

Assessment of Benzene Exposures in the Working Environment at Gasoline Stations

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Abstract

This study aimed to investigate benzene exposure in the working environment of workers at gasoline stations. Ambient air ($n=20$) and inhaled air samples ($n=101$) of benzene were collected in the city of Khon Kaen, Thailand and analyzed with gas chromatography (GC-FID). Data records were also kept of the amounts of various petroleum products sold. The results of inhaled air benzene indicated the range concentration from 0.03 ppb to 65.71 ppb and showed significant differences between concentrations of each zone ($p<0.05$). The highest mean concentration was found in suburban stations (35.55 ppb), followed by urban stations (18.19 ppb), and rural stations (2.52 ppb). The highest mean concentration of ambient air was found in urban stations (45.55 ppb). Regarding different job functions, the benzene concentration of fueling workers in the inhalation zone (27.29 ppb) was significantly higher than that of cashiers (0.56 ppb). The amounts of petroleum products with high benzene content sold were relatively consistent with inhaled benzene concentration, indicated by the significant differences between suburban and rural zones ($p<0.05$). In conclusion, this study found the inhaled air benzene concentration ranged 0.03 to 65.71 ppb depending on locations and job functions of workers. Therefore, workers should be protected of adversely affected health from long-term exposure by training on safe working practice and awareness of the different risks associated with their job functions, locations of stations and daily amounts of petroleum products sold.

Keywords: ambient air; personal sampling; fueling workers; cashiers; petroleum; benzene

1. Introduction

Benzene is classified as a human carcinogen by the International Agency for Research on Cancer (IARC) and widely used as a component of inks in the printing industry. It is also used as a solvent for organic materials and as a starting material and intermediary in the chemical and drug industries (for example, the manufacture of lubricants, dyes, detergents, synthetic rubbers, and pesticides) (IARC monograph, 2007). It is a 1.63% component in benzine (by volume) (Lekcharernkul *et al.*, 2007), which can be evaporated into the air from petroleum refineries, while fueling at gasoline stations and it is also found on vehicle exhaust emission. Some previous studies found high benzene concentrations at gasoline stations (Talamanca *et al.*, 2001; Karakitsios *et al.*, 2007).

Previous studies in Thailand indicated that benzene is one of volatile compounds found in the working environment of workers at gasoline stations (Thaveevongs *et al.*, 2010; Suda, 2005). Those reports were confirmed by the detection of benzene from monitoring at gasoline stations in the capital city of Bangkok (Khanawapee, 2009) and Nakhon Rachasima province (Sukreta *et al.*, 2008).

Concerning health impacts, the Bureau of Epidemiology, Thailand (2011) reported that, among 78 cases of petroleum poisoning between 2003 to 2009, benzene poisoning accounted for 12 cases. Thaveevongs *et al.* (2010) pointed out that exposure to benzene through inhalation elevated risks of cancer among workers at gasoline stations. However, US EPA (2009) states that there was only 50% of inhaled benzene could be the uptake via inhalation. By exposure under low concentration, the S-Phenylmercapturic acid (PMA) is benzene metabolite which could be found in urine as a specific biomarker (Sukreta *et al.*, 2008). In a systematic review 53% of relevant studies found statistically a significant association between probable benzene exposure and the risk of non-Hodgkin lymphoma (NHL) (Smith *et al.*, 2007) and Schnatter *et al.* (1996) found a relationship between low-level benzene exposure and leukemia. In a review of studies about leukemia etiology, benzene was considered to be leukaemogenic at relatively low occupational levels of exposure (Smith *et al.*, 2011). Furthermore, benzene exposure can be spermatotoxic and damage sperm DNA (Wiwanitkit, 2006).

The quantity of benzene sold each year has been increasing and it reached about 47.1 million liters a

day in 2014 in Thailand. Khon Kaen, a province in Northeast of Thailand, has become on top sales record of benzene with benzene content was 14.6 million liter a day (Department of Energy Business, 2015).

In terms of its geographical position, Khon Kaen is a hub for transportation from Bangkok, Thailand to Mekong sub-region countries, and this will rapidly become more important because of the establishment of ASEAN Economic Community. As a consequence, benzene from benzene containing products and exhaust gases will be an increasingly important issue due to its economic and health impacts. It is within this context that the present study was designed to investigate the level of benzene concentrations in the working environment at gasoline stations. Locations, different functions of workers and the daily quantity of petroleum products sold were considered as influencing factors for benzene concentrations.

2. Materials and Methods

2.1. Sampling site and study population

This study was conducted in the city of Khon Kaen, Thailand. There were 98 gasoline stations in the city of Khon Kaen during the study period and these employed 686 workers (The office of Energy Khon Kaen province, 2012). The sample size was calculated by stratified random sampling (Levy and Lemeshow, 2008). The zones were categorized into 3 zones as 'urban', 'suburban' and 'rural'. The gasoline stations in the urban zone were defined as those located in the Nai Muang Sub district of the city of Khon Kaen, Thailand and where the majority of the residents' occupation were not in agriculture; the suburban gasoline stations were located around the Nai Muang Subdistrict and near the main highway which connects the provincial city of Khon Kaen to the capital city of Bangkok (Mittraphap Road); the rural gasoline stations were those located outside the Nai Muang Subdistrict and where the majority of the residents worked in agriculture. The individual variances of each zone were based on concentrations from the study of Lekcharernkul (2006). The required minimum sample size was 88 workers for personal sampling. Additionally, the personal samplings were based on different job functions, 15% of total numbers were added for cashiers because Pimpasaeng and Chaiklieng (2013) found that one fourth of gasoline station workers were employed as cashiers. Therefore, the total sample size was 101 workers. The inclusion criteria to recruit of subjects for personal sampling were; 1) worked in various selected gasoline stations in the city of Khon Kaen 2) held full time job at least 8 hours per day 3) aged older than 18 years, and 4)

non-smokers. The simple random sampling was done for representative subjects from each zone by taking into consideration of the total population of workers in each zone. The numbers of subjects selected in each zone were 30, 51 and 20 workers from total population (TP) of urban (TP=154), suburban (TP=238), and rural (TP=294) stations, respectively. For demographic characteristics of participants, there were 52 male and 49 female workers participated in the study. The age ranged 18-60 years, and work experience was 6 months to 30 years at the current station. This study was approved from human research ethic committee, Khon Kaen University no. HE562237. All subjects were given informed consent before entering into this study.

2.2. Air sampling for measurement of benzene concentration

Air samplings were personal sampling and ambient air; 1) personal sampling was conducted in breathing zone of each worker, 2) ambient air was collected by locating sampling equipment in the center of each station at 1.5 meter height. Benzene samples were collected using a coconut charcoal sorbent tube (ZEFON, USA) connected to active personal pumps with a flow-rate of 0.2 liter per minute followed the method of NIOSH number 1501 (NIOSH, 2003). The sampling was carried out during dry season (December). The mean recorded air temperature was 24.1 ± 2.06 °C, the mean humidity was $60.98 \pm 6.39\%$, the mean wind velocity was 22.85 ± 0.19 kilometers per hour and there was no rain fall. The monitoring of benzene concentration was conducted for a 8-hour period in the working day while the subjects were performing their usual activities. At the end of the sampling period, the tube was sealed, transported to the laboratory and kept in refrigerator at 4°C until analysis.

2.3. Sample analysis

The benzene concentrations were analyzed by gas chromatograph with flame ionization detector: GC-FID (Hewlett Packard 1996, Germany). The desorbed eluent was transferred via a heated column of Durabond-1(DB-1) (30 m×0.25 mm of length×diameter) (Agilent Technologies, USA) under 250°C and split less, with the use of ACS grade chemical. The quantitative control of analysis was performed by the calibration with five concentrations and an external standard was also analyzed.

2.4. Amounts of daily petroleum product sold

Records of the sales volume of various petroleum

products were collected from the gasoline stations. Petroleum product refers to a fuel or gasoline containing benzene or diesel. There were only five types of products available at gasoline stations in city of Khon Kean which were; 1) benzene E10 octane 91, 2) benzene E10 octane 95, 3) benzene E20, 4) benzene octane 95 and 5) diesel. These records were daily sales volume of these five types of petroleum products and were compiled by the gasoline station managers at the end of the days of air sampling.

2.5. Statistical analysis

Data were analyzed using STATA version 10 software. For data analysis, descriptive statistics (mean, standard deviation, minimum, maximum) and 95% confidence interval (95%CI) were used. Analytical statistics were Kruskal-Wallis test and Mann-whitney U test. The statistic significance was identified at p -value <0.05 .

3. Results and Discussion

3.1. Benzene concentrations in working environment of gasoline stations classified by zone

Personal air monitoring indicated that the benzene concentration in inhaled air ranged from 0.03 to 65.71 parts per billion (ppb). The highest level occurred at the suburban gasoline stations and the lowest one was found in the rural area. Interestingly, there was a significant difference in the concentrations between different zones ($p < 0.05$), particularly, a large difference was found between individual concentrations in the rural zone

compared to other zones. Data were also presented in microgram per cubic meter ($\mu\text{g}/\text{m}^3$) as shown in Table 1.

As the finding, the highest concentration of benzene was found in the inhaled air of workers in the suburban station. This might be explained by their locations along a main highway Mittraparp road-connecting Bangkok and some Mekong sub-region countries (i.e. Laos, Cambodia, Vietnam, and Burma) with heavy traffic. The mean value across all zones was 23.85 ppb which did not exceed the occupational safety standard of REL-TWA (recommended exposure level-time weight average) set at 100 ppb by National Institute for Occupational Safety and Health (NIOSH, 2014). Based on inhalation uptake, US. EPA (2009) indicated the assumption that only 50% of inhaled benzene can be adsorbed. By the mean concentration and calculation, it can be estimated for inhalation uptake in these workers for the daily uptake of benzene to be $0.017 \text{ mg}/\text{m}^3$. This value did not exceed inhalation reference concentration (RfC) at $0.03 \text{ mg}/\text{m}^3$ (Rothman *et al.*, 1996; US. EPA, 2003). However, at maximum concentration across all zones, the estimation for inhalation uptake could reach $0.047 \text{ mg}/\text{m}^3$, which is higher than such the RfC.

Moreover, the previous study have found that workers had potential exposure to benzene from other sources via food contaminated consumption and skin absorption during working period (Pimpaseng and Chaiklieng, 2014), that was confirmed by US. EPA (2009). Sukreta *et al.* (2008) also supported that the proportion of the S-PMA was 3 times higher in workers who eat food in workplace compared to who did not eat. A study in the inner city of Bangkok indicated

Table 1. Benzene concentrations in inhaled air of workers classified by zone (n = 101)

	Zone			Total
	Urban zone (n=30)	Suburban zone (n=51)	Rural zone (n=20)	
Benzene concentration (ppb)				
Mean \pm SD	18.19 \pm 23.12 ^{*,+}	35.55 \pm 21.92 ^{*,†}	2.52 \pm 11.17 ^{+,†}	23.85 \pm 24.27
Min	0.03	0.03	0.03	0.03
Max	50.00	65.71	50.00	65.71
95%CI	9.56 - 26.83	29.38 - 41.71	2.70 - 7.77	19.06 - 28.64
Benzene concentration ($\mu\text{g}/\text{m}^3$)				
Mean \pm SD	57.90 \pm 73.56	113.14 \pm 69.75	8.04 \pm 35.54	75.92 \pm 77.25
Min	0.10	0.10	0.10	0.10
Max	159.08	210.00	159.08	210.00
95%CI	30.44 - 85.37	93.52 - 132.76	8.58 - 24.68	60.67 - 91.17

Remark: *significant difference between urban zone and suburban zone ($p < 0.05$)

+significant difference between urban zone and rural zone ($p < 0.05$)

†significant difference between suburban zone and rural zone ($p < 0.05$)

Table 2. Benzene concentrations in ambient air classified by zone (n=20)

	Zone			Total
	Urban zone (n=7)	Suburban zone (n=8)	Rural zone (n= 5)	
Benzene concentration (ppb)				
Mean ± SD	45.55 ± 11.75	45.30 ± 13.29	34.24 ± 21.69	42.62 ± 15.24
Min	18.90	12.40	7.50	7.50
Max	50.00	50.00	50.00	50.00
95%CI	34.68 - 56.42	34.18 - 56.41	7.30 - 61.17	35.48 - 49.76
Benzene concentration (µg/m ³)				
Mean ± SD	144.94 ± 37.39	144.12 ± 42.29	108.94 ± 69.01	135.61 ± 48.51
Min	60.13	39.45	23.86	23.86
Max	159.08	159.08	159.08	159.08
95%CI	110.35 - 179.53	108.76 - 179.48	23.24 - 194.63	112.90 - 158.30

that, even though the benzene concentration in inhaled air was less than 0.1 ppm (100 ppb), The assessment on health risk indicated that such workers were under unacceptable level of risk for cancer development ($>1 \times 10^{-6}$) (Thaveevongs *et al.*, 2010). This seems to be unsafe condition when workers have no protections exposure.

According to ambient air, the benzene concentration ranged from 7.50 to 50.0 ppb. When ambient air concentration was examined by zone, there were no differences of concentrations between suburban samples and urban samples but both were distinctively different from the rural gasoline stations where benzene could be detected in the lowest concentration as shown in Table 2.

This finding is consistent with a previous study in the inner city of the city district of Khon Kaen, which found benzene in ambient air containing volatile compounds at gasoline stations (Suda, 2005). Benzene in ambient air might come from other sources. The previous studies found benzene in diesel exhaust gases that might contribute to ambient air (Muzyka *et al.*, 1998) as well as in the areas with traffic congestion (Navasumrit *et al.*, 2005). European commission (2010) established the annual limited value of benzene concentration in public ambient air to be less than 5 µg/m³ or about 2 ppb in 2010. The significant higher concentration of benzene compared to the European commission's guideline could be the warning for adversely affecting the attendant's health at gasoline stations after long-term exposure without protection.

Nantanuch and Chaiklieng (2013) reported adverse health symptoms related to benzene toxicity among over 80% of workers exposed to benzene via inhalation at gasoline stations. Moreover, the results of a hematology study indicated the differences in both eosinophil and hemoglobin counts between workers who reported

adverse symptoms and those who did not have health problems (Thansruangkan *et al.*, 2005). In addition, Lan *et al.* (2004) reported the significantly hematological changes i.e. decreases of WBCs, granulocytes, lymphocytes, B cells, and platelets after workers inhaled air containing less than 1 ppm (1,000 ppb) benzene. Another biomarker which is urine trans,trans-Muconic acid (tt-MA) is one specific identification of low benzene exposure (Fustinoni *et al.*, 2005) and it's level can further confirm the exposure to benzene among the gasoline station workers in this study.

3.2. Benzene concentrations in inhaled air of fueling workers and cashiers

Considering job functions, fueling workers had significantly higher concentration of benzene exposures compared to cashiers ($p < 0.05$). The mean concentration of inhaled benzene by fueling workers was 27.29 ppb (95%CI: 22.17 to 32.41 ppb). For cashiers, the mean concentration was 0.56 ppb (95%CI: 0.60 to 1.74). Concentrations were also presented in µg/m³ (see Table 3).

Praengkrathok and Chaiklieng (2013) reported that fueling caused the highest risk on benzene exposure among all procedures for working at gasoline stations. Later, Pimpasaeng and Chaiklieng (2014) confirmed that fueling workers had 2 times higher frequency of benzene exposure via direct skin contact and inhalation in comparison to the cashiers. Using biomarker of exposure to benzene Sukreta *et al.* (2008) found that the levels of urine S-PMA in fueling workers were higher than in other types of employees at gasoline stations. And Beerappa *et al.* (2013) showed that detected oxidative DNA damage (8-oxo-7,8-dihydro-2-deoxyquanosine lesion) in fueling workers was higher than in the cashiers.

Table 3. Benzene concentrations classified by job functions (n=101)

	Job function		
	Fueling workers (n=88)	Cashiers (n=13)	Total
Benzene concentration (ppb)			
Mean \pm SD	27.29 \pm 24.16 [†]	0.56 \pm 1.94 [†]	23.85 \pm 24.27
Min	0.03	0.03	0.03
Max	65.71	7.04	65.71
95% CI	22.17 - 32.41	0.60 - 1.74	19.06 - 28.64
Benzene concentration ($\mu\text{g}/\text{m}^3$)			
Mean \pm SD	86.87 \pm 76.89	1.82 \pm 6.20	75.92 \pm 77.25
Min	0.10	0.10	0.10
Max	210.00	22.49	210.00
95%CI	70.58 - 103.16	1.93 - 5.57	60.67 - 91.16

Remark: [†]significant difference between fueling workers and cashiers ($p < 0.05$)

3.3. The correlation between benzene concentration in the work environment and amount of petroleum product sold

Regarding the quantities of five kinds of petroleum products sold, the highest sales across all zones were for diesel, followed (in descending quantities) by benzine E10 octane 91, benzine E10 octane 95, benzine E20, benzene octane 95. In terms of the relative amounts of each product sold in the different zones, the highest amounts of benzine E20 and benzene octane 95 were sold in the urban gasoline stations, while the highest sales for benzine E10 octane 91, benzine E10 octane 95 and diesel occurred in the suburban zone. Moreover, benzine E10 octane 91 sold in suburban zone compared with rural zone was significantly different ($p < 0.05$). The lowest sales for each of the five different petroleum products were all in the rural areas.

The Ministry of Energy in Thailand has observed that, benzene E10 octane 91, benzene E10 octane 95, benzine E20 and benzene octane 95 all include benzene. These affected benzene percentage by volume with content varied from one type of fuel to another.

According to a study of the amount of benzene in different petroleum products, the quantities of benzene in benzene octane 91 and benzine octane 95 were 1.69 and 1.55 percentages by volume, respectively (Lekcharernkul *et al.*, 2007). However, at present, Thai government has promoted using benzine E10 octane 91 instead of benzine octane 91 which was withdrawn from the market.

Benzene was found in diesel exhaust gases. In a study evaluating the carcinogenic risk associated with diesel, Muzyka *et al.* (1998) found that the concentration of benzene in airborne PM 2.5 particles and in diesel exhausts were 354 $\mu\text{g}/\text{m}^3$ and 194 $\mu\text{g}/\text{m}^3$, respectively. The diesel exhaust condition might also contribute to ambient air concentration of benzene. Additionally, it could cause more exposure concentration for workers and leads to adverse symptoms as reported before (Nantanuch and Chaiklieng, 2013).

Therefore, it is interesting to note that the rank order of differences in inhaled benzene concentrations among gasoline station workers across the three zones correlated with that of the relative amounts of benzene E10 octane 91 sold in these zones (see Table 4).

Table 4. Amount of petroleum product sold (thousand liter per day) (n= 26)

Petroleum product	Zone (1,000 L/day)			
	Urban zone	Suburban zone	Rural zone	Total
Benzine E10 octane 91	6.49 \pm 5.59	7.44 \pm 6.52 [†]	2.32 \pm 5.77 [†]	5.18 \pm 6.17
Benzine E10 octane 95	2.72 \pm 1.95	3.49 \pm 2.19	2.02 \pm 3.38	2.83 \pm 2.45
Benzine E20	2.75 \pm 1.06	1.50 \pm 0.38	1.15 \pm 1.20	1.80 \pm 1.05
Benzine octane 95	0.62 \pm 0.29	0.61 \pm 0.25	0.40 \pm 0.14	0.57 \pm 0.24
Diesel	10.04 \pm 8.97	10.55 \pm 8.14	3.64 \pm 4.25	7.99 \pm 7.70

Remark: [†] significant difference between suburban zone and rural zone ($p < 0.05$)

The correlation might be good explanation for the link of each percentage of benzene in petroleum type to the benzene concentration in working environment of the worker at the gasoline station.

4. Conclusions

Levels of benzene in the air were assessed at gasoline stations in the capital city district of Khon Kaen province, Thailand, by both personal sampling and ambient air sampling. The amounts of petroleum product sold were also recorded. Levels of benzene exposure were compared for two different job functions and for three different city zones. The results showed that the overall mean concentration of inhaled air benzene was 23.55 ppb, and levels of each zone were significantly different. The highest mean concentration was found in the suburban zone (35.55 ppb), followed by urban zone. The overall mean concentration of ambient air was 42.62 ppb.

Benzene concentrations and the amount of different types of petroleum product sold were consistent across three zones. The benzene concentration was highest in the suburban zone, and gasoline stations in this zone sold the highest amounts of benzene E10 octane 91 and 95 which had the high content of benzene.

Moreover, the estimation for inhalation uptake could reach risk level of that higher than the reference dose concentration for daily uptake of benzene in working environment of the workers. Therefore, it is recommended that training on safe working to protect gasoline station employees from benzene exposure should take into account to the different risks associated with their job functions, the environment of the gasoline station located particularly in suburban zone and the amounts of different petroleum products sold at gasoline stations. This study presented only exposure concentration of benzene, future publication of the biomarker of benzene exposure among these gasoline station workers will be well confirmed result.

Acknowledgements

This study was financial supported by the Khon Kaen University Research Fund, Khon Kaen, Thailand. Special thanks to all owners and employees of the gasoline stations in Muang Khon Kaen for their great participation in this study. Particularly, very much appreciated the valuable discussion to Associate Professor Dr. Chalermchai Chaikittiporn and Professor Dr. Herman Autrup.

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Received 28 November 2014

Accepted 31 March 2015

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