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 µg/g Cr) [14]. Meantime, the median of HA concentration in this study was also lower than parking workers in Bangkok, Thailand (0.269 µg/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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