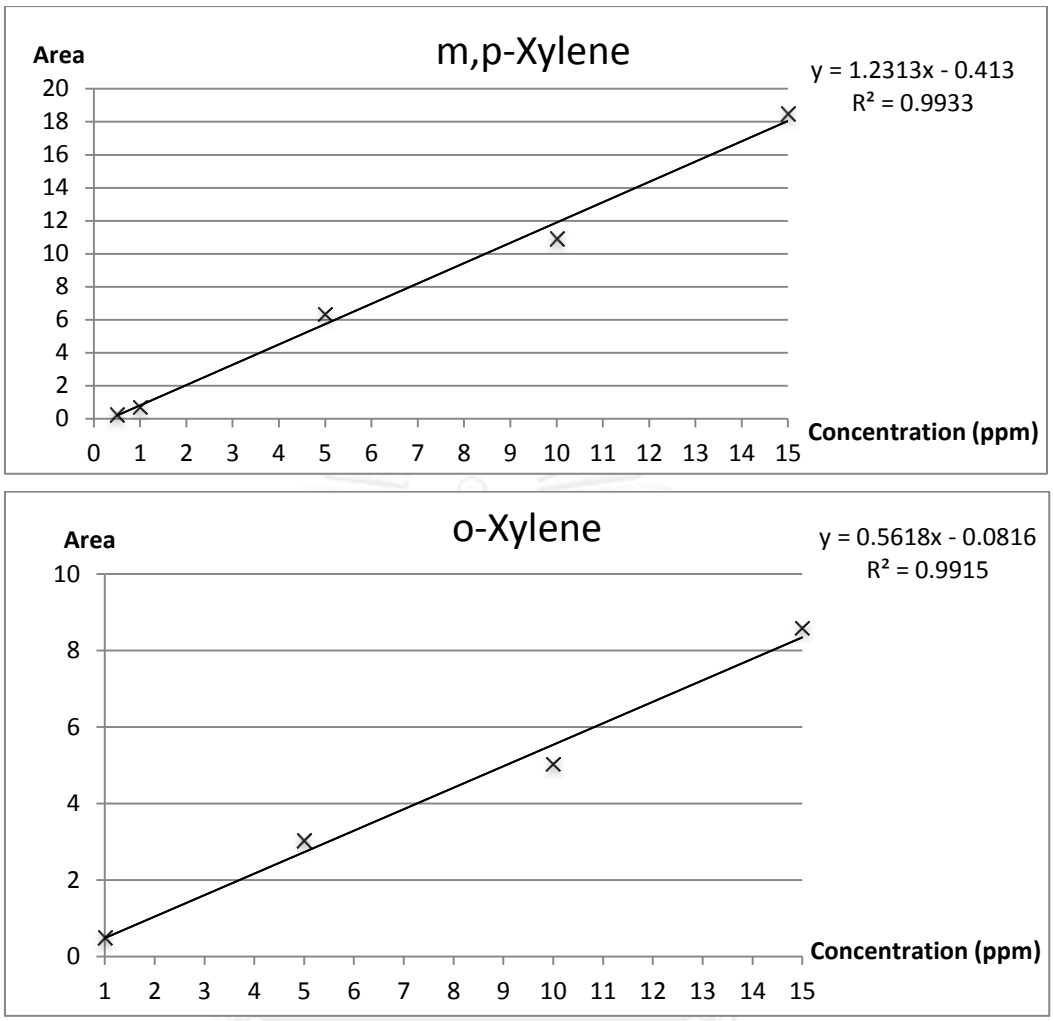
Calibration Curves

C.1 Calibration Curves for BTEX

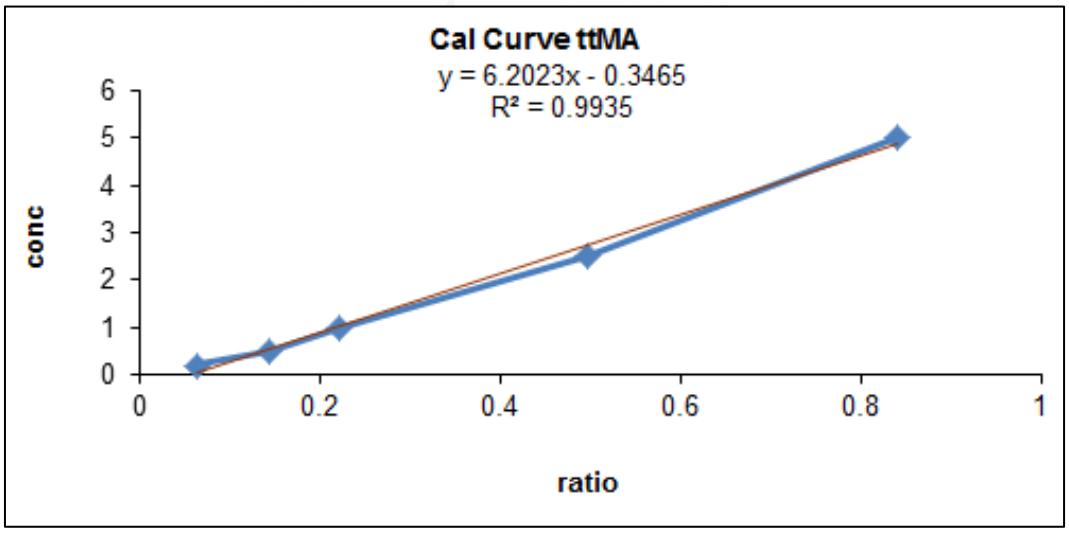


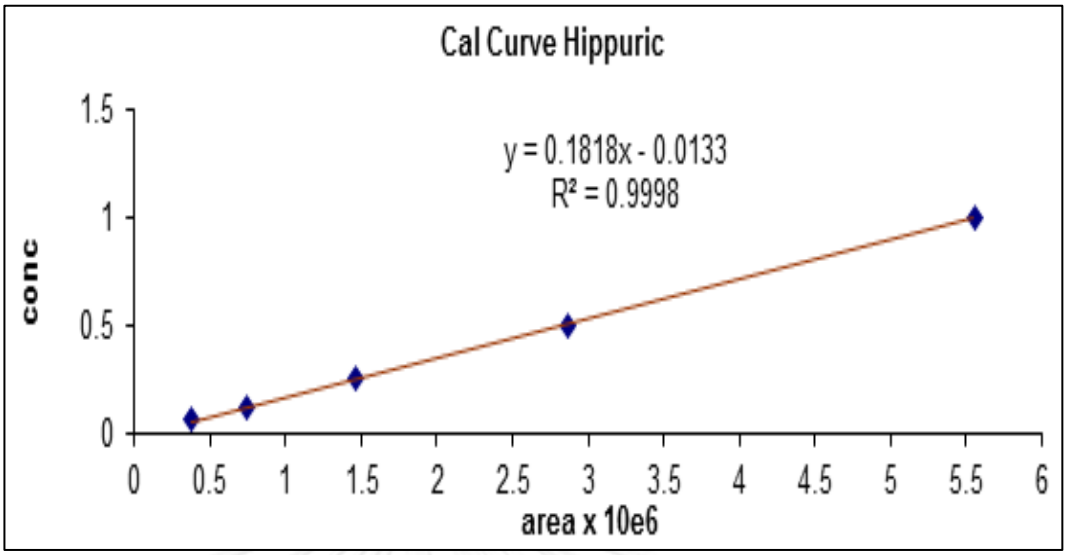


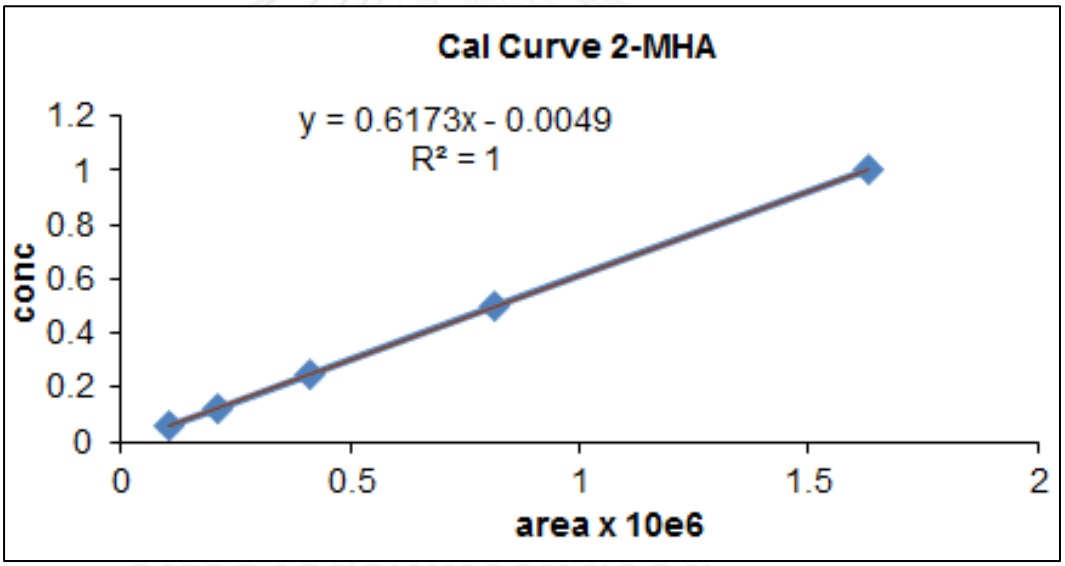


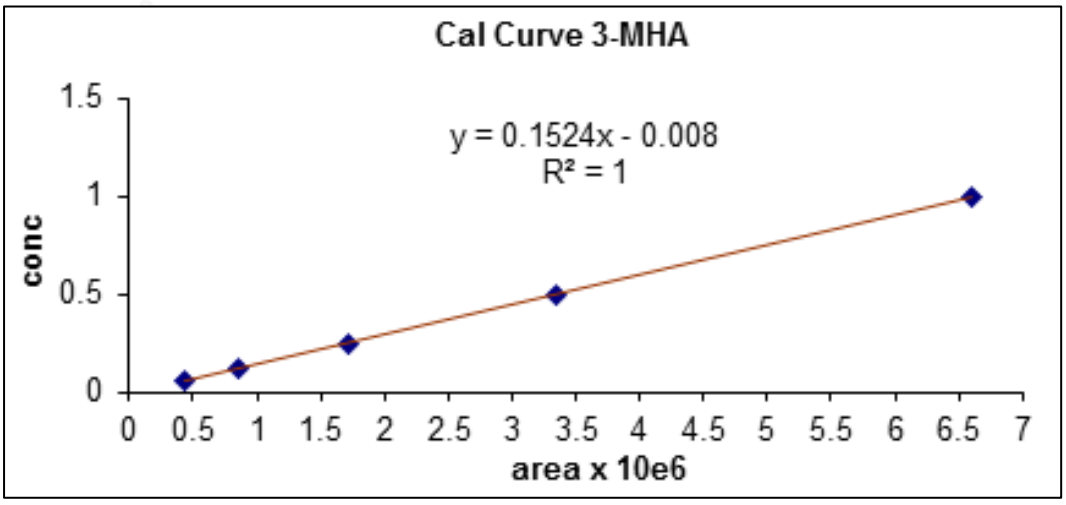


C.2 Calibration Curves for urinary metabolites




Cal Curve Hippuric
y = 0.1818x - 0.0133
R² = 0.9998
conc
area x 10e6
0
0.5
1
1.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6


Cal Curve 2-MHA
y = 0.6173x - 0.0049
R² = 1
conc
area x 10e6
0
0.2
0.4
0.6
0.8
1
1.2
0
0.5
1
1.5
2


Cal Curve 3-MHA
y = 0.1524x - 0.008
R² = 1
conc
area x 10e6
0
0.5
1
1.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7

APPEXDIX D

Participant Information Sheet

ข้อมูลสำหรับกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัย

ชื่อโครงการวิจัยเรื่อง การประเมินความเสี่ยงต่อสุขภาพจากการรับสัมผัสสารอินทรีย์ระเหยกลุ่ม BTEX ของพนักงานในลานจอดรถชั้นใต้ดิน ในกรุงเทพมหานคร ประเทศไทย

ชื่อผู้วิจัย นางสาววราสนา ฉนสำโรง ตำแหน่ง นิสิตระดับปริญญาโท

สถานที่ติดต่อผู้วิจัย (ที่ทำงาน) วิทยาลัยวิทยาศาสตร์สาธารณสุข จุฬาลงกรณ์มหาวิทยาลัย

(ที่บ้าน) 49/265 นนท์ทาวเวอร์ลอนโดมิเนียม ถ.ติวานนท์ ต.ตลาดขวัญ อ.เมืองนนทบุรี จ.นนทบุรี

โทรศัพท์ (ที่ทำงาน) 0 2218-8193 ต่อ - โทรศัพท์ที่บ้าน -

โทรศัพท์มือถือ 086 646 7727 E-mail : yabuki_kenji2514@hotmail.com

1. ขอเรียนเชิญท่านเข้าร่วมในการวิจัย ก่อนที่ท่านจะตัดสินใจเข้าร่วมในการวิจัย มีความจำเป็นที่ท่านควรทำความเข้าใจว่างานวิจัยนี้ทำเพราะต้องการประเมินระดับความเสี่ยงต่อสุขภาพของพนักงานในอาคารจอดรถ จากการหายใจเอาอากาศที่มีการปนเปื้อนของสารเบนซีน โทลูอีน เอธิลเบนซีน และไซลีน ซึ่งเป็นสารเคมีที่มักจะเกิดจากการเผาไหม้น้ำมันหรือแก๊สในรถยนต์ และเนื่องจากท่านเป็นผู้ทำงานในอาคารจอดรถ ที่ซึ่งมีรถยนต์แล่นเข้าออกตลอดเวลา จึงเป็นกลุ่มคนที่อาจมีความเสี่ยงต่อการหายใจเอาสารเคมีดังกล่าวเข้าไปจนเป็นผลเสียต่อสุขภาพ กรุณาใช้เวลาในการอ่านข้อมูลต่อไปนี้อย่างละเอียดรอบคอบ และสอบถามข้อมูลเพิ่มเติมหรือข้อมูลที่ไม่ชัดเจนได้ตลอดเวลา

2. โครงการนี้เกี่ยวข้องกับการวิจัยความเสี่ยงต่อสุขภาพ โดยประเมินความเสี่ยงจากการรับสัมผัสทางการหายใจ ซึ่งการวิจัยนี้สนใจการรับสัมผัสอากาศในสถานที่ทำงานของท่าน เนื่องจากมีรถยนต์วิ่งเข้าออกตลอดเวลา ไอเสียจากรถยนต์จะมีสารเคมีลอยออกมาปะปนอยู่ในอากาศ และท่านหายใจเอาอากาศปนเปื้อนสารเคมีเข้าไป ผู้วิจัยจึงอยากทราบว่าปริมาณสารเคมีที่ท่านหายใจเข้าไปในระหว่างทำงาน และด้วยปริมาณดังกล่าวนั้น จะมีผลกระทบต่อสุขภาพของท่านหรือไม่ นอกจากนั้นจะมีการเก็บตัวอย่างปัสสาวะของท่าน เพื่อวัดปริมาณสารเคมีด้วย

3. วัตถุประสงค์ของการวิจัยนี้เพื่อวัดระดับการรับสัมผัสสารอินทรีย์ระเหยกลุ่ม BTEX (ได้แก่ เบนซีน โทลูอีน เอธิลเบนซีน และไซลีน) ผ่านทางการหายใจของพนักงานในลานจอดรถ พร้อมทั้งนำค่าที่ตรวจวัดได้มาประเมินความเสี่ยงต่อสุขภาพที่พนักงานได้รับสัมผัส

4. รายละเอียดของกลุ่มผู้มีส่วนร่วมในการวิจัย

- กลุ่มเป้าหมายในการวิจัยนี้ คือพนักงานที่ทำงานในลานจอดรถภายในอาคารจุรัสจามจุรี เป็นประจำอย่างน้อยวันละ 8 ชั่วโมง ทั้งเพศชายและหญิง อายุระหว่าง 18 – 59 ปี ซึ่งลานจอดรถชั้นใต้ดินเป็นบริเวณที่คาดว่าบรรยากาศของสถานที่ทำงานในลักษณะดังกล่าวจะมีการ

ปนเปื้อนของสารเบนซีน โทลูอีน เอธิลเบนซีน และไซลีน ในปริมาณที่สูงกว่าบริเวณอื่น รวมทั้งผู้เข้าร่วมงานวิจัยครั้งนี้ต้องมีความสมัครใจที่จะเข้าร่วมในงานวิจัยในครั้งนี้ สำหรับพนักงานที่ไม่สามารถสื่อสารด้วยภาษาไทย จะไม่ได้รับคัดเข้ามาในการวิจัยนี้

- ผู้วิจัยได้พิจารณาเลือกลานจอดรถที่มีขนาดใหญ่ มีความสามารถรองรับรถยนต์ที่จะเข้าจอดได้มากกว่า 1,000 คัน เพื่อให้สอดคล้องกับวัตถุประสงค์ของการวิจัย ได้เลือกลานจอดรถ*ภายในอาคารจุรัสจามจุรี*
- กลุ่มประชากรที่ทำการศึกษาวิจัยครั้งนี้*จำนวน 30 คน*
- การเลือกกลุ่มประชากรเพื่อการศึกษาวิจัยครั้งนี้ เลือกจากผู้ปฏิบัติบริเวณลานจอดรถทั้งหมดที่ปฏิบัติงานอยู่ในช่วงเวลาที่ดำเนินการเก็บข้อมูล แต่อย่างไรก็ตามผู้ปฏิบัติงานต้องมีความสมัครใจที่จะเข้าร่วมในงานวิจัยในครั้งนี้
- ในการศึกษาวิจัยครั้งนี้ไม่ได้มีการแบ่งกลุ่มผู้เข้าร่วมในงานวิจัย เป็นการศึกษาผู้ปฏิบัติงานในบริเวณลานจอดรถของอาคารเพียงกลุ่มเดียวเท่านั้น

5. กระบวนการให้ข้อมูลแก่ผู้มีส่วนร่วมในการวิจัย ผู้วิจัยจะเป็นผู้ให้ข้อมูล รายละเอียดเกี่ยวกับงานวิจัยครั้งนี้แก่ท่าน โดยข้อมูลที่จะแจ้งได้แก่ การเก็บตัวอย่างอากาศ การเก็บตัวอย่างปัสสาวะ และการตอบแบบสอบถาม รวมทั้งสอบถามถึงความสมัครใจในการเข้าร่วมในการทำวิจัยครั้งนี้กับท่าน เมื่อท่านยินยอมเข้าเป็นส่วนหนึ่งของการวิจัยครั้งนี้ ผู้วิจัยจะให้ท่านเซ็นชื่อ*เพื่อเป็นการแสดงความสมัครใจและยินยอมให้ผู้วิจัยเก็บข้อมูลได้* ทั้งนี้ผู้ที่ไม่สามารถสื่อสารด้วยภาษาไทย จะไม่ได้ถูกเชิญเข้าร่วมในการศึกษานี้ และการตอบแบบสอบถามจะดำเนินการในลักษณะการสัมภาษณ์ จึงไม่เป็นอุปสรรคสำหรับผู้ที่อ่านหรือเขียนหนังสือไม่ได้

6. กระบวนการการวิจัยที่กระทำต่อผู้มีส่วนร่วมในการวิจัยนั้น จะดำเนินการดังนี้

6.1 เก็บตัวอย่างอากาศที่ตัวบุคคล โดยผู้วิจัยจะนำอุปกรณ์หลอดเก็บตัวอย่างอากาศมาติดไว้บริเวณปกเสื้อหรือกระเป๋าเสื้อเหนือหน้าอกของพนักงาน ตั้งแต่เวลาเช้าที่พนักงานมารายงานตัวเข้าทำงานและติดไว้ตลอดเวลาทำงาน 8 ชั่วโมง เมื่อสิ้นสุดเวลาทำงานผู้วิจัยจะมานำหลอดเก็บตัวอย่างอากาศออกไป

6.2 หลังจากนำหลอดเก็บตัวอย่างอากาศออกจากปกเสื้อของผู้มีส่วนร่วมในการวิจัยแล้ว ผู้วิจัยจะขอเก็บตัวอย่างปัสสาวะ ผู้มีส่วนร่วมในการวิจัยจะได้รับขวดพลาสติกมีฝาปิดที่ใช้สำหรับเก็บตัวอย่างปัสสาวะ โดยให้ปัสสาวะในห้องน้ำ*ประมาณครึ่งถ้วยกาแฟ* ปิดฝา และเช็ดทำความสะอาดให้เรียบร้อย แล้วนำขวดปัสสาวะออกมาส่งให้ผู้วิจัย

6.3 หลังจากส่งขวดปัสสาวะแล้ว ผู้วิจัยจะขอสัมภาษณ์ผู้มีส่วนร่วมในการวิจัย โดยผู้วิจัยจะอ่านคำถามจากแบบสอบถาม แล้วให้ผู้มีส่วนร่วมในการวิจัยตอบด้วยวาจา ซึ่งผู้วิจัยจะเขียนคำตอบดังกล่าวลงในแบบสอบถามเอง ซึ่งการตอบแบบสอบถามนี้จะให้เวลาประมาณ 5 – 10 นาที

หลอดที่บรรจุอากาศและขวดบรรจุตัวอย่างปัสสาวะ จะถูกเก็บในภาชนะอย่างเหมาะสมตามหลักวิทยาศาสตร์ และผู้วิจัยจะขนส่งไปยังห้องปฏิบัติการเพื่อวิเคราะห์ผลต่อไป ทั้งนี้หากมีตัวอย่างปัสสาวะเหลือจากการวิเคราะห์ จะถูกกำจัดตามมาตรฐานห้องปฏิบัติการ ส่วนแบบสอบถามจะนำไปบันทึกข้อมูลในโปรแกรมวิเคราะห์ทางสถิติ ซึ่งจะไม่มีการระบุชื่อของผู้มีส่วนร่วมในการวิจัย และแบบสอบถามจะถูกทำลายภายหลังการวิจัยเสร็จสิ้น

7. ในการ**คัดกรอง**ผู้มีส่วนร่วมในการวิจัยนี้ ไม่มีการคัดเลือกผู้มีส่วนร่วมในการวิจัยด้วยเกณฑ์คัดเข้าที่เกี่ยวกับสภาวะสุขภาพ อาการเจ็บป่วยด้วยโรค หรือการดูแลรักษาโรค

8. *ในการติดตั้งอุปกรณ์เก็บตัวอย่างอากาศส่วนบุคคลไว้บนเสื้อของผู้มีส่วนร่วมในการวิจัยอาจทำให้มีความกังวลและรู้สึกเคลื่อนไหวไม่สะดวกเหมือนที่เคย อย่างไรก็ตามอุปกรณ์ดังกล่าวมีขนาดเล็กและน้ำหนักเบา จึงจะไม่กระทบกับการปฏิบัติงานของผู้มีส่วนร่วมในการวิจัย นอกจากนี้ยังต้องสละเวลาปัสสาวะใส่ขวดบรรจุตัวอย่างและตอบแบบสอบถามประมาณ 5 – 10 นาที*

9. **ประโยชน์**ในการเข้าร่วมวิจัย ประโยชน์สำหรับผู้มีส่วนร่วมในการวิจัยคือ ผลการวิจัยจะบอกค่าปริมาณการรับสัมผัสสารเบนซีน โทลูอีน เอธิลเบนซีน และไซลีน ซึ่งจะทำให้ทราบระดับความเสี่ยงจากการรับสัมผัสสารเคมีเหล่านี้ (บอกได้ทั้งความเสี่ยงต่อการเป็นมะเร็งและกรณีความเสี่ยงที่ไม่ใช่มะเร็ง) นอกจากนี้ค่าตัวชี้วัดทางชีวภาพที่ตรวจวัดได้จากปัสสาวะก็สามารถบ่งบอกถึงการได้รับสารเคมีที่เข้าสู่ร่างกายว่าอยู่ในระดับที่ปกติหรือไม่ ซึ่งพนักงานต้องหาวิธีป้องกันการรับสัมผัสสารเคมีเหล่านี้ *ประโยชน์สำหรับส่วนรวมคือทำให้ได้ทราบสภาพแวดล้อมในการทำงาน*

10. การเข้าร่วมในการวิจัยของท่านเป็นโด**ยสมัครใจ** และสามารถ**ปฏิเสธ**ที่จะเข้าร่วมหรือ**ถอนตัว**จากการวิจัยได้ทุกขณะ โดยไม่ต้องให้เหตุผลและไม่สูญเสียประโยชน์ที่พึงได้รับ และ**ไม่มีผลกระทบต่อตำแหน่งหรือการทำงานของท่านแต่อย่างใด**

11. หากท่านมีข้อสงสัยให้สอบถามเพิ่มเติมได้โดยสามารถติดต่อผู้วิจัยได้ตลอดเวลา

12. ข้อมูลที่เกี่ยวข้องกับท่านจะเก็บเป็น**ความลับ** หากมีการเสนอผลการวิจัยจะเสนอเป็นภาพรวม ข้อมูลใดที่สามารถระบุถึงตัวท่านได้จะไม่ปรากฏในรายงาน

13. ท่านจะได้รับค่าชดเชยการเสียเวลาเป็นจำนวนเงิน 300 บาท และ*ของที่ระลึกเป็นกระเป๋าผ้า* เพื่อตอบแทนการให้ความร่วมมือแก่ผู้วิจัย

14. หากท่านไม่ได้รับการปฏิบัติตามข้อมูลดังกล่าวสามารถร้องเรียนได้ที่ คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน กลุ่มสหสถาบัน ชุดที่ 1 จุฬาลงกรณ์มหาวิทยาลัย ชั้น 4 อาคารสถาบัน 2 ซอยจุฬาลงกรณ์ 62 ถนนพญาไท เขตปทุมวัน กรุงเทพฯ 10330 โทรศัพท์ 0-2218-8147 หรือ 0-2218-8141 โทรสาร 0-2218-8147 E-mail: eccu@chula.ac.th

เลขที่โครงการวิจัย 012.1157
วันที่รับรอง - 2 เม.ย. 2557
วันหมดอายุ - 1 เม.ย. 2558

APPEXDIX E

Informed Consent Form

AF 05-07

หนังสือแสดงความยินยอมเข้าร่วมการวิจัย

ทำที่.....

วันที่.....เดือน.....พ.ศ. .....

เลขที่ของผู้มีส่วนร่วมในการวิจัย.....

เลขที่โครงการวิจัย 012.1/57

วันที่รับรอง - 2 เม.ย. 2557

วันหมดอายุ - 1 เม.ย. 2558

ข้าพเจ้า ซึ่งได้ลงนามท้ายหนังสือนี้ ขอแสดงความยินยอมเข้าร่วมโครงการวิจัย

ชื่อโครงการวิจัย *การประเมินความเสี่ยงต่อสุขภาพจากการรับสัมผัสสารอินทรีย์ระเหยกลุ่ม BTEX ของพนักงานในลานจอดรถชั้นใต้ดิน ในกรุงเทพมหานคร ประเทศไทย*

ชื่อผู้วิจัย นางสาววาสนา ลุนสำโรง

ที่อยู่ที่ติดต่อ วิทยาลัยวิทยาศาสตร์สาธรณสุข จุฬาลงกรณ์มหาวิทยาลัย (อาคารสถาบัน 3 ชั้น 11)

โทรศัพท์ 086 6467727

ข้าพเจ้า **ได้รับทราบ**รายละเอียดเกี่ยวกับที่มาและวัตถุประสงค์ในการทำวิจัย รายละเอียดขั้นตอนต่างๆ ที่จะต้องปฏิบัติหรือได้รับการปฏิบัติ ความเสี่ยง/อันตราย และประโยชน์ซึ่งจะเกิดขึ้นจากการวิจัยเรื่องนี้ โดยได้อ่านรายละเอียดในเอกสารชี้แจงผู้เข้าร่วมการวิจัยโดยตลอด และ**ได้รับคำอธิบาย**จากผู้วิจัย **จนเข้าใจเป็นอย่างดีแล้ว**

ข้าพเจ้าจึงสมัครใจเข้าร่วมในโครงการวิจัยนี้ ตามที่ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย โดยข้าพเจ้ายินยอมให้ 1) เก็บตัวอย่างอากาศที่ตัวบุคคลโดยการใช้หลอดเก็บอากาศติดไว้บริเวณปกเสื้อหรือเหนือหน้าอกเป็นระยะเวลา 8 ชั่วโมง จำนวน 1 ครั้ง 2) เก็บตัวอย่างปัสสาวะ*ประมาณครึ่งถ้วยกาแฟ* หลังเลิกงาน จำนวน 1 ครั้ง และ 3) ตอบแบบสอบถามการได้รับสารอินทรีย์ระเหยในบรรยากาศของสถานที่ทำงาน จำนวน 1 ครั้ง ซึ่งเมื่อเสร็จสิ้นการวิจัยแล้ว ตัวอย่างปัสสาวะของข้าพเจ้าจะถูกทำลายด้วยวิธีที่เหมาะสม

ข้าพเจ้า**มีสิทธิ**ถอนตัวออกจากการวิจัยเมื่อใดก็ได้ตามความประสงค์ **โดยไม่ต้องแจ้งเหตุผล** ซึ่งการถอนตัวออกจากการวิจัยนั้น จะไม่มีผลกระทบในทางใดๆ ต่อตำแหน่งการงานของข้าพเจ้าทั้งสิ้น

ข้าพเจ้าได้รับคำรับรองว่า ผู้วิจัยจะปฏิบัติต่อข้าพเจ้าตามข้อมูลที่ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย และข้อมูลใดๆ ที่เกี่ยวข้องกับข้าพเจ้า ผู้วิจัยจะ**เก็บรักษาเป็นความลับ** โดยจะนำเสนอข้อมูลการวิจัยเป็นภาพรวมเท่านั้น ไม่มีข้อมูลใดในการรายงานที่จะนำไปสู่การระบุตัวข้าพเจ้า

หากข้าพเจ้าไม่ได้รับการปฏิบัติตรงตามที่ได้ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าสามารถร้องเรียนได้ที่คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน กลุ่มสหสถาบัน ชุดที่ 1 จุฬาลงกรณ์มหาวิทยาลัย ชั้น 4 อาคารสถาบัน 2 ซอยจุฬาลงกรณ์ 62 ถนนพญาไท เขตปทุมวัน กรุงเทพฯ 10330 โทรศัพท์ 0-2218-8147, 0-2218-8141 โทรสาร 0-2218-8147 **E-mail: eccu@chula.ac.th**

ข้าพเจ้าได้ลงลายมือชื่อไว้เป็นสำคัญต่อหน้าพยาน ทั้งนี้ข้าพเจ้าได้รับสำเนาเอกสารชี้แจงผู้เข้าร่วมการวิจัย และสำเนาหนังสือแสดงความยินยอมไว้แล้ว

ลงชื่อ.....
(นางสาววาสนา ลุนำโรง)
ผู้วิจัยหลัก

ลงชื่อ.....
(.....)
ผู้มีส่วนร่วมในการวิจัย

ลงชื่อ.....
(.....)
พยาน

VITA

Name: Wassana Loonsamrong

Date of birth: July 9, 1985

Ducation Achievement: B.Sc. in Sanitary Science (Public Health) With Secound Class Honours. Khon Kaen University, Khon Kaen, Thailand.

Email Address: yabuki_kenji2514@hotmail.com