کارگاه‌های آموزشی مرکز اطلاعات علمی

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اصول تنظیم قراردادها

آموزش مهارت‌های کاربردی در تدوین و چاپ مقاله
Occupational Exposure of Gasoline Station Workers to BTEX Compounds in Bangkok, Thailand

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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 $1.75 \times 10^{-4}$ and $9.55 \times 10^{-7}$. 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. Benzene can also affect hematopoietic system, the central nervous system and the reproductive system. Toluene can affect the reproductive and the central nervous systems too. Ethylbenzene and xylene can have respiratory and neuro-
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.\(^8\) 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 carbon disulphide (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 logical effects.\(^7\) 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.

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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, H₂ 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 (r²) was 0.9981.

Forty-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:

\[ CDI = \frac{(CA \times IR \times ET \times EF \times ED)}{(BW \times AT)} \]

and

\[ Cancer \ risk = CDI \times CSF \]

where CDI represents chronic daily intake (mg/kg/day), CSF, cancer slope factor (mg/kg/day)⁻¹, CA contaminant concentration in air (mg/m³ or ppm), IR inhalation rate (0.875 m³/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 ≤10⁻⁶ was considered an “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-
respectively, 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×⁻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 1: Basic characteristics of gasoline workers |
|------------------|------------------|------------------|------------------|------------------|
| **Parameter**    | **Men (n=38)**   | **Women (n=11)** | **Total**        | **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/m²)**  | 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

| Table 2: Mean±SEM concentrations of BTEX compounds (ppb) in different areas |
|------------------|------------------|------------------|------------------|
| **Parameter**    | **Benzene**      | **Toluene**      | **Ethylbenzene** |
| **Inner Area**   |                  |                  |                  |
| Gasoline workers | 92.75±16.77      | 195.34±61.04     | 6.25±4.29        |
| Roadside         | 70.08±9.81       | 162.23±55.34     | 0.01±0.01        |
| **Outer Area**   |                  |                  |                  |
| Gasoline workers | 137.53±57.89     | 289.35±96.84     | 8.25±7.60        |
| Roadside         | 65.00±1.70       | 116.70±35.20     | 0.00±0.00        |
| **Average workers exposure** | 107.68±21.55 | 226.68±51.10 | 7.25±5.95 |
| **Average roadside exposure** | 68.38±6.31 | 147.05±37.41 | 0.01±0.01 |
station exposure ($9.55 \times 10^{-7}$). 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. 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 3: The average BTEX exposure and the associated risks among gasoline station workers |
|-------------------------------|---------------------------------|-----------------|-----------------|
| **Site**                     | **BTEX compounds**              | **CDI (mg/kg/day)** | **EC (mg/m³)**  |
| Gasoline station workers     | Benzene                         | $6.41 \times 10^{-3}$ | $1.81 \times 10^{-2}$ |
|                              | Toluene                         | $3.82 \times 10^{-2}$ | $0.008$          |
|                              | Ethylbenzene                    | $2.48 \times 10^{-4}$ | $0.007$          |
|                              | Xylene                          | $1.58 \times 10^{-3}$ | $0.002$          |
| Total risk                   |                                |                  | $0.617$          |
| Roadside                     | Benzene                         | $3.19 \times 10^{-3}$ | $1.15 \times 10^{-2}$ |
|                              | Toluene                         | $2.48 \times 10^{-2}$ | $0.005$          |
|                              | Ethylbenzene                    | $3.24 \times 10^{-4}$ | $0.009$          |
|                              | Xylene                          | $1.56 \times 10^{-3}$ | $0.002$          |
| Total risk                   |                                |                  | $0.396$          |

| Table 4: Frequency of symptoms among gasoline station workers |
|----------------|---------------|---------------|
| **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)         |
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.\textsuperscript{13} We showed that the level of ethylbenzene was nearly zero for both studied areas—ethylbenzene is volatile.\textsuperscript{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.\textsuperscript{14}

Benzene, an important component of gasoline, was found at a lower level in gasoline stations (107.68 µg/m$^3$) than that reported earlier in other studies (308–852 µg/m$^3$)\textsuperscript{15} which might be due to the change in the formulation of gasoline. However, the concentration of benzene at roadside (68.38 µg/m$^3$) was higher than the a previous report (15.1–42.4 µg/m$^3$)\textsuperscript{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/m$^3$.\textsuperscript{17} However, the concentration of toluene in the ambient air was lower than the ACGIH limit of 188 mg/m$^3$.\textsuperscript{18} It may be the adverse effect of a long period of exposures.\textsuperscript{19} The BTEX concentrations recorded were higher than those in the ambient air of gasoline stations in China (Pearl River Delta),\textsuperscript{20} Korea (Taegu)\textsuperscript{21} but were lower than those in India (Kolkata),\textsuperscript{22} Peru (Trujillo),\textsuperscript{23} United States (Mexico),\textsuperscript{24} and Italy (Biella and Torino).\textsuperscript{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 petrochemi-

\begin{table}[h]
\centering
\begin{tabular}{|l|l|l|l|l|}
\hline
\textbf{Independent parameter} & \textbf{Dependent Parameter} & \textbf{Unadjusted prevalence} & \textbf{Logistic regression analysis} \\
\hline
\textbf{Compound} & \textbf{Symptom} & (\%) & \textbf{OR (95\% CI)*} \\
\hline
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) \\
\hline
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) \\
\hline
\end{tabular}
\caption{Association between BTEX exposure and frequency of symptoms among gasoline station workers}
\end{table}
and other chemical industries. The derived mean cancer risk for gasoline station workers in this study was lower than that reported previously. The cancer risk in each year can be translated into new cancer cases per 1,000,000 workers in the gasoline station and 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. 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. However, the frequency of these symptoms had increased over past years. This may be due to the change in the formulation of the gasoline to gasohol and also to the increased volume of gasoline sales. Neurotoxicity studies showed that benzene exposure mostly associates with headache, 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. 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. Toluene and benzene have synergistic effects; there was also a good correlation between toluene and benzene concentrations which was in parallel to previous studies. Considering the risks described, there should be a plan to further protect the gasoline station workers.

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Conflicts of Interest: None declared.

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