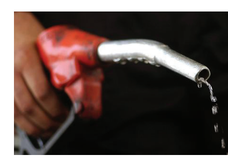
Original Article

Occupational Exposure of Gasoline Station Workers to BTEX Compounds in Bangkok, Thailand

T Tunsaringkarn, W Siriwong, A Rungsiyothin, S Nopparatbundit

The College of Public Health Sciences, Chulalongkorn University, Bangkok 10330, Thailand



Abstract

Background: Gasoline station workers are exposed to volatile organic compounds such as benzene, toluene, ethylbenzene and xylene (BTEX).

Objectives: To determine the level of exposure to BTEX compounds among gasoline station workers and measure the roadside concentrations of these compounds in the inner and outer areas of Bangkok, Thailand.

Methods: 49 workers at 6 gasoline stations in the inner and outer areas of Bangkok participated in this study. Samples of ambient air were collected from the area near gas pumps at each station and at the roadside in front of the gas stations by charcoal tubes. All samples were analyzed for BTEX compounds by gas chromatography-flame ionized detector (GC-FID).

Results: The mean BTEX concentration in gas stations was slightly higher than that of the roadside; there was no significant difference in the concentration between inner and outer areas. The mean lifetime cancer risks for workers exposed to benzene and ethylbenzene for 30 years were estimated at 1.75×10^{-4} and 9.55×10^{-7}. The estimated hazard quotients for BTEX compounds were 0.600, 0.008, 0.007 and 0.002, respectively. The most prevalent symptoms of workers were headache (61%), fatigue (29%) and throat irritation (11%), respectively. Exposure to benzene and toluene was significantly associated with fatigue ($p<0.05$).

Conclusion: Exposure to BTEX compounds would increase the risk of cancer in gasoline station workers. Exposure to benzene and toluene may cause fatigue.

Keywords: Benzene; Toluene; Ethylbenzene; Xylene; Gasoline; Risk; Occupational

Introduction

Benzene, toluene, ethylbenzene and xylene (BTEX) are volatile organic compounds. Benzene and ethylbenzene are well known carcinogens.[1-2] Benzene can also affect hematopoietic system, the central nervous system and the reproductive system.[3-5] Toluene can affect the reproductive and the central nervous systems too.[6] Ethylbenzene and xylene can have respiratory and neuro-

Cite this article as: Tunsaringkarn T, Siriwong W, Rungsiyothin A, Nopparatbundit S. Occupational Exposure of Gasoline Station Workers to BTEX Compounds in Bangkok, Thailand. *The International Journal of Occupational and Environmental Medicine* 2012;**3**:117-25.

Correspondence to Tanasorn Tunsaringkarn, The College of Public Health Sciences, Chulalongkorn University, Bangkok 10330, Thailand
Tel: +66-2-218-8156
Fax: +66-2-253-2395
E-mail: tkalayan@chula.ac.th

Received: Dec 30, 2011
Accepted: Feb 28, 2012

TAKE-HOME MESSAGE

- Air pollution may cause serious health problems including respiratory diseases, cancer and cardiovascular diseases.
- Exposure to BTEX compounds is associated with serious health problems not only in those working in petrochemical industries but also in other people who live near the plants or commute to work.
- Contamination with BTEX is mostly due to uncontrolled industrial activity and lack of the awareness of workers.
- Exposure to BTEX compounds was not significantly different between the inner and outer areas for both gasoline stations and the roadside in front of the stations.
- The cancer risk in each year can be translated into 175 new cancer cases per 1 000 000 workers in the gasoline station and 87 new cancer cases per 1 000 000 at people exposed to BTEX compounds at the roadside.

For more information on occupational exposure of petroleum depot workers to BTEX compounds see www.theijoem.com/ijoem/index.php/ijoem/article/view/110

logical effects.[7-8] The BTEX compounds can be produced during various oil and gas operation activities including flaring, venting and operating various types of machinery. Gasoline station workers are directly exposed to BTEX compounds through inhalation, ingestion and dermal contacts. However, the main route of exposure is the respiratory system.

There is a serious problem of air pollution in Bangkok, Thailand, that is mainly caused by the rapid increase in the number of gasoline stations and gasoline consumption that might lead to health problems in workers.[9-10] We conducted this study to determine the level of exposure to BTEX compounds among gasoline station workers and measure the roadside concentrations of these compounds in the inner and outer areas of Bangkok, Thailand. We also assessed the associated risk of health problems among studied workers.

Materials and Methods

The study was conducted in six gas stations of which four were located on Sukhumvit Road (soi 58, 59, 62/1 and 103/2), two stations were located on Bangna Road (at kilometer 4 and 6), representing the inner and outer areas of Bangkok, respectively. All studied stations were near the highway.

The study population consisted of 49 workers (38 men and 11 women) working in six gasoline stations in the inner (Sukhumvit Road) and outer (Bangna Road) areas. All workers aged more than 18 years and had worked for more than three months.

This study was approved by the Ethical Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University.

The exposure to BTEX in ambient air was monitored during work shifts of eight hours (6:00–14:00) by active sampling with a charcoal tube at a flow rate of 100 mL/min. Two air samples taken from the personnel working area and one ambient air sample at the roadside in front of the gasoline station were collected in each station. All air samples were kept at 4 °C while transported to the laboratory. The charcoal tube was extracted with carbondisulphide (CS_2), and the sample solution was then analyzed by gas chromatography (GC) with an FID detector (Varian, CP3800) and column CP 52 wax (30 m × 0.25 µm × 0.25 mm). The initial oven temperature was 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 (make up: He 28 mL/min, air 300 mL/min, H_2 30 mL/min). 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. The limit of detection (LOD) of benzene, toluene, ethylbenzene and xylene were set to 0.06, 0.03, 0.05, and 0.03 ppm (mg/L), respectively and the average coefficient of determination (r^2) was 0.9981.

Fourty-nine workers were asked face to face about their age, body mass index (BMI), length of service at gasoline station work, days of work per week, hours of work per day, and any symptoms aggravating during their work shift.

Cancer and non-cancer risk calculation

The lifetime cancer risk assessment was calculated according to the following equation:

$$CDI = (CA \times IR \times ET \times EF \times ED)/(BW \times AT)$$

and

$$\text{Cancer risk} = CDI \times CSF_i$$

where CDI represents chronic daily intake (mg/kg/day), CSF_i cancer slope factor $(mg/kg/day)^{-1}$, CA contaminant concentration in air (mg/m^3 or ppm), IR inhalation rate (0.875 m^3/hr assumed for adult), BW body weight (57.8 kg, the average BW of workers), ET the exposure time (9.9 hrs/day for workers), EF exposure frequency (350 days/year for gasoline station workers), ED exposure duration (presumably 30 years for workers), and AT is the average time (70 years).

A cancer risk of > 10^{-6} was considered "carcinogenic effects of concern;" a value $\leq 10^{-6}$ was considered an "acceptable level."

Risk assessment for non-malignant conditions was expressed by hazard quotient (HQ) calculated according to the following equation:[11]

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

$$HQ = EC/RfC$$

where EC, and RfC represent exposure concentration (µg/m^3 or ppb), reference exposure concentration (mg/m^3 or ppm), respectively.

An HQ of >1 was considered "adverse non-carcinogenic effects of concern;" a value HQ of ≤1 was considered "acceptable level."

The non-cancer health impact was expressed as the hazard index determined by the summation of all HQs at a certain location.

Statistical Analysis

All analyses were done by SPSS® 17.0 for Windows®. Normality of data distribution was assessed by Kolmogorov-Smirnov test. The correlation between BTEX concentrations was computed by Pearson's correlation. The association between BTEX exposure and symptoms was evaluated by linear regression analysis. A p value <0.05 was considered statistically significant.

Results

Basic characteristics of studied workers are presented in Table 1. All the studied parameters but the days of work per week did not significantly different between men and women; the mean±SD days of work per week for women (6.8±0.6) was significantly ($p<0.05$) higher than men (6.3±0.5).

The mean concentration of BTEX compounds of gasoline station workers was not significantly different between the inner and outer areas (Table 2). The mean concentration of BTEX compounds in ambient air measured at the roadside was also not significantly different between the inner and outer areas (Table 2).

The B/T ratio at gasoline station and the roadside were 0.48 and 0.47, re-

Table 1: Basic characteristics of gasoline workers

Parameter	Men (n=38) Mean±SD	Women (n=11) Mean±SD	Total Mean±SD	p value*
Age (yrs)	27.6±7.7	29.9±10.2	28.1±8.0	NS†
Weight (kg)	59.7±8.8	58.9±17.0	59.8±10.5	NS
BMI (kg/m^2)	22.8±2.7	23.9±5.7	23.0±3.7	NS
Length of service at gasoline station (yrs)	2.9±1.6	3.1±3.1	2.9±2.5	NS
Days of work per week	6.3±0.5	6.8±0.6	6.4±0.6	<0.05
Hours of work per day	10.2±1.6	9.0±2.0	9.9±1.8	NS

*Difference between men and women, †NS: Not significant

spectively, *i.e.*, the highest emissions of volatile organic compounds were attributed to toluene and benzene. We found a good Pearson's correlation coefficient (r) among the mean concentrations of BTEX in all gas stations workers; 0.838 between benzene and toluene ($p=0.001$), and 0.994 between ethylbenzene and xylene ($p<0.001$). At the roadside, a good correlation was observed between benzene and ethylbenzene ($r=0.845$, $p<0.05$), as well as between toluene and ethylbenzene ($r=0.845$, $p<0.05$).

The mean lifetime cancer risks for exposure of gasoline station workers to benzene and ethylbenzene were estimate at 1.75×10^{-4} and 9.55×10^{-7}, respectively (Table 3); the cancer risk for benzene was more than acceptable limit of $10\times^{-6}$. The cancer risk for workers in gasoline stations was slightly higher than the risk at the roadside where the mean lifetime cancer risk for exposure to benzene was 8.71×10^{-5}, however, the risk for exposure to ethylbenzene at roadside (1.26×10^{-6}) was slightly higher than that for gasoline

Table 2: Mean±SEM concentrations of BTEX compounds (ppb) in different areas

Parameter	Benzene	Toluene	Ethylbenzene	Xylene
Inner Area				
Gasoline workers	92.75±16.77	195.34±61.04	6.25±4.29	11.65±4.45
Roadside	70.08±9.81	162.23±55.34	0.01±0.01	4.09±0.00
Outer Area				
Gasoline workers	137.53±57.89	289.35±96.84	8.25±7.60	11.47±6.58
Roadside	65.00±1.70	116.70±35.20	0.00±0.00	4.90±0.00
Average workers exposure	107.68±21.55	226.68±51.10	7.25±5.95	11.56±5.51
Average roadside exposure	68.38±6.31	147.05±37.41	0.01±0.01	4.50±0.00

Table 3: The average BTEX exposure and the associated risks among gasoline station workers

Site	BTEX compounds	CDI (mg/kg/day)	EC (mg/m³)	Non-cancer risk (HQ)	Cancer risk
Gasoline station workers	Benzene	6.41×10^{-3}	1.81×10^{-2}	0.600	1.75×10^{-4}
	Toluene		3.82×10^{-2}	0.008	
	Ethylbenzene	2.48×10^{-4}	0.70×10^{-3}	0.007	9.55×10^{-7}
	Xylene		1.58×10^{-3}	0.002	
Total risk				0.617	1.76×10^{-4}
Roadside	Benzene	3.19×10^{-3}	1.15×10^{-2}	0.380	8.71×10^{-5}
	Toluene		2.48×10^{-2}	0.005	
	Ethylbenzene	3.24×10^{-4}	0.93×10^{-3}	0.009	1.26×10^{-6}
	Xylene		1.56×10^{-3}	0.002	
Total risk				0.396	8.84×10^{-5}

station exposure (9.55×10^{-7}). The cancer risks for exposure to ethylbenzene—either in gasoline station or roadside—were within the acceptable limits.

The non-cancer risks for exposure to BTEX compounds, as assessed by HQ, were within acceptable limits for humans (HQ<1, Table 3). In addition, the hazard index, determined by the adding up the HQs at a certain location of gasoline station and roadside, was 0.617 and 0.396, which were <1.

The most common complaint reported by gasoline station workers was headache followed by fatigue and throat irritation (Table 4). There was no difference in the frequency of symptoms between men and women. Exposure to benzene and toluene was positively associated with fatigue ($p<0.05$, Table 5).

Discussion

All of the basic characteristics studied in gasoline station workers except days of work per week, were not significantly different between men and women. Women worked more days per week than men as was the common behavior of workers.[12] Exposure to BTEX compounds was not significantly different between the inner and outer areas for both gasoline stations and the roadside in front of the stations. However, exposure to BTEX compounds was slightly higher in the gas stations than

Table 4: Frequency of symptoms among gasoline station workers

	n (%)		
Symptom	Men (n=38)	Women (n=11)	Total (%)
Headache	18 (47)	5 (45)	23 (47)
Fatigue	10 (26)	1 (9)	11 (22)
Throat irritation	2 (5)	2 (18)	4 (8)
Nose irritation	2 (5)	1 (9)	3 (6)
Nausea	0 (0)	2 (18)	2 (4)
Dizziness	0 (0)	1 (9)	1 (2)
Depression	0 (0)	1 (9)	1 (2)

Table 5: Association between BTEX exposure and frequency of symptoms among gasoline station workers

Independent parameter Compound	Dependent Parameter Symptom	Unadjusted prevalence (%)	Logistic regression analysis OR (95% CI)*
Benzene			
	Headache	61	0.996 (0.980–1.012)
	Fatigue	29	0.964 (0.933–0.997)
	Throat irritation	11	0.980 (0.942–1.019)
Toluene			
	Headache	61	0.998 (0.991–1.005)
	Fatigue	29	0.990 (0.980–0.999)
	Throat irritation	11	0.994 (0.981–1.007)

*Adjusted for sex, age, BMI, length of service, days of work per week, and hours of work per day at gasoline station

the roadside area that means the main sources of benzene and toluene should be contaminations while the source of ethylbenzene and xylene are most probably emissions from vehicle exhausts.[13] We showed that the level of ethylbenzene was nearly zero for both studied areas—ethylbenzene is volatile.[7] The B/T ratios at gasoline station and the roadside were 0.48 and 0.47, respectively. The lower than one ratio was attributed to the higher toluene concentration detected; such a high level of toluene cannot be achieved by mobile sources and it should have a specific source in the area.[14]

Benzene, an important component of gasoline, was found at a lower level in gasoline stations (107.68 µg/m³) than that reported earlier in other studies (308–852 µg/m³)[15] which might be due to the change in the formulation of gasoline. However, the concentration of benzene at roadside (68.38 µg/m³) was higher than the a previous report (15.1–42.4 µg/m³)[16] which might be attributed to the increasing number of the transporting vehicles. The measured concentration of benzene in the ambient air was much higher than the Thailand's annual average levels of volatile organic compounds in the ambient air limit of 1.70 µg/m³.[17] However, the concentration of toluene in the ambient air was lower than the ACGIH limit of 188 mg/m³.[18] It may be the adverse effect of a long period of exposures.[19] The BTEX concentrations recorded were higher than those in the ambient air of gasoline stations in China (Pearl River Delta),[20] Korea (Taegu)[21] but were lower than those in India (Kolkata),[22] Peru (Trujillo),[23] United States (Mexico),[24] and Italy (Biella and Torino).[25]

The workers had an mean lifetime cancer risk for exposure to benzene that exceeded the acceptable limit of 10^{-6}. The mean lifetime cancer risk for exposure to ethylbenzene was however, in the acceptable range in both gasoline stations and the roadside. The total mean cancer risk for worker exposure and at the roadside was 1.75×10^{-4} and 8.71×10^{-5}, respectively that means that the cancer risk for workers is mainly due to benzene exposure. In Thailand, the upper limit for benzene content in gasoline is set to 3.5%; in some industrialized countries like the USA, the maximum allowable content is only 1%. Benzene is also used in many petrochemical and other chemical industries.[26] The derived mean cancer risk for gasoline station workers in this study was lower than that reported previously.[15,27,28] The cancer risk in each year can be translated into 175 new cancer cases per 1 000 000 workers in the gasoline station and 87 new cancer cases per 1 000 000 at people exposed to BTEX compounds at the roadside. Therefore, some employees like vendors on the street may also carry a risk of cancer for being exposed to BTEX compounds. These people should use personal protective equipment like mask during their working hours to reduce the exposure.

The non-carcinogenic risk of exposure to BTEX compounds, expressed as HQ, were lower than the reference hazard level of one for both gasoline station and the roadside. The hazard indices calculated for the gasoline station and roadside was 0.617 and 0.396, respectively; these reflect no adverse health effects to the bone marrow, hematological and neurological toxicities.[29-30] Some potential health effects like neurological abnormalities are mainly from exposure to benzene.

The most prevalent symptoms reported by workers were headache, fatigue and throat irritation. There was no significant difference in the frequency of these symptoms between men and women. These findings are in keeping with a previous study, which revealed that low concentrations of benzene caused drowsiness, dizziness, and headaches.[29] However, the frequency of these symptoms had increased over past years.[31] This may be due to the change in the formulation of the gasoline to gasohol and also to the increased volume of gasoline sales.[15,32,33] Neurotoxicity studies showed that benzene exposure mostly associates with headache,[34,35] however, in this study we showed that benzene and toluene exposures were significantly associated with fatigue.

A prominent feature of the chronic fatigue syndrome is that it has no certain etiology and is characterized by a persistent, debilitating fatigue resulting in a reduction of at least 50% of everyday activities. Some researchers consider the chronic fatigue syndrome as a disorder of the immune system. Various immune abnormalities have been reported in patients with this illness; these abnormalities increase the decay of the stress protein mRNAs through proteins 2-5A synthetase (2-5A) and protein kinase RNA (PKR) activity in those exposed to MTBE (methyl tertiarybutyl ether) and benzene.[36] Toluene is more rapidly absorbed; it soluble in the blood and excreted with a half life 15–20 hours; though it has chronic effect on some organs it does not harm the liver, lungs, kidneys and heart.[6,37] Toluene and benzene have synergistic effects; there was also a good correlation between toluene and benzene concentrations which was in parallel to previous studies.[38] Considering the risks described, there should be a plan to further protect the gasoline station workers.

Acknowledgements

This work was funded and supported by the Thai Fogarty ITREOH Center (D43 TW007849 NIH FIC), College of Public Health Sciences and Chulalongkorn University Centenary Academic Development Project, Chulalongkorn University.

Conflicts of Interest: None declared.

References

1. ACGIH. TLVs and BEIs. *Based on the documentation of the threshold limit values for chemical substances and physical agents & biological exposure indices.* Cincinnati, OH, USA, **2010**:13-29.

2. US EPA. *Integrated Risk Information System (IRIS)*

on Benzene. National Center for Environmental Assessment, Office of Research and Development, Washington DC, **2002.**

3. ATSDR. *Toxicological Profile for benzene.* (Draft for Public Comment). Atlanta, GA, USA, **2005.**
4. Snyder R, Witz G, Golstein BD. The toxicology of benzene. *Environ Health Perspect* 1993;**100**:293-306.
5. Inoue O, Seiji K, Watanabe T, *et al*. Mutual metabolic suppression between benzene and toluene in man. *Int Arch Occup Environ Health* 1988;**60**:15-20.
6. US EPA. Toxicological review of toluene: In support of summary information on Integrated risk information system (IRIS). 2005, Available from *www.epa.gov/iris* (Accessed October 15, 2011).
7. ATSDR. *Toxicological profile for ethylbenzene.* Atlanta, GA, USA, **2010.**
8. US EPA. Toxicological review of xylene: In support of summary information on Integrated risk information system (IRIS). 2003, Available from *www.epa.gov/iris* (Accessed October 20, 2011).
9. Ministry of Energy, Energy Policy and Planning Office. Energy Situation in Thailand 2009 (in Thai), Available from *http://new.energy.go.th/sites/all/files/situation52.pdf* (Accessed August 25, 2011).
10. Uzma N, Salar BM, Kumar BS, *et al.* Impact of organic solvents and environmental pollutants on the physiological function in petrol filling workers. *Int J Environ Res Public Health* 2008;**5**:139-46.
11. Cal/EPA. *Technical Support Document for Describing Available Cancer Potency Factors.* California, USA, **2005.**
12. Shipman T. More women than men in work within four years as Full Monty recession brings jobs revolution. 2011, Available from *www.dailymail.co.uk/news/article-1239783/More-women-men-work-4-years.html* (Accessed June 15, 2011).
13. RAIS. Toxicity Profiles RAGs A Format for Ethylbenzene – CAS Number 100414. The University of Tennessee. 2009, Available from *http://rais.ornl.gov/tox/profiles/ethylbenzene_ragsa.html* (Accessed June 25, 2011).
14. Scheff PA, Wadden RA. Receptor Modeling of Volatile Organic Compounds, 1. Emission Inventory and Validation. *Environ Sci Technol* 1993;**27**:617-25.
15. Thaveevongs P, Panyamateekul S, Prueksasit T. Exposure Risk Assessment of Volatile Organic Compounds (VOCs) of the Workers at Gas Station in Bangkok. *Engineering Journal* 2010;**2**:1-12[in Thai].
16. Leong ST, Laortanakul P. Indicators of benzene emissions and exposure in Bangkok street. *Environ Res* 2003;**92**:173-81.
17. Simachaya W. Overview of Air Quality Management in Thailand. Pollution Control. Department Ministry of Natural Resources and Environment,Thailand. Available from *http://infofile.pcd.go.th/air/AIT061109_sec5.pdf?CFID=5138686&CFTOKEN=60042639* (Accessed March 20, 2011).
18. ACGIH. *TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents. Biological Exposure Indices*. Cincinnati, OH, USA, **1999.**
19. US EPA. Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures. EPA/630/R-00/002. 2000, Available from *http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=20533* (Accessed June 26, 2011).
20. Wang XM, Sheng GV, Fu JM, *et al.* Urban roadside aromatic hydrocarbons in three cities of the Pearl River Delta, People's Republic of China. *Atmos Environ* 2002;**36**:5141-8.
21. Jo WK, Song KB. Exposure to volatile organic compounds for individuals with occupations associated with potential exposure to motor vehicle exhaust and/or gasoline vapor emissions. *Sci Total Environ* 2001;**269**:25-37.
22. Majumdar D, Dutta C, Mukherjee AK, *et al.* Source apportionment of VOCs at the petrol pumps in Kolkata, India; exposure of workers and assessment of associated health risk. *Transportation Research Part D: Trans Environ* 2008;**13**:524-30.
23. Han X. A preliminary study on traffic-related occupational exposures to PM2.5, CO, and VOCs in Trujillo, Peru. The thesis submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree Masrer of Science. Athens, Georgia, **2004.**
24. Romieu I, Ramirez M, Maneses F, *et al.* Environmental exposure to volatile organic compounds among workers in Mexico City as assessed by personal monitors and blood concentrations. *Environ Health Perspect* 1999;**107**:511-5.
25. Bono R, Scursatone E, Schiliro T, *et al.* Ambient air levels and occupational exposure to benzene, toluene, and xylenes in Northwestern Italy. *J Toxicol Environ Health, Part A* 2003;**66**:519-31.
26. Navasumrit P, Chanvaivit S, Intarasunanont P, *et*

al. Environmental and occupational exposure to benzene in Thailand. *Chem Biol Interact* 2005;**153-154**:75-83.

27. Tunsaringkarn T, Prueksasit T, Kitwattanavong M, *et al.* Cancer risk assessment of the workers exposure to benzene, formaldehyde and acetaldehyde in gasoline station, Bangkok, Thailand and investigation of theirs possible risk reduction. Proceedings of the 42nd APACPH Conference, 24-27 November **2010**, Bali, Indonesia: 318.
28. Yimrungruang D, Cheevaporn V, Boonphakdee T, *et al.* Characterization and health risk assessment of volatile organic compounds in gasoline station workers. *EnvironmentAsia* 2008;**2**:21-9.
29. US EPA. Toxicological review of benzene (non cancer effects): In support of summary information on Integrated risk information system (IRIS). 2002, Available from *www.epa.gov/iris* (Accessed November 2, 2011).
30. Rana SV, Verma Y. Biochemical toxicity of benzene. *J Environ Biol* 2005;**26**:157-68.
31. Tunsaringkarn T, Soogarun S, Rungsiyothin A, *et al.* Health status of gasoline station workers in Pathumwan area, Bangkok, Thailand, in 2002 and 2007. *J Health Res* 2011;**25**:15-9.
32. Keprasertsup C, Bashkin V, Wangwongwatana S, *et al.* Concentrations of MTBE, benzene, toluene, ethyl-benzene, and xylene in ambient air at gas stations and traffic area in Bangkok . Proceedings of the 2nd Regional Conference on Energy Technology Towards a Clean Environment 12-14 February **2003**, Phuket, Thailand.
33. Periago JF, Zambudio A, Prado C. Evaluation of environmental levels of aromatic hydrocarbons in gasoline service stations by gas chromatography. *J Chromatogr A* 1997;**778**:263-8.
34. Polakowska B. Headaches in female workers in the rubber industry exposed to benzene vapors. *Med Pr* 1985;**36**:139-44.
35. Wiwanitkit V. Headaches in subjects occupationally exposed to benzene vapors. *J Headache Pain* 2008;**9**:253-4.
36. Vojdania A, Lapp CW. Interferon-induced proteins are elevated in blood samples of patients with chemically or virally induced chronic fatigue syndrome. *Immunopharmacol Immunotoxicol.* 1999;**21**:175-202.
37. Satake M, Mido Y, Sethi SE, *et al.* Petroleum and solvents In: *Environmental Toxicology*. Publish by Discovery Publishing house, Darya Ganji, New Delhi 110 002, India **2001:** 52-81.
38. Kitwattanavong M, Prueksasit T, Morknoy D, *et al.* Inhalation exposure to carbonyl compounds and BTEX and health risk assessment of gas station workers in the inner city of Bangkok. Proceedings of the 42nd Asia-pacific Academic Consortium for Public Health (APACPH) Conference on Strengthening Public Health Institutions to Address Non Communicable Diseases and Emerging Health Challenges, 24-27 November **2010**, Bali, Indonesia: 87-8.