BENZENE AND TOLUENE EXPOSURE IN RELATION TO THEIR HEALTH EFFECTS AMONG SKY-TRAIN STATION GUARDS IN BANGKOK THAILAND

Miss Teepimon Chimplee

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ผลกระทบทางสุขภาพจากการรับสัมผัสสารเบนซีนและโทลูอีน
ของพนักงานรักษาความปลอดภัยบนสถานีรถไฟฟ้าในกรุงเทพมหานคร ประเทศไทย

นางสาวธีพิมล ฉิมพลี

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาสาธารณสุขศาสตรมหาบัณฑิต
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Thesis Title	BENZENE AND TOLUENE EXPOSURE IN RELATION TO THEIR HEALTH EFFECTS AMONG SKY-TRAIN STATION GUARDSIN BANGKOK THAILAND
By	Miss Teepimon Chimplee
Field of Study	Public Health
Thesis Advisor	Professor Surasak Taneepanichskul, M.D.
Thesis Co-Advisor	Nutta Taneepanichskul, 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
(Associate Professor Sathirakorn Pongpanich, Ph.D.)

THESIS COMMITTEE

....Chairman
(Associate Professor Wattasit Siriwong, Ph.D.)

....Thesis Advisor
(Professor Surasak Taneepanichskul, M.D.)

....Thesis Co-Advisor
(Nutta Taneepanichskul, Ph.D.)

....Examiner
(Robert S. chapman, M.D.)

....External Examiner
(Nipunporn Voramongkol, M.D., Ph.D.)

ธีพิมล ฉิมพลี : ผลกระทบทางสุขภาพจากการรับสัมผัสสารเบนซีนและโทลูอีน ของพนักงานรักษาความปลอดภัยบนสถานีรถไฟฟ้าในกรุงเทพมหานคร ประเทศไทย (BENZENE AND TOLUENE EXPOSURE IN RELATION TO THEIR HEALTH EFFECTS AMONG SKY-TRAIN STATION GUARDSIN BANGKOK THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ศ. นพ. สุรศักดิ์ ฐานีพานิชสกุล, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ดร. ณัฏฐา ฐานีพานิชสกุล, 80 หน้า.

ปัญหามลพิษทางอากาศในกรุงเทพมหานครมีค่าเพิ่มสูงขึ้นจากการเพิ่มขึ้นอย่างหนาแน่นของการจราจรและการขนส่งซึ่งเป็นแหล่งที่มาที่สำคัญของมลพิษทางอากาศ เนื่องด้วยสาเหตุนั้นส่งผลให้สารเบนซีนและโทลูอีนถูกปล่อยออกมาสู่บรรยากาศผ่านทางท่อไอเสียของรถยนต์ ซึ่งสารเบนซีนและโทลูอีนสามารถส่งผลกระทบต่อสุขภาพทั้งในระยะสั้นและระยะยาว ดังนั้น จุดมุ่งหมายของการศึกษาครั้งนี้คือ เพื่อตรวจสอบความสัมพันธ์ระหว่างการรับสัมผัสของสารเบนซีนและโทลูอีนและการอาการทางสุขภาพที่อาจเกิดขึ้นในเจ้าหน้าที่รักษาความปลอดภัยจำนวน 40 คนที่สถานีรถไฟฟ้าสายสุขุมวิทจำนวน 20 สถานี การรับสัมผัสสารเบนซีนและโทลูอีนจะถูกวัดในขณะเวลาทำงานโดยใช้หลอดเก็บตัวอย่างอากาศและปั๊มสำหรับเก็บตัวอย่างอากาศ เป็นเวลา 8 ชั่วโมง ตั้งแต่ 08:00 นาฬิกา ถึง 16:00 นาฬิกา ส่วนการเก็บตัวอย่างปัสสาวะเพื่อหาค่าความเข้มข้นของสารเมตาบอลิซึมของเบนซีนและโทลูอีน ซึ่งปฏิบัติตามคู่มือของสถาบันแห่งชาติเพื่อความปลอดภัยด้านอาชีวอนามัย (NIOSH method 8301) โดยปัสสาวะจะถูกรวบรวมหลังเวลาเลิกงาน จากการศึกษาพบว่า ความเข้มข้นเฉลี่ยของเบนซีนและโทลูอีนมีค่าต่ำกว่าค่าเฉลี่ยความเข้มข้นของสารเคมีในอากาศที่ระยะเวลา 8 ชั่วโมงตลอดการทำงาน (TWA) ซึ่งมีค่าเท่ากับที่ 0.21 และ 242.40 ไมโครกรัมต่อลูกบาศก์เมตร ตามลำดับ นอกจากนี้ค่าความเข้มข้นเฉลี่ยของสารเมตาบอไลท์ของสารเบนซีนในปัสสาวะมีค่าสูงกว่าค่ามาตรฐานตัวบ่งชี้ทางชีวภาพขององค์กรนักสุขศาสตร์อุตสาหกรรมภาครัฐแห่งประเทศอเมริกา (American Conference of Governmental Industrial Hygienist; ACGIH) โดยสารเมตาบอไลท์ของเบนซีน (trans,trans-Muconic acid) มีค่าอยู่ที่ 1.02×10^3 (± 0.35) ไมโครกรัมต่อกรัมครีเอทินีน แต่ในทางตรงกันข้าม ความเข้มข้นเฉลี่ยของสารเมตาบอไลท์ของโทลูอีน (Hippuric acid) ซึ่งมีค่าอยู่ที่ 269.32 (± 55.95) มิลลิกรัมต่อกรัมครีเอทินีน แต่อย่างไรก็ตามความเข้มข้นของสารเบนซีนก็ไม่ได้มีความสัมพันธ์กับความเข้มข้นของสาร trans,trans-Muconic acid (p-value = 0.295) เช่นเดียวกับความเข้มข้นของโทลูอีนก็ไม่ได้มีความสัมพันธ์กับ Hippuric acid (p-value > 0.05) เช่นกัน สำหรับอาการทางสุขภาพที่เกี่ยวข้องกับการรับสัมผัสสารเบนซีน พบว่าการรับสัมผัสสารเบนซีนทำให้มีโอกาสเกิดความเสี่ยงต่อการเกิดอาการเมื่อยล้า (OR = 21.166; 95% CI, 1.297 – 345.494)

สาขาวิชา สาธารณสุขศาสตร์	ลายมือชื่อนิสิต ....
ปีการศึกษา 2557	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
	ลายมือชื่อ อ.ที่ปรึกษาร่วม ....

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TEEPIMON CHIMPLEE: BENZENE AND TOLUENE EXPOSURE IN RELATION TO THEIR HEALTH EFFECTS AMONG SKY-TRAIN STATION GUARDSIN BANGKOK THAILAND. ADVISOR: PROF. SURASAK TANEEPANICHSKUL, M.D., CO-ADVISOR: NUTTA TANEEPANICHSKUL, Ph.D., 80 pp.

The problem of air pollution in Bangkok has been exacerbated by increasingly crowded traffic and transportation, the major sources of pollution. As a result, Benzene and Toluene are commonly often emitted into the atmosphere through exhausts of vehicles and they can contribute to both short-term and long-term health hazards. The aim of this study has been narrowed down to examine Benzene and Toluene and health symptoms exposure among 40 sky train security guards of 20 electric sky train stations in Sukhumvit Line. The exposure of Benzene and Toluene was measured during time of work by using Charcoal Glass tube and personal air pump, for 8 hours, from 8 a.m. to 4 p.m. The collection of urine sampling method to determine metabolite of Benzene, t,t-muconic acid and metabolite of Toluene and hippuric acid follows the NIOSH method 8301. Urine was collected after work. The median concentration of Benzene and Toluene were lower than Time Weight Average (TWA), defined by OSHA and NIOSH, at 0.21(± 4.08) and 242.40 (± 17.11) µg/m^3. In addition, the average concentration of Benzene urinary metabolites was higher than the BEIs (Biological Exposure Indices) which defined by ACGIH , 1.02 mg /g Cr of t,t-Muconic acid. In contrary, trans,trans Muconic acid, urinary metabolite of Toluene, was not exceeded the BEIs of ACGIH (269.32 mg/g Cr). BEIs of trans,trans-Muconic acid is defined at 500µg /g Cr and BEIs of Hippuric acid is defined at 1.6 g/g Cr. However, Benzene concentration was not positively correlated with concentration of its urinary metabolite, t,t-Muconic acid at 0.295 of p-value. Meanwhile, Toluene concentration was also not correlated with its urinary metabolite, Hippuric acid, in negative direction at p-value > 0.05. According to Benzene exposure and health symptoms association, increasing Benzene exposure was associated with fatigue occurrence (OR = 21.166; 95% CI, 1.297 – 345.494).

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

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CONTENTS

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental and Industrial Hygienist
ASTDR	Agency for Toxic Substances and Disease Registry
BT	Benzene and Toluene
BTEX	Benzene, Toluene, Ethyl-benzene and Xylene
BTS	Bangkok Transit System
GC-FID	Gas Chromatography with Flame Ionization Detector
HPLC-UV	High Performance Liquid Chromatography with Ultraviolet Detection
IRIS	Integrated Risk Information System
LOD	Limit of Detection
MDE	Maryland Department of the Environment
NIOSH	National Institute of Occupational Safety and Health
NTP	National Toxicology Program
O_3	Ozone
OSHA	Occupational Safety and Health Administration
OTAQ	Office of Transportation and Air Quality
PAHs	Polycyclic Aromatic Hydrocarbons
PCD	Pollution Control Department
$PM_{2.5}$	Particles less than 2.5 micrometers in diameter
TLC	Thin-layer chromatography
U.S.EPA	U.S. Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organizati

CHAPTER I
INTRODUCTION

1.1 Background and Rational

For the past few decades, the problem of air pollution in Bangkok has been exacerbated by increasingly crowded traffic and transportation, the major sources of pollution. As a result, volatile organic compounds from the exhaust of vehicles have also increased following the rising number of vehicles (Pollution Control Department, Ministry of Natural Resources and Environment, 2013).

Benzene and Toluene are naturally arising volatile organic compounds commonly found in crude oil (Maryland Department of The Environment, 2007) categorized under the aromatic hydrocarbons subgroup. They are often emitted into the atmosphere through exhausts of aircrafts, automobiles and smokes of tobacco. Benzene and Toluene are also produced and utilized during industrial processes, including the refining of coals and petroleum products (World Health Organization, 2010) and the making of chemical intermediates and final household products ranging from cosmetics to pharmaceuticals (Frederic Leusch and Michael Bartkow, 2010). Benzene and Toluene's wide-ranging utility contributes to considerable annual global production—statistically, 8-10 Benzene million tons of (World Health Organization, 2000), 5-10 Toluene million tons (Frederic Leusch and Michael Bartkow, 2010).

In general, exposure to Benzene and Toluene components can contribute to both short-term and long-term health hazards. In the short-run, Benzene and Toluene can cause eye and throat irritations, headaches, drowsiness, dizziness, narcosis, and fatigue. In the long run, Benzene and Toluene can disrupt hematopoietic system, the central nervous system and the reproductive system (Mayurie Gunatilaka, 2003). In addition, Benzene, in particular, is carcinogens or cancer-inducing agents (International Agency for Research on Cancer, 1987).

According to the Office of Transportation and Air Quality (OTAQ) under the Environmental Protection Agency (EPA), indirect exposure to volatile organic compounds, especially Benzene and Toluene (BT) can be traced back to career-related involvement with fuels and vehicles. Increased incidence and severity of health problems associated with exposures to traffic air pollution are apparently observed among those who live or work near major roads (Office of Transportation and Air Quality, 2014).

Therefore, this study focuses its attention on indirect exposures to Benzene and Toluene among personnel who work in risk areas, in particular, major road with congested. While some preliminary researches, have been conducted on exposure of passenger to BTEX (Benzene, Toluene, ethyl Benzene and xylene) in public transportation features in Bangkok, Thailand (Ongwandee and Chavalparit, 2010), no studies about BTEX effects on health among Bangkok Transit System (BTS) sky train security guards—whose working hours could potentially expose them to frequent contact with Benzene and Toluene—have been found. Therefore, the aim of this study has been narrowed down to examine Benzene and Toluene exposure among sky train security guards, defined as those personnel who patrol or station on the BTS train platforms and the automatic entry gate at the concourse level. Train drivers and ticketing personnel in office room are excluded.

1.2 Research Questions

1.2.1 Are there any associations between Benzene and Toluene exposure concentration and health symptoms among sky train security guards?

1.2.2 Are urinary metabolites of Benzene and Toluene relate to Benzene and Toluene exposure concentration among sky train security guards?

1.3 Research Hypothesis

1.3.1 There is an association between Benzene and Toluene exposure concentration and health symptoms among sky train security guards.

1.3.2 Urinary metabolites of Benzene and Toluene are related to Benzene and Toluene exposure concentration among sky train security guards.

1.4 Research Objectives

1.4.1 General Objective:

- To investigate an association between Benzene and Toluene exposure concentration and health symptoms among sky train security guards.

1.4.2 Specific Objectives:

- To quantitatively determine the dose of Benzene and Toluene exposure concentration and urinary metabolite concentration among sky train security guards.
- To find a correlation between Benzene and Toluene exposure concentration and urinary metabolite concentration among sky train security guards.
- To examine association between Benzene and Toluene exposure concentration and health symptoms among sky train security guards.

1.5 Conceptual Framework

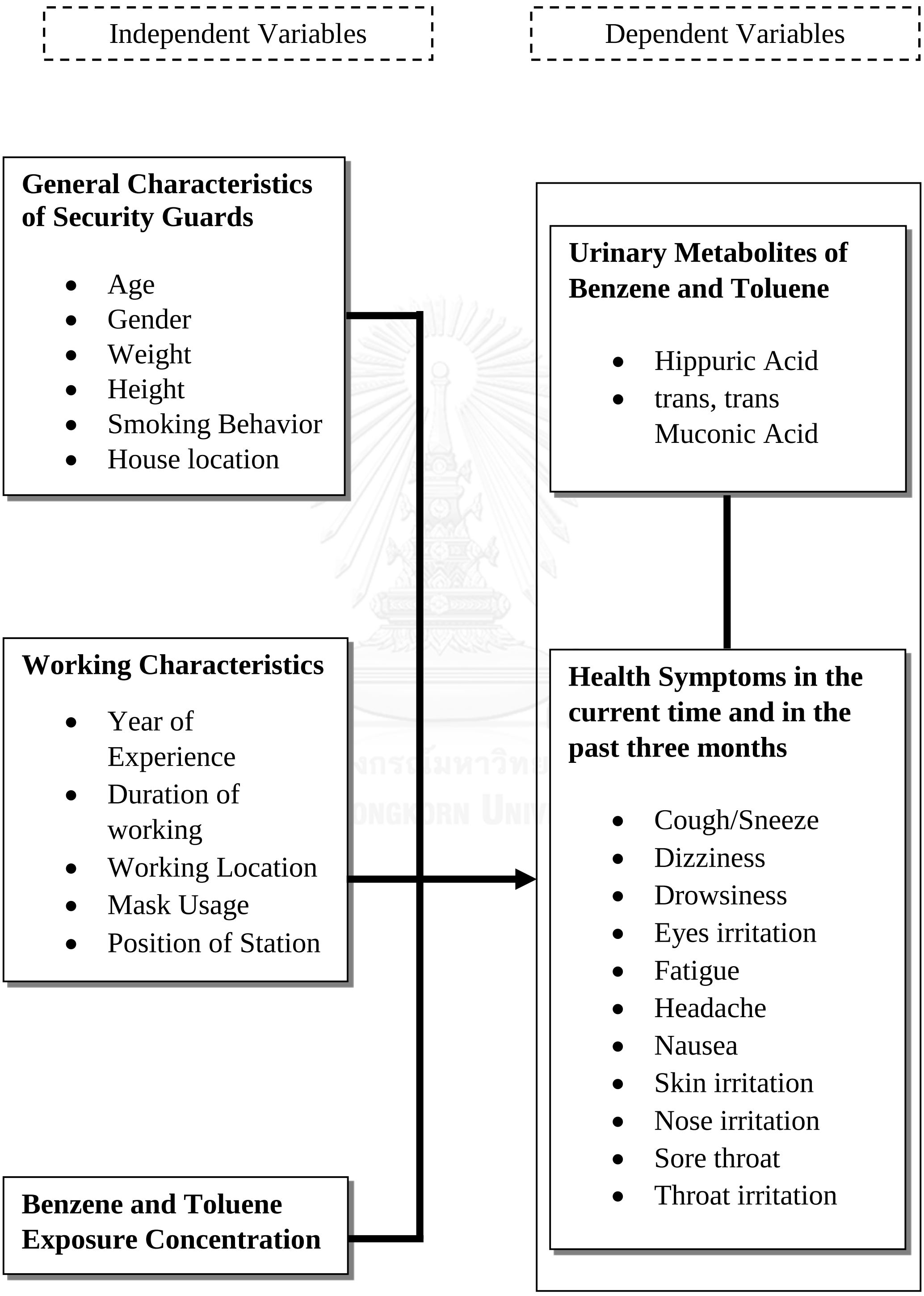

Figure 1 Conceptual Framework

1.6 Operational Definitions

Benzene and Toluene exposure level in this case study refers to the contact with Benzene, and Toluene through inhalation by sky-train security guards.

Benzene and Toluene exposure refers to the numerical concentration of Benzene and Toluene measured from the individual's BTEX exposure ($\mu g/m^3$).

Health symptoms in this study refers to acute symptoms from Benzene and Toluene exposure consisting of cough/sneeze, dizziness, drowsiness, nose irritation, eyes, skin and throat irritations, fatigue, headaches, and mucous irritation.

Sky trains security guards refers to those security personnel who patrol or station on the train platforms and the concourse level (to ensure safety of customers).

Bangkok Mass Transit System (BTS) refers to transportation service (system) by electric sky train in Bangkok, Thailand.

Smoking behavior refers to the ways in which participants are exposed (or not exposed) to smoking. These include both direct and passive smoking. Direct smokers are categorized into those who are currently smoking and those who smoked in the past but not in the present. Passive smokers include both smokers and non-smokers exposed to family members who smoke at present.

House location refers to the home place where the security guard is shelters at and could be nearly the air pollution source, for example, nearly the major road, and nearly the building.

Year of experience refers to number of years that security guards have experience in their jobs segment.

Duration of work refers to the security guard's morning shift, which lasts for about 8 hours.

Working location refers to the designated place where the security guard is stationed at, in this case, behind the yellow line near the train platform, and stationed at ticket level and concourse level.

Urinary metabolites in this case refers to the intermediates or biomarkers and products of urine metabolism from an interaction between Benzene and Toluene and cell that is determined in the human body. The urinary metabolite of Benzene is trans,trans-muconic acid (t,t-muconic acid) due to it can be detected at low level exposure (Scherer, Renner, and Meger, 1998) and more sensitive and reliable indicators than other metabolites of benzene exposure, and hippuric acid is urinary metabolite of Toluene (μg/g creatinine) due to it can be detected in high amounts.

Creatinine refers to normal waste product come from the break-down of muscle tissue in the body. Healthy kidneys filter creatinine and other waste products from the blood and send them out of body through urine. For a creatinine urine test, measure the amount of creatinine in urine and can help to evaluate how well your kidneys filter waste. Creatinine is released into the circulation at a relatively constant rate. Thus, the serum creatinine concentration is usually stable. As a consequence, creatinine adjustment has been used to remove the influence of the effect of urine dilution on exposure biomarkers measured in spot samples.

CHAPTER II
LITERATURE REVIEW

2.1 VOCs Situation, Thailand

Air quality situation in Thailand as a whole in 2011 is more serious than that of the past because of weather and drought.

According to PCD report in 2009 (Air Quality and Noise Management Bureau and Pollution Control Department, 2009; Pollution Control Department, Air Quality and Noise Management Bereau, 2009), entitled Development of Environmental Emission Standards of Volatile Organic Compounds (VOCs) in Thailand, the overall data of Benzene and Toluene utilization—importation, exportation, production and consumption that illustrated in demand – supply form, were shown in figure 2 and 3, respectively. From figure 2, the demand – supply data of benzene from 2001 - 2005 was clearly shown that export, production and consumption from 2002 was continually rising up in every year until 2005. In 2005, it was noticeable that the consumption slightly got down. It might be due to their toxicity and banning of that chemical or usage of other chemical replacement.

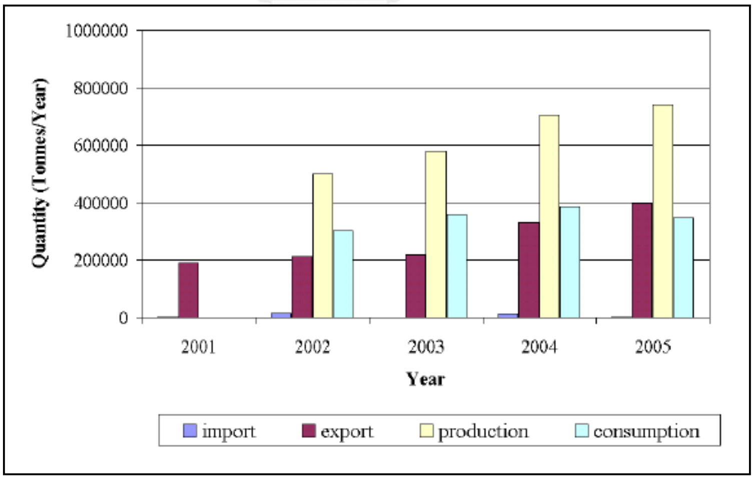

Figure 2 Demand – Supply of Benzene (PCD, 2009)

In terms of figure 3, the exportation of Toluene continually increased from 2001 to 2003, then, it decreased in 2004 and 2005, respectively. In the same way, the production increased in 2002 and 2003 while in 2004 and 2005, it widely decreased from 2003.

In the Bangkok area, dust pollution problems mostly occur on the roadside, primarily due to the improvement of transportation. From figure 4, in 2008, It's noticeable that Benzene level were higher level than the standard in all areas. However, the levels descended from the previous year due to improved new vehicle standards and fuel standards. Using more environmentally friendly vehicles and fuels may help to steadily decrease these problems (Pollution control Department, Ministry of Natural Resources and Environment, 2012, 2013). Still, from 2007 to the present, the average annual amount of dust and the maximum amount of dust in some locations, measured by the Pollution Control Department, remain in excess of the desired standard amount.

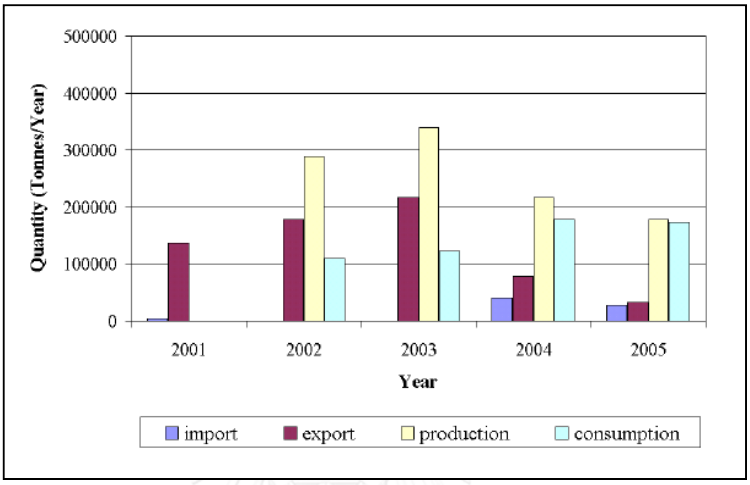

Figure 3 Demand – Supply of Toluene (PCD, 2009)

Pollution that exceeds the standard in most parts of the country—the ozone (O_3)—was found to be the highest in metropolitan areas. In addition, it was also found that volatile organic compounds (VOCs) and particulate matter with the size of less than 2.5 microns (PM 2.5 are present in notable amount in some areas. VOCs are measured at multiple inspection points across 1 8areas in six provinces, including Bangkok, Pathumthani, Rayong, Chiang Mai, Khon Kaen and Songkhla. The investigation found that Benzene is still a major problem in the 5 provinces except Pathumthani.

Problem areas were rated according to the amount of dust found at the corresponding inspection points and were given rankings. For Bangkok, Rama 6 Road was ranked 6 and Chatuchak Road was ranked 7 overall. VOCs in the atmosphere have been measured in Bangkok and its metropolitan, Rayong, Chiangmai, Phuket and Khon Kaen. Benzene, one of the VOCs, was found to exceed the standard in all provinces. Chloroform was also discovered to surpass the standard at two inspection points—one in Bangkok and one in Rayong. Furthermore, 1,3-butadiene and 1,2-dichloroethane were beyond acceptable standard in one Rayong inspection point. Meanwhile, there were five types of VOCs that manage to stay within the required standard (Pollution Control Department, Ministry of Natural Resources and Environment, 2013).

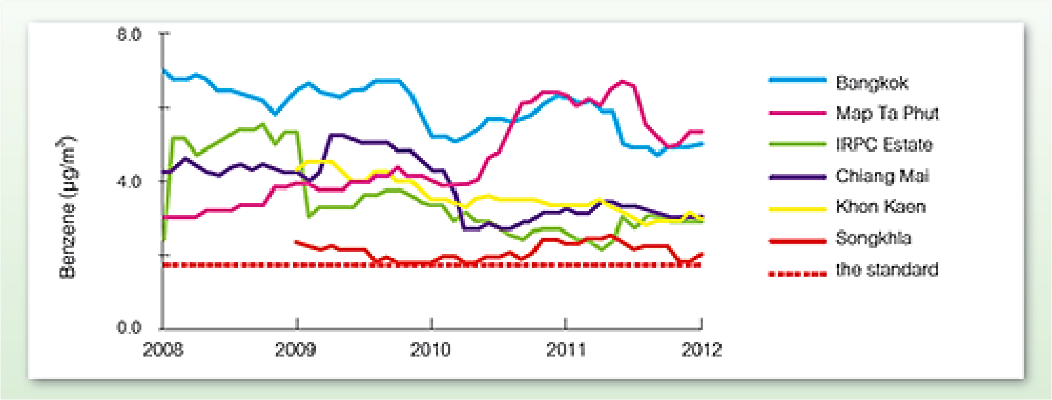

Figure 4 Highest 12-Month Moving-Average Benzene Amount (in µg/m^3) in the Atmosphere in Different Thai Provinces from 2008 to 2012
(Pollution Control Department and Environment, 2012)

2.2 Distribution of Benzene and Toluene

Benzene and Toluene are emitted into the atmosphere in the exhaust smoke form. According to the previous study found that, emission of pollutants into the atmosphere depends on ambient temperature, wind, atmospheric pressure and natural radioactivity. Meanwhile, pollutants concentration inverses with wind speed, high pollutants concentration but wind speed is low. On the other hand, wind direction does not affect to the concentration of pollutants (Pimla Raddawannapong, 2011). Distribution of the smoke depends on the temperature which will change with height. Distribution of the smoke can be classified into 6 features: Looping, Coning, Fanning, Fumigation, Lofting and Trapping (Watcharadetch Thaiwat, 2009). The figure of smoke distribution is shown below (figure 5).

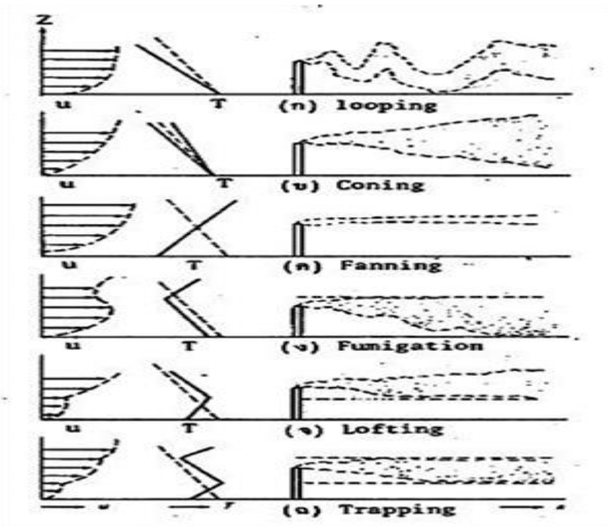

Figure 5 Smoke distribution
(Watcharadetch Thaiwat, 2009)

In addition, narrow roads and high buildings at roadside can cause important effects on the atmospheric dispersion of pollutants. It cause at that roadside has more concentration of pollutants than the surrounding (Caselli, de Gennaro, Marzocca, Trizio, and Tutino, 2010). Moreover, to support the fact that Benzene and Toluene can be detected at the electric sky-train station—12 meters from ground. Lin CC *et al* (2011) studied on vertical and diurnal characterization of volatile organic compounds in ambient air in urban areas during four period rush hours at the height 2, 13, 32, 58 and 111 meters of a skyscraper building, BTEX levels at 32 and 13 meters were higher than the BTEX levels at the ground, respectively. The researchers also concluded that BTEX levels associated with transportation activities of vehicles (Lin, Lin, Hsieh, Chen, and Wang, 2011).

2.3 Chemical and Physical Property of Benzene and Toluene

2.3.1 Benzene

Benzene—volatile organic chemical—is widely utilized in the industry and also a component of gasoline. Benzene can enter the body through inhalation and absorption through the skin and the digestive tract (United States Environmental Protection Agency, 2002).

Benzene affects to the whole body both in the short and long term. For health effects in the short term, Benzene causes drowsiness, dizziness, nausea, vomiting, and headache. In the long term, Benzene causes leukemia and anemia because it destroys the body's immune system. If people receive Benzene in very high doses for a long time, it may causes death.
The detection of Benzene in the body can be studied through blood and urine. In the case of urine test, the t,t-muconic acid, a metabolite of Benzene potentially present in the urine, is examined (Mayurie Gunatilaka, 2003). ACGIH and OSHA suggested concentration levels of Benzene’s biomarker in urine (trans, trans Muconic acid; t,t-MA) which detected at the end of work shift as Biological Exposure Index (BEI) should be no greater than 500 µg/g creatinine (Occupational Safety and Health Administration, 2012).

Table 1 Physical and chemical properties of Benzene

Property	Information
Chemical Name	Benzene
Chemical Formula	C_6H_6
Molecular Weight	78.11
Color	Clear
Melting Point	5.5 °C
Boiling Point	80.1 °C
Density at 15 °C, g/cm^3	0.8787
Odor	Aromatic
Odor Threshold: Air	Detection range: 34-119 ppm Recognition: 97 ppm
Vapor Pressure at 20 °C	75 mmHg
Auto Ignition Temperature	498 °C
Flashpoint	-11 °C (close cup)
Limits of Flammability in Air	1.2% (lower limit), 7.8% (upper limit)

Source: Toxicological Profile for Benzene (Agency for Toxic Substances and Disease Registry, 2007)

2.3.2 Toluene

Toluene—a volatile organic compound like Benzene—is used as a solvent in the tanning industry, glue and markers, and as a component of the car fuel. Toluene can enter the body through inhalation, skin absorption and ingestion. Toluene is a health hazard classified under two types of toxic levels: extreme toxicity and chronic toxicity. In extreme toxicity, Toluene induces headaches, confusion, nausea, vomiting, listlessness, and unconsciousness. For chronic toxicity, it inflicts the brain and the central nervous system with negative symptoms, including memory loss, fatigue, and impatience. Like Benzene, Toluene in the body can be detected in blood and urine. In urine tests, the presence of hippuric acid—a metabolite of Toluene—indicates the exposure to Toluene. Standard amount of Toluene that should be detected in the urine after work must be no greater than 0.03 mg / L (Mayurie Gunatilaka, 2003).

Table 2 Physical and chemical properties of Toluene

Property	Information
Chemical Name	Toluene
Chemical Formula	$C_6H_5CH_3$
Molecular Weight	92.14
Color	Colorless
Melting Point	-95 °C
Boiling Point	110.6 °C
Density at 20 °C, g/ml	0.8669
Odor	Like a Benzene
Odor Threshold: Air	8 ppm
Vapor Pressure at 25 °C	28.4 mmHg
Auto Ignition Temperature	480 °C (896 °F)
Flashpoint	4 °C (40 °F)
Limits of Flammability in Air	1.2-7.1 %

Source: Toxicological Profile for Toluene (Agency for Toxic Substances and Disease Registry, 2000)

2.4 Metabolites of Benzene and Toluene

2.4.1 Metabolism of Benzene

Benzene is well absorbed in humans and animals in laboratory after inhalation and oral exposures, but it is not as readily absorbed dermally. In human, absorption occurs around 50% during continuous exposure for a long period. Men may experience a lesser percentage of Benzene inhalation than women do.

The liver is the organ where the metabolism of Benzene begins. Benzene metabolism is primarily transmitted through the cytochrome P-450 IIE1 enzyme system and consist of the procession of unsteady reactive metabolites sequences. In the urine, the metabolic products are mainly excreted and the known metabolites—phenol, catechol and hydroquinone—are discovered at appreciable levels in bone marrow. The prime urinary metabolite in humans is phenol. It is mostly found as an incorporeal sulfate conjugate until its level reaches near 480 mg/liter; beyond this level glucuronides are discovered. Current studies advice that toxicity of Benzene is the consequence of the effects of the interaction of many forms of Benzene metabolites in both the liver and the bone marrow (World Health Organization, 1993).

2.4.2 Metabolism of Toluene

Hippuric acid is a major metabolite of Toluene. It can be extracted from the urine by a number of methods including colorimetry, UV spectrometry, and thin-layer chromatography (TLC).

Hippuric acid, a common component of urine, is mostly from food with benzoic acid (benzoates). Comparing the occurrence of hippuric acid in the urine of people unexposed to Toluene with those of Toluene-exposed subjects, the mean hippuric acid in urine excretion in females is higher than in males.

A mean concentration of < 1.0 g hippuric acid/ litre were excreted by unexposed personnel, whilst concentration of excreted hippuric acid of exposed personnel is at least 2-6 times that of the former, depending on ranks of exposure.

At present, the calculation of the average hippuric acid concentration in urine collection at the operation seems to be the most widely applied method for assessing overall work-related exposure to over 375 mg/m^3 of Toluene in air. A group average of lesser than 2 g/litre or g creatinine suggests that the air contains lesser than 375 mg/m^3 (100 ppm) Toluene (World Health Organization, 1985).

.2.5 Health Effects Related to Benzene and Toluene

Health effects caused by acute exposure to Benzene and Toluene. Its health effects have different symptoms that depending on level of Benzene and Toluene, duration of exposure and the exposure routes—inhalation, absorption, and consumption. Symptoms that may occur from level of exposure to Benzene and Toluene, as shown in table 3-4

Table 3 Symptoms that may occur from Benzene and Toluene exposure reviewed by IRIS

Benzene (IRIS, 2002)	Concentration (ppm)	Notation
Dizziness	250–3000 (799–9584 mg/m^3)	Workers will headaches, become tired easily, have difficulties sleeping, and complain of memory loss more often at concentration 6–15.6 ppm (20–50 mg/m^3) for 2–9 years.
Headache		
Drowsiness	700–3000 (2236–9584 mg/m^3)	
Loss of consciousness		
Toluene (IRIS, 2005)		
Altered color vision	at high exposure levels (generally 600 ppm or greater)	-
Dizziness		
Fatigue		
Headache		

Source: (Integrated Risk Information System, 2002); (Integrated Risk Information System, 2005)

Table 4 Symptoms that may occur from Benzene and Toluene exposure

Symptoms	Exposure/Duration frequency	NOAEL (ppm)	LOAEL Less serious (ppm)
Benzene (Agency for Toxic Substances and Disease Registry, 2007)			
Dizziness	1 – 21 days 2.5 – 8 hr./day	-	60
Fatigue			
Headache			
Mucous membrane irritation			
Nausea			
Skin irritation			
Dizziness	30 minutes	-	300
Drowsiness			
Headache			
Toluene (Agency for Toxic Substances and Disease Registry, 2000)			
Dizziness	6 hr.	40	100
Eyes irritation			
Headache		40^b	100
Nose irritation			
Decrease manual performance and color perception	6.5 hr.	-	100
Dizziness			
Eyes irritation			
Throat irritation			
Mild-throat irritation	7-8 hr.	-	200
Eyes irritation			
Drowsiness	3 or 8 hr.	-	200
Headache			

2.6 Related Articles

(Borgie et al., 2014) studied on traffic-related air pollution: a pilot exposure assessment in Beirut, Lebanon. Benzene and 1,3-butadiene (BD) were measured from twenty-five policemen at traffic and twenty-three policemen in office by bio-monitoring—personal air monitoring. They found individual exposure to Benzene among traffic polices were higher than traffic police in other countries. t,t-MA levels possibly will differentiate between traffic and office polices. Meanwhile, median monohydroxy-butenyl mercapturic acid (MHBMA) levels in traffic police were faintly raised up, even though not significantly higher than in office police.

(Demirel, Ozden, Dogeroglu, and Gaga, 2014) studied on personal exposure of primary school children to BTEX, NO_2 and Ozone in Eskişehir, Turkey: relationship with indoor/outdoor concentrations and risk assessment. Personal exposures of sixty-five primary school children from two schools were selected. BTEX, Nitrogen dioxide (NO_2) and Ozone (O_3) were collected by Organic vapor monitors and tailor-made passive samplers during 24 hours in this study. Questionnaires were used to itemize socio-demographic and personal time–activity data. The mean of risk of cancer was found that the borough school kids (1.7×10^{-5}) to be higher than the sub- borough school kids (0.88×10^{-5}). Children living with parentages who smoked had higher risk levels (1.7×10^{-5}) than children living with nonsmoking parentages (1.08×10^{-5}).

(Majumdar, Mukherjeea, and Sen, 2011) studied on BTEX in ambient air of a metropolitan city. They investigated in BTEX at three monitoring sites at commercial and residential area. The researchers found, the cumulative lifetime cancer risk for Benzene and ethyl Benzene was found to be higher than the acceptable value and range between 3.0×10^2 and 8.9×10^6 in three sites, although the non-cancer health risk was found to be within acceptable limit.

(D. Som et al., 2007) studied on commuters' exposure to BTEX in passenger cars in Kolkata, India. Passenger in cars along two crowded urban roads, both roads from University College of Science, during office hours between 10:30 am and 4:00 pm in two trips were selected. BTEX were collected by VOCs sampling and charcoal sorbent tubes. Results were founded passengers' exposure to Benzene and other VOCs are pretty high in Kolkata, even after aromatic content decreasing in gasoline. The amount of exposure depends on the type of engine and technology of the cars.

(Milena B. Fernandes, Leila S.R. Brickus, J.C.Moreira, and J.N.Cardoso, 2002; Milena B.Fernandes, LeilaS.R. Brickus, J.C Moreira, and J.N. Cardoso, 2002) studied on atmospheric BTX and polyaromatic hydrocarbons in Rio de Janeiro, Brazil. Semi-volatile PAHs and BTX were measured in four main roads in the city of Rio, during the summer. Semi-volatile PAHs were measured by filtration of ambient air and BTX were measured by ambient air samplers. For the results, the relatively low PAH and BTX levels between during the summer are probably a consequence of a number of factors: the summer rainy season, the absence of heating systems throughout the city of Rio, and the use of ethanol–gasoline mixtures with low Benzene content, neat ethanol and LPG fuel in light-duty vehicles. Concentrations of these compounds are not only low in comparison to other cities worldwide.

(Wasssana Loonsamrong, Nutta Taneepanichskul, Sitthichok Puangthongthub, and Tanasorn Tungsaringkarn, 2013) studied on health risk assessment of BTEX exposure to parking workers at one of parking structure in Bangkok, Thailand. This study estimated level of BTEX exposure and showed the identity of BTEX exposure related with a health risk assessment via inhalation among workers at the car parking. Air samples were collected by active diffusion sampling tubes while urine were collected from the workers after work shift. Result showed that mean concentrations of BTEX were 11.282, 56.129, 7.166 and 10.587 $\mu g/m^3$, respectively. Meanwhile, mean concentrations of t,t-Muconic acid and Hippuric acid, urinary metabolites, were 177.07 and 0.39 g/g creatinine, respectively. Additionally, there was no correlation between BTEX concentration and the urinary metabolites concentration. On the other hand, there was association between increasing of Ethyl-benzene exposure and likelihood increasing of demonstrating nausea (OR = 1.14, 95%CI; 1.008 – 1.288), as well as increasing of xylene exposure was associated with likelihood increasing of demonstrating cough (OR = 1.137, 95%CI; 1.012 – 1.278).

(Ongwandee and Chavalparit, 2010) studied on commuter exposure to BTEX in public transportation modes in metropolitan Bangkok, Thailand. They investigated BTEX concentrations among 75 passengers from four public transportation features, including an air-conditioned bus (A/C bus), non-air-conditioned bus (non-A/C bus), electric sky train, and a passenger boat traveling along the canal. Comparison during two rush hour periods (7–9 a.m. and 4–7 p.m.) by personal sampling pump. The study results were shown that, median concentrations of BTEX in A/C bus were 11.7, 103, 11.7, and 42.8 $\mu g/m^3$; in non-A/C bus were 37.1, 174, 14.7, and 55.4 $\mu g/m^3$; 2.0, 36.9, 0.5, and 0.5 $\mu g/m^3$ in sky train; and 3.1, 58.5, 0.5, and 6.2 $\mu g/m^3$ in boat, respectively. Moreover, the results indicated that, in sky train, Toluene and m, p-xylene level were statistically less than both of A/C and non-A/C buses. Meanwhile, vehicle-traffic-generated BTEX only softly contributes to the in-sky train levels because of its elevation beyond the traffic.

(Pakanon Promsuwan and Winai Nutmakool, 2012) studied on determination and health risk assessment of BTEX at bus stop area in Bangkok. BTEX were measured by Diffusive Sampler at four bus stops for 24 hours. The researchers found the level of volatile organic compounds in the test area was not severely harm to public health and people who has lived or worked nearby the bus stop that we had monitored.

(Sasithorn Ruangtrakula, Tassanee Prueaksasit, and Morknoyc, 2013) studied on health risk assessment of toll-way station workers exposed to BTEX via inhalation in Bangkok. In this study, workers from 4 stations of toll-way were conducted during 8 work hours (6 A.M. – 2 P.M.) on Friday and Sunday and BTEX were collected by personal air pump. It was found Benzene and ethyl Benzene exposure were higher than the acceptable risks (1×10^{-4}), whereas the hazard quotients of non-carcinogenic compounds. Toluene and xylene were in total less than 1, which indicated that there were no health risks of concern.

(Lan, Tran Thi Ngoc, Minh, and Pham Anh, 2013; T. T. N. Lan and Minh, 2013) studied on BTEX pollution caused by motorcycles in the megacity of HoChiMinh, Vietnam to investigate BTEX pollution at roadside in urban areas and effect of different means of transportation on BTEX pollution. BTEX monitoring was proceeded along with 17 inspection points placed on main roads in 9 residential district, points 13 – 17 were placed on the central district at the university motorcycle park entrance. Air sampling was applied from The NIOSH 1501 method and was operated on works day during rush hours. They found that, Benzene concentration at 254 $\mu g/m^3$ was the maximum observed hour-average. Additionally, there are high correlations among BTEX species, between BTEX concentrations and the volume of on-road motorcycles, and between inter-species ratios in air and in gasoline indicate the motorcycle-exhaust origin of BTEX species. In conclusion, the roadside BTEX main source is traffic discharge in HoChiMinh. The biggest contributor to BTEX pollution in HoChiMinh is motorcycles.

(Velasco et al., 2013; Velasco, Ho, and Ziegler, 2013) studied on Commuter exposure to black carbon, carbon monoxide and noise in the mass transport khlong boats of Bangkok, Thailand. Passengers at piers during the morning rush hours were selected and black carbon (BC), CO and noise were measured. They found, the BC and CO concentrations at the Pratunam pier were higher than those recorded inside the boats during traveling trips. While travelling along the canal, and occurred at maximum speeds, the highest noise levels were recorded.

(Violante et al., 2006; F. S. Violante et al., 2006) researched on urban atmospheric pollution: personal exposure versus fixed monitoring station measurements. To examined exposure to traffic of pedestrians, 126 traffic police workers and 50 parking wardens, related with atmospheric pollutants: BTEX and $PM_{10.}$ For data collection, information were gathered from work shifts throughout four 1-week periods in different seasons of 2000–2001. For the result, the researchers found that exposure of wayside personal to Benzene associates more powerfully with Toluene, xylenes and ethyl Benzene than PM10. In addition, the records from fixed monitoring stations, both of Benzene and PM10 related with climatological variables, and were also influenced by traffic local density.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Design

This study was approved by The Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University, Thailand with the certified code No. 070.1/2015. All participants in this study agreed on participant information sheet and signed in informed consent form before this study was conducted.

This is a cross-sectional study to investigate an association between Benzene and Toluene exposure level and health effects, as well as an association between urinary metabolites and Benzene and Toluene exposure among sky train security guards.

3.2 Study Area

This study involves electric sky train stations in Bangkok following Sukhumvit Line which has a total of 22 stations along the 22.25 km. track length. According to Office of Transport and Traffic Policy and Planning's report, Sukhumvit road is one of the ten roads with the worst traffic congestion during rush hours. The average vehicle speed on Sukhumvit road, which runs parallel to the BTS Sukhumvit line (as shown on the map; figure 6) is only about 13.3 km/hr. (Ministry of transport, 2014). Therefore, the Sukhumvit line, which runs from Mo Chit to Bearing station, was selected to be a representative region in this study.

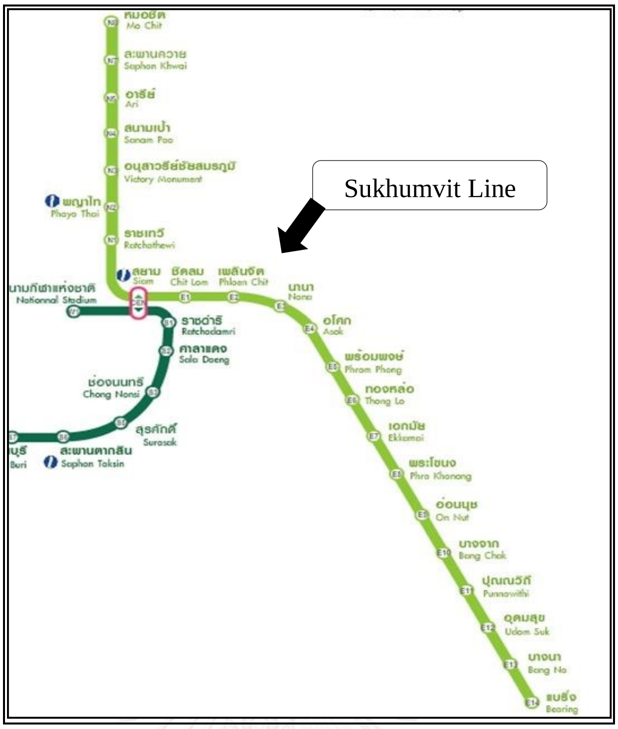

Figure 6 Map of electric sky train stations in Bangkok
(Service Routes of Bangkok Mass Transit System Public Company)

However, only a total of 20 stations will be examined. Siam station was excluded in this study due to the fact that the physical structure of Siam station is materially different from those of other station along Sukhumvit line; Siam station has two levels of train platforms whereas other stations each have only one level. Asok was also excluded following the suggestion from a thesis examination committee; Asok station has more number of passengers than those of other stations that have normal physical structure.

3.3 Study Population

Population in this study is all of sky train security guards of 20 electric sky train stations in Sukhumvit Line. The exposure of Benzene and Toluene was measured during time of work and urine were collected after work.

3.4 Inclusion and Exclusion Criteria

In terms of inclusion criteria, this study focuses on sky-train security guards who are healthy Thai—using annual health checkup report from company for screening health of participants—and aged between 18-60 years. For exclusion criteria, train drivers, ticketing personnel and workers with respiratory diseases and kidney disease are excluded. Siam and Asok station will be also excluded from 22 total station.

3.5 Sample and Sample Size

In this study, sample size calculation was calculated.

Formula; $$n = \frac{z^2pq}{d^2}$$

Where; n = Sample size

z = Normal standard deviate, usually set at 1.96 which correspond to 95% Confident Interval level

p = The proportion in the target population estimate to exposed group

q = 1 – p

d = Degree of accuracy required in this study set at 0.1

$$n = \frac{(1.96)^2 \times \ 0.9 \times \ 0.1}{(0.1)^2}$$

n = 34.57 samples × 10% (sample losses)

= 34.57 + 3.5

= 38.07

≈ 40

Therefore, the required sample size in this study is 40 samples.

3.6 Sampling Technique

Step 1: Purposive selection of BTS route

In terms of the BTS station sampling technique, this study used purposive sampling in order to follow the objectives of this research. A total of 20 stations along the Sukhumvit line, excluding Siam and Asok station, were selected specifically along the road with heavy traffic.

Step 2: Random selection of workers at each station

This study pre-screened participants using the annual health checkup report as permitted by the company and the participants. Generally, workers at each station can be classified into two groups: workers from the concourse level and workers from the platform level. Four workers (two from each group) who are the most qualified in terms of health condition were added to the list. From the list, random sampling was used to select two workers (one from each group) at each station. The sampling technique is shown in figure 7.

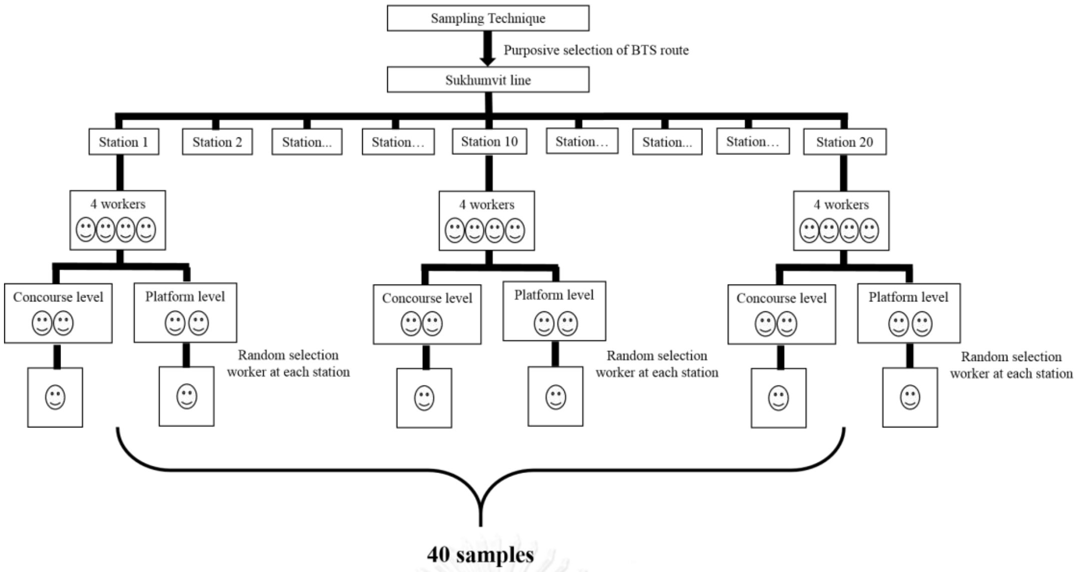

Figure 7 Diagram of Sampling Techniques

3.7 Measurement Tools

3.7.1 Questionnaires

The questionnaires comprises of 3 parts: general characteristics of workers, working characteristics and health effects, respectively. The questionnaires were tested for validity by three specialists. For reliability, the questionnaires were tested with 30 security guards in the other route (Silom line) of the BTS before the actual use. Cronbach's Alpha test for reliability analysis was used, so the reliability value is 0.873.

1st part: General characteristics of workers (age, gender, weight, height, house location and smoking behavior); a total of 10 items.

2nd part: Working characteristics (years of experience, duration of work and location); a total of 9 items.

3rd part: Health effects (symptoms that workers get during work or after work within 24 hours and within the past 3 months.); a total of 11 items.

3.7.2 Air Sampling

Charcoal Glass tube and personal air pump were used in order to sampling concentration of BTEX continuously throughout the duration of work for 8 hours, from 8 a.m. to 4 p.m.

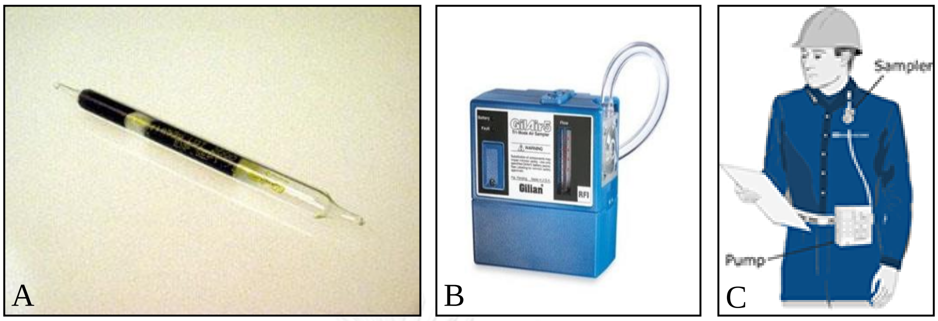

Figure 8 Equipment for Air sampling
A. Charcoal Glass tube and personal air pump,
B. Personal Air sampling pump, and C. Location of air sampling

3.7.3 Urine Sampling

The collection of urine sampling method to determine metabolite of Benzene, t,t-muconic acid and metabolite of Toluene and hippuric acid follows the NIOSH method 8301 (National Institute for Occupational Safety and Health, 2003). 50 to 100 mL of urine was collected after work in a 125-mL plastic bottle. The samples were preserved by keeping them in mobile cooling units at about 4 °C.

3.8 Data Collection

The data collections include urine sampling, air sampling and questionnaires from face-to-face interviews.

Firstly, urine samples were collected in plastic bottles (given separately to each participants), once before working shift in the morning. The samples were preserved by keeping them in mobile cooling units at about 4 °C. Secondly, the process of air sampling commences. Air sampling equipment includes a charcoal sorbent sample tubes and personal air pumps. Sample tubes were attached to the shirt collars of the participants so that the tubes would be near to the the inhalation zone. Air pumps were continually turn on throughout the duration of work for 8 hours, from 8 a.m. to 4 p.m.. After the air pumps were turned off, the second urine samples were collected. Once again, the samples were preserved by keeping them in mobile cooling units at about 4 °C. Finally, questionnaires were collected from face-to-face interviews, each of which took about 10 minutes, after all the sampling processes had been completed. The timeline of data collections is shown in figure 9.

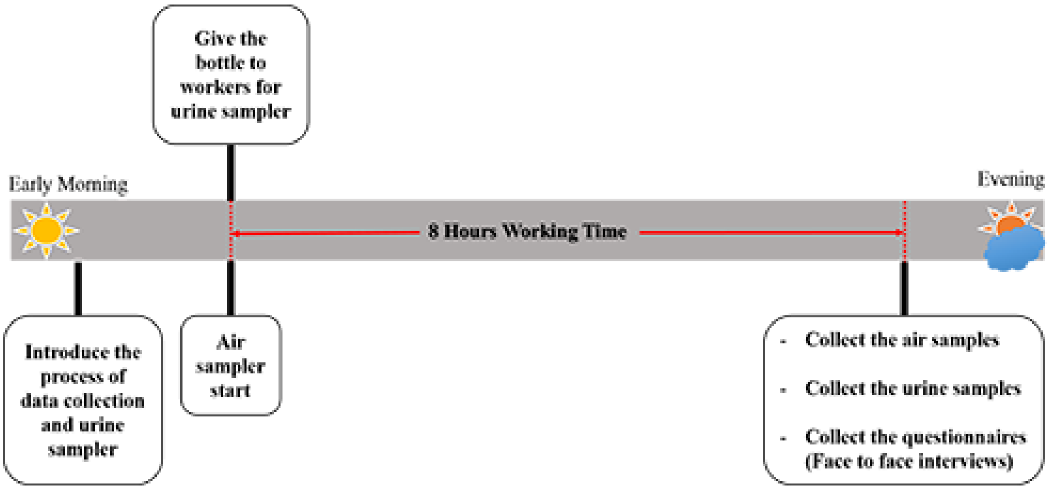

Figure 9 The timeline of data collections

3.9 Laboratory Analysis

3.9.1 Air Sample Analytical Method

3.9.1.1 Sample Preparation

Benzene and Toluene analysis use carbon disulfide (CS_2) for distillation and squirt standard solvent (Internal Standard) and then, it were released for 30 minutes. The solvent separation clear distillation solution and diversify to 2 mL glass vials squirted into Gas Chromatography with the flame ionization detector (GC-FID). The flow of sample preparation presented in figure 10.

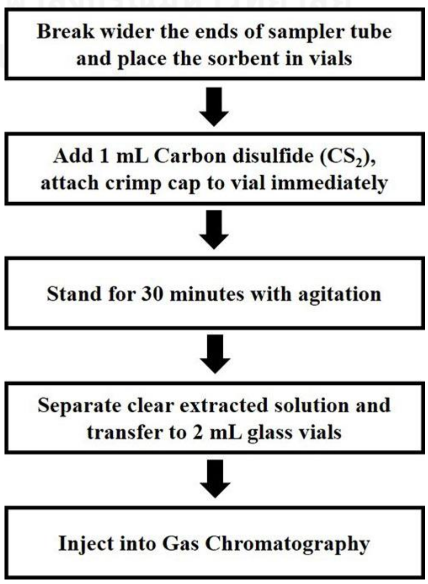

Figure 10 The flow Chart of sample preparation

3.9.1.2 Sample Analysis

Analytical technique

The sample analysis process of Benzene and Toluene was based on the NIOSH Manual of Analytical Method No.1501 (NIOSH, 2003). Gas Chromatography with Flame Ionization Detector (GC-FID) was used to be examination technique. The GC condition for analysis displayed in the table 5.

Table 5 The condition of BTEX analysis

Capillary Column	CP-Silica 24 CB 30m x 0.32-mm ID; 1-µm film 100% PEG or equivalent, #CP7831
Carrier Gas	Helium (He) Make up Helium (He) – 2.6 mL/min
He Flow rate	1 mL/min
Injection Type	Split 5:1
Injection Volume	1 µL
Injector Temperature	250 ºC
Detector	Flame ionization
Detector Temperature	300 ºC
Oven	Temperature at 40 ºC, Hold 10 minutes to 230 ºC, Rate 10 ºC/min

Quality Control

The limitation of detection (LOD) was specified by preparing the lowest concentration of mix standard. The concentration of sample lower than LOD was informed as not detected. The calculation of LOD follows equation 1

Equation 1
$$\text{LOD} = \frac{3 \times \text{the lowest concentration used} \times \text{standard deviation}}{X_{bar}}$$

$$\text{Standard deviation} = \sqrt{\sum_{i=1} \frac{(Xi - Xbar)^2}{(n-1)}}$$

Where; Xi = Peak area of target compound observed
Xbar = Average area of these observations

Mix standard were inserted into GC-FID for 3 times, the average was calculated. The limit of detection (LOD) of Benzene, Toluene, ethyl Benzene, and xylene were set to 0.2, 0.3, 0.2, and 0.03 µg/m^3 respectively. Recovery percentage of Benzene and Toluene 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 examined as to check Benzene and Toluene species contamination. Benzene and Toluene concentration measured in repetitive samples were in good arrangement. The validation of laboratory analysis was illustrated in table 6.

Table 6 Precision and accuracy of Benzene and Toluene analysis

Parameter	LOD	%Recovery	%RSD (Relative Standard Deviation)
Benzene	0.5	95.56	4.76
Toluene	0.7	98.66	4.47

Calibration Curve

With mix standard solution usage (Mix of aromatic hydrocarbons), five difference concentrations were organized as 0.5, 1.0, 5.0, 10.0, and 15.0 ppm. In each standard Benzene and Toluene concentration, alpha, alpha, alpha-TrifluoroToluene (Ehrenstorfer, Gernany) with concentration 2,000 ng/µL in methanol was added as the internal standard.

Calculation of Concentration Values

According to calibration curve and linear equation, the mass of Benzene and Toluene and Benzene and Toluene concentrations might be calculated.

$$MS = \frac{(P_A - P_B)}{P_S} \times C_S \times \frac{V_S}{V_1}$$

Where;

MS (µg) = Mass of contaminants (Benzene and Toluene)

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

PS = 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)

To calculate concentration, this formula was used.

$$C = \frac{(W_f + W_b - B_f - B_b)}{V}$$

Where; C = Concentration of the air sampled (mg/m^3) (NOTE: $\mu g/L = mg/m^3$)
W_f = Sample front sorbent sections
W_b = Sample back sorbent sections
B_f = The average media blank front sorbent sections
B_b = The average media blank back sorbent sections
V = Air volume sampled (L)

3.9.2 Urinary Analytical Method

Analytical Technique

The samples analysis practice of Benzene and Toluene was based on the NIOSH Manual of Analytical Method No.8301 (NIOSH, 2003) to analyze hippuric acid. Analyzing trans,trans-muconic acid (t,t-muconic acid) in house method was used. Analysis technique used high performance liquid chromatography with ultraviolet detection method (HPLC-UV).

Creatinine is a compound that acts as a source of energy in muscle. Creatinine is a useful indicator of renal health because it is excreted in the urine as an unchanged and easily measured by-product of muscle metabolism. Therefore, creatinine will be used for indicator to analyze urine.

Calibration Curve and Concentration Values Calculation

Stock solution for t,t-muconic acid was prepared in methanol. Urine samples were obstructed with the t,t-MA (working solutions) to attain ultimate concentration 0.20, 0.50, 1.00, 2.50, and 5.00 µg/mL. The vanillic acid solution at the concentration of 100 µg/mL was arranged as interior standard. These solutions were used to arrange the calibration curves and for quality control. Determination was carried out based on inward standardization.

3.10 Data Analysis (Statistics)

The SPSS Program was used in this research for analyzed the data. General data, worker amount, age, and gender, were delineated by descriptive statistic including mean, median, frequency, percentage, standard error and standard deviation. Normal distribution test used to test all parameters of study by Shapiro-Wilk test first. For finding association between BT detected concentration and different working location, Mann Whitney U test was used. Fisher's exact test was used to find association between health effects and Benzene and Toluene exposure level. Logistic regression was used to determine health effects and level of Benzene and Toluene exposure. Correlation between urinary metabolites and Benzene and Toluene exposure will be analyzed by Spearman correlation test ($p < 0.05$).

3.11 Ethical Consideration

The experimental document was submitted to the Ethics Review Committee for Research relating Human Research Subjects under Chulalongkorn University's Health Sciences Group. The objective of the research was clearly reported to the targeted study sample and was approved on COA No. 070.1/2015. Reported acquiescence was signed by subjects before the study.

CHAPTER IV
RESULT

4.1 General Information

The total number of participants in this study is 40, consisting of 23 males and 17 females, all of whom are security guards stationed on ticket or platform level of the electric sky-train station along the Sukhumvit line. All participants were questioned via face-to-face interviews and questionnaires. The questions in each questionnaire included three sections: general characteristics of workers (age, gender, weight, height, housing location and smoking behavior), working characteristics (years of experience, duration of work and location), and health effects (symptoms that workers get during work or after work within 24 hours and within the past 3 months.). The results from the questionnaires were displayed in table below.

Table 7 Fundamental characteristic of BTS security guards (n = 40)

General Characteristic	Frequency (Percent), (n = 40)
Gender	
Male	23 (57.5)
Female	17 (42.5)
Age (years)	
< 30	9 (22.5)
30 – 39	14 (35.0)
≥ 40	17 (42.5)
Min. – Max.	22 – 54
Mean ± SD	37.8 ± 8.5
Body Mass Index (BMI, kg. / m^2)	
< 18.50 (Underweight)	2 (5.0)
18.50 – 24.99 (Normal Range)	25 (62.5)
25.00 – 29.99 (Overweight)	9 (22.5)
≥ 30 (Obese)	4 (10.0)
Mean ± SD	23.79 ± 3.52
Smoking Behavior	
Never Smoke	22 (55.0)
Former Smoker	10 (25.0)
Current Smoking	8 (20.0)

General Characteristic	Frequency (Percent), (n = 40)
Number of Cigarette (per day), (n = 8)	
1-5	6 (15.0)
6-10	2 (5.0)
Mean ± SD	5.25 ± 2.50
Second Hand Smoker	
No	25 (62.5)
Yes	15 (37.5)
House Located near Other Air Pollution Sources*	
No	30 (75.0)
Yes	10 (25.0)

*Garage and Major road.

The percentages of participants in this study were 57.5% and 42.5% for male and female, respectively. The age of most participants (42.5%) was 40 years old or above while the mean age was 37.8 (± 8.5). The average body weight and height were 64.4 (±8.4) and 163.5 (±1.49), respectively *(Appendix C)*. 62.5% of the participants fall within the body mass index (BMI) range of 18.50 – 24.99, which is considered the normal range. Of the security guards who were currently smoking (20% of participants), the average number of cigarettes smoked per day was 5.25 (±2.50) and 37.5% of this group were second hand smokers exposed to family members who smoke at present. 25% of the participants indicated that their houses are located near other sources of air pollution such as major roads and garages *(Appendix C)*. Most of the security guards (28.2%) went to work by BTS and 25.6% commuted by walking. On the other hand, commuting by motorcycles and other means was the lowest at 7.7% (Table 7).

4.2 Working Characteristics

In terms of working characteristics, security guards worked 12 hours per day with half of them working on the platform level and the other half on the ticketing level; 77.5% never rotated jobs between platform and ticketing level. 41.1% had working experience in the range of 1 – 5 years, while the median working years was 1.2 (± 0.57). The majority (85%) worked 7 days a week with 24.0 (±2.14) average day offs per year. When asked about potential reasons for using masks, 64% cited pollution protection while 4% and 28% cited influenza protection and sickness, respectively. Only 4% would do so to follow regulations and 37.5% of participants did not state the reasons. As a matter of fact, 47.5% of the security guards never used any forms of personal protective equipment during working shifts. The summary of working characteristics data was shown in table 8.

Table 8 Working characteristics of BTS security guards.

Working Characteristic	Frequency (Percent), (n = 40)
Working Area	
Platform	20 (50.0)
Ticketing	20 (50.0)
Working Experiences (years)	
< 1	14 (35.0)
1 – 5	17 (42.5)
≥ 6	9 (22.5)
Median ± SE	1.2 ± 0.57
Job Rotating	
No	31 (77.5)
Yes	9 (22.5)
Duration of work (days/week)	
6	6 (15.0)
7	34 (85.0)
Median ± SE	7.0 ± 0.06
Personal Protective Equipment Use (Mask)	
No	19 (47.5)
Yes	21 (52.5)
Reasons for using mask	
Pollution Protection	16 (64.0)
Influenza Protection	1 (4.0)
Sickness	7 (28.0)
Do by Regulations	1 (4.0)

4.3 Concentration of BT in Air Samples

4.3.1 Descriptive of BT Concentrations

From table 9, the comparisons of Benzene and Toluene concentrations from exposure showed that the average of concentration of Benzene and Toluene is 0.21 (± 4.08) and 242.40 (±17.11), respectively. The maximum concentration of Benzene is 136.98 µg/m^3 while that of Toluene is 354.17 µg/m^3. Meanwhile, the minimum concentration detected was 0.21 µg/m^3 and 0.07 µg/m^3 for Benzene and Toluene, respectively.

Table 9 Comparisons between concentration of Benzene and Toluene exposure among security guards working at BTS stations (µg/m^3, n = 40)

Parameter	Concentration (µg/m^3)	
	Benzene	**Toluene**
Median	0.21	242.40
Standard error	4.08	17.11
Mean	7.52	214.30
Standard deviation	24.46	102.64
Mode	0.21	0.07
Min.	0.21	0.07
Max.	136.98	354.17

4.3.2 Comparisons of detected BT Concentration in ticketing and platform level

Mann-Whitney U test was used to analyze for association finding. BT concentrations detected from 40 participants were compared between those participants working in the ticketing level and those in the platform level. The comparisons of concentration of Benzene and Toluene exposure were illustrated in table 10. From the table, the result shows that both BT concentrations at ticketing and platform level were not significant (p-value of 0.188, 0.350, respectively). Therefore, there was no material difference in terms of Benzene and Toluene concentration detected in the ticketing and platform level.

Table 10 Comparisons between concentration of Benzene and Toluene exposure in the ticketing and platform level
at BTS stations located among security guards working (µg/m^3, n = 40)

		Ticketing (n = 20)	Platform (n = 20)	p-value
Benzene	Median	0.21	0.21	0.188
	Standard error	8.55	3.56	
	Mean	8.76	6.82	
	Standard deviation	34.19	14.25	
	Min.	0.21	0.21	
	Max.	136.98	37.50	
Toluene	Median	247.03	242.39	0.350
	Standard error	19.14	31.25	
	Mean	242.23	177.25	
	Standard deviation	76.55	124.99	
	Min.	0.07	0.07	
	Max.	354.17	298.13	

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

4.3.3 Comparisons of BT Concentration between inner Bangkok and outer Bangkok

Comparisons of BT concentration between stations located within inner Bangkok (14 stations) and outer Bangkok (6 stations) were displayed in table 11. With 0.549 p-value, the results show that the difference in concentration of Benzene within inner and outer Bangkok was not significant. At the same time, the difference in Toluene concentration between the two areas was also not significant with the p-value of 0.558.

Table 11 Comparisons of concentration of Benzene and Toluene exposure in the inner Bangkok and outer Bangkok
among security guards working at BTS stations located (µg/m^3,n = 40)

		Inner Bangkok [a] (n = 28)	**Outer Bangkok [b] (n = 12)**	**p-value**
Benzene	Median	0.21	0.21	0.549
	Standard error	2.27	3.59	
	Mean	9.44	3.15	
	Standard deviation	28.65	9.74	
	Min.	0.21	0.21	
	Max.	136.98	32.50	
Toluene	Median	242.29	250.00	0.558
	Standard error	28.01	29.82	
	Mean	205.01	235.40	
	Standard deviation	109.32	86.55	
	Min.	0.07	0.07	
	Max.	354.17	334.90	

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

[a] Inner Bangkok of Bangkok refers to Mo Chit, Saphan Khwai, Ari, Sanam Pao, Victory Monument, Phaya Thai, Ratchathewi, Chit Lom, Phloen Chit, Na Na, Phrom Phong, Thong Lo, Ekkamai and Phra Khanong station.

[b] Outer Bangkok of Bangkok refers to On Nut, Bang Chak, Punnawithi, Udom Suk, Bang Na and Bearing station.

4.3.4 Comparisons of BT Concentration between North and East BTS Sky-Train Line

The table 12 below compares the Benzene and Toluene concentration detected from participating security guards who worked for the North BTS Sky-Train Line (7 stations) and the East BTS Sky-Train Line (13 stations). With 0.435 p-value, the results show that the difference in concentration of Benzene for the North BTS Sky-Train Line and the East BTS Sky-Train Line was not significant. Simultaneously, the difference in Toluene concentration between the two BTS Line was also not significant with the p-value of 0.053.

Table 12 Comparisons of concentration of Benzene and Toluene exposure among security guards working at BTS stations located in the North (N) and East (E) of BTS Line ($\mu g/m^3$, n = 40)

		North Line (N) *a* (n = 14)	**East Line (E) *b* (n = 26)**	**p-value**
Benzene	Median	0.21	0.21	0.435
	Standard error	1.86	34.34	
	Mean	1.92	10.32	
	Standard deviation	5.89	29.49	
	Min.	0.21	0.21	
	Max.	20.63	136.98	
Toluene	Median	224.01	253.13	0.053
	Standard error	12.57	33.03	
	Mean	179.74	231.58	
	Standard deviation	110.36	96.30	
	Min.	0.07	0.07	
	Max.	286.04	354.17	

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

a N refers to Mo Chit (N8), Saphan Khwai (N7), Ari (N5), Sanam Pao (N4), Victory Monument (N3), Phaya Thai (N2) and Ratchathewi (N1) station

b E refers to Chit Lom (E1), Phloen Chit (E2), Na Na (E3), Phrom Phong (E5), Thong Lo (E6), Ekkamai (E7), Phra Khanong (E8), On Nut (E9), Bang Chak (E10), Punnawithi (E11), Udom Suk (E12), Bang Na (E13) and Bearing (E14) station

4.4 Urinary metabolites of BT

4.4.1 General comparisons of detected BT urinary metabolites

Comparative results of urinary metabolites of BT collected after the working shift are shown in table 13. Trans,trans-Muconic acid and Hippuric Acid are urinary metabolites of Benzene and Toluene, respectively. The highest amount of trans,trans-Muconic acid detected was 12.36 mg/g creatinine, while that of Hippuric acid was at 1,842.42 mg/g creatinine. Meanwhile, the lowest amount of trans,trans-Muconic acid detected was less than LOD, while that of Hippuric acid was 51.28 mg/g creatinine. The medians of trans,trans-Muconic acid and Hippuric acid detected were noticeably different, with the former at 1.02 mg/g creatinine and the latter at 269.32 mg/g creatinine. It is also notable that the min-max range of the Hippuric acid is especially broad (1,791.14 mg/g creatinine).

Table 13 Comparisons of urinary metabolites of Benzene (trans,trans-Muconic acid) and of Toluene (Hippuric acid)
among security guards working at BTS stations (mg/g creatinine, n = 40)

Parameter	Concentration (mg/g Creatinine)	
	Urinary Metabolite of Benzene (n = 40) (trans,trans-Muconic acid)	Urinary Metabolite of Toluene (n = 40) (Hippuric acid)
Median	1.02	269.32
Standard error	0.35	55.95
Mean	1.52	368.31
Standard deviation	2.22	353.85
Mode	0.00	51.28
Min.	< LOD	51.28
Max.	12.36	1,842.42

4.4.2 Comparisons of BT urinary metabolites detected from ticketing and platform level

BT urinary metabolites detected from participants' exposure were compared between those participants working in the ticketing and platform level. The comparisons of concentration of Benzene urinary metabolite and of Toluene urinary metabolites are illustrated in table 14. From the table, the results shows that the difference between urinary metabolite of Benzene detected from the ticketing and from the platform level was not statistically significant (p-value of 0.079). Meanwhile, with a p-value of 0.007, the difference in urinary metabolite of Toluene between the two areas was considered statistically significant. In fact, the mean value found from the ticketing level (507.02 mg/g creatinine) almost doubled that of the platform, while the maximum amount detected from the former almost tripled that of the latter.

Table 14 Comparisons of urinary metabolites of Benzene (trans,trans-Muconic acid) and of Toluene (Hippuric acid) located in the ticketing and platform level among security guards working at BTS stations (mg/g creatinine, n = 40)

		Ticketing (n = 20)	**Platform (n = 20)**	**p-value**
trans,trans-Muconic acid	Median	1.26	0.62	0.079
	Standard error	0.65	0.12	
	Mean	2.29	0.76	
	Standard deviation	2.93	0.56	
	Min.	< LOD	< LOD	
	Max.	12.36	1.89	
Hippuric acid	Median	380.85	202.02	0.007*
	Standard error	96.61	38.62	
	Mean	507.02	229.60	
	Standard deviation	432.07	172.70	
	Min.	51.28	52.46	
	Max.	1,842.42	655.84	

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

* Statistic significant between ticketing and platform

4.4.3 Comparisons of BT urinary metabolites detected within inner Bangkok and outer Bangkok.

Comparisons of BT urinary metabolites detected within inner and outer Bangkok are illustrated in table 15. The results show that the difference in BT urinary metabolites within inner and outer Bangkok was not statistically significant with the p-value of 0.114 and 0.791, respectively.

Table 15 Comparisons of urinary metabolites of Benzene (trans,trans-Muconic acid) and of Toluene (Hippuric acid) located in Inner Bangkok and Outer Bangkok among security guards working at BTS Stations (in mg/g creatinine, n = 40)

		Inner Bangkok (n = 28)	**Outer Bangkok (n = 12)**	**p-value**
trans,trans-Muconic acid	Median	0.92	1.64	0.114
	Standard error	0.25	1.01	
	Mean	1.03	2.68	
	Standard deviation	1.15	3.48	
	Min.	< LOD	0.09	
	Max.	5.66	12.36	
Hippuric acid	Median	276.62	246.77	0.791
	Standard error	70.22	93.49	
	Mean	373.11	357.09	
	Standard deviation	371.55	323.86	
	Min.	51.28	52.46	
	Max.	1,842.42	1,050.00	

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

4.4.4 Comparisons of BT urinary metabolites detected from the North and the East BTS Sky-Train Line.

Table 16 illustrates the comparisons between the amount of Benzene and Toluene urinary metabolites detected from the two BTS Sky-Train lines the North Line (7 stations) and the East Line (13 station), marked as N and E, respectively, on the BTS map. With a p-value of 0.876, the results show that the difference in Benzene urinary metabolite between the two locations was not statistically significant. Meanwhile, Toluene urinary metabolite, with a p-value of 0.070, was also considered not statistically significant.

Table 16 Comparisons of urinary metabolites of Benzene (trans,trans-Muconic acid) and of Toluene (Hippuric acid) located within the North (N) and the East (E) BTS Line among security guards working at BTS stations (mg/g creatinine, n = 40)

		North Line (N) (n = 14)	East Line (E) (n = 26)	p-value
trans,trans-Muconic acid	Median	1.20	0.78	0.876
	Standard error	0.22	0.38	
	Mean	1.03	1.79	
	Standard deviation	0.82	2.67	
	Min.	< LOD	< LOD	
	Max.	3.08	12.36	
Hippuric acid	Median	330.95	221.61	0.070
	Standard error	116.70	72.29	
	Mean	476.28	310.17	
	Standard deviation	436.61	293.53	
	Min.	87.30	51.28	
	Max.	1,842.42	1,105.26	

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

4.5 Health Symptoms of Security Guards Related to BT exposure

The results, shown in percentages of the total security guards participated, illustrate the extent to which health symptoms related to BT exposure were experienced by security guards. Fatigue was the most common symptoms experienced, both while working (72.5%) and in the past three months (69.2%. Meanwhile, nausea was the least prevalent, with only 10% and 5% of the participants who had experienced it while working and in the past the three months, respectively. More comprehensive results are displayed in table 17.

Table 17 Percentages of health symptoms occurrence (n = 40)

Symptoms	While working				In the past 3 months			
	Yes		No		Yes		No	
	n	%	n	%	N	%	n	%
Cough/Sneeze	12	30.0	28	70.0	11	27.5	29	72.5
Dizziness	7	17.5	33	82.5	8	20.0	32	80.0
Drowsiness	6	15.0	34	85.0	5	12.5	35	87.5
Eyes Irritation	16	40.0	24	60.0	16	41.0	23	59.0
Fatigue	29	72.5	11	27.5	27	69.2	12	30.8
Headache	14	35.0	26	65.0	15	38.5	24	61.5
Nausea	4	10.0	36	90.0	2	5.1	37	94.9
Nose Irritation	10	25.0	30	75.0	11	28.2	28	71.8
Sore Throat	9	22.5	31	77.5	7	18.4	31	81.6
Skin Irritation	12	30.0	28	70.0	10	25.6	29	74.4
Throat Irritation	9	23.1	30	76.9	9	23.1	30	76.9

4.6 Correlations between BT concentrations and urinary metabolites

Spearman's correlation, a non-parametric statistical tool, was used to find the possible correlations between BT concentrations and urinary metabolites concentrations. From the table, Benzene concentration had no relation with its urinary metabolite concentration (t,t-Muconic acid) in positive direction and magnitude (r_s) at 0.180 that means little if any correlation. The result may be concluded that Benzene concentrations and trans, trans-Muconic acid concentrations has weak direct correlation while the p-value of 0.295 shows that such correlation was not statistically significant. Meanwhile, Toluene concentration and its urinary metabolite concentration (Hippuric acid) have negative direction and have magnitude (-0.084 of r_s) in little if any correlation which magnitude values between 0.00 – 0.30. It might be concluded that Toluene concentrations and Hippuric acid concentrations has very weak inverse correlation while the p-value of 0.625 illustrates that such correlation was not statistically significant (Table 18).

Table 18 Correlations between BT and their urinary concentrations

Correlations	r_S	p-value
Benzene & trans,trans-Muconic acid	0.180	0.295
Toluene & Hippuric acid	-0.084	0.625

* Spearman's correlation was used to test, significant level at 0.05

4.7 Association between BT concentrations and health symptoms

To find association between BT concentration and health symptoms, Fisher's exact test was used. Using median concentration as a benchmark, Benzene and Toluene concentration can be classified into two levels: low and high. Concentration ranging from minimum to median value is classified as "low level" while concentration ranging from median to maximum value is classified as "high". Health symptoms included 11 symptoms: cough/sneeze, dizziness, drowsiness, eyes irritation, fatigue, headache, nausea, nose irritation, sore throat, skin irritation and throat irritation.

4.7.1 Association between Benzene concentration and health symptoms

The table 19 shows associations between Benzene concentration and health symptoms, given in percentages and p-value. The results shows that Benzene concentration is only associated in a statistically significant manner with fatigue within the past three months (p-value of 0.038). It might be concluded that the concentration of benzene at low levels can cause fatigue in up to 77.4% of the subjects exposed to Benzene at this level. Meanwhile, exposure to benzene at high concentrations may not cause fatigue in up to 66.7% of the cases. For the other 10 symptoms, there were no statistically significant results ($p < 0.05$)

Table 19 Association between Benzene concentration and health symptoms in the currently time and in the past three months (n of participants = 40)

	Benzene Concentration		p-value
	Low n (%)	High n (%)	
Cough/Sneeze			
While working			
Yes	11 (91.7)	1 (8.3)	1.000
No	24 (85.7)	4 (14.3)	
In the past 3 months			
Yes	10 (90.0)	1 (9.1)	1.000
No	25 (86.2)	4 (13.8)	
Dizziness			
While working			
Yes	7 (100.0)	0	0.565
No	28 (84.9)	5 (15.2)	
In the past 3 months			
Yes	7 (87.5)	1 (12.5)	1.000
No	28 (87.5)	4 (12.5)	
Drowsiness			
While working			
Yes	6 (100.0)	0	1.000
No	29 (85.3)	5 (14.7)	
In the past 3 months			
Yes	5 (100.0)	1 (11.1)	1.000
No	30 (85.7)	5 (14.3)	
Eyes Irritation			
While working			
Yes	15 (93.8)	1 (6.2)	0.272
No	20 (83.3)	4 (16.7)	
In the past 3 months			
Yes	14 (87.5)	2 (12.5)	1.000
No	21 (87.5)	3 (12.5)	
Fatigue			
While working			
Yes	27 (93.1)	2 (6.9)	0.083
No	8 (72.7)	3 (27.3)	
In the past 3 months			
Yes	26 (92.9)	2 (7.1)	0.038*
No	9 (75.0)	3 (25.0)	
Headache			

	Benzene Concentration		p-value
	Low n (%)	High n (%)	
While working			
Yes	13 (92.9)	1 (7.1)	0.124
No	22 (84.6)	4 (15.4)	
In the past 3 months			
Yes	15 (93.8)	1 (6.2)	0.117
No	20 (83.3)	4 (16.7)	
Nausea			
While working			
Yes	4 (100.0)	0	1.000
No	31 (86.1)	5 (13.9)	
In the past 3 months			
Yes	2 (100.0)	0	1.000
No	33 (86.8)	5 (13.2)	
Nose Irritation			
While working			
Yes	10 (100.0)	0	0.404
No	25 (83.3)	5 (16.7)	
In the past 3 months			
Yes	11 (100)	0	0.399
No	24 (82.2)	5 (17.2)	
Sore Throat			
While working			
Yes	9 (100.0)	0	0.654
No	26 (83.9)	5 (16.1)	
In the past 3 months			
Yes	7 (100.0)	0	0.175
No	28 (84.8)	5 (15.2)	
Skin Irritation			
While working			
Yes	11 (91.7)	1 (8.3)	0.697
No	24 (85.7)	4 (14.3)	
In the past 3 months			
Yes	9 (90.0)	1 (10.0)	0.404
No	26 (86.7)	4 (13.3)	
Throat Irritation			
While working			
Yes	9 (90.0)	1 (10.0)	0.654
No	26 (86.7)	4 (13.3)	
In the past 3 months			
Yes	8 (88.9)	1 (11.1)	0.654
No	23 (87.1)	4 (12.9)	

For test association, Fisher' exact test was used, the significant level was set at 0.05

* There was association between Benzene concentration and fatigue occurring in the past 3 months.

4.7.2 Association between Toluene concentration and health symptoms

Associations between the concentration of Toluene and health symptoms are illustrated in table 20. The results shows that Toluene concentration and all the 11 symptoms were not significantly associated (p-value > 0.05) at both low and high level. Therefore, it may be concluded that there was no association between Toluene concentration and all symptoms.

Table 20 Association between Toluene concentration and health symptoms in the currently time and in the past three months (n of participants = 40)

	Toluene Concentration		**p-value**
	Low n (%)	**High n (%)**	
Cough/Sneeze			
While working			
Yes	5 (41.7)	7 (58.3)	1.000
No	17 (60.7)	11 (39.3)	
In the past 3 months			
Yes	5 (45.5)	6 (54.5)	1.000
No	17 (58.6)	12 (41.4)	
Dizziness			
While working			
Yes	1 (14.3)	6 (85.7)	0.567
No	21 (63.6)	12 (36.4)	
In the past 3 months			
Yes	1 (12.5)	7 (87.5)	1.000
No	21 (65.6)	11 (34.4)	
Drowsiness			
While working			
Yes	3 (50.0)	3 (50.0)	1.000
No	19 (55.9)	15 (44.1)	
In the past 3 months			
Yes	2 (40.0)	3 (60.0)	1.000
No	20 (57.1)	15 (42.9)	
Eyes Irritation			
While working			
Yes	8 (50.0)	8 (50.0)	1.000
No	14 (58.3)	10 (41.7)	
In the past 3 months			
Yes	7 (43.8)	9 (56.2)	1.000
No	15 (62.5)	9 (37.5)	
Fatigue			
While working			
Yes	15 (51.7)	14 (48.3)	0.162
No	7 (63.6)	4 (36.4)	
In the past 3 months			
Yes	13 (46.4)	15 (53.6)	0.643
No	9 (75.0)	3 (25.0)	

	Toluene Concentration		p-value
	Low n (%)	High n (%)	
Headache			
While working			
Yes	6 (42.9)	8 (57.1)	1.000
No	16 (61.5)	10 (38.5)	
In the past 3 months			
Yes	6 (37.5)	10 (62.5)	0.654
No	16 (66.7)	8 (33.3)	
Nausea			
While working			
Yes	3 (75.0)	1 (25.0)	0.493
No	19 (52.8)	17 (47.2)	
In the past 3 months			
Yes	1 (50.0)	1 (50.0)	0.281
No	21 (55.3)	17 (44.7)	
Nose Irritation			
While working			
Yes	5 (50.0)	5 (50.0)	1.000
No	17 (56.7)	13 (43.3)	
In the past 3 months			
Yes	5 (45.5)	6 (54.5)	1.000
No	17 (58.6)	12 (41.4)	
Sore Throat			
While working			
Yes	5 (55.6)	4 (44.4)	1.000
No	17 (54.8)	14 (45.2)	
In the past 3 months			
Yes	3 (42.9)	4 (57.1)	1.000
No	19 (57.6)	14 (42.4)	
Skin Irritation			
While working			
Yes	6 (50.0)	6 (50.0)	0.648
No	16 (57.1)	12 (42.9)	
In the past 3 months			
Yes	3 (70.0)	7 (70.0)	0.307
No	19 (63.3)	11 (36.7)	
Throat Irritation			
While working			
Yes	5 (50.0)	5 (50.0)	0.115
No	3 (50.0)	28 (82.4)	
In the past 3 months			
Yes	3 (50.0)	6 (17.6)	0.115
No	17 (56.7)	13 (43.3)	

*For test association, Fisher' exact test was used

4.8 Association between BT urinary metabolites and health symptoms

Fisher's exact test was used to find association between urinary metabolites concentration and health symptoms. Using median concentration obtained from collected data as a benchmark, urinary metabolite concentration of Benzene and of Toluene can be classified into two levels: low and high. Concentration ranging from minimum to median value is classified as "low" while concentration ranging from median to maximum value is classified as "high". The health symptoms, include the 11 symptoms mentioned earlier in section 4.7. The results are shown in table 21 and table 22.

4.8.1 Association between Benzene Urinary Metabolite (trans, trans-Muconic acid) and health symptoms

The table 21 illustrates associations between trans, trans Muconic acid concentration and health symptoms, given in percentages and p-value. The results show that trans, trans-Muconic acid concentration is associated in a statistically significant manner with eyes irritation (p-value of 0.010), fatigue (p-value of 0.041), headache (p-value of 0.048), and throat irritations (p-value of 0.020) within the past three months. Firstly, 63.2% of the participants exposed to this "low" concentration of trans, trans Muconic acid are believed to have experienced eyes irritation within the past three months. At the same time, exposure to high concentration level influence the occurrence of eyes irritation in 80% of the subjects exposed to that concentration level. Secondly, 85% of those exposed to trans, trans Muconic acid at low concentrations appeared to experience fatigue. Meanwhile, there was a 50-50 split between those who had and had not experienced fatigue after being exposed to this urinary metabolite at high concentration. Exposure to trans, trans Muconic acid at high concentrations, however, did not appear to affect the incidence of headache in 80% of the cases, while exposure at low concentrations seemed to influence the occurrence of headache in 55% of the cases. Additionally, throat irritation also occurred among 40% of those exposed to low concentrations but only 5% among those exposed to high concentrations.

Table 21 Association between trans, trans Muconic acid and health symptoms in the currently time and in the past three months (n of participants = 40)

	t,t-Muconic acid concentration		
	Low n (%)	**High n (%)**	**p-value**
Cough/Sneeze			
While working			
Yes	7 (58.3)	5 (41.7)	0.301
No	13 (46.4)	15 (53.6)	
In the past 3 months			
Yes	7 (63.6)	4 (36.4)	0.155
No	13 (44.8)	16 (55.2)	
Dizziness			
While working			
Yes	2 (28.6)	5 (71.4)	1.000
No	18 (54.5)	15 (45.5)	
In the past 3 months			
Yes	16 (50.0)	16 (50.0)	0.695
No	20 (50.0)	20 (50.0)	
Drowsiness			
While working			
Yes	5 (83.3)	1 (16.7)	0.182
No	15 (44.1)	19 (55.9)	
In the past 3 months			
Yes	4 (80.0)	1 (20.0)	0.342
No	16 (45.7)	19 (54.3)	
Eyes Irritation			
While working			
Yes	10 (62.5)	6 (37.5)	0.105
No	10 (41.7)	14 (58.3)	
In the past 3 months			
Yes	11 (68.8)	5 (31.2)	0.010*
No	9 (37.5)	15 (62.5)	
Fatigue			
While working			
Yes	16 (55.2)	12 (60.0)	0.155
No	4 (36.4)	7 (63.6)	
In the past 3 months			
Yes	17 (60.7)	11 (39.3)	0.041*
No	3 (25.0)	9 (75.0)	
Headache			
While working			
Yes	7 (50.0)	7 (50.0)	0.741
No	13 (50.0)	13 (50.0)	

	t,t-Muconic acid concentration		p-value
	Low n (%)	High n (%)	
In the past 3 months			
Yes	11 (68.8)	5 (31.2)	0.048*
No	9 (37.5)	15 (62.5)	
Nausea			
While working			
Yes	2 (50.0)	2 (50.0)	1.000
No	18 (50.0)	18 (50.0)	
In the past 3 months			
Yes	19 (50.0)	19 (50.0)	1.000
No	20 (50.0)	20 (50.0)	
Nose Irritation			
While working			
Yes	6 (60.0)	4 (40.0)	0.273
No	14 (46.7)	16 (53.3)	
In the past 3 months			
Yes	7 (63.6)	4 (36.4)	0.155
No	13 (44.8)	16 (55.2)	
Sore Throat			
While working			
Yes	6 (66.7)	3 (33.3)	0.127
No	14 (45.2)	17 (54.8)	
In the past 3 months			
Yes	5 (71.4)	2 (28.6)	0.091
No	15 (45.5)	18 (54.5)	
Skin Irritation			
While working			
Yes	6 (50.0)	6 (50.0)	0.731
No	14 (50.0)	14 (50.0)	
In the past 3 months			
Yes	6 (60.0)	4 (40.0)	0.273
No	14 (46.7)	16 (53.3)	
Throat Irritation			
While working			
Yes	7 (70.0)	3 (30.0)	0.127
No	13 (43.3)	17 (56.7)	
In the past 3 months			
Yes	7 (77.8)	2 (22.2)	0.020*
No	13 (41.9)	18 (58.1)	

Test of association by using Fisher' exact test, statistic significant was set at 0.05

*There was association between trans,trans Muconic acid and eyes irritation, fatigue, headache, and throat irritation in the past 3 months.

4.8.2 Association between Hippuric acid and health symptoms

Associations between Hippuric acid concentration and health symptoms, given in percentages and p-value are displayed in table below (Table 22). Hippuric acid concentration is only associated in a statistically significant manner with the symptom of drowsiness shown both during work (p-value of 0.020) and within the past three months (p-value of 0.047). Among those exposed to low concentrations, 30% experienced drowsiness during work hours whereas 25% experienced the same symptom within the past three months. For other symptoms, there were no statistically significant results for both low and high concentration level ($p > 0.05$).

Table 22 Association between Hippuric acid and health symptoms in the currently time and in the past three months (n of participants = 40)

	Hippuric acid concentration		**p-value**
	Low n (%)	**High n (%)**	
Cough/Sneeze			
While working			
Yes	7 (58.3)	5 (41.7)	0.731
No	13 (46.4)	15 (53.6)	
In the past 3 months			
Yes	7 (63.6)	4 (36.4)	0.480
No	13 (44.8)	16 (55.2)	
Dizziness			
While working			
Yes	3 (42.9)	4 (57.1)	1.000
No	17 (51.5)	16 (48.5)	
In the past 3 months			
Yes	4 (50.0)	4 (50.0)	1.000
No	16 (50.0)	16 (50.0)	
Drowsiness			
While working			
Yes	6 (100.0)	0	0.020*
No	14 (41.2)	20 (58.8)	
In the past 3 months			
Yes	5 (100.0)	0	0.047*
No	15 (42.9)	20 (57.1)	
Eyes Irritation			
While working			
Yes	6 (37.5)	10 (62.5)	0.333
No	14 (58.3)	10 (41.7)	
In the past 3 months			
Yes	6 (37.5)	10 (62.5)	0.333
No	14 (58.3)	10 (41.7)	

	Hippuric acid concentration		p-value
	Low n (%)	**High n (%)**	
Fatigue			
While working			
Yes	14 (48.3)	15 (51.7)	1.000
No	6 (54.5)	5 (45.5)	
In the past 3 months			
Yes	13 (46.4)	15 (53.6)	1.000
No	7 (58.3)	5 (41.7)	
Headache			
While working			
Yes	6 (42.9)	8 (57.1)	0.741
No	14 (53.8)	12 (46.2)	
In the past 3 months			
Yes	7 (43.8)	9 (56.2)	1.000
No	13 (54.2)	11 (45.8)	
Nausea			
While working			
Yes	1 (25.0)	3 (75.0)	0.605
No	19 (52.8)	17 (47.2)	
In the past 3 months			
Yes	0	2 (100.0)	0.487
No	20 (52.6)	18 (47.4)	
Nose Irritation			
While working			
Yes	5 (50.0)	5 (50.0)	1.000
No	15 (50.0)	15 (50.0)	
In the past 3 months			
Yes	5 (45.5)	6 (54.5)	1.000
No	15 (51.7)	14 (48.3)	
Sore Throat			
While working			
Yes	3 (33.3)	6 (66.7)	0.451
No	17 (54.8)	14 (45.2)	
In the past 3 months			
Yes	3 (42.9)	4 (57.1)	1.000
No	17 (51.5)	16 (48.5)	
Skin Irritation			
While working			
Yes	7 (58.3)	5 (41.7)	0.731
No	13 (46.4)	15 (53.6)	
In the past 3 months			
Yes	5 (50.0)	5 (50.0)	1.000
No	15 (50.0)	15 (50.0)	

	Hippuric Acid Concentration		p-value
	Low n (%)	**High n (%)**	
Throat Irritation			
While working			
Yes	7 (70.0)	3 (30.0)	0.451
No	13 (43.3)	17 (56.7)	
In the past 3 months			
Yes	5 (55.6)	4 (44.4)	1.000
No	15 (48.4)	16 (51.6)	

*There was association between Hippuric acid and drowsiness both while working and in the past 3 months.

4.9 Association between BT exposure and health symptoms

According to the study about the association between environmental factors, personal information, and health symptoms that occurred with exposure to Benzene, Toluene and their urinary metabolites were not similar such above. However, since the results from Fisher's exact test were not clear enough to determine the relationship between the factors so as to find associations between risk factors and health symptoms occurrence, logistic regression test was used. Such logistic regression analysis, personal information and environmental factors (gender, age, BMI, smoking behavior, second hand smoke, house location, and mask usage) were employed for the analysis to adjust for the confounding factors that could interfere with the results. Logistic regression analysis displays associations between Benzene exposure and one of those symptoms. Benzene exposure is associated with fatigue in a statistically significant manner (p-value of 0.032; OR = 21.166; 95% CI, 1.297 – 345.494) (Table 23). On the other hand, the analysis did not find that increasing amount of Toluene exposure influence those health symptoms in a statistically significant manner (p-value > 0.05) (Table 24).

Table 23 Adjusted ORs for association Benzene exposure and health symptoms
(Adjusted for gender, age, BMI, smoking behavior, second hand smoke, house location, mask usage, working area, working experiences, job rotating and duration of work)

	Adjusted ORs	95% CI		p-value
		Lower	Upper	
Benzene				
Cough/Sneeze	47.951	0.755	3.046×10^{3}	0.068
Drowsiness	1.636	0.002	1.284×10^{3}	0.885
Eyes Irritation	1.704	0.215	13.496	0.614
Fatigue	21.166	1.297	345.494	0.032*
Headache	6.140	0.414	91.030	0.187
Nose Irritation	4.470	0.163	122.824	0.376
Sore Throat	4.630	0.280	76.445	0.284
Skin Irritation	1.854	0.162	21.191	0.619
Throat Irritation	6.681	0.106	420.337	0.369

*Statistic significantly ($p < 0.05$)

Table 24 Adjusted ORs for association Toluene exposure and health symptoms
(Adjusted for gender, age, BMI, smoking behavior, second hand smoke, house location, mask usage, working area, working experiences, job rotating and duration of work)

	Adjusted ORs	95%CI		p-value
		Lower	Upper	
Toluene				
Cough/Sneeze	0.782	0.024	25.797	0.891
Eyes Irritation	2.628	0.086	80.728	0.580
Headache	2.040	0.128	32.650	0.614
Nose Irritation	0.376	0.013	10.836	0.569
Sore Throat	0.058	0.001	6.103	0.231
Skin Irritation	0.712	0.030	17.044	0.834

*Statistic significantly ($p < 0.05$)

4.10 Association between BT urinary metabolites and health symptoms

Apart from Fisher' exact test was used to find relationship between BT urinary metabolites and health symptoms. Logistic regression method was also used to determine risk factors that may affect the health symptoms. The essential facts were loaded into the method for analysis, as BT exposure association. The analysis results illustrate t,t-Muconic acid, urinary metabolite of Benzene, associated statistical significantly with cough/sneeze cough/sneeze (p-value of 0.035; OR = 45.826, 95% CI, 1.303 – 1.611×10^{3}), eyes irritation (p-value of 0.034; OR = 23.662, 95% CI, 1.273 - 439.664) and sore throat (p-value of 0.041; OR = 130.638, 95%

CI, 1.219 - 1.400 × 10^4). In contrast, Hippuric acid was not associated with any health symptoms (p-value > 0.05). The result were displayed in the table 25 and table 26.

Table 25 Adjusted ORs for association Benzene urinary metabolite exposure (trans,trans-Muconic acid) and health symptoms
(Adjusted for gender, age, BMI, smoking behavior, second hand smoke, house location, mask usage, working area, working experiences, job rotating and duration of work)

	Adjusted ORs	95% CI		p-value
		Lower	Upper	
trans,trans-Muconic acid				
Cough/Sneeze	45.826	1.303	1.611×10^3	0.035*
Dizziness	1.818	0.084	39.402	0.703
Drowsiness	21.732	0.660	715.973	0.084
Eyes Irritation	23.662	1.273	439.664	0.034*
Fatigue	17.711	0.876	357.943	0.061
Headache	11.836	0.601	233.117	0.104
Nausea	4.118	0.160	105.785	0.393
Nose Irritation	225.285	0.543	9.349E4	0.078
Sore Throat	130.638	1.219	1.400×10^4	0.041*
Skin Irritation	4.856	0.490	48.108	0.177
Throat Irritation	20.809	0.619	699.556	0.091

*Statistic significantly ($p < 0.05$)

Table 26 Adjusted ORs for association Toluene urinary metabolite exposure (Hippuric Acid) and health symptoms
(Adjusted for gender, age, BMI, smoking behavior, second hand smoke, house location, mask usage, working area, working experiences, job rotating and duration of work)

Hippuric acid				
Cough/Sneeze	3.302	0.228	47.932	0.381
Dizziness	0.128	0.002	8.046	0.331
Eyes Irritation	0.414	0.072	2.393	0.325
Fatigue	0.367	0.044	3.032	0.352
Headache	0.286	0.035	2.320	0.241
Nose Irritation	0.384	0.031	4.743	0.455
Sore Throat	0.406	0.050	3.285	0.398
Skin Irritation	1.586	0.277	9.081	0.604
Throat Irritation	0.406	0.014	11.430	0.596

*Statistic significantly ($p < 0.05$)

CHAPTER V
DISCUSSIONS

5.1 General Information

All security guards who are responsible for the security and convenience of passengers at the sky train stations were the participants in this study. Most of the security guards are male. The results show that sky train security guards had an average age of 37 years old and an average age range of 40 or above, which is comparatively higher than the average working age range of Thais (25 to 59 years), according to defined by the National Bureau of Statistics, 2012. The average Body Mass Index (BMI) of sky train security guards was 18.50 – 24.99, which can be considered under a normal range.

One factor that may interfere with BT exposure is smoking behavior. According to the data from the study, 20% of the participants are smokers; of that figure, the average number of cigarettes smoked was 5.25 (±2.50) per day. Meanwhile, 37.5% of the participants are second-hand smokers. 25% of the sky train security guards stated that their houses are located near sources of air pollution: 20% reside near major roads and 2.5% near garages that provide vehicle maintenance service. Additionally, the data also show that BTS sky-train is the most popular means that the participants (28.2%) used to commute to work, while another popular way is to commute on foot (25.6%). Those commuting by buses with air conditioning (Bus with AC) and without air conditioning (Bus without AC) constitute 20.5% and 10.3%, respectively. Meanwhile, commuting by motorcycle and other ways is the least popular option used only by 7.7% of the participants. Most of the sky train security guards (85%) worked 7 days per week for 12 hours per day with an average day offs at 24.9 (±13.6) per year. Half of them stationed on the platform level and the other half on the ticketing level; 77.5% of participants in fact has never rotated jobs between ticketing and platform level. In addition, the data shows that their average working years is 1.2 (± 0.57) and that the majority (41.1%) has working experience in the range of 1 – 5 years. When questioned on the potential reasons for using masks, 64% cited pollution protection while 4% and 28% cited influenza protection and sickness, respectively. Only 4% would do so to follow regulations. In actual fact, 47.5% of the security guards never used any forms of Personal Protective Equipment during their working shifts.

5.2 BT concentration in air samples

The study found that the concentration of benzene and toluene does not follow the normal distribution curve, and thus presented them on the basis of median concentration.

According to the results, BT concentrations were lower than Time Weight Average (TWA) defined by OSHA (2010) and NIOSH (2012). Additionally, the average concentrations were also lower than permissible exposure limits specified by Thailand Labor Law (Ministry of Interior, 1977).

Table 27 Comparisons between Benzene and Toluene concentrations and their occupational exposure limits

Chemical	Average detected Concentration exposure (µg/m^3)	OSHA; TWA (µg/m^3)	NIOSH; TWA (µg/m^3)	Thailand Labor Law (µg/m^3)
Benzene	0.21 ± 4.08 (6.56 × 10^{-5} ppm)	1,597 (0.5 ppm)	320 (0.1 ppm)	31,947 (10 ppm)
Toluene	242.40 ± 17.11 (0.076 ppm)	753,700 (200 ppm)	3.75 × 10^5 (100 ppm)	753,700 (200 ppm)

The study also found that the concentration of Benzene and Toluene were lower than those found in previous studies. The average concentration of benzene was similar to the findings discovered by Borgie through studying traffic policemen in Lebanon, in which an average Benzene concentration was at 0.3 µg/m^3 (Borgie et al., 2014). Meanwhile, in a study targeted at passengers commuted by sky-train by Ongwandee, average Benzene concentration was found to be as high as 2 µg/m^3, which can be considered inconsistent with this study (Ongwandee and Chavalparit, 2010). Benzene concentration in air samples of this study was inconsistent with those of other related studies, most of which show much higher concentration.

In terms of Toluene concentration, what we found is that the high concentration at 242.40 µg/m^3 is in conflict with the study of Ongwandee, which found only 36.9 µg/m^3 of Toluene concentration and that of Loonsamrong's study studied in parking workers at 53.97 µg/m^3 (Wasssana Loonsamrong et al., 2013). Hence, smokers can be exposed to amounts of toluene in cigarette smoke. Therefore, the reason of higher concentration of Toluene was probably due to smoking behavior of participants and second hand smokers. Still, the Toluene concentration of this study is similar to the 101.8 µg/m^3 concentration presented in Borgie's study. However, on the contrary, most studies found that Toluene concentration was lower. Figures of BT concentrations from other related research are displayed in the table below (Table 28).

Table 28 BT concentrations from related research.

Location	Study population/ study area	Average Benzene ($\mu g/m^3$)	Average Toluene ($\mu g/m^3$)	Reference
Beirut, Lebanon	Traffic policemen, Office policemen	0.3, 0.3	101.8, 9.3	Borgie et al. ,2014
Kolkata, India	Passenger cars	445.4	627.9	D. Som et al., 2007
Bangkok, Thailand	Parking workers	11.28	56.129	Loonsamrong, 2013
Bangkok, Thailand	Commuter on sky train	2.0	36.9	Ongwandee et al., 2010
Bangkok, Thailand	Toll-way station workers	99.29	146.06	Ruangtrakul et al., 2008
HoChiMinh, Vietnam	Roadside in urban areas	56.0	121.0	Tran Thi Ngoc et al., 2013
Central-northern, Italy	Traffic police workers, parking wardens / roadside	21.1, 91.1	13.5, 72.1	Violante et al., 2006

Moreover, this study also compared BT concentration under three different sub-criteria, according to the location of BT exposure: (1) ticketing v. platform level within the BTS sky train station (2) inner v. outer Bangkok (3) North v. East BTS sky train line. The non-parametric, Mann-Whitney U test, was used to test the difference.

First of all, BT concentrations were compared between the two locations where security guards are stationed at: the ticketing level and the platform level. The results show that the median concentration of Benzene detected in both ticketing and platform level was exactly the same at 0.21 ($\mu g/m^3$), a figure that is very close to the lowest Benzene concentration detected. The p-value of 0.188 also indicates that the difference in concentration between the two levels is not statistically significant. Meanwhile, the highest Benzene concentrations in the vicinity of the ticketing and platform level were widely different—the former at 136.98 and the latter at 37.50 $\mu g/m^3$. In terms of Toluene concentration, the maximum figure detected in the ticketing and the platform guards were 354.17 and 298.13 $\mu g/m^3$, respectively, while the minimum figure for both was 0.07 $\mu g/m^3$. The average concentration of Toluene was 247.03 $\mu g/m^3$ at the ticketing level and 238.60 $\mu g/m^3$ at the platform level. Supported by the p-value of 0.350, the difference in Toluene concentration may then be considered as not statistically significant between ticketing and platform level.

Secondly, since, the PCD found two measuring point of Benzene concentration above the standard (Pollution Control Department, Ministry of Natural Resources and Environment, 2013) at Din Daeng District (inner Bangkok) and Chokchai 4 (outer Bangkok). Consequently, BT concentrations between the 14 stations of inner Bangkok and the 6 stations of outer Bangkok were compared, the maximum concentration of Benzene of inner and outer Bangkok were 136.98 and 32.50 $\mu g/m^3$, respectively. Meanwhile, approximately 0.21 $\mu g/m^3$ was both the minimum and the average concentration of Benzene for both inner and outer Bangkok. This average concentration of 0.21 $\mu g/m^3$ is higher than the study of Tunsaringkarn et al (2012) in both inner (92.75±16.77 ppb) and outer Bangkok (137.53±57.89 ppb). There was no statistically significant difference in Benzene concentration between inner and outer Bangkok (p-value 0.549). Similarly, there also was no difference in Toluene concentration between inner and outer Bangkok (p-value of 0.549). It was found that 354.17 and 334.90 $\mu g/m^3$ were the maximum Toluene concentration of inner and outer Bangkok while the minimum concentration was 0.07 $\mu g/m^3$ for both regions. The average concentration of Toluene of both inner and outer Bangkok was higher than those figures found in the study targeted at gasoline station workers, at 242.29 and 250 $\mu g/m^3$ for inner and outer Bangkok, respectively (T Tunsaringkarn, W Siriwong, A Rungsiyothin, and S Nopparabundit, 2012). Additionally, at p-value of 0.558, the difference in Toluene concentration was not considered statistically significant between inner and outer Bangkok.

Finally, for comparisons of BT Concentration between North (N) and East (E) BTS Sky-Train Line, the results illustrate no statistically significant difference in both Benzene and Toluene concentration between the 7 stations of North BTS Sky-Train Line and the 13 stations of East BTS Sky-Train Line (p-value 0.435 and 0.053, respectively). The highest concentration of Benzene detected in the N-Line and the E- Line were 20.63 and 136.98 $\mu g/m^3$, respectively, while those of Toluene were 286.04 and 354.17 $\mu g/m^3$, respectively. Meanwhile, 0.21 $\mu g/m^3$ was both the lowest and the median concentration of Benzene detected in the N-Line and the E- Line. On the other hand, the lowest concentration of Toluene in both inner and outer Bangkok was 0.07 $\mu g/m^3$, while its median concentration was 224.01 $\mu g/m^3$ for the N-Line and 253.13 $\mu g/m^3$ for the E-Line.

5.3 BT urinary metabolites in urine samples

According to the results, the average concentration of Benzene urinary metabolites (1.02 mg /g Cr of t,t-Muconic acid) was higher than the ACGIH BEIs (Biological Exposure Indices). Meanwhile, trans,trans Muconic acid, urinary metabolite of Toluene, was not exceeded the BEIs of ACGIH (269.32 mg/g Cr). BEIs of trans,trans-Muconic acid is defined at 500µg /g Cr and BEIs of Hippuric acid is defined at 1.6 g/g Cr (American Conference of Government Industrial Hygienists, 2005). Increasing of urinary metabolites concentration might result from the usage of mask because most of participant did not use the mask to protect pollution in working time. The transportation that how participants went to work may be another reason that influence such increasing. The comparisons between BT urinary metabolite concentration and BEIs were shown in table 29.

Table 29 Comparisons between Benzene and Toluene urinary metabolites concentrations and their occupational exposure limits

Chemical	Average detected Concentration exposure (mg/g Creatinine)	ACGIH; BEIs
trans, trans Muconic acid (urinary metabolite of Benzene)	1.02 ± 0.35 (1.02×10^3 µg/g Cr)	0.5 mg/g Cr (500 µg/g Cr)
Hippuric acid (urinary metabolite of Toluene)	269.32 ± 55.95 (269×10^3 g/g Cr)	1,600 mg/g Cr (1.6 g/g Cr)

In addition, the average concentration of t,t-Muconic at 960 µg/g Cratinine was higher than the figure of 84.4 µg/g Cr found in traffic policeman and indoor policeman in Lebanon (Borgie et al., 2014). Moreover, both t,t-Muconic and Hippuric acid (26.9×10^4 g /g Cr) concentrations were much higher than those figures found in parking workers in Thailand (Wasssana Loonsamrong et al., 2013).

In terms of comparisons of BT urinary metabolites among security guards working at either the ticketing or the platform level, there was no statistically significant difference in the median level of Hippuric acid (p-value of 0.007) and of the t,t-Muconic acid between the two levels (p-value > 0.05). For comparisons between inner and outer Bangkok, as well as between the N-Line and the E-Line, the differences were also not statistically significant.

To find correlations between BT concentration and their urinary metabolites, Spearman's correlation was used. BT concentrations display little or no correlations with their urinary metabolites, corresponding with a previous study (Borgie et al., 2014; Wassana

Loonsamrong et al., 2013). From the study of Borgie et al, it is suggested that the possible reason for the lack of correlation between BT concentrations and their urinary metabolite might be due to the fact that certain data of t,t-Muconic acid concentration was recorded at less than LOD (< 0.5). Meanwhile, some research found t,t-Muconic acid to be best associated with Benzene exposure (r_s = 0.87, p-value < 0.01) and suggested that t,t-Muconic acid may have a promising role in the biological monitoring of benzene for both environmental and occupational exposure (Ong et al., 1995). On the other hand, WILCZOK (Wilczok and Bieniek, 1978) found that Hippuric acid exposure and the average concentration of toluene were correlated. This conclusion is inconsistent with our results; however, the possible reasons may be based on personal exposure, personal factors and other interfering factors (Veulemas and Masschelein, 1979; Panev, Popov, Georgieva, and Chohadjieva, 2002). Most research related found good or strong correlation with BT concentration and their urinary metabolites in high risk workers who smoke cigarettes too much or work near pollution sources, for example, gasoline workers and urban policemen (Jamsai Suwansaksri and Viroj Wiwanitkit, 2000).

5.4 BT concentration and health symptoms

Fisher's exact test was used to find association between BT concentration and health symptoms and also find BT urinary metabolites and health symptoms association while working and within the past three months.

The most of Benzene and Toluene concentration exposure and health symptoms association was not associated (p-value > 0.05). However, there was only one pair that associated between Benzene concentration exposure and fatigue within the past three months at p-value of 0.038 due to fatigue had the highest percentage of health symptoms occurrence. On the other hand, the result from logistic regression analysis shows Benzene exposure only associated with fatigue, statistic significantly, at p-value of 0.032 (OR = 21.166; 95% CI, 1.297 – 345.494). There was not consist with study of Loonsamrong et al (2013) studied in parking workers, and study of Tunsaringkarn et al (2014) studied in street venders which reported fatigue was not associated with Benzene and Toluene exposure. However, Tunsaringkarn et al (2012), studied in gasoline station workers, found that Benzene and Toluene exposure was significantly associated with fatigue (p-value < 0.05). On the other hand, the analysis did not find that the increasing Toluene exposure affects to those health symptoms (p-value > 0.05). It might be due to other risk factors that influenced to possibility of health symptoms occurrence. However, the health symptoms were questioned by questionnaires might cause a bias from the responses. Hence, the health symptoms may occur from a variety of causes not only occur from Volatile Organic Compounds exposure.

5.5 Urinary metabolites of BT and health symptoms

In terms of association between t,t-Muconic acid and health symptoms, the result was found that there was statistically significant (p-value < 0.05) association between trans, trans Muconic acid and eyes irritation (p-value of 0.010), fatigue (p-value of 0.041), headache (p-value of 0.048), and throat irritation (p-value of 0.020) in the past 3 months since the three symptoms were the top three of health symptoms occurrence from response of participants.

For association of Hippuric acid and health symptoms, the result was found concentration of Hippuric acid was only associated statistically significant with Drowsiness within working (0.020 of p-value) and the past 3 months (0.047 of p-value). In contrast, the analysis results from logistic regression illustrate t,t-Muconic acid, urinary metabolite of Benzene, was associated statistical significantly (p-value of 0.035) with cough/sneeze (OR = 45.826, 95% CI, 1.303 – 1.611×10^3) ,eyes irritation, (p-value of 0.034; OR = 23.662, 95% CI, 1.273 - 439.664) and associated statistically significant (p-value of 0.041) with sore throat (OR = 130.638, 95% CI, 1.219 - 1.400×10^4). On contrary, Hippuric acid was not associated with any health symptoms (p-value > 0.05) which since there was other risk factors that affect to likelihood of health symptoms occurrence. The relativity between concentration of urinary metabolites and health symptoms may be depend on other factors, for example, personal habits, alcohol consumption, living places and distance from pollution sources (Siqueira and Paiva, 2002). However, there is few knowledge about association between exposure of BT urinary metabolites and health symptoms.

CHAPTER VI
CONCLUSION

6.1 Conclusion

Concentration of Benzene in median was lower than former studies whilst median concentration of Toluene was higher than previous studies. In the fact that, concentration of Benzene and Toluene might depend on the height of the sky-train station, about 12 meters from ground and air ventilation in that area as well as personal exposure. Although the concentration of Benzene and Toluene were much deference than previous studies, the concentration of the Benzene and Toluene had not been exceeded the permissible exposure limits value at average 8 hours that assigned by international organizations. Comparison of BT concentration in difference working locations was not difference in all locations. For BT urinary metabolites concentration, both BT urinary metabolites, t,t-Muconic acid and Hippuric acid, were higher than BEIs (Biological Exposure Indices) which defined by American Conference of Governmental and Industrial Hygienist (ACGIH). Comparison of urinary metabolites concentration was difference between ticketing and platform level, the Hippuric acid concentration at ticketing level was higher than that of platform level which depended on personal exposure and other factors involving.

Correlation between BT concentration in the air and their urinary metabolites from urine examination presents these two variables were not correlated significantly. For this root, it may be interfered from various confounding factors.

Association between BT concentration exposure and likelihood of health symptoms occurrence investigation shows Benzene exposure was associated with fatigue while their urinary metabolite, t,t-Muconic acid, exposure was associated with cough/sneeze, eyes irriatation and sore throat. In addition, the result did not present any association between Toluene and their urinary metabolite, Hippuric acid, exposure and health symptoms. However, the association finding seems to be not strong enough to verify because of the small sample size and short sampling period.

6.2 Limitation

Limitations of this study include the small sample size that may have caused the skewed distribution of the data. In addition, the sampling period did not cover the entire 12-hour period of normal operation of the sky-train security guards. The period from 8 a.m. to 4 p.m. also did not completely cover the morning rush hours and ignored the evening rush-hours. Since the samples were only collected during two of the weekdays, the true volume of traffic (and hence, pollution) may not be accurately reflected. Meanwhile, as technical difficulties relating to the operation of air pumps were also experienced during data collection, measurement of the concentration of pollutants may not be accurate. In addition, questionnaire responses from participants are also subjected to answering biases. The individual perception towards his physical and mental well-being may have also influenced the manner in which he responded to the "Health Symptoms" section, which was used to calculate the correlation and association with the concentration of Benzene, Toluene and BT metabolites.

6.3 Recommendation

Further studies should increase the sample size and duration of the sampling. In addition, the sampling should be repeated to accurately analyze the data. Additionally, the researcher will provide relevant suggestions, including the utilization of Personal Protective equipment (PPE) and the implementation of other best practices, policies and regulations in the workplace, to the companies involved.

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APPENDIX

APPENDIX A

Institutional Review Board (IRB) Approval

AF 01-12

คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน กลุ่มสหสถาบัน ชุดที่ 1 จุฬาลงกรณ์มหาวิทยาลัย
254 อาคารจามจุรี 1 ชั้น 2 ถนนพญาไท เขตปทุมวัน กรุงเทพฯ 10330
โทรศัพท์/โทรสาร: 0-2218-3202 E-mail: eccu@chula.ac.th

COA No. 108/2558

ใบรับรองโครงการวิจัย

โครงการวิจัยที่ 070.1/58	:	ผลกระทบทางสุขภาพจากการรับสัมผัสสารเบนซีนและไทลูอีนของเจ้าหน้าที่รักษาความปลอดภัยบนสถานีรถไฟฟ้าในกรุงเทพมหานคร ประเทศไทย
ผู้วิจัยหลัก	:	นางสาวธีพิมล นิมพลี
หน่วยงาน	:	วิทยาลัยวิทยาศาสตร์สาธารณสุข จุฬาลงกรณ์มหาวิทยาลัย

คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน กลุ่มสหสถาบัน ชุดที่ 1 จุฬาลงกรณ์มหาวิทยาลัย ได้พิจารณา โดยใช้หลัก ของ The International Conference on Harmonization – Good Clinical Practice (ICH-GCP) อนุมัติให้ดำเนินการศึกษาวิจัยเรื่องดังกล่าวได้

ลงนาม...................................... ลงนาม......................................
(รองศาสตราจารย์ นายแพทย์ปรีดา ทัศนประดิษฐ) (ผู้ช่วยศาสตราจารย์ ดร.นันทรี ชัยชนะวงศาโรจน์)
ประธาน กรรมการและเลขานุการ

วันที่รับรอง : 22 พฤษภาคม 2558 **วันหมดอายุ** : 21 พฤษภาคม 2559

เอกสารที่คณะกรรมการรับรอง

1) โครงการวิจัย
2) ข้อมูลสำหรับกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัยและใบยินยอมของกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัย
3) ผู้วิจัย
4) แบบสอบถาม

เลขที่โครงการวิจัย 070.1/58
วันที่รับรอง 22 พ.ค. 2558
วันหมดอายุ 21 พ.ค. 2559

เงื่อนไข

1. ข้าพเจ้ารับทราบว่าเป็นการผิดจริยธรรม หากดำเนินการเก็บข้อมูลการวิจัยก่อนได้รับการอนุมัติจากคณะกรรมการพิจารณาจริยธรรมการวิจัยฯ
2. หากใบรับรองโครงการวิจัยหมดอายุ การดำเนินการวิจัยต้องยุติ เมื่อต้องการต่ออายุต้องขออนุมัติใหม่ล่วงหน้าไม่ต่ำกว่า 1 เดือน พร้อมส่งรายงานความก้าวหน้าการวิจัย
3. ต้องดำเนินการวิจัยตามที่ระบุไว้ในโครงการวิจัยอย่างเคร่งครัด
4. ใช้เอกสารข้อมูลสำหรับกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัย ใบยินยอมของกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัย และเอกสารเชิญเข้าร่วมวิจัย (ถ้ามี) ***เฉพาะที่ประทับตราคณะกรรมการเท่านั้น***
5. หากเกิดเหตุการณ์ไม่พึงประสงค์ร้ายแรงในสถานที่เก็บข้อมูลที่ขออนุมัติจากคณะกรรมการ ต้องรายงานคณะกรรมการภายใน 5 วันทำการ
6. หากมีการเปลี่ยนแปลงการดำเนินการวิจัย ให้ส่งคณะกรรมการพิจารณารับรองก่อนดำเนินการ
7. โครงการวิจัยไม่เกิน 1 ปี ส่งแบบรายงานสิ้นสุดโครงการวิจัย (AF 03-12) และบทคัดย่อผลการวิจัยภายใน 30 วัน เมื่อโครงการวิจัยเสร็จสิ้น สำหรับโครงการวิจัยที่เป็นวิทยานิพนธ์ให้ส่งบทคัดย่อผลการวิจัย ภายใน 30 วัน เมื่อโครงการวิจัยเสร็จสิ้น

APPENDIX B

Questionnaire English Version

Participant ID____

Benzene and Toluene Exposure in Relation to Their Health Effects among Sky-train Station Security Guards in Bangkok Thailand.

Explanation

This questionnaire is a part of Master Degree of Public Health Curriculum (M.P.H.), College of Public Health Science, Chulalongkorn University. The consequence from the questionnaire responsiveness of participant will be used for only researching.

Objective

To investigate health effects from Benzene and Toluene exposure among sky train security guards.

The questionnaire comprise of 3 part:

Part I General Characteristics of Workers
Part II Working characteristics
Part III Symptoms of health

Part I General Characteristics of Workers

1. Gender ☐ Male ☐ Female

2. Age……………………year

3. *Body Weight………………………kg.*

4. *Height……………………cm.*

5. Have you ever been smoked?

☐ Never

☐ Smoked, but now stopped smoking

☐ Yes, I still smoke. How many number of smoke? ……………..per day

Protocol No. 070.1/58
Date of Approval 22 MAY 2015
Approval Expire Date 21 MAY 2016

5. Does any place around/near your house have the sources of air pollution, for example, major road, construction, industrial factory and gas station?

☐ No

☐ Yes. Give the name/type of source.....................

6. How do you go to work? (The way that you mostly use)

☐ Walked

☐ By bus (air condition)

☐ By bus (non-air condition)

☐ By van

☐ Others .... Please identified.

7. Do you have a part time job?

☐ No ☐ Yes, please identified place of work............................

8. Do you drink alcohol?

☐ No ☐ Yes

Part II Working characteristics

9. Station where you regular work ....

10. Where is your location when you worked? Please mark in the box ☐

☐ Platform Level

☐ Concourse Level

11. How many years which you have been worked here? ....months/year

12. Do you rotate job between platform and ground?

☐ No ☐ Yes

13. How many hours which you work per day? ....hours/day

14. How many days which you work per week? ....days/week

15. How many days per year, including holidays working, vacation leave and other leave for personal, which you have a day off? ....days/year

16. Do you use personal protective equipment (PPE) such as a mask while you work?

☐ Never

☐ Yes, sometimes or 1-2 times/week

☐ Yes, every time

17. Why do you use the mask while you work as the main reason? Please select only one potential explanation is actually the most?

☐ For protect yourself from pollution

☐ For protect yourself from the sickness of others

☐ Because of your sickness

☐ Because you have to comply the rules

Protocol No. 070.1/58

Date of Approval 22 MAY 2015

Approval Expire Date 21 MAY 2016

Part III Symptoms of health

Have you ever had health symptoms *during and/or after working hours within 24 hours or within the past 3 months?*
Please mark (✓) in this table when you have or do not have some symptoms.

	Symptoms	Within 24 hours		Within the past 3 months	
		Yes	No	Yes	No
18	Cough/Sneeze				
19	Dizziness				
20	Drowsiness				
21	Eyes irritation				
22	Fatigue				
23	Headache				
24	Nausea				
25	Nose irritation				
26	Sore throat				
27	Skin irritation				
28	Throat irritation				

APPENDIX C

Questionnaire Thai Version

หมายเลขแบบสอบถาม_____

แบบสอบถาม

ผลกระทบทางสุขภาพจากการรับสัมผัสสารเบนซีนและโทลูอีนของเจ้าหน้าที่รักษาความปลอดภัย

บนสถานีรถไฟฟ้าในกรุงเทพมหานคร ประเทศไทย

คำชี้แจง

แบบสอบถามชุดนี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรสาธารณสุขศาสตร์มหาบัณฑิต (ปริญญาโท) วิทยาลัยวิทยาศาสตร์สาธารณสุข จุฬาลงกรณ์มหาวิทยาลัย โดยผลที่ได้จากการตอบแบบสอบถามของท่านจะนำไปใช้เพื่อวัตถุประสงค์ทางการศึกษาเท่านั้น

วัตถุประสงค์

เพื่อศึกษาหาผลกระทบทางสุขภาพจากการรับสัมผัสสารเบนซีนและโทลูอีนของเจ้าหน้าที่รักษาความปลอดภัยบนสถานีรถไฟฟ้าในกรุงเทพมหานคร

แบบสอบถามประกอบด้วย 3 ส่วน ดังนี้

ส่วนที่ 1 ข้อมูลทั่วไป

ส่วนที่ 2 ข้อมูลเกี่ยวกับลักษณะการทำงาน

ส่วนที่ 3 อาการทางด้านสุขภาพ

ส่วนที่ 1 ข้อมูลทั่วไป

1. เพศ ☐ ชาย ☐ หญิง

2. อายุ.........................

3. น้ำหนัก.................................กิโลกรัม

4. ความสูง.................................เซนติเมตร

เลขที่โครงการวิจัย 070.1/59

วันที่รับรอง 22 พ.ค. 2558

วันหมดอายุ 21 พ.ค. 2559

5. บ้านหรือที่พักอาศัยของท่านอยู่ใกล้แหล่งมลพิษหรือไม่ เช่น อยู่ใกล้ถนนสายหลัก, พื้นที่ก่อสร้าง, โรงงานอุตสาหกรรม หรือสถานีเติมเชื้อเพลงรถยนต์?

☐ ไม่

☐ ใช่ โปรดระบุ......................

6. ท่านเดินทางไปทำงานด้วยวิธีใดเป็นหลัก?

☐ เดินเท้า

☐ รถโดยสารประจำทาง (รถปรับอากาศ)

☐ รถโดยสารประจำทาง (ไม่ใช่รถปรับอากาศ)

☐ รถตู้ประจำทาง

☐ อื่นๆ โปรดระบุ.......................

7. ท่านทำงานอื่นที่เป็นงานนอกเวลาด้วยหรือไม่?

☐ ไม่ ☐ ใช่, โปรดระบุสถานที่ทำงาน..

8. ท่านดื่มเครื่องดื่มแอลกอฮอล์หรือไม่

☐ ไม่ ☐ ใช่

ส่วนที่ 2 ข้อมูลเกี่ยวกับลักษณะการทำงาน

9. สถานีรถไฟฟ้าที่ท่านประจำตำแหน่งอยู่ คือ ....

10. บริเวณใดของสถานีรถไฟฟ้าที่ท่านต้องอยู่ประจำหน้าที่ กรุณาระบุเครื่องหมายให้ตรงกับชั้นที่ท่านประจำงานอยู่

☐ ชานชาลา

☐ บริเวณการจำหน่ายตั๋ว

11. ท่านทำงานในตำแหน่งนี้มาเป็นเวลานานเท่าไหร่? ....เดือน/ปี

12. ท่านหมุนเวียนการประจำหน้าที่ระหว่างชั้นชานชาลากับบริเวณการจำหน่ายตั๋วหรือไม่?

☐ ไม่ใช่ ☐ ใช่

13. ท่านทำงานวันละกี่ชั่วโมงต่อวัน? ....ชั่วโมง/วัน

14. ท่านทำงานกี่วันต่อสัปดาห์? ....วัน/สัปดาห์

15. ในระยะเวลาหนึ่งปี ท่านหยุดงานที่เป็นวันหยุดทำงานปกติ วันหยุดจากการลากิจและรวมถึงวันหยุดพิเศษโดยเฉลี่ยกี่วันต่อปี

.... วัน/ปี

15. ท่านสวมผ้าปิดจมูกขณะทำงานหรือไม่?

- ☐ ไม่เคยสวม
- ☐ สวมเป็นบางครั้งหรือสวม 1-2 ครั้งต่อสัปดาห์
- ☐ สวมทุกครั้งขณะทำงาน

17. เหตุใดท่านจึงสวมผ้าปิดจมูกขณะทำงานเป็นเหตุผลหลัก โดยสามารถเลือกตอบได้เพียงข้อเดียวที่อธิบายได้ตรงตามความเป็นจริงมากที่สุด?

- ☐ เพื่อป้องกันมลพิษ
- ☐ สำหรับป้องกันตัวเองจากโรคไข้หวัดใหญ่ของผู้อื่น
- ☐ เพราะคุณป่วย
- ☐ เพราะต้องปฏิบัติตามกฎระเบียบ

ส่วนที่ 3 อาการทางด้านสุขภาพ

ท่านเคยมีอาการทางสุขภาพเหล่านี้ขณะปฏิบัติงานหรือในช่วงเวลา 3 เดือนที่ผ่านมาขณะปฏิบัติงานหรือไม่?

หากท่านมีอาการหรือไม่มีอาการทางสุขภาพดังต่อไปนี้ กรุณาระบุเครื่องหมาย (✓) ลงในตารางด้านล่าง

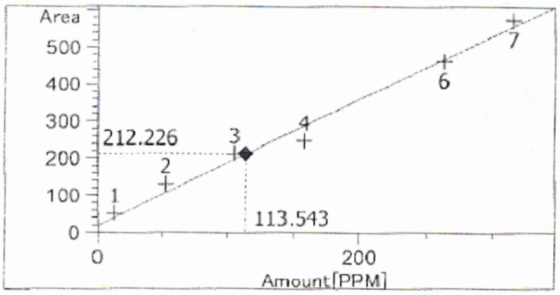
	อาการที่เกิดขึ้น	ขณะปฏิบัติงาน		ในช่วงเวลา 3 เดือนที่ผ่านมาขณะปฏิบัติงาน	
		ใช่	ไม่ใช่	ใช่	ไม่ใช่
18	ไอ/จาม				
19	หน้ามืด เวียนศีรษะ				
20	เซื่องซึมหรือง่วงซึม				
21	ระคายเคืองตา				
22	เหนื่อย เมื่อยล้า				
23	ปวดศีรษะ				
24	คลื่นไส้				
25	ระคายเคืองจมูก				
26	เจ็บคอ				
27	ระคายเคืองผิว				
28	ระคายเคืองคอ				

APPENDIX D

Table 1-D Fundamental Characteristics of BTS Security Guards

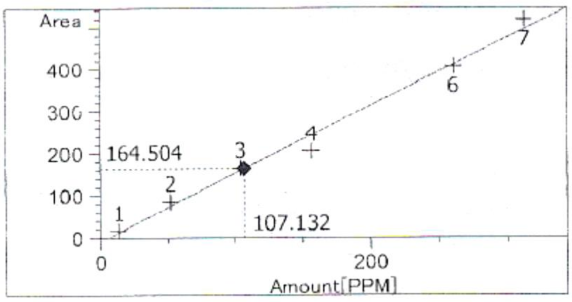
General Characteristic	Frequency (Percent) (n = 40)
Body Weight (kilograms.)	
≤ 60	12 (30.0)
61 – 70	17 (42.5)
71 – 80	11 (27.5)
Mean ± SD	64.4 ± 8.4
Height (centimeters.)	
≤ 160	14 (35.0)
161 – 170	19 (47.5)
≥ 171	7 (17.5)
Median ± SE	163.50 ± 1.49
Pollution Sources near house	
Garage	2 (5.0)
Major Road	8 (20.0)
Type of Transportation	
Walking	10 (25.6)
Bus with AC	8 (20.5)
Bus without AC	5 (12.5)
BTS	11 (28.2)
Motorcycle	3 (7.7)
Others	3 (7.7)
a day off (days/year)	
≤ 10	4 (10.0)
11 – 20	12 (30.0)
21 – 30	14 (35.0)
31 – 40	2 (5.0)
41 – 50	8 (20.0)
Median ± SE	24.0 ± 2.14

APPENDIX E




```
BENZENE at exp. RT: 3.329
FID1 A, Front Signal
Correlation:              0.99421
Residual Std. Dev.:      24.80528
Formula: y = mx + b
       m:       1.70885
       b:      18.19839
       x: Amount
       y: Area
```

Figure 1-E Calibration Curve of Benzene




```
TOLUENE at exp. RT: 5.533
FID1 A, Front Signal
Correlation:              0.99520
Residual Std. Dev.:      21.05467
Formula: y = mx + b
       m:       1.60940
       b:      -7.91373
       x: Amount
       y: Area
```

Figure 2-E Calibration Curve of Toluene

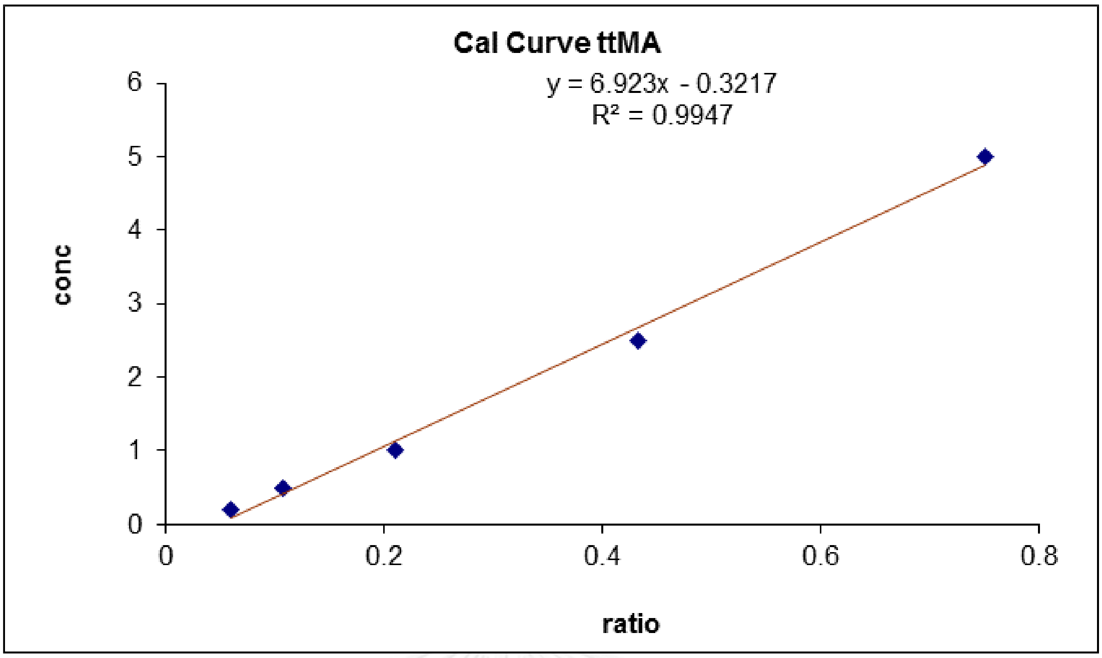


Figure 3-E Calibration Curve of trans, trans Muconic acid

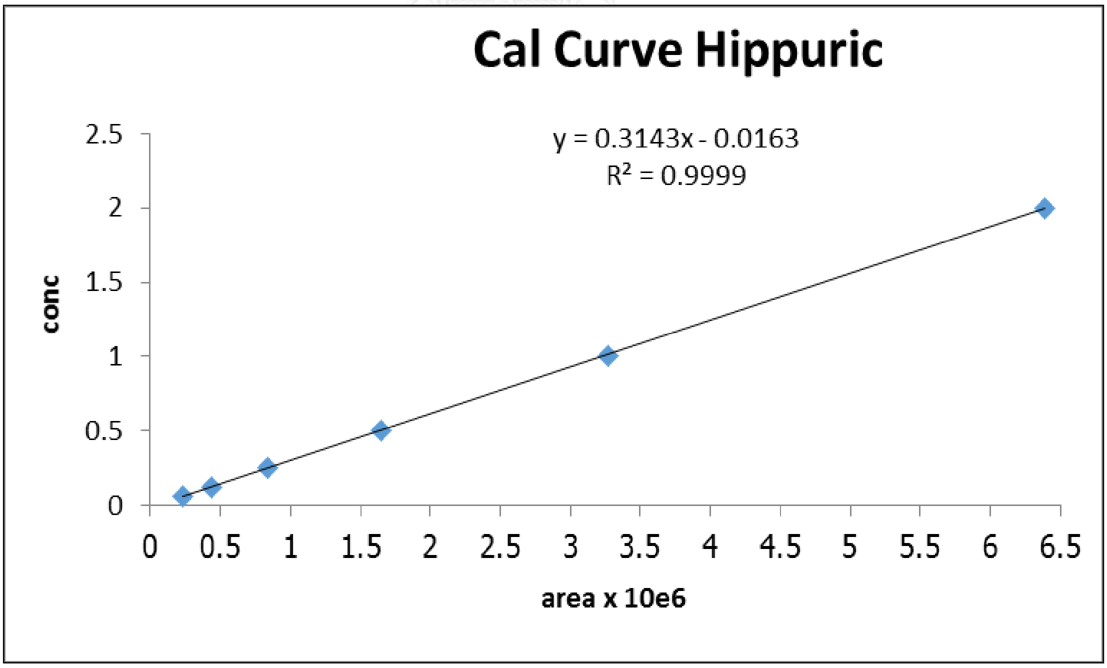


Figure 4-E Calibration Curve of Hippuric acid

APPENDIX F

Table 1-F Odds-ratio of BT concentration and health symptoms within the past 3 months

Health Symptoms	ORs	95% CI		p-value
		Lower	Upper	
Benzene				
Cough/Sneeze	3.810	0.417	34.763	0.399
Dizziness	2.333	0.248	21.981	0.655
Drowsiness	1.185	0.115	12.169	1.000
Eyes Irritation	1.444	0.304	6.865	0.717
Fatigue	6.857	1.355	34.705	0.038*
Headache	6.588	0.733	59.216	0.117
Nose Irritation	3.810	0.417	34.763	0.399
Skin Irritation	3.273	0.356	30.097	0.404
Throat Irritation	2.783	0.299	25.854	0.654
Toluene				
Cough/Sneeze	1.389	0.216	8.927	1.000
Dizziness	0.771	0.077	7.712	1.000
Eyes Irritation	0.714	0.115	4.451	1.000
Fatigue	2.727	0.285	26.118	0.643
Headache	1.833	0.319	10.530	0.654
Nausea	6.600	0.353	123.238	0.281
Nose Irritation	0.480	0.050	4.647	1.000
Sore Throat	0.933	0.092	9.507	1.000
Throat Irritation	4.667	0.751	29.008	0.115

Test of association by using Odds ratio, the level of significant was set at 0.05
*Statistically significant between Benzene concentration and fatigue ($p < 0.05$)

Table 2-F Odds-ratio of urinary metabolite concentration and health symptoms within the past 3 months

Health Symptoms	ORs	95% CI		p-value
		Lower	Upper	
trans, trans Muconic acid				
Cough/Sneeze	3.778	0.827	17.252	0.155
Dizziness	1.889	0.385	9.271	0.695
Drowsiness	4.750	0.481	46.906	0.342
Eyes Irritation	6.000	1.458	24.686	0.022*
Fatigue	5.667	1.254	25.606	0.041*
Headache	4.889	1.199	19.942	0.048*
Nausea	1.000	0.058	17.181	1.000
Nose Irritation	3.778	0.827	17.252	0.155
Sore Throat	8.143	0.878	75.479	0.091
Skin Irritation	3.051	0.659	14.137	0.273
Throat Irritation	12.667	1.402	114.419	0.020*
Hippuric acid				
Cough/Sneeze	2.154	0.515	9.000	0.480
Dizziness	1.000	0.212	4.709	1.000
Eyes Irritation	0.429	0.117	1.568	0.333
Fatigue	0.796	0.211	2.998	1.000
Headache	0.808	0.224	2.912	1.000
Nose Irritation	0.778	0.193	3.130	1.000
Sore Throat	0.706	0.136	3.658	1.000
Skin Irritation	1.000	0.239	4.184	1.000
Throat Irritation	1.333	0.300	5.926	1.000

Test of association by using Odds ratio, the level of significant was set at 0.05

*Statistically significant between trans, trans Muconic acid concentration and eyes irritation, fatigue, headache and throat irritation ($p < 0.05$)

APPENDIX G

Participant Information Sheet

AF 04-07

ข้อมูลสำหรับกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัย

ชื่อโครงการวิจัยผลกระทบทางสุขภาพจากการรับสัมผัสสารเบนซีนและโทลูอีนของเจ้าหน้าที่รักษาความปลอดภัยบนสถานีรถไฟฟ้าในกรุงเทพมหานคร ประเทศไทย

ชื่อผู้วิจัยนางสาวธีพิมล ฉิมหลี ตำแหน่ง นิสิตหลักสูตรสาธารณสุขศาสตร์มหาบัณฑิต

สถานที่ติดต่อผู้วิจัย (ที่ทำงาน)วิทยาลัยวิทยาศาสตร์สาธารณสุข ชั้น 11 อาคารสถาบัน3 ซอยจุฬาลงกรณ์62 ถนนพญาไท เขตปทุมวัน กรุงเทพฯ 10330

(ที่บ้าน) 64/2 หมู่ 1 ตำบลทุ่งมะพร้าว อำเภอท้ายเหมือง จังหวัดพังงา 82120

โทรศัพท์ (ที่ทำงาน) 0 2363 6419

โทรศัพท์มือถือ 0926604378 E-mail : teepimon.ch@gmail.com

1. ขอเรียนเชิญท่านเข้าร่วมในการวิจัยก่อนที่ท่านจะตัดสินใจเข้าร่วมในการวิจัย จึงมีความจำเป็นที่ท่านควรทำความเข้าใจว่าโครงการนี้เกี่ยวข้องกับการวิจัยผลกระทบทางสุขภาพจากการรับสัมผัสสารเบนซีนและโทลูอีนผ่านทางการหายใจตลอดระยะเวลาปฏิบัติงานของเจ้าหน้าที่รักษาความปลอดภัยบนสถานีรถไฟฟ้าในกรุงเทพมหานคร เนื่องจากด้านล่างของสถานีรถไฟฟ้ามีการจราจรที่ค่อนข้างแออัดทำให้ไอเสียของรถยนต์ถูกปล่อยออกมาลอยออกมาปะปนอยู่ในอากาศการหายใจอากาศที่มีการปนเปื้อนของสารเบนซีนและโทลูอีน ซึ่งเป็นสารเคมีที่เกิดจากการเผาไหม้ของน้ำมันหรือแก๊สในรถยนต์นั้น หากท่านหายใจเอาสารเคมีเหล่านี้เข้าสู่ร่างกายเป็นระยะเวลาต่อเนื่อง อาจก่อให้เกิดผลกระทบต่อร่างกายของท่านได้ และเนื่องจากในฐานะที่ท่านเป็นผู้ปฏิบัติงานบนสถานีรถไฟฟ้า มีโอกาสได้รับสัมผัสสารเหล่านี้ทางอ้อมจากไอเสียของการจราจรแออัดบนถนนที่ระเหยขึ้นมาบนสถานีรถไฟฟ้า ทางผู้วิจัยจึงอยากทราบว่าปริมาณสารเคมีที่ท่านหายใจเข้าไปในระหว่างปฏิบัติงานนั้นจะมีผลกระทบต่อสุขภาพของท่านหรือไม่และมีผลกระทบอย่างไร นอกจากนี้ จะมีการเก็บตัวอย่างปัสสาวะของท่านหลังเวลาปฏิบัติงานเพื่อวัดปริมาณสารเคมีที่มาจากการรับสัมผัสสารเคมีเหล่านี้ด้วยกรุณาใช้เวลาในการอ่านข้อมูลต่อไปนี้อย่างละเอียดรอบคอบ และสอบถามข้อมูลเพิ่มเติมหรือข้อมูลที่ไม่ชัดเจนได้ตลอดเวลา

2.วัตถุประสงค์ของการวิจัยนี้เพื่อวัดระดับการรับสัมผัสสารเบนซีนและโทลูอีน ผ่านทางการหายใจของเจ้าหน้าที่รักษาความปลอดภัยบนสถานีรถไฟฟ้าในกรุงเทพมหานคร และวัดระดับปริมาณสารเมตาบอไลท์ของสารเคมีเหล่านี้ในปัสสาวะพร้อมทั้งนำค่าที่ได้จากการตรวจวัดมาวิเคราะห์ถึงผลกระทบทางด้านสุขภาพที่เจ้าหน้าที่รักษาความปลอดภัยได้รับสัมผัส

3. รายละเอียดของกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัย

- ผู้มีส่วนร่วมในการศึกษาครั้งนี้คือเจ้าหน้าที่รักษาความปลอดภัยบนสถานีรถไฟฟ้า ทั้งเพศชายและเพศหญิงสัญชาติไทย เป็นผู้มีสุขภาพดี และมีอายุระหว่าง 18 – 60 ปี ในเส้นทางสายสุขุมวิท โดยเริ่มจากสถานีแบริ่งไปสิ้นสุดที่สถานีหมอชิตไม่รวมสถานีสยามและสถานีอโศกทั้งสิ้น 20 สถานี ซึ่งเส้นทางดังกล่าวค่อนข้างมีการจราจรที่แออัด ซึ่งมีการปนเปื้อนของสารเบนซีนและโทลูอีนในปริมาณสูง ทั้งนี้ผู้เข้าร่วมการวิจัย[illegible]สมัครใจที่จะเข้าร่วมในงานวิจัยครั้งนี้
- ผู้ที่มีหน้าที่ขายตั๋ว และเป็นพนัก[illegible]ฟ้า รวมถึงผู้ที่เป็นโรคระบบทางเดินหายใจและโรคไต นั้น ไม่ได้รวมอยู่ในการวิจัยครั้งนี้

เลขที่โครงการวิจัย 070.1/58
วันที่รับรอง 22 พ.ค. 2558
วันหมดอายุ 21 พ.ค. 2559

- ผู้มีส่วนร่วมในการศึกษาวิจัยครั้งนี้มีจำนวน 40คนโดยแบ่งเป็นเจ้าหน้าที่รักษาความปลอดภัยที่ประจำหน้าที่บนชั้นชานชาลา 1 คน และประจำหน้าที่บริเวณประตูอัตโนมัติบนชั้นจำหน่ายตั๋ว 1 คน รวมเป็นสถานีละ 2 คน
- เหตุผลที่ได้เชิญท่านเข้าร่วมโครงการวิจัยเนื่องจากท่านเป็นผู้ที่มีคุณสมบัติตรงตามคุณสมบัติดังที่กำหนดมาข้างต้นจึงขอเชิญท่านเข้าร่วมในโครงการวิจัยนี้

4. กระบวนการให้ข้อมูลแก่ผู้มีส่วนร่วมในการวิจัยนี้ ผู้วิจัยจะเป็นผู้ให้รายละเอียดสำคัญที่เกี่ยวข้องกับงานวิจัย ได้แก่ การเก็บตัวอย่างอากาศ การเก็บตัวอย่างปัสสาวะ และการตอบแบบสอบถาม รวมถึงใบประชาสัมพันธ์เพื่อเป็นการแจ้งข้อมูลและถามความสมัครใจของผู้มีส่วนร่วมให้ได้ทราบล่วงหน้าก่อนจะเข้าร่วมโครงการวิจัย หากท่านยินยอมเข้าเป็นส่วนหนึ่งของการวิจัยครั้งนี้ ผู้วิจัยจะให้ท่านเซ็นชื่อเพื่อเป็นการแสดงความสมัครใจและยินยอมให้ผู้วิจัยเก็บข้อมูลได้และการตอบแบบสอบถามจะดำเนินการในลักษณะการสัมภาษณ์โดยใช้เวลาประมาณ 10 นาทีต่อการตอบแบบสอบถาม 1 ชุด

เมื่อเสร็จสิ้นการวิจัยแล้วข้อมูลที่เกี่ยวข้องกับผู้มีส่วนร่วมในการวิจัยได้แก่ แบบสอบถามและปัสสาวะจะถูกทำลาย หลังจากงานวิจัยสิ้นสุดลง

5. กระบวนการวิจัยที่กระทำต่อผู้มีส่วนร่วมในการวิจัย จะดำเนินการดังนี้

5.1 การเก็บตัวอย่างอากาศส่วนบุคคล โดยทางผู้วิจัยจะนำอุปกรณ์หลอดเก็บตัวอย่างอากาศมาติดไว้ที่บริเวณปกเสื้อหรือกระเป๋าเสื้อและเหน็บเครื่องดูดอากาศบริเวณขอบกางเกงเครื่องแบบของผู้มีส่วนร่วมในการวิจัยดังภาพด้านล่างซึ่งการติดอุปกรณ์นี้จะไม่ส่งผลกระทบหรือเป็นอุปสรรคในการปฏิบัติหน้าที่ประจำของท่าน เครื่องดูดอากาศดังกล่าวมีขนาดเล็กและมีน้ำหนักประมาณ 1 กิโลกรัม การเก็บตัวอย่างจะเริ่มติดตั้งอุปกรณ์ตั้งแต่เวลาเช้าที่พนักงานเริ่มปฏิบัติหน้าที่โดยผู้วิจัยจะเป็นผู้ติดตั้งอุปกรณ์ให้แก่ท่าน และติดไว้ตลอดระยะเวลาการทำงานเป็นเวลา 8 ชั่วโมงโดยเริ่มจากเวลา 7.00 น.และสิ้นสุดที่เวลา 16.00 น.เมื่อสิ้นสุดเวลาทำงานผู้วิจัยจะมานำหลอดเก็บตัวอย่างอากาศออกไป

เลขที่โครงการวิจัย 070.1/58
วันที่รับรอง 22 พ.ค. 2558
วันหมดอายุ 21 พ.ค. 2559

5.2หลังจากเก็บหลอดตัวอย่างเก็บอากาศออกไปแล้ว ผู้วิจัยจะขอเก็บตัวอย่างปัสสาวะของท่าน โดยท่านจะได้รับขวดพลาสติกมีฝาปิดใช้สำหรับเก็บตัวอย่างปัสสาวะ โดยให้ปัสสาวะในห้องน้ำใส่ขวดพลาสติกที่ได้รับประมาณครึ่งถ้วยเก็บตัวอย่างที่ผู้วิจัยได้มอบให้จากนั้นปิดฝา และเช็ดทำความสะอาดขวดให้เรียบร้อยแล้วนำขวดพลาสติกเก็บตัวอย่างมาคืนผู้วิจัย

5.3 หลังจากส่งขวดเก็บตัวอย่างปัสสาวะแล้ว ผู้วิจัยจะขอสัมภาษณ์ผู้มีส่วนร่วมในการวิจัยโดยใช้แบบสอบถาม ซึ่งประกอบด้วยคำถาม 3 ส่วน *จำนวน 4 หน้ารวมคำถามทั้งสิ้น 30* ข้อผู้วิจัยจะอ่านคำถามจากแบบสอบถาม แล้วให้ผู้มีส่วนร่วมตอบคำถามตามความเป็นจริงด้วยวาจา ซึ่งผู้วิจัยจะเขียนคำตอบลงในแบบสอบถามเอง ซึ่งการตอบแบบสอบถามนี้จะใช้เวลาประมาณ 10 นาที

หลอดที่บรรจุตัวอย่างอากาศและขวดที่บรรจุตัวอย่างปัสสาวะ จะถูกเก็บในภาชนะอย่างเหมาะสมตามหลักการทางวิทยาศาสตร์ และผู้วิจัยจะส่งไปยังห้องปฏิบัติการเพื่อวิเคราะห์ต่อไป ทั้งนี้หากมีตัวอย่างปัสสาวะเหลือจากการวิเคราะห์ ปัสสาวะจะถูกกำจัดตามมาตรฐานของห้องปฏิบัติการ ส่วนแบบสอบถามจะนำไปบันทึกข้อมูลลงในโปรแกรมวิเคราะห์ทางสถิติ ซึ่งจะไม่มีการระบุชื่อของผู้มีส่วนร่วมในการวิจัย จากนั้นแบบสอบถามจะถูกทำลายภายหลังจากการวิจัยเสร็จสิ้นช่วงเวลาดำเนินการดังกล่าวข้างต้นอาจรบกวนเวลาปฏิบัติงานของท่าน ทางผู้วิจัยต้องขออภัยไว้ ณ ที่นี้

6.**ความเสี่ยง**ที่อาจเกิดขึ้นแก่ผู้มีส่วนร่วมในการวิจัยคือ หากพบว่าผลจากการวิจัยพบสารเบนซีนและโทลูอีนในปัสสาวะในระดับสูง และอาการทางด้านสุขภาพส่วนใหญ่เกิดขึ้นจากการรับสัมผัสสารเบนซีนและโทลูอีนนั้น จำเป็นต้องได้รับการป้องกันในวิธีที่ถูกต้องโดยให้คำแนะนำเกี่ยวกับวิธีการป้องกันการรับสัมผัสสารเบนซีนและโทลูอีนโดยใช้อุปกรณ์ป้องกันอันตรายส่วนบุคคล เช่น หน้ากากอนามัยหรือผ้าปิดจมูกที่ป้องกันฝุ่นและควันในวิธีที่ถูกต้องแก่ผู้มีส่วนร่วมในการวิจัย รวมถึงทางผู้วิจัยจะรายงานไปยังหน่วยงานที่รับผิดชอบให้ทราบเช่นกัน ซึ่งในที่นี้คือ บริษัท ระบบขนส่งมวลชนกรุงเทพ จำกัด (มหาชน)

7.**ประโยชน์**ในการเข้าร่วมการวิจัย ประโยชน์สำหรับผู้มีส่วนร่วมในการวิจัยคือ ผลการวิจัยจะบอกค่าปริมาณการสัมผัสสารเบนซีนและโทลูอีน ซึ่งจะทำให้ทราบถึงผลกระทบทางสุขภาพที่เกิดขึ้นกับท่านจากการหายใจเอาอากาศที่ปนเปื้อนสารเคมีดังกล่าวเข้าไปซึ่งผู้มีส่วนร่วมในการวิจัยต้องหาวิธีป้องกันจากการรับสัมผัสสารเคมีเหล่านี้ สำหรับประโยชน์ส่วนรวมคือ การได้ทราบถึงสภาพแวดล้อมในการทำงาน

8.การเข้าร่วมในการวิจัยของท่านเป็นไปโดย**สมัครใจ** และสามารถ**ปฏิเสธ**ที่จะเข้าร่วมหรือ**ถอนตัว**จากการวิจัยได้ทุกขณะ โดยไม่ต้องให้เหตุผลและ**ไม่มีผลกระทบต่ออาชีพการทำงานของท่านแต่อย่างใด**

9. หากท่านมีข้อสงสัยให้สอบถามเพิ่มเติมได้โดยสามารถติดต่อผู้วิจัยได้ตลอดเวลา

10.ข้อมูลที่เกี่ยวข้องกับท่านจะเก็บเป็น**ความลับ** หากมีการเสนอผลการวิจัยจะเสนอเป็นภาพรวมข้อมูลใดที่สามารถระบุถึงตัวท่าน ได้จะไม่ปรากฏในรายงาน

11. ทางผู้วิจัยมีของที่ระลึกมอบให้คือกระเป๋าผ้าสะพายข้างเพื่อแสดงความขอบคุณที่ท่านกรุณาสละเวลาบางช่วงในระหว่างปฏิบัติงานของท่านสำหรับความร่วมมือในการวิจัยครั้งนี้

"หากท่านไม่ได้รับการปฏิบัติตามข้อมูลดังกล่าวสามารถร้องเรียนได้ที่คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน กลุ่มสหสถาบัน ชุดที่ 1จุฬาลงกรณ์มหาวิทยาลัยอาคารจามจุรี 1ชั้น 2 ห้อง 211 ถนนพญาไท แขวงวังใหม่ เขตปทุมวัน กรุงเทพฯ 10330
โทรศัพท์ 0-2218-8147 หรือ 0-2218-8141 โทรสาร 0-2218-8147 E-mail:eccu@chula.ac.th"

เลขที่โครงการวิจัย 070.1/58
วันที่รับรอง 22 พ.ค. 2558
วันหมดอายุ 21 พ.ค. 2559

APPENDIX H

Advertisement for Participation

ใบประชาสัมพันธ์

เชิญเข้าร่วมโครงการวิจัยเกี่ยวกับสุขภาพของเจ้าหน้าที่รักษาความปลอดภัย

บนสถานีรถไฟฟ้าสายสุขุมวิท

- **ท่านสามารถเข้าร่วมโครงการวิจัยนี้ได้ หากท่านมีคุณสมบัติดังนี้**
  - *ท่านที่เป็น<u>เจ้าหน้าที่รักษาความปลอดภัยบนสถานีรถไฟฟ้า</u> สายสุขุมวิท ที่มี <u>อายุระหว่าง 18-60 ปี</u>*
  - *ท่านมีเวลาให้เราไปพูดคุยและสอบถามท่านในเรื่องข้อมูลทั่วไปและลักษณะอาการทางสุขภาพที่เกิดจากการรับสัมผัสสารอินทรีย์ระเหยง่าย โดยใช้เวลาประมาณ 5-10 นาที*
- **ท่านยินดีให้เราติดชุดอุปกรณ์ส่วนตัวบุคคลเก็บตัวอย่างอากาศในขณะปฏิบัติงาน และเก็บตัวอย่างปัสสาวะหลังปฏิบัติงาน**
- **หากท่านยินดีเข้าร่วมโครงการวิจัย และมีเวลาทำกิจกรรมข้างต้นกับเราได้ครบถ้วน ท่านจะได้รับของที่ระลึกเป็นกระเป๋าผ้าสะพายข้าง และท่านจะได้รับคำแนะนำจากผู้วิจัยเพื่อลดความเสี่ยงจากการรับสัมผัสสารอินทรีย์ระเหยง่ายในขณะปฏิบัติงาน**
- **ข้อมูลทุกอย่างที่เกี่ยวข้องกับตัวท่านจะได้รับการเก็บเป็นความลับ**

สนใจสอบถามข้อมูลเพิ่มเติมได้ที่ นางสาวชีพิมล ฉิมพลี โทรศัพท์ 092-660-4378

ดร.ณัฏฐา ฐานีพานิชสกุล โทรศัพท์ 089-206-6534

ชื่อหัวข้องานวิจัย ผลกระทบทางสุขภาพจากการรับสัมผัสสารเบนซีนและโทลูอีนของเจ้าหน้าที่รักษาความปลอดภัยบนสถานีรถไฟฟ้าใน[illegible]านคร ประเทศไทย

เลขที่โครงการวิจัย 070.1/58

วันที่รับรอง 22 พ.ค. 2558

วันหมดอายุ 21 พ.ค. 2559

VITA

Name: Teepimon Chimplee

Date of birth: September 19, 1992

Education: B.Sc. in Environmental Health, Faculty of Public Health with Second Class Honors. Huachiew Chalermprakiet University, Samutprakan, Thailand.

Contact: 092-6604378

E-mail Address: teepimon.ch@gmail.com