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Original Research

Volatile organic compounds exposure and health risks among street venders in urban area, Bangkok

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Summary

Air pollution has been for a long time a dang er to human health and ecosystems. Many of the world's large cities today have bad air quality and can have a lot of health problems because of air pollution. Health risk of volatile organic compounds (VOCs: benzene, toluene, ethylbenzene and xylene (BTEX) and carbonyl compounds; CCs) exposures and their associations with non-specific symptoms of street venders at main roadsides were assessed in Pathumwan Area, central Bangkok, Thailand. A questionnaire was performed for characteristics and non-specific symptoms of street venders. Ambient air and personal air samples were collected at 5 sites of main roadsides and street venders for 8 h during work time. They were collected using 2,4 DNPH cartridge for carbonyl compounds (CCs) by HPLC/UV and activated charcoal tube for BTEX analyses by GC/FID. The results of this study showed that ambient air and personal air samples were not significant different. The life time cancer risk of street venders of benzene, ethylbenzene, formaldehyde and acetaldehyde exposures were 3.12E-06, 8.00E-08, 3.20E-06 and 6.02E-07 which total cancer risk was higher than acceptable limited. But hazard quoteint (HQ) ranges of benzene, xylene, formaldehyde, acetaldehyde and propionaldehyde exposures were lower than 1. The total cancer risk (7.00E-06) of these workers was higher than acceptable limited but hazard index (HI) was lower than limited value. The prevalence of headache, fatigue, dizziness and throat irritation symptoms of street venders were 58.0%, 47.8%, 26.5% and 24.6% respectively which most of them were associated with VOCs exposures.

INTRODUCTION

Thailand presently faces many environmental problems such as water, soil and air pollutions. The three major sources of air pollution are vehicle emissions, biomass burning in rural and industrial discharges in industrialized zones [1]. Bangkok, the capital city of Thailand, is one of the most densely populated places in the world, particularly from the emission of traffic vehicles [2]. Volatile organic compounds (VOCs) are organic compounds whose composition makes it possible for them to evaporate under normal atmospheric. Examples are polycyclic aromatic hydrocarbons (PAHs) and carbonyl compounds, which contribute to the most serious air pollution problems. VOCs are major source of ambient air pollutants in Bangkok [3], especially along the congested roadsides where the air qualities are generally below the standard. They have been demonstrated to be active in the formation of photochemical smog and ground-level ozone production [4]. Several VOCs found in the urban air [5] are classified as carcinogenic compounds, for examples benzene, ethylbenzene, formaldehyde and acetaldehyde [6, 7, 8]. Exposures to VOCs commonly resulted in either acute effects, such as eye, nose, throat and skin irritation [9] or chronic effects, such as liver and kidney damage which lead to liver enzyme elevation and lipid metabolism changes [10].

Study on the motor vehicle exhaustion revealed that it is the source of carbonyl compounds (CCs) and BTEX (benzene, toluene, ethylbenzene and xylene) emission, especially in the urban areas [11]. The CCs are the major organic compunds involved in photochemical air pollution [12]. BTEX are in a class of chemicals known as of VOCs, are found in petroleum hydrocarbons, such as gasoline, and other common environmental contaminants [13]. They typically make up about 18% of gasoline. Xylene has 3 isomers of m-xylene, p-xylene and o-xylene [14] which have potential synergistic effects in liver, kidney and lung microsomes [15]. Direct and continuing exposures to motor vehicle exhaustion, either to VOCs of CCs and BTEX, are the major concerns to human health, especially among the street venders. In 2007, there were more than 16,000 registered street vending businesses in Bangkok Metropolitan Administration (BMA). However, the number should be higher when accounted for the unregistered businesses [16]. Therefore, it is our main objective to assess any health risks of the street venders along the main roadsides in district, urban area, Bangkok, Thailand.

METHODOLOGY

Study area

Ambient air and personal air samples were collected at Pathumwan area roadsides (from the main traffic road of Rama road 1, Phyathai road and Henrydunant road which are in Chulalongkorn University area). The air collections are adjacent to Maboonklong, Siam square, Siam discovery and Paragon Centers which leads to the BTS Skytrain station. The traffic volume of the road is extremely high per day. Ten air-quality monitoring collections chosen for urban data comparison were located at CPC (Community Pharmacy Clerkship), BBL (Bangkok Bank Public Company Limited), KTB (Krung Thai Bank Public Company Limited), SCB (Siam Commercial Bank Public Company Limited) and FS (Faculty of Science) as shown in Figure 1. Personal–quality monitoring collections of 20 street venders comparison were located at the same areas of air-quality collections.

Inclusion criteria of volunteers

All workers were healthy and had worked for more than three months. Age was more than 18 years old. They were provided with a consent form before the study. Permission to conduct cancer risk assessment from human subjects in this study was approved by the Ethical Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University.

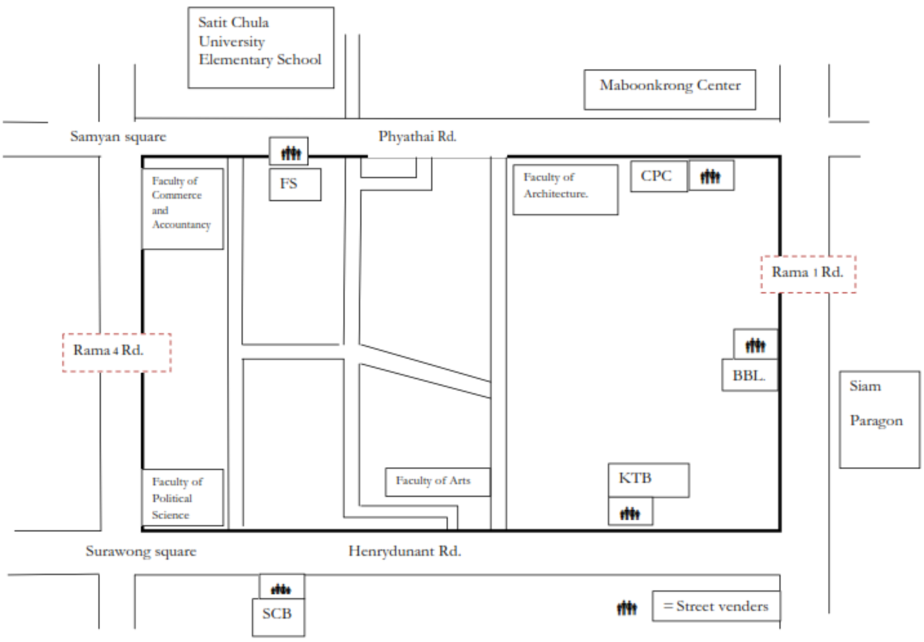

Figure 1. Site of ambient air and personal air collections

Sampling and analysis

Ambient air and personal air samples of street venders were collected through the active sampling method for 8 h during the hours of 8.00.-16.00 by the sampling train system consisting of a 2,4 DNPH cartridge (for CCs) and activated charcoal tube (for benzene, toluene, ethylbenzene and xylene) connected to a low flow personal air pump. Both cartridge and charcoal tube were kept at 4°C during transportation to the laboratory and were stored in a refrigerator for further analysis. All samples were collected between September and October 2012.

For BTEX analysis [17] benzene, toluene, ethylbenzene and xylene activated charcoal was extracted with carbon disulfide (CS_2), and the sample solution was then analyzed by GC/FID. The initial oven temperature was set set to 40 °C, increased at a rate of 10 °C/min to 100 °C, and held at that temperature for 2 min; FID temperature was set at 225 °C. The carrier gas was He pushed at a flow rate of 1.0 mL/min. BTEX levels were analyzed under the relative intensity of chromatographic signal for 20 min.

For carbonyl compounds analysis [18], the 2,4-DNPH cartridge was extracted immediately after sample collection, and was eluted with acetonitrile (ACN) and analyzed formaldehyde, acetaldehyde, acrolein, propionaldehyde, crotonaldehyde, butyraldehyde, benzaldehyde, valeraldehyde, o-tolualdehyde, m,p-tolualdehyde, hexanaldehyde and 2,5-dimethylbenaldehyde by HPLC with a gradient mobile phase 60/40% of ACN/water at flow rate 1 mL/min. The detection was by UV detector at a wavelength of 360 nm. All samples of ambient and personal air were analyzed by duplicate with high accuracy and precision of the relative standard deviation (%RSD) less than 0.178 and the relative variance (R^2) of each standard calibration varied from 0.9963 to 0.9999.

Interview data collection

All volunteers of sixty-eight street venders on the main roadside in study sites were interviewed for their characteristics of age, weight, height, period of time working, working time a day, working time a week and current non-specific symptoms of headache, dizziness, fatigue and throat irritation. The data collection was used for cancer and non cancer risk prediction and the association of VOCs exposures and current symptoms by adjust for age, sex, BMI, period time of working, working time a day and working time a month.

Statistical analysis

All analytical measurements were performed in duplication to give value with standard error. All analyses were carried out with SPSS 17.0 for Windows statistical software package. Descriptive statistical analysis was evaluated on concentrations of parameters. Independent t-test was computed to compare between ambient and personal air concentrations. Linear regression was analyzed the association between VOCs exposures and non-specific symptoms of street venders.

Cancer and non-cancer risk calculation

The inhalation exposures were estimated in terms of Chronic Daily Intake (CDI) for cancer and Exposure Concentration (EC) for non-cancer. The calculation of CDI and EC according to Risk Assessment Guidance for Superfund (RAGS) Part A and Part F approaches, respectively can be expressed as follow:

CDI = CA x IR x ET x EF x ED/(BW x AT)

EC = CA x ET x EF x ED/AT

Where; CDI (mg/kg/d) = Chronic Daily Intake = Average Daily Dose (ADD) for non-cancer

EC (μg/m^3) = Exposure Concentration

CA (mg/m^3) = Contaminant concentration in Air

IR (m^3/h) = Inhalation Rate (0.875 m^3/h assumed for adult)

BW (kg) = Body Weight (average body weight of workers)

ET (h/d) = Exposure Time (8 h/d)

EF (d/y) = Exposure Frequency (350 d/y assumed for workers)

ED (y) = Exposure Duration (30 y)

AT (d) = Averaging Time (70 y × 365 for cancer or ED × 365 for non-cancer)

Cancer risk was evaluated by multiplying CDI by inhalation cancer slope factor (CSFi).

Hazard quotient (HQ) for non-cancer can be calculated by dividing EC by the reference concentration for inhalation (RfC), as following equations.

Cancer risk = CDI x CSFi

Risk = IUR x EC

IUR = Inhalation Unit Risk [(μg/m3)-1]

where; Cancer risk > 1.00E-6 means Carcinogenic effects of concern

Cancer risk ≤ 1.00E-6 means Acceptable level

HQ = ADD/RfD

RfD = the reference dose for inhalation

HQ = EC/(RfC x 1000 μg/mg)

where; HQ > 1 means Adverse non-carcinogenic effects of concern

HQ ≤ 1 means Acceptable level

RESULTS

Exposure assessment

The sixty-eight street venders were 25 men and 43 women which had mean age, BMI, period of working, working time a day and working time a week of street venders were 40.0 years, 24.9 kg/m^2, 5.8 years, 10.0 hrs and 6.2 days which they were not significant difference between gender (Table 1). But men had significant higher weight than women (Independent t-test, *p<0.01*).

The mean ambient of benzene, toluene, ethylbenzene, m-xylene, p-xylene and o-xylene **w**ere 15.14, 51.20, 2.96, 0.07, 5.80 and 14.66 µg/m^3 respectively while most of carbonuyl compounds of formaldehyde, acetaldehyde and o-tolualdehyde were 13.9, 7.28 and 1.71 µg/m^3 respectively (Table 2). Ambient air BTEX and CCs concentrations were 90.46 and 23.83 µg/m^3 The average ambient air concentration of VOCs exposure was 114.29 µg/m^3 which the highest concentration was at FS.

Table 1. Characteristic of Street Venders

Characteristic	Men (n=25)	Women (n=43)	Total Workers (n=68)
	Mean ± SD	Mean ± SD	Mean ± SD
Age (year)	39.1 ± 11.8	40.4 ± 11.8	40.0 ± 1.2
Weight (kg)	69.5 ± 14.3 **	60.2 ± 10.9 **	63.88 ± 1.30
BMI (kg/m^2)	24.9 ± 4.2	24.7 ± 4.7	24.9 ± 4.6
Period of Working (year)	6.8 ± 6.9	5.4 ± 5.3	5.8 ± 5.9
Working time a day (hours)	10.4 ± 3.3	9.7 ± 1.9	10.0 ± 2.5
Working time a week (days)	6.1 ± 0.4	6.2 ± 0.7	6.2 ± 0.6

** Significant difference between men and women at *p<0.01*

Table 2. Quantitation of Volatile organic Compounds (VOCs) in Ambient Air

Volatile organic Compounds (VOCs)	CPC	BBL	KTB	SCB	FS	Total
	Mean (µg/m^3)	Mean (µg/m^3)	Mean (µg/m^3)	Mean (µg/m^3)	Mean (µg/m^3)	Mean ± SD (µg/m^3)
Benzene	18.30	15.72	7.56	12.32	21.78	15.14 ± 5.47
Toluene	59.00	36.25	9.00	25.63	126.12	51.20 ± 45.64
Ethylbenzene	2.22	5.13	1.70	3.06	2.67	2.96 ± 1.31
m-Xylene	1.20	0.00	0.00	1.44	0.88	0.70 ± 0.67
p-Xylene	0.15	9.36	4.95	13.91	0.63	5.80 ± 5.87
o-Xylene	9.98	22.26	18.36	20.84	1.85	14.66 ± 8.60
Sum of BTEX	90.87	88.72	41.57	77.21	153.92	90.46 ± 40.61
Formaldehyde	10.23	16.31	3.76	11.88	8.19	13.90 ± 4.62
Acetaldehyde	4.77	5.28	2.87	21.10	3.44	7.28 ± 7.67
Propionaldehyde	0.79	1.10	0.43	0.75	0.58	0.85 ± 0.25
Crotonaldehyde	0.38	0.27	3.44	0.16	0.10	1.00 ± 1.44
Butyraldehyde	0.15	0.82	0.18	1.72	0.36	0.27 ± 0.66
Benzaldehyde	0.15	0.31	0.48	0.54	0.21	0.36 ± 0.17
Isovaleraldehyde	0.21	0.58	0.32	0.65	0.21	0.37 ± 0.21
Valeraldehyde	0.00	0.72	0.00	0.54	0.31	0.39 ± 0.21
o-Tolualdehyde	1.20	0.00	2.44	0.00	0.41	1.71 ± 1.02
m,p- Tolualdehyde	0.00	0.00	0.00	0.00	0.00	0.00 ± 0.05
Hexanaldehyde	0.00	0.96	0.00	2.58	1.75	0.28 ± 0.81
2,5-Dimethylbenal dehyde	0.51	0.41	0.00	4.30	0.31	1.05 ± 1.95
Sum of CCs	18.39	26.76	13.92	44.22	15.87	23.83 ± 11.10
Total Exposures	109.24	115.48	55.49	121.43	169.80	114.29 ± 36.38

The mean personal exposure of benzene, toluene, ethylbenzene, m-xylene, p-xylene and o-xylene of street venders were 11.16, 21.12, 2.08, 0.70, 5.80, 11.27 and 49.59 μg/m^3 respectively while most of carbonyl compounds of formaldehyde, acetaldehyde, o-tolualdehyde were 15.40, 7.36 and 1.72 μg/m^3 respectively (Table 3). Personal BTEX and CCs concentrations were 49.59 and 28.90 μg/m^3. The average personal air concentration of VOCs exposure was 78.50 μg/m^3 which the highest concentration was also at FS. The personal exposure were not significant different from ambient air concentrations.

Cancer risk and non-cancer assessments

The reference values for carcinogenic and non-carcinogenic substances were shown in Table 4. The life time cancer risk ranges of street vender of benzene, ethylbenzene, formaldehyde and acetaldehyde were 3.12E-06, 8.00E-08, 3.20E-06, and 6.02E-07 which cancer risk of benzene and formaldehyde were higher than acceptable limited. Total cancer risk of street venders was 7.00E-06. The HQs of benzene, xylene, formaldehyde, acetaldehyde and propionaldehyde were higher than 1 (Table 5) So, HI (Hazard Index = sum of HQ) of street vender was 1.99E+02 which was higher than acceptable limited (HI >1).

Table 3. Quantitation of Volatile organic Compounds (VOCs) in Personal Air Exposures

Volatile organic Compounds (VOCs)	CPC	BBL	KTB	SCB	FS	Total
	Mean (μg/m^3)	Mean (μg/m^3)	Mean (μg/m^3)	Mean (μg/m^3)	Mean (μg/m^3)	Mean ± SD (μg/m^3)
Benzene	10.30	14.94	7.63	5.67	17.26	11.16 ± 5.47
Toluene	18.53	9.20	12.75	33.53	31.57	21.12 ± 45.64
Ethylbenzene	1.25	1.60	2.28	2.52	2.73	2.08 ± 1.31
m-Xylene	0.73	0.53	0.69	1.12	1.40	0.70 ± 0.67
p-Xylene	2.61	2.54	5.55	3.47	1.24	5.80 ± 5.87
o-Xylene	6.85	7.15	15.82	13.28	13.23	11.27 ± 8.60
Sum of BTEX	40.26	35.96	44.73	59.58	67.44	49.59 ± 13.37
Formaldehyde	22.91	13.24	8.93	13.37	8.19	15.40 ± 5.16
Acetaldehyde	7.74	6.26	5.77	4.32	12.71	7.36 ± 4.62
Propionaldehyde	1.04	0.91	1.00	0.72	0.73	0.88 ± 0.15
Crotonaldehyde	0.82	0.60	0.44	1.94	1.05	0.97 ± 0.59
Butyraldehyde	0.66	0.41	0.62	0.40	1.06	0.63 ± 0.27
Benzaldehyde	0.41	0.28	0.30	0.39	0.46	0.37 ± 0.08
Isovaleraldehyde	0.23	0.22	0.40	0.36	0.50	0.34 ± 0.12
Valeraldehyde	0.19	0.19	0.46	0.46	0.50	0.36 ± 0.15
o-Tolualdehyde	1.74	1.47	1.47	1.95	1.95	1.72 ± 0.24
m,p-Tolualdehyde	0.48	0.48	0.48	0.48	0.48	0.48 ± 0.00
Hexanaldehyde	1.47	1.47	1.21	1.21	1.90	1.45 ± 0.28
2,5-Dimethylbenal dehyde	0.86	0.69	0.55	0.55	2.43	1.02 ± 0.80
Sum of CCs	38.55	26.22	21.63	26.15	31.96	28.90 ± 6.52
Total Exposures	78.82	62.18	66.35	85.74	99.39	78.50 ± 15.02

Table 4. The reference values for carcinogenic and non-carcinogenic substances

Chemicals	CAS no.	Inhalation RfCa (mg/m^3)	Inhalation Cancer Slope Factor (mg/kg-d)$^{-1}$	Carcinogenicity[c]
Carcinogenic Substances				
Benzene	71-43-2	3.00×10^{-2} [b]	2.73×10^{-2} [a]	Group A
Ethylbenzene	100-41-4	1.00 [a]	3.85×10^{-3} [b]	Group B2
Formaldehyde	50-00-0	9.83×10^{-3}	2.1×10^{-2} [c]	Group B1
Acetaldehyde	75-07-0	9.00×10^{-3}	1.0×10^{-2} [c]	Group B2
Non-Carcinogenic Substances				
Toluene	108-88-3	5 [a,b]	-	-
Xylenes (m-xylene)	108-38-3	0.1 [a,b]	-	-
(p-xylene)	106-42-3	0.1 [a,b]		
(0-xylene)	95-47-6	0.1 [a,b]		
Propionaldehyde	123-38-6	8×10^{-3} [a,b]	-	-
Valeraldehyde	110-62-3	4.2×10^{-1} [c]		

[a]Integrated Risk Information System (IRIS)
[b]The Risk Assessment Information System (RAIS)
[c]California Office of Environmental Health Hazard Assessment (OEHHA)

Table 5. Cancer Risk and Hazard Quotient (HQ) Assessments of Street Venders

Parameter	CDI (mg/kg.d)	Average Life Time Cancer Risk	EC (µg/m^3)	Average HQ
Benzene	1.20E-04	3.12E-06	7.94E-01	2.65E-02
Toluene	-	-	1.50E+00	3.00E-04
Ethylbenzene	2.23E-05	8.00E-08	1.48E-01	1.48E-04
Xylene	-	-	4.34E-01	4.34E-03
Formaldehyde	1.61E-04	3.20E-06	1.06E+00	1.09E-01
Acetaldehyde	6.21E-05	6.02E-07	4.11E-01	4.57E-02
Propionaldehyde	-	-	1.04E-01	1.30E-02
Valeraldehyde	-	-	3.77E-02	8.98E-05
Sum of risk	3.65E-04	7.00E-06	4.58E+00	1.99E-01

Table 6. Association between VOCs and current symptoms of Street Venders

Dependent symptoms	Independent VOCs	Prevalence %	Linear regression model results*		
			Standardize Coefficient	95% CI	p-value
Headache					
	Ethylbenzene		-0.254	-0.216 to -0.002	0.054
	Acetylbenzene		-0.269	-0.054 to -0.001	0.044
Fatigue		47.8			
	-	-	-	-	-
Dizziness		26.5			
	Benzene		0.313	0.006 to 0.050	0.015
	Xylene		-0.305	-0.021 to -0.002	0.014
	Formaldehyde		0.313	0.004 to 0.034	0.013
Throat irritation		24.6			
	Benzene		0.359	0.010 to 0.053	0.005
	Toluene		0.251	0.000 to 0.005	0.004
	Formaldehyde		0.273	0.001 to 0.031	0.003

*Adjust for age, sex, BMI, period time of working, working time a day and working time a month

Non-specific symptoms

The prevalence of headache, fatigue, dizziness and throat irritation symptoms of street venders were 58.0%, 47.8%, 26.5% and 24.6% respectively (Table 6). In addition, headache showed association with ethylbenzene and acetaldehyde *($p<0.05$)* while dizziness was also associated with benzene, xylene and formaldehyde *($p<0.05$)*. Throat irritation was strong associated with benzene, toluene and formaldehyde *($p<0.01$)* but fatigue was not associated with any VOCs.

Non-specific symptoms

The prevalence of headache, fatigue, dizziness and throat irritation symptoms of street venders were 58.0%, 47.8%, 26.5% and 24.6% respectively (Table 6). In addition, headache showed association with ethylbenzene and acetaldehyde *($p<0.05$)* while dizziness was also associated with benzene, xylene and formaldehyde *($p<0.05$)*. Throat irritation was strong associated with benzene, toluene and formaldehyde *($p<0.01$)* but fatigue was not associated with any VOCs.

DISCUSSION

Most characteristics studies of street venders were not significant difference except weight which men was higher than women (Independent t-test, $p < 0.01$). So, the life time cancer risk of women should be higher than men. The highest VOCs of ambient and personal exposures were toluene and benzene which toluene and benzene ratios (T/B) of ambient air and personal exposure were 3.38 and 1.89 respectively. The T/B ratio can act as an indicator of traffic emissions when this ratio is within the range of 1.5-4.3, as reported by previous studies [19, 20]. The T/B ratio is more useful to characterization of vehicular emission source than absolute concentration of pollutants [21]. The result of ambient air T/B ratio in this study was lower than previous study of Bangkok (10.33) [22]. This study showed that ambient air benzene at roadside was 15.14 ± 5.47 µg/m^3 which was lower than previous report [23]. While formaldehyde/ acetaldehyde ratios (F/A) of ambient and personal exposures were 1.91 and 2.09 respectively. This study showed ambient air F/A was higher than roadside concentration of Bangkok in 2010 [24] and in Hong Kong [25] (1.27 to 1.35). CCs are the common constituents in the urban atmosphere and are also important precursors to ozone and other toxic products such as peroxyacyl nitrates [26]. Vehicle emissions are a major source of carbonyls in outdoor. And the higher formaldehyde and acetaldehyde concentrations are due to the high diesel traffic volume and atmospheric photooxidation [25]. Total VOCs of ambient and personal air exposure was not significantly difference ($p = 0.065$) but ambient air exposure trended higher than personal exposure. It may be caused of activity of workers. The highest concentration of ambient air and personal exposures at FS may cause of nearly bus station.

The life time cancer risk of street venders was higher (7.00E-06) than acceptable limited (1.00E-06) which was mainly caused by benzene and formaldehyde. As well as HI (1.99E-01) was lower than acceptable limited (1.00). The major effects from chronic (long-term) inhalation exposure to humans and animals consist of general respiratory congestion and eye, nose, and throat irritation [27]. So, these workers have both cancer risk and adverse effects from VOCs exposures. Health risk assessment in this study was underestimated because there were various air pollutants from sources of emission. It should manage to reduce emission of air pollutant for people or workers to expose them. Non-specific symptoms of headache, fatigue, dizziness and throat irritation symptoms of street venders were 58.0%, 47.8%, 26.5% and 24.6% respectively which higher than previous study in gasoline station workers [28]. Most of non-specific symptoms in this study were associated with VOCs exposure except fatigue. Chronic fatigue syndrome (CFS) is an illness characterized by persistent fatigue and significant associated disability, but without evident physical or psychological disorder to explain the problem [29]. The previous study presented that mitochondrial dysfunction is as the immediate cause of CFS symptoms [30, 31].

CONCLUSIONS

VOCs include a variety of chemicals some of which may have harmful effects on human health and the environment. Air quality has become an issue of major concern and considered to be related to motor vehicle emissions. BTEX and CCs are common constituents in the urban atmosphere which may effect people or worker exposures. Street venders are one of occupational workers who are exposed to VOCs. They had cancer risk at 7.00E-06 which was higher than acceptable limited. And non-cancer risk (HI) was 1.99E-01 which was lower than acceptable limited. The non-specific symptom prevalence of headache, fatigue, dizziness and throat irritation were 58.0%, 47.8%, 26.5% and 24.6% respectively. Most of these symptoms were associated with VOCs.

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