รายงานโครงการวิจัย

การประเมินความเสี่ยงด้านสุขภาพจากการรับสัมผัสสารอินทรีย์ระเหยง่ายจากการจราจรของผู้ปฏิบัติงานบนรถไฟฟ้าและรถไฟใต้ดินในกรุงเทพมหานคร

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สนับสนุนโดย สำนักงานคณะกรรมการวิจัยแห่งชาติ
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สารบัญ

หัวข้อ	หน้า
Introduction	2
Literature review	4
Methodology	7
Results	12
Discussion and Conclusion	27
ปัญหาและอุปสรรคในการดำเนินงาน	32
Appendix	33

ผู้รับผิดชอบโครงการวิจัย

<u>หัวหน้าโครงการ</u>

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<u>ผู้ร่วมงานวิจัย</u>

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<u>ที่ปรึกษาโครงการวิจัย</u>

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Introduction

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).

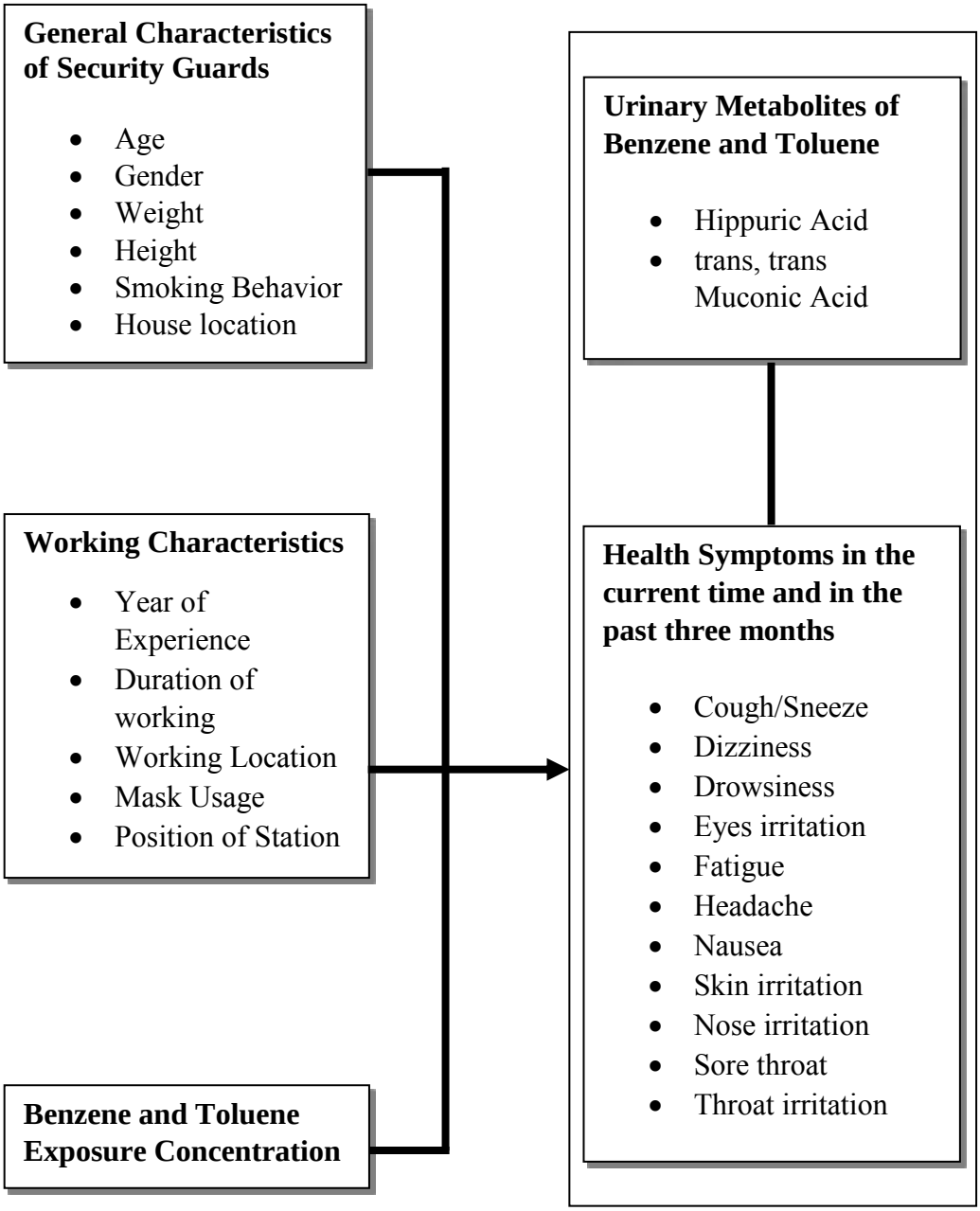
Benzene and Toluene are naturally arising volatile organic compounds commonly found in crude oil (Maryland Department of The Environment, 2007) categorized under the aromatic hydrocarbons subgroup. They are often emitted into the atmosphere through exhausts of aircrafts, automobiles and smokes of tobacco. 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

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).

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, 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, 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.

Conceptual Framework



Literature review

Chemical and Physical Property of Benzene and Toluene

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). Physical and chemical properties of Benzene were shown below.

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)

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. Physical and chemical properties of Toluene were shown in table below.

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 %

Health Effects Related to Benzene and Toluene

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			

Research Methodology

Research Design and Study Area

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.

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.

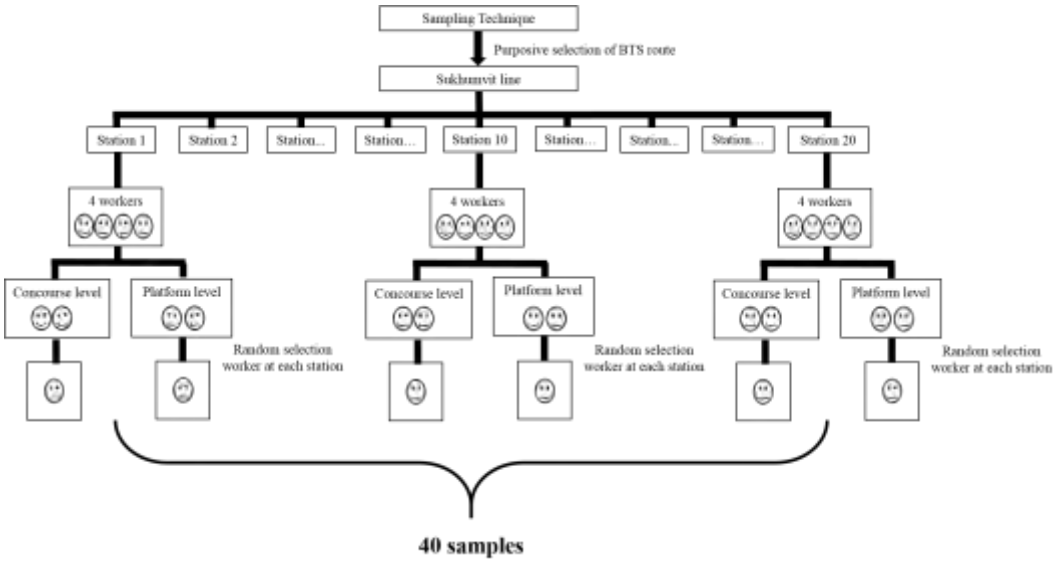
Study Population

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.

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.

Sampling Technique



Measurement Tools

1. Questionnaires

The questionnaires were tested for validity by three specialists. Cronbach's Alpha test for reliability analysis was used, so the reliability value is 0.873. The questionnaires comprises of 3 parts:

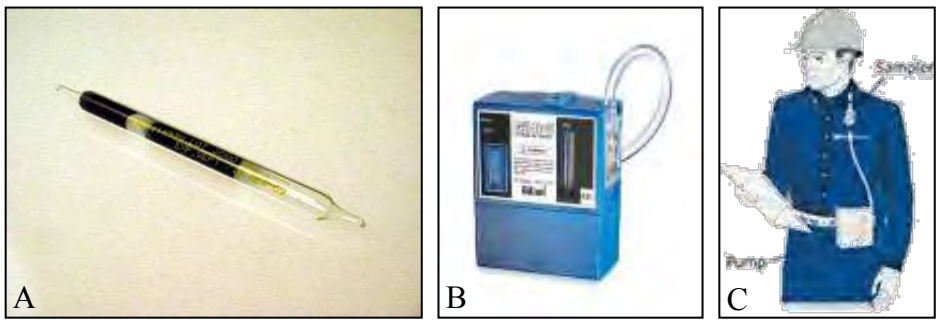
1st part: General characteristics of workers (age, gender, weight, height, house location and smoking behavior); a total of 10 items.

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.

2. Air Sampling

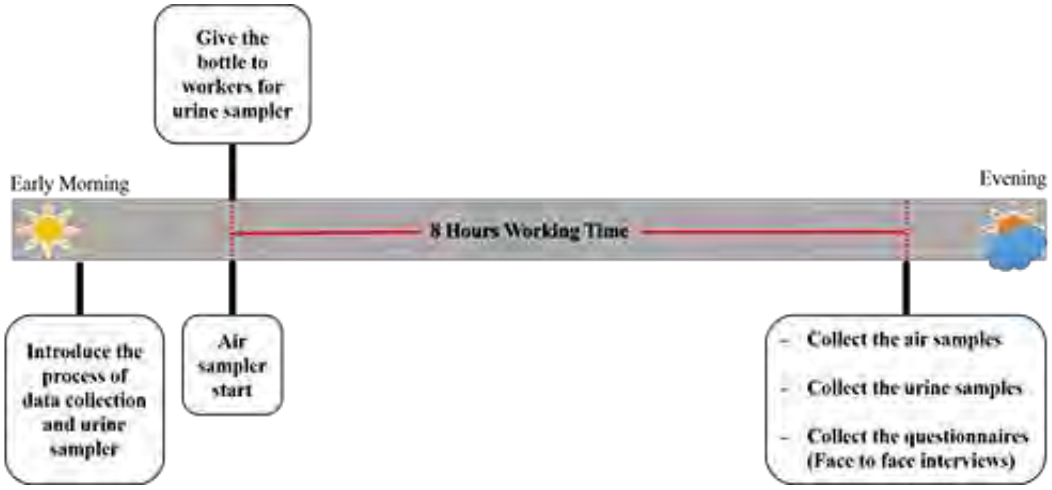
Charcoal Glass tube and personal air pump were used in order to sampling concentration of BTEX continuously throughout the duration of work for 8 hours, from 8 a.m. to 4 p.m.



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.

Data Collection



Data Analysis (Statistics): The SPSS Program was used in this research for analyzed the data.

- ***Descriptive statistic:*** general data, worker amount, age, and gender → mean, median, frequency, percentage, standard error and standard deviation
- ***Normal distribution test by Shapiro-Wilk test:*** test all parameters of study
- ***Mann Whitney U test:*** To find association between BT detected concentration and different working location
- ***Fisher's exact test:*** Finding association between health effects and Benzene and Toluene exposure level.
- ***Logistic regression:*** To determine health effects and level of Benzene and Toluene exposure
- ***Spearman correlation test:*** Correlation between urinary metabolites and Benzene and Toluene exposure ($p < 0.05$).

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.

Results

1. General Information

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)
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)

2. **Working Characteristic**

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)

Working Characteristic	Frequency (Percent), (n = 40)
Reasons for using mask	
Pollution Protection	16 (64.0)
Influenza Protection	1 (4.0)
Sickness	7 (28.0)
Do by Regulations	1 (4.0)

3. Concentration of BT in Air Samples

3.1 Descriptive of BT Concentrations

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

3.2 Comparisons of Detected BT Concentration between Ticketing and Platform Level

		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

3.3 Comparisons of BT Concentration between Inner Bangkok and Outer Bangkok

		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.

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

		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. Urinary metabolites of BT

4.1 General Comparisons of Detected BT Urinary Metabolites

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

4.2 Comparisons of BT Urinary Metabolites Detected from Ticketing and Platform Level

		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

4.3 Comparisons of BT Urinary Metabolites Detected within Inner Bangkok and Outer Bangkok

		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 Comparisons of BT Urinary Metabolites Detected from the North and the East BTS Sky-Train Line

		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

5. Health Symptoms of Security Guards Related to BT Exposure

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

6. Correlations between BT Concentrations and Urinary Metabolites

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

7. Association between BT Concentrations and Health Symptoms

7.1 Association between Benzene Concentration and Health Symptoms

	Benzene Concentration		
	Low	**High**	**p-value**
	n (%)	**n (%)**	
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)	

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.

8. Association between BT Urinary Metabolites and Health Symptoms

8.1 Association between Benzene Urinary Metabolite (trans, trans-Muconic acid) and Health Symptoms

	t,t-Muconic acid concentration		
	Low	**High**	**p-value**
	n (%)	**n (%)**	
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

	t,t-Muconic acid concentration		
	Low	High	p-value
	n (%)	n (%)	
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)	
In the past 3 months			
Yes	11 (68.8)	5 (31.2)	0.048*
No	9 (37.5)	15 (62.5)	
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.

8.2 Association between Toluene Urinary Metabolite (Hippuric acid) and Health Symptoms

	Hippuric acid concentration		p-value
	Low n (%)	High n (%)	
Drowsiness			
While working			
Yes	6 (100.0)	0	0.020*
No	14 (41.2)	20 (58.8)	
In the past 3			
months	5 (100.0)	0	0.047*
Yes	15 (42.9)	20 (57.1)	
No			

9. Association between BT Exposure and Health Symptoms

9.1 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 ($p < 0.05$)

9.2 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

10. Association between BT Urinary Metabolites and Health Symptoms

10.1 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 ($p < 0.05$)

10.2 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 ($p < 0.05$)

Discussion and Conclusion

1. General Information

- 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
- 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.
    - 20% of the participants are smokers; of that figure, the average number of cigarettes smoked was 5.25 (±2.50) per day.
    - 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
    - 2.5% near garages that provide vehicle maintenance service
- Commuting to work
    - BTS sky-train is the most popular means that the participants (28.2%)
    - 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.
    - 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.
- The majority (41.1%) has working experience in the range of 1 – 5 years.

- Mask Using: 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.

2. BT concentration in air samples

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).

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)

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).

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)

4. BT concentration and health symptoms

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.

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. 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, fatigue, headache, and throat irritation 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 and the past 3 months.

In contrast, the analysis results from logistic regression illustrate t,t-Muconic acid, urinary metabolite of Benzene, was associated statistical significantly with cough/sneeze, eyes irritation, and sore throat. On contrary, Hippuric acid was not associated with any health symptoms (p-value > 0.05). 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

6. Conclusion

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. 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.

7. Limitation

- The small sample size that may have caused the skewed distribution of the data.
- 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.

- 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.
- 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.

8. Recommendation

Further studies should:

- Increase the sample size and duration of the sampling
- The sampling should be repeated to accurately analyze the data

ปัญหาและอุปสรรคในการดำเนินงานวิจัย

เนื่องด้วยการดำเนินงานภายใต้โครงการวิจัยในครั้งนี้มีอุปสรรคจากการดำเนินงาน ดังนี้

1. การติดต่อหน่วยงานที่เกี่ยวข้องในการเข้าเก็บข้อมูล
   จากการติดต่อขอเข้าเก็บข้อมูลในบริเวณรถไฟฟ้าใต้ดินนั้น ทางโครงการได้มีการดำเนินการติดต่อไปทางบริษัทที่เกี่ยวข้อง แต่ไม่ได้รับการตอบรับกลับ ทางโครงการจึงเล็งเห็นว่าจะมีการเปลี่ยนแปลงสถานที่เก็บตัวอย่างและกลุ่มประชากรในการดำเนินการเก็บตัวอย่างเป็นการขนส่งสาธารณะในลักษณะอื่นต่อไปในการดำเนินงาน ปีที่ 2
2. การดำเนินงานด้านห้องปฏิบัติการ
   การวิเคราะห์ทางห้องปฏิบัติการมีความล่าช้ากว่ากำหนด เนื่องจากทางโครงการได้พัฒนาวิธีวิเคราะห์และเครื่องมือทางห้องปฏิบัติการ โดยเปลี่ยนจากการวิเคราะห์ที่ ศูนย์วิจัยและฝึกอบรมด้านสิ่งแวดล้อม กรมส่งเสริมคุณภาพสิ่งแวดล้อม มาเป็นการวิเคราะห์ที่ วิทยาลัยวิทยาศาสตร์สาธารณสุข จุฬาลงกรณ์มหาวิทยาลัย

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

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ABSTRACT:

Background: Benzene (B) and toluene (T), contributed to short-term and long-term health hazards, are naturally emitted into the atmosphere through exhausts of vehicles. This cross-sectional study aimed to examine BT exposure concentrations and to investigate BT exposure health effects among sky train station security guards in Bangkok.

Methods: Charcoal Glass tube connected to active personal pump was used to collect benzene and toluene concentration during 8 working hours from 40 sky train security guards; 20 guards working at platform level and 20 guards working at ticket level. Post shift urinary metabolites, trans, trans-muconic acid (t,t-MA) and hippuric acid (HA) were accessed. Questionnaires were collected from security guards at the end of work shift. Multiple logistic regression performed to find an association between BT exposure and their health effects.

Results: The median concentration of benzene and toluene were 0.21 and 242.40 μg/m^3. Statistical difference between ticket and platform level was not found. Post-shift urine t,t-MA and HA, were not correlated with their parent compounds. Benzene exposure was positively associated with fatigue. On contrary, an association between toluene exposure and health effects was not found after adjusted possible confounders.

Conclusion: Sky train security guards were exposed to low concentrations of BT, which could partially explain their low levels of adverse health effects.

Keywords: Benzene, Toluene, Health effects, Sky-train station, Security guards, Thailand

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INTRODUCTION

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 [1]. Benzene (B) and toluene (T) are commonly found in crude oil [2] 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 [3]. 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 [4]. 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 [5]. In the long run, benzene and toluene can disrupt hematopoietic system, the central nervous system and the reproductive system [5]. In addition, benzene is carcinogens or cancer-inducing agents [6].

Previous studies focused direct occupational exposure to BT, such as street vendors [7], gasoline workers [8] and car park workers [9] while few studies paid attention to occupational indirect exposures to BT. Moreover, none study was conducted on sky train station security guards in Thailand before. Therefore, this study sought to 1)

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determine the BT exposure and their urinary metabolite concentrations 2) find a correlation between BT concentration and urinary metabolite 3) investigate an association between BT exposure and health symptoms among sky train station security guards.

MATERIALS AND METHODS

Study population

A cross-sectional study was conducted during April – May 2015 to investigate an association between BT exposure and health effects among sky train security guards. Two security guards; one guard from ticket level on first floor (approximate 8 meters high above the road level) and another from platform level on the next floor an approximately 4 meters high from ticket level, in each station were randomly selected. Totally, forty security guards participated in this study.

Study area

Twenty electric sky train stations along Sukhumvit line (22.25 km length) were selected as a study area because of the worst traffic congestion during rush hours reported by office of transport and traffic policy and planning of Thailand [10].

Data collection

Personal air samples and post-shift urine samples were collected in weekdays (Monday - Friday) to represent BT high exposed concentration. Charcoal Glass tube (SKC 226-09; coconut charcoal; 8 x 110 mm; 200 mg/400 mg) connected to active personal air sample were used to collected BT concentration at security guards breathing zone followed by the National Institute for Occupational Safety and Health (NIOSH) 1501 method [11]. Air pumps were continually turned on throughout the duration of work for 8 hours, from 8 a.m. to 4 p.m. Post-shift urine samples were collected at the end of air sample collection day. Air and urine samples were preserved by keeping them at about 4°C during transportation and storage until analyses.

Face to face interview was performed after collecting post-shift urine. Questionnaire, composed of general information, working characteristic and health symptoms, was tested validity (index of item-objective congruence (IOC) = 0.52) and reliability (average cronbach's alpha = 0.873). Study protocol was approved by ethics review committee for research involving human research subjects, health sciences group, Chulalongkorn University, Thailand (COA No. 070.1/2015).

Benzene and toluene (BT) analysis

Benzene and toluene air sample analysis was based on the NIOSH Manual of Analytical Method No.1501 [11]. Briefly, the activated charcoal was desorbed in 1.0 ml of CS_2 for 30 min with occasional shaking. Analysis was performed by using gas chromatography with flame ionization detector (GC-FID). A 1 µL of sample was used for one injection. The oven temperature was initially set at 40ºC for 2 min and was programmed to increase at 10ºC/min to 100ºC. Injector and detector temperature were set at 150°C. Extraction recovery rate of benzene and toluene were 95.56% and 98.66%. The limit of detection (LOD) of benzene and toluene were 0.5 and 0.7 µg/L respectively. Linear standard curve over the range of 10, 50, 100, 150, 200, 250, and 300 ppm were obtained with the correlation coefficients at 99.42% of benzene and 99.52% of toluene.

Urinary analysis

Urine t,t-MA samples were sent for standardized laboratory analysis [12]. In house analysis method was performed. A 0.5 mL of urine sample was pipetted into a 10 ml tube, spiked with 50 µL vanillic acid (IS) solution (100 ppm) and added 100 µl of 2M HCL. Liquid-liquid extraction was done by ethyl acetate solvent. The supernatant was transferred into a new tube and was then reduced to be able and dry via N_2 gas at 40 ºC. After that, 500 µL of mobile phase was added to adjust the last volume for injection into the HPLC-UV (high performance liquid chromatography-ultraviolet). Linear standard curve over the range of 0.20, 0.50, 1.00, 2.50, 2.00 µg/ml were obtained with the correlation coefficient of 0.999 or greater. Urine t,t-MA sample's correlation coefficient was 99.47%.

Urine HA analysis method was in followed by NIOSH 8301 [13]. A 1 mL of urine sample was mixed with mobile phase (1 % acetic acid: methanol (90:10)) and centrifuged for 10 minutes at 2000 U/min. 1 mL of clear supernatant was transferred vial for injection into HPLC-UV. Linear standard curve over the range of 0.13, 0.25, 0.50, 1.00, 2.00 g/L were obtained. Correlation coefficient of urine HA sample was 99.99%.

Statistical analysis

First, socio-demographic and work characteristic were explored as mean (±standard deviation), median, frequency and percentage. Some parameters were tested normal distribution by Shapiro-Wilk test before performing an analysis. According to a skewed concentration data, Mann Whitney U test was done to find an association between BT detected concentration and different working location (platform and ticket level).

Table 1 General characteristics of sky train station security guards (n=40)

General characteristics	Sky-train security guards						*p*-value*
	Total (n = 40)		Ticking (n = 20)		Platform (n = 20)		
	N	%	N	%	N	%	
Gender							
Male	23	57.5	3	15.0	20	100.0	<0.001
Female	17	42.5	17	85.0	0	0.0	
Age (years)							
< 30	9	22.5	6	30.0	3	15.0	
30 – 39	14	35.0	6	30.0	8	40.0	0.607
≥ 40	17	42.5	8	40.0	9	45.0	
(Mean ± SD)	(37.8 ± 8.5)		(36.0±8.5)		(39.65±8.33)		
Body Mass Index (BMI, kg/m^2)							
Underweight	2	5.0	2	10.0	1	5.0	
Normal-weight	25	62.5	10	50.0	14	70.0	0.648
Overweight	13	32.5	8	40.0	5	25.0	
(Mean ± SD)	(23.8 ± 3.52)		(24.6±3.75)		(22.9±3.13)		
Current smoking							
No	32	80.0	19	95.0	13	65.0	0.044
Yes	8	20.0	1	5.0	7	35.0	
Second hand smoker							
No	25	62.5	12	60.0	13	65.0	1.000
Yes	15	37.5	8	40.0	7	35.0	
House located near other air pollution sources [a]							
No	30	75.0	15	75.0	15	75.0	1.000
Yes	10	25.0	5	25.0	5	25.0	

[a] Other air pollution sources includes garage and main road.
*Fisher's Exact Test

Fisher's exact test was used to find association between health symptoms and BT exposure level (low exposure level: < median concentration and high exposure level: ≥ median concentration). The statistical analysis of regression was performed to find out the relationship between BT exposure and urinary metabolite of workers as same as the association between BT exposure and health symptoms. Linear regression model was adjusted for gender, age, BMI, smoking behavior, second hand smoke, house location, mask usage, working area. SPSS version 16 for windows (Chicago, IL) was used for analyses.

RESULTS

General information

Table 1 showed general characteristic of security guards. The total number of participants in this study is 40 (mean age 37.8 ± 8.5 years and mean BMI 23.79 ± 3.52), consisting of 23 males and 17 females, all of whom are security guards stationed on ticket or platform level. Sixty percent of the participants fall within the body mass index (BMI) range of normal. Of the security guards who were currently smoking (20%), the average number of cigarettes smoked per day was 5.25 (±2.50). Twenty-five percent of the participants indicated that their houses are located near other sources of air pollution such as main roads and garages

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) as shown in Table 2.

The majority (85%) worked 7 days a week with 24.9 (±13.6) average days off 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. As a matter of fact, 47.5% of the security guards never used any forms of personal protective equipment during working shifts.

BT exposure concentrations

From Table 3, the comparisons of BT concentrations from exposure showed that the average of concentration of benzene and toluene

Table 2 Working characteristics of sky train station security guards (n=40)

Working characteristics	Sky-train security guards						*p*-value*
	Total (n = 40)		Ticking (n = 20)		Platform (n = 20)		
	N	%	N	%	N	%	
Working experiences (years)							
< 1	14	35.0	9	45.0	6	30.0	
1 – 5	17	42.5	9	45.0	7	35.0	0.868
≥ 6	9	22.5	2	10.0	7	35.0	
(Median ± SE)	(1.2 ± 0.57)		(1.68 ± 1.01)		(2.05 ± 0.99)		
Job rotating							
No	31	77.5	17	85.0	14	70.0	0.451
Yes	9	22.5	3	15.0	6	30.0	
Duration of work (days/week)							
6	6	15.0	1	5.0	5	25.0	0.182
7	34	85.0	19	95.0	15	75.0	
(Median ± SE)	(7.0 ± 0.06)		(6.95±0.99)		(6.8±0.99)		
Personal protective equipment use (Mask)							
No	20	47.5	10	50.0	10	50.0	1.000
Yes	20	52.5	11	55.0	9	45.0	
Reasons for using mask							
Pollution protection	16	64.0	8	40.0	8	40.0	
Influenza protection	1	4.0	0	0.0	1	5.0	0.665
Sickness	7	28.0	5	25.0	2	10.0	
Do by Regulations	1	4.0	1	5.0	0	0.0	

* Fisher's Exact Test

Table 3 Comparisons of concentration of benzene and toluene exposure among guards working at ticketing and platform levels (μg/m^3, n = 40)

		Total (n = 40)	Ticketing (n = 20)	Platform (n = 20)	*p*-value
Benzene	Median	0.21	0.21	0.21	0.188
	Standard error	4.08	8.55	3.56	
	Mean	7.52	8.76	6.82	
	Standard deviation	24.46	34.19	14.25	
	Min.	0.21	0.21	0.21	
	Max.	136.98	136.98	37.50	
Toluene	Median	242.40	247.03	242.39	0.350
	Standard error	17.11	19.14	31.25	
	Mean	214.30	245.22	177.25	
	Standard deviation	102.64	76.55	124.99	
	Min.	0.07	0.07	0.07	
	Max.	354.17	354.17	298.13	

were 0.21(±4.08) μg/m^3 and 242.40 (±17.11) μg/m^3, respectively. The maximum concentration of B was 136.98μg/m^3 while that of T was 354.17μg/m^3. Meanwhile, the minimum concentration detected was 0.21μg/m^3 and 0.07μg/m^3 for B and T, respectively. Statistical difference of BT concentrations between ticket and platform level was not found (p>0.05).

Urinary metabolites of BT

Comparative results of urinary metabolites of BT collected after the working shift are shown in Table 4. Trans, trans-muconic acid and hippuric acid are urinary metabolites of benzene and toluene, respectively. The results showed that the difference between urinary t,t-MA detected from the ticketing and from the platform level was not statistically significant. Meanwhile, with a p-value of 0.007, the difference in HA urinary metabolite between the two areas was considered statistically significant.

Association between BT concentration and its urinary metabolites

The results found benzene concentration did not statistically associate with its urinary metabolite concentration (t,t-MA) (β= -0.53; p-value =0.86). Meanwhile, toluene concentration and its urinary metabolite concentration (HA) did not an association (β= -0.03; p-value =0.53). Finding suggested that urine t,t-MA and HA might not be

Table 4 Comparisons of urinary metabolites of benzene and toluene among guards working at ticket and platform levels (mg/g creatinine)

		Total (n = 40)	Ticketing (n = 20)	Platform (n = 20)	*p*-value
t,t-MA	Median	1.02	1.26	0.62	0.079
	Standard error	0.35	0.65	0.12	
	Mean	1.52	2.29	0.76	
	Standard deviation	2.22	2.93	0.56	
	Min.	< LOD	< LOD	< LOD	
	Max.	12.36	12.36	1.89	
HA	Median	269.32	380.85	202.02	0.007*
	Standard error	55.95	96.61	38.62	
	Mean	368.31	507.02	229.60	
	Standard deviation	353.85	432.07	172.70	
	Min.	51.28	51.28	52.46	
	Max.	1,842.42	1,842.42	655.84	

* Statistic significantly at p < 0.01

Table 5 Health symptoms of sky train workers

Symptoms	Total (n=40)		Ticketing(n=20)		Platform(n=20)		*p*-value*
	n	%	n	%	n	%	
Cough/Sneeze	12	30.0	6	30.0	6	30.0	1.000
Dizziness	7	17.5	5	25.0	2	10.0	0.407
Drowsiness	6	15.0	2	10.0	4	20.0	0.661
Eyes Irritation	16	40.0	8	40.0	8	40.0	1.000
Fatigue	29	72.5	13	65.0	16	80.0	0.480
Headache	14	35.0	7	35.0	7	35.0	1.000
Nausea	4	10.0	3	15.0	1	5.0	0.605
Nose Irritation	10	25.0	5	25.0	5	25.0	1.000
Sore Throat	9	22.5	4	20.0	5	25.0	1.000
Skin Irritation	12	30.0	8	40.0	4	20.0	0.301
Throat Irritation	9	23.1	3	15.0	7	35.0	0.127

** Fisher's Exact Test

Table 6 Adjusted ORs for association BT exposure and health symptoms

	Adjusted ORs	95% CI		p-value
		Lower	Upper	
Benzene				
Cough/Sneeze	47.951	0.755	3.046E3	0.068
Drowsiness	1.636	0.002	1.284E3	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
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

Adjusted for gender, age, BMI, smoking behavior, second hand smoke, house location, mask usage, working area, working experiences, job rotating and duration of work

*Statistic significantly (p < 0.05)

able to predict their concentration of exposure to their parent compounds, benzene and toluene.

Association between BT exposure and health symptoms

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 while working (72.5%). On the contrary, nausea was the least prevalent, with only 10%. More comprehensive results are displayed in Table 5.

Logistic regression analysis displays associations between benzene exposure and one of those symptoms. Benzene exposure is associated with fatigue in a statistically significant manner ($p < 0.05$; OR = 21.166; 95% CI, 1.297 – 345.494). 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 6.

DISCUSSION

Concentration of benzene in median was lower than former studies whilst median concentration of toluene was higher than previous studies [14, 15]. The average concentration of benzene was lower than the findings discovered by Borgie, M. et al. (2014) through studying traffic policemen in Lebanon, in which an average benzene concentration was at 0.3 $\mu g/m^3$ [14]. Meanwhile, in a study targeted at passengers commuted by sky-train by Ongwandee, M. and O. Chavalparit (2010), average benzene concentration was found to be as high as 2 $\mu g/m^3$ [15]. On the other hand, the toluene concentration of this study was higher than the 101.8 $\mu g/m^3$ concentration presented in Borgie, M. et al. study [14]. The high concentration at 242.40 $\mu g/m^3$ is in conflict with the study of Ongwandee, M. and O. Chavalparit [15], which found only 36.9 $\mu g/m^3$ of toluene concentration. In the fact that, the concentration of benzene and toluene may be come from 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 [9, 14-19], 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—Occupational Safety and Health Administration (OSHA) determined the permissible exposure limits value at 1,597 $\mu g/m^3$ (0.5 ppm) for benzene while at 753,700 $\mu g/m^3$ (200 ppm) for toluene. Meanwhile, National Institute of Occupational Safety and Health (NIOSH) assigned at 320 $\mu g/m^3$ (0.1 ppm) for benzene and 3.75×10^5 $\mu g/m^3$ (100 ppm) for toluene [20]. Comparison of BT concentration in difference working locations was not difference in all locations. Comparison of urinary metabolites concentration was difference between ticketing and platform level, the HA concentration at ticketing level was higher than that of platform level which depended on height from the road and ventilation of the station because ticketing level is closer the ground than platform level, as a consequence, the ventilation is quite not good as the platform level.

Our study found no association between BT concentration and their urinary metabolites. Similarly, correlation between BT concentration in the air and their urinary metabolites from urine examination presents these two variables were not correlated significantly (p-value > 0.05) in previous study [9, 14]. The average concentration of urinary metabolite, t,t-MA, was lower than that measured in traffic and office policemen in Beirut, Lebanon (0.001 $\mu g/g$ Cr) [14]. Meantime, the median of HA concentration in this study was also lower than parking workers in Bangkok, Thailand (0.269 $\mu g/g$ Cr) [9]. Personal factors, alcohol consumption, living places and distance from pollution sources might be the interfering factors of this event [21-23].

Association between BT concentration exposure and likelihood of health symptoms occurrence investigation shows benzene exposure were associated with fatigue which consisted with study of Tunsaringkarn et al. in 2012 [8] found that benzene exposure was significantly associated with fatigue. In addition, the result did not present any association between toluene and urinary metabolite and health symptoms. The difference of health symptoms occurrence between ticketing and platform workers might depend on distance or high from the road and also the metabolism differences of their body [24]. BT concentration might depends on the temperature which will change with height [25]. The difference between worker groups indicated that they are not much difference in parameter of exposure such as working experience, age group, personal protective equipment usage and the BT concentration, as a consequence, it might affect to the difference of metabolite concentration and health symptoms occurrence. However, the association finding seems to be not strong enough to verify because of the small sample size and short sampling period.

Limitations of this study include the small sample size that may have caused the skewed

distribution of the data. Additionally, the sampling period did not cover the entire 12-hours period of normal operation of the sky-train security guards. Further studies should increase the sample size and duration of the sampling including the sampling should be repeated to accurately analyze the data. In addition, the researcher 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. Based on our finding, platform level should take into account for increasing air movement and air ventilation.

In conclusion, sky train security guards exposed continuously to benzene and toluene in low concentrations which might pose to less health effects.

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REFERENCES

1. Thailand, Ministry of Natural Resources and Environment, Pollution Control Department. Situation and management of the air pollution and noise. Bangkok: Pollution Control Department; 2013.
2. Maryland Department of The Environment. Fact sheet of BTEX. Washington Boulevard, Baltimore MD: Maryland Department of the Environment; 2007.
3. World Health Organization [WHO]. WHO guidelines for indoor air quality: selected pollutants. Copenhagen, Denmark: WHO Regional Office for Europe; 2010.
4. United States Environmental Protection Agency, Office of Transportation and Air Quality. Near roadway air pollution and health: frequently asked questions. US: Pollution Control Department; 2014.
5. Gunatilaka M. Hazardous air pollutants: concentrations of benzene, toluene, ethylbenzene and xylene (BTEX) in Christchurch 2001/2002. (Report No. R03/9). Christchurch: Environment Canterbury; 2003.
6. International Agency for Research on Cancer. Benzene: IARC Monographs-100f. Lyon: Internationa Agency for Research on Cancer; 1987.
7. Tunsaringkarn T, Prueksasit T, Sematong S, Siriwong W, Kanjanasiranont N, Zapuang K, et al. Volatile organic compounds exposure and health risks among street venders in urban area, Bangkok. J Environ Occup Sci. 2014; 3(1): 31-8.
8. Tunsaringkarn T, Siriwong W, Rungsiyothin A, Nopparatbundit S. Occupational exposure of gasoline station workers to BTEX compounds in Bangkok, Thailand. Int J Occup Environ Med. 2012 Jul; 3(3): 117-25.
9. Loonsamrong W, Taneepanichskul N, Puangthongthub S, Tungsaringkarn T. Health risk assessment of BTEX exposure to parking workers at one of parking structure in Bangkok Thailand. J Health Res. 2015; 29(4): 285-92.
10. Ministry of Transportation, Office of Transportation and Traffic Policy and Planning. Annual report 2013. Bangkok, Thailand: Office of Transportation and Traffic Policy and Planning; 2013.
11. National Institute for Occupational Safety and Health [NIOSH]. Manual of Analytical Methods (NMAM): Hydrocarbons, arotic: method 1501. National Institute for Occupational Safety and Health; 2003.
12. Marten S. Determination of trans, trans-muconic acid in urine sample. Germany: [n.p]; 2011.
13. National Institute for Occupational Safety and Health [NIOSH]. NIOSH manual of analyticsl methods (NMAM) in hippuric and methyl hippuric acids in urine: method 8301. US: National Institute for Occupational Safety and Health; 2003. p.5
14. Borgie M, Garat A, Cazier F, Delbende A, Allorge D, Ledoux F, et al. Traffic-related air pollution. A pilot exposure assessment in Beirut, Lebanon. Chemosphere. 2014 Feb; 96: 122-8. doi: 10.1016/j.chemosphere. 2013.09.034
15. Ongwandee M, Chavalparit O. Commuter exposure to BTEX in public transportation modes in Bangkok, Thailand. J Environ Sci (China). 2010; 22(3): 397-404. doi: 10.1016/s1001-0742(09)60121-2
16. Som D, Dutta C, Chatterjee A, Mallick D, Jana TK, Sen S. Studies on commuters' exposure to BTEX in passenger cars in Kolkata, India. Sci Total Environ. 2007 Jan; 372(2-3): 426-32. doi: 10.1016/j.scitotenv. 2006.09.025
17. Lan TT, Minh PA. BTEX pollution caused by motorcycles in the megacity of HoChiMinh. J Environ Sci (China). 2013 Feb; 25(2): 348-56. doi: 10.1016/s1001 -0742(12)60045-x
18. Ruangtrakul S, Prueaksasit T, Morknoy D. Health risk assessment of tollway station workers exposed to BTEX via Inhalation in Bangkok. Journal of Environmental Management. 2013; 9: 1-22.
19. Violante FS, Barbieri A, Curti S, Sanguinetti G, Graziosi F, Mattioli S. Urban atmospheric pollution: personal exposure versus fixed monitoring station measurements. Chemosphere. 2006 Sep; 64(10): 1722-9. doi: 10.1016/j.chemosphere.2006.01.011
20. U.S. Department of Labor, Occupational Safety and Health Administration. OSHA Info Sheet. United States: Occupational Safety and Health Administration; 2010.
21. Panev T, Popov T, Georgieva T, Chohadjieva D. Assessment of the correlation between exposure to benzene and urinary excretion of t, t-muconic acid in workers from a petrochemical plant. Int Arch Occup Environ Health. 2002 Oct; 75(Suppl): S97-100. doi: 10.1007/s00420-002-0388-3

22. Siqueira ME, Paiva MJ. Hippuric acid in urine: reference values. Rev Saude Publica. 2002 Dec; 36(6): 723-7.
23. Veulemans H, Masschelein R. Experimental human exposure to toluene, III. Urinary hippuric acid excretion as a measure of individual solvent uptake. Int Arch Occup Environ Health. 1979 Mar; 43(1): 53-62.
24. Lin CC, Lin C, Hsieh LT, Chen CY, Wang JP. Vertical and diurnal characterization of volatile organic compounds in ambient air in urban areas. J Air Waste Manag Assoc. 2011 Jul; 61(7): 714-20. doi: 10.3155/1047-3289.61.7.714
25. Thaiwat W. Estimate of particulate matter distribution from large scaled construction project for air quality index assessment. Chaing Mai: Chiang Mai University; 2009.