[Downloaded free from http://www.ijehe.org on Sunday, January 15, 2023, IP: 178.173.131.240]

Cancer and Noncancer Risk Assessment for Workers Exposed to the Chemical Pollutants in Ahvaz Gas Stations, Iran

Ali Askari[1,2], Ali Salehi Sahl Abadi[3], Farideh Golbabaei[4], Emad Jafarzadeh[5], Kamal Aazam[6]

[1]Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran, [2]Department of Health, Safety, and Environment, OICO Occupational Health Expert, Azar Oilfield, Ilam, Iran, [3]Department of Occupational Health and Safety at Work, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran, [4]Department of Occupational Health Engineering, School of Public Health, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran, [5]Department of Toxicology and Pharmacology, Faculty of Pharmacy, Tehran University of Medical Sciences, Tehran, Iran, [6]Department of Epidemiology and Biostatistics, School of Public Health, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran

Abstract

Aim: This article evaluates the health risk of occupational exposure to BTEX compounds, cancer risk, and noncancer risk analysis among gas station workers. **Materials and Methods:** This cross-sectional research evaluates pollutants rank of risk released at Ahvaz stations in Iran. We have collected 96 samples of workers exposed to BTEX and eight samples for control in the ambient air. The National Institute for Occupational Safety and Health (NIOSH) recommended BTEX method numbers 1500 and 1501 for sampling and analysis. To evaluate the risk assessment of pollutants, we utilized a semi-quantitative method offered by Singapore's Occupational Safety and Health Division. **Results:** The average benzene concentration in the operators' breathing zone (1.202 0.83 ppm) was greater than the threshold limit values-time weighted average (TLVs-TWA) ($P < 0.05$). Other contaminants had concentrations that were lower than the ACGIH's TLV-TWA ($P < 0.05$). In gas stations, benzene has a very high danger ranking among chemical compounds. Toluene, ethyl benzene, and xylene in the employees' breathing zone posed a modest risk. The average cancer risk for benzene-exposed operators, head shift workers, and supervisors was calculated to be 4.46×10^{-3}, 2.90×10^{-3}, and 2.08×10^{-3}, respectively. The risk of cancer is projected to be higher than the tolerable level of 10-6. **Conclusion:** In unique, long-term exposure to benzene has been linked to an increased risk of cancer and toxic effects, and a health-risk assessment can provide useful information about current workplace contaminants.

Keywords: Benzene, BTEX, cancer risk assessment, gas station, risk analysis, volatile organic compounds

Introduction

Many people worldwide are in contact with various chemicals in different jobs. Exposure to these substances can lead to multiple health effects.[1] World Health Organization (WHO) statistic evaluations indicate that 4 million worldwide people employ in the chemical industries.[2] Many compounds play a role in the emergence of air pollution. Essential air pollutants are among these VOCs. Solvents are used in various vocations and sectors, including the petrochemical industry, printing industry, and refinery.[3] VOCs are also some chemical compounds released evaporative throughout different fossil fuel processing stages.[4] Gasoline is a complex combination of 50 different hydrocarbons with a concentration of about 1% and trivial amounts of other materials. Gasoline hydrocarbons have 3–12 carbons. The gasoline index formula is C6H18, and its average molecular weight is about 113. Gasoline composition varies in different seasons and from one refinery to another.[5] The health effects of acute exposure to Gasoline via breathing, swallowing, and skin (less than 14 days) are irritation in the place of vulnerability.[6] For example, temporary nerve damage includes headaches, nausea, dizziness, and drowsiness during the refueling process or sudden discharge of car tank vapors and inhalation from gasoline spills at the fuel station.[7] VOCs

Access this article online

Quick Response Code:

Website: www.ijehe.org

DOI: 10.4103/ijehe.ijehe_5_22

Address for correspondence: Dr. Farideh Golbabaei, Department of Occupational Health Engineering, School of Public Health, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran.
E-mail: fgolbabaei@tums.ac.ir

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Askari A, Abadi AS, Golbabaei F, Jafarzadeh E, Aazam K. Cancer and noncancer risk assessment for workers exposed to the chemical pollutants in ahvaz gas stations, Iran. Int J Env Health Eng 2022;11:19.

Received: 31-01-2022, **Revised:** 11-05-2022,
Accepted: 28-05-2022, **Published:** 13-12-2022

[Downloaded free from http://www.ijehe.org on Sunday, January 15, 2023, IP: 178.173.131.240]

are an essential part of gasoline compounds and pollutants in the air. According to research, BTEX compounds, which include benzene, toluene, ethylbenzene, and xylene, are index compounds that are constantly present alongside each other and are detrimental to human health, even at low doses.[8] The BTX has adverse health effects, including hematological[9] and neurological systems.[10] Benzene is classified as a human and animal definitive carcinogen by the International Agency for Research on Cancer (IRAC).[11] According to Lerner *et al*., (2012) benzene had the highest concentration among the 23 VOCs detected in employees' breathing zones.[12] Leukemia can be caused by long-term exposure to benzene.[13] Tiwari *et al*. (2009) conducted research and their purpose was to study the environmental concentration of VOCs in the vicinity of the industrial petrochemical area of Yokohama, Japan. The research results showed that BTEX had the highest concentration.[14] Gariazzo *et al*. (2004) conducted research. Their purpose was to study the analysis of VOCs around an oil refinery in Italy. The research results showed that BTEX had the highest concentration.[15] The study by Jafari *et al*. (2007) demonstrated that, among BTX compounds, the cancer risk of benzene in the gas station was higher than the standard level recommended by EPA.[16] The increase of gasoline distribution in fueling stations during recent years has resulted in the high exposure of workers of these stations to gasoline compounds.[17] Epidemiological studies show that the death rate from cancer among gas station workers is significant.[18] The risk assessment and cancer risk analysis of chemical substances are essential for implementing appropriate programs to reduce the rate of worker's exposure.[19] For decision-making about control measures and protecting workers against the adverse effects of chemical substances, it is necessary to evaluate health risks from exposure to these substances.[20] The risk evaluation process is the primary solution and key for evaluating risks related to environmental and occupational exposures to chemical substances.[21] There are more than 3000 active gas stations in Iran, which pose a significant risk to the workers in this industry sector. Considering the dangers of exposure to chemicals and increasing their use in daily life, the present study was conducted to investigate the health, cancer, and non-cancer risks of BTEX in gas stations in Ahvaz.

Materials and Methods

Sample size determining

This investigation was cross-sectional research conducted during the spring of 2018 to assess the rank of pollutants risk releases in Ahvaz gas stations. We applied the study[22] results to calculate the required number of samples to estimate the amount of BTEX in gas stations. The mentioned research reported the standard deviation (SD) of ethylene benzene SD = 6.4 ppm; therefore, considering the 95% confidence coefficient and d = 2 ppm for accuracy (wrong estimation limit), the sample size was calculated from Eq. 1.

$$N = \frac{Z^2_{1-\alpha/2} \times \delta^2}{d^2} = 39.54 \quad (1)$$

N is the number of samples

$Z^2_{1-\alpha/2}$ is confidence coefficient 95% =1.96

δ^2 is SD

d is accuracy

Considering the 20% probability of sampling error, the minimum number of required samples in this study was 48. Furthermore, for the present study, considering that the urban divisions of Ahvaz at the time of the survey included eight municipal areas, we randomly selected a gas station from each region. As a result, according to Table 1, 104 samples were collected from the gas stations surveyed. To organize workers exposed to chemical pollutants, we divided personnel based on job descriptions into three different jobs, including operators, head shifts, and supervisors. For the ambient air of gas stations, we collected 104 samples (64 samples for operators, 16 samples for head shifts, 16 samples for supervisors, and eight samples for blank (control). Before participating in the study, all participants signed a consent form. Based on a similar study, exposure to pollution for more than 3 h/day is considered inclusion criteria in the present investigation.[23]

BTEX analysis and sampling method

We used 1501 method numbers from the National Institute for Occupational Safety and Health (NIOSH) to sample and evaluate BTEX. We also used Coconut shell charcoal (100/50 mg) to collect BTEX air samples in the employees' breathing zones. Inline, a representative sampler calibrated the micropump (SKC 222 model series) at a flow rate of 0.1 L/min before personal sampling. After collecting the samples, we extracted the analyte with CS2 (1 ml). Finally, the Gas Chromatography-Flame Ionization Detector VARIAN CP-3800 was utilized to identify and quantify chemical substances. In the next step, to calculate the concentration of pollutants in workers' breathing zone, we used Eq. 2. Table reference doses are expressed in this method.

$$C = \frac{(Wf + Wb - Bf - Bb)}{V} \quad (2)$$

where,

C: Pollutant concentration (mg/m^3)

W_f: Analyte discovered in the sample's front

W_b: The analyte found in the sample back

B_f: In the blank front, average media is used

Table 1: Samples size

Job group	Number of workers in each gas station	Number of samples for each worker		Total samples
		Evening	Afternoon	Evening
Operators	2	4	4	64
Head shifts	1	1	1	16
Supervisor	1	1	1	16
Control: One blank sample was collected for each gas station				8
Sum				104

[Downloaded free from http://www.ijehe.org on Sunday, January 15, 2023, IP: 178.173.131.240]

B_b: Standard media in the blank back

V: Sample of air volume (L)

The pollutant concentration in Eq. 2 is given in the form mg/m3, which, at a vapor pressure of 760 mmHg, is converted (ppm) using Eq. 3

$$ppm = \frac{(\frac{mg}{m3}) \times 24.45}{M} \quad (3)$$

M: Pollutant molecular weight

The total time required to collect all samples was 288 h (3 h/sample); to calculate the time-weight average (TWA), we utilized Eq. 4.

$$TWA = \frac{(C1T1 + C2T2)}{8} \quad (4)$$

where;

C: Concentration of exposure (ppm)

T: Corresponding exposure time (hr.)

Health risk evaluation method

Based on the following steps to determine health risks due to exposure to pollutants, we used the semi-quantities methods presented by the Singapore Occupational Health Department.[24]

Hazard rating

The method proposed by the Singapore Department of Occupational Health recommends that the hazard rate be calculated according to the toxic effects of the chemicals or through the lethal dose (LD50) and lethal concentration (LC50) of the substances. However, in this study, we used the reliable American Conference of Governmental Industrial Hygienists (ACGIH) classification regarding the possible carcinogenicity of chemicals to determine the hazard rate (HR). ACGIH has divided substances into five groups based on their carcinogenic potential. This grouping includes A1 (definitely carcinogenic) to A5 (non-carcinogenic) [Table 2].

Exposure rating

We determined the weekly exposure rate (ER) (ppm or mg/m^3) using the results of measuring and analyzing pollutants based on NIOSH 1501 in the workers breathing zone and using Eq. 5.

$$E = \frac{F \times D \times M}{W}.^{[5]}$$

E: Weekly exposure (ppm or mg/m^3)

F: Number of times per week that you are exposed (no. per week)

D: Exposure's average duration (hours)

M: Exposure magnitude (ppm or mg/m^3)

W: Week's average number of working hours (40 h)

Table 3 determines the ER by comparing weekly exposure (E) with the permissible exposure limit.

Risk level calculation

Risk levels calculated by using Eq. 6.

$$Risk\ Level = (ER \times HR)^{1/2}.^{[6]}$$

where;

HR = Hazard rating on the scale of 1 to 5 [Table 2].

ER = Exposure rating on the scale of 1 to 5 [Table 3].

Risk ranking evaluation

The risk rating scaling of 1 to 5 is increasing in magnitude. A rating of 1 implies negligible risk, and a rating of 5 means very high risk. This ranking will enable the prioritization of action plans to reduce the risk of exposure. Risk ranking determines according to Table 4.

Cancer and noncancer risk assessment

Prolonged exposure to benzene leads to leukemia. On the other hand, benzene can cause cancer even at low concentrations.[25] Therefore, cancer risk analysis is vital to identify hazardous substances and prioritize risk rankings in the workplace. Chronic daily intake (CDI) for cancer risk assessment due to benzene among job groups was illustrated by Eq. 7.

Cancer risk = CDI × CSFi.[7]

$$CDI(\text{mg/kg/day}) = \frac{\text{CA} \times \text{IR} \times \text{ET} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

Table 2: Pollutants hazard rating

Pollutants	Hazard category	HR
Benzene	ACGIH A1 carcinogens	5
Toluene, ethyl benzene, xylene	ACGIH A3 carcinogens	3

HR: Hazard rating, ACGIH: American Conference of Governmental Industrial Hygienists

Table 3: Exposure rating

E/PEL	ER
<0.1	1
0.1-<0.5	2
0.5-<1.0	3
1.0-<2.0	4
≥2.0	5

E: Exposure, ER: E rating, PEL: Permissible exposure limit

Table 4: Risk rating

Risk rating	Ranking
1.7	Negligible
1.7-2.8	Low
2.8-3.5	Medium
3.5-4.5	High
4.5-5	Very high

[Downloaded free from http://www.ijehe.org on Sunday, January 15, 2023, IP: 178.173.131.240]

CA: Contaminates Concentration in air (mg/m3)

IR: Inhalation Rate (for adults 0.875 m^3/h)

BW: Body Weight (for average person's 60.54 Kg)

ET: Exposure Time (8 h for workers)

EF: Exposure Frequency per year (350 days/year)

ED: Exposure Duration (30 years for individuals)

AT: Average Time (70 years × 365 days for carcinogenesis or ED × 365 for noncancer)

Carcinogenic effects of more than 10^{-6} were deemed concerning, whereas a value of 10^{-6} was deemed acceptable.

We used the hazard quotient (HQ) parameter for the noncancer situation assessment is represented in Eq. 8.

$$HQ = \frac{\mathrm{EC}}{\mathrm{Rfc}} \qquad (8).$$

$$EC = \frac{\mathrm{CA} \times \mathrm{ET} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{AT}}$$

Rfc: Exposure concentration (µg/m3 or ppb)

HQ 1 denotes adverse noncarcinogenic effects of concern; an HQ of 1 was deemed an acceptable level.

Statistics analysis

We used the Statistical Package for the Social Science (SPSS) version 23 to analyze the collected data. Finally, to compare the mean concentration of measured pollutants (BTEX) with the threshold limit value (TLV) *t*-test exam was performed, and for significance evaluation, the considered *P*-value was <0.05.

Results

Exposure rate to BTEX

We have measured 104 VOCs samples in selected gas stations, 64 related to the operators. The average TWA of benzene, toluene, ethyl benzene, and xylene in the operators breathing zone were 1.202 ± 0.83, 0.381 ± 0.36, 0.461 ± 0.29, and 0.036 ± 0.04 ppm, respectively [Table 5 and Figure 1].

Altogether 16 samples were measured from VOCs for the head shifts. Benzene, toluene, ethyl benzene, and xylene concentration average in head shifts breathing zone were 0.465 ± 0.14,0.296 ± 0.40,0.243 ± 0.14, and 0.126 ± 0.22 ppm, respectively [Table 5 and Figure 1].

Furthermore, we have measured 16 samples from the VOCs of the supervisors. The average TWA of benzene, toluene, and ethyl benzene in the supervisors breathing zone were 0.336 ± 0.15, 0.103 ± 0.14, 0.239 ± 0.15, and 0.035 ± 0.03 ppm, respectively [Table 5 and Figure 1].

The average content of benzene (1.202 0.83) in the breathing zone of operators was greater than the ACGIH's recommended TLVs-TWA (P < 0.05) for the three work categories evaluated. For all analyzed work groups, average toluene, ethyl benzene, and xylene concentrations were significantly lower than the TLV-TWA suggested by the ACGIH (P < 0.05).

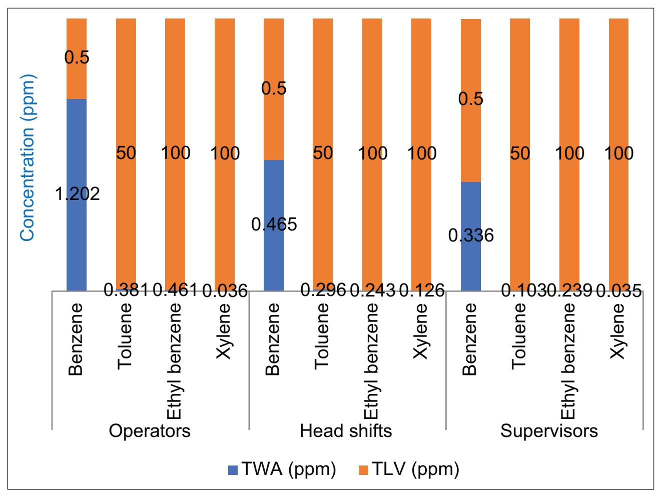

Figure 1: Worker's BTEX exposure level compared with TLV. TLV: Threshold limit value

Table 5: Exposure levels of benzene, toluene, ethylbenzene, and xylene, in workers of gas stations

Job group	Pollutants	TWA (mean±SD)	Range	TLV-TWA (ACGIH) (ppm)	*P*
Operators	Benzene	1.202±0.83	0.026-2.706	0.5	0.034
	Toluene	0.381±0.36	0.005-3.051	50	0.001
	Ethyl benzene	0.461±0.29	0.078-0.942	100	0.001
	Xylene	0.036±0.04	0.000-0.084	100	0.001
Head shifts	Benzene	0.465±0.14	0.226-0.639	0.5	0.022
	Toluene	0.296±0.40	0.000-0.922	50	0.001
	Ethyl benzene	0.243±0.14	0.067-0.526	100	0.001
	Xylene	0.126±0.22	0.000-0.642	100	0.001
Supervisors	Benzene	0.336±0.15	0.136-0.527	0.5	0.012
	Toluene	0.103±0.14	0.000-0.382	50	0.001
	Ethyl benzene	0.239±0.15	0.065-0.515	100	0.001
	Xylene	0.035±0.03	0.000-0.064	100	0.001

ACGIH: American Conference of Governmental Industrial Hygienists, SD: Standard deviation, TLV: Threshold limit values, TWA: Time-weighted average

[Downloaded free from http://www.ijehe.org on Sunday, January 15, 2023, IP: 178.173.131.240]

Health risk evaluation

The risk evaluation and ranking of contaminants for exposure to gas station personnel is shown in Table 4. Benzene discovered across chemical components posed a very high risk to operators, as well as a high risk to each of the three employment groups surveyed. In all investigated job groups, the rank of risk for toluene, ethyl benzene, and xylene in the worker's breathing zone was low [Table 6 and Figure 2].

Cancer and noncancer risk assessment

We used the Chronic Daily Intake (CDI) to calculate cancer risk and the Exposure Concentration (EC) applied to determine the non-cancer risk. Table 7, Figures 3 and 4 show the cancer risk and noncancer risk levels among gas station workers. Results show that the mean cancer risk for the operators was more than other groups (4.46×10^{-3}), and in all discussed job groups, the cancer risk was higher than the acceptable limit of 10^{-6}. The CDI for the operators was 0.163 (mg/kg/day). In addition, the non-cancer risk for the operators calculated more than the other groups and in all investigated groups was higher than the acceptable level (HQ ≤1). The EC for the operators was 12.62 (mg/m^3).

Discussion

Risk assessment utilizes different methods to rank chemical dangers, such as qualitative, semi-quantitative, and quantitative techniques.[24-28] The IARC studies show that many people worldwide have exposure to various chemical substances in different jobs. Exposure to these substances can cause various health effects for individuals.[29-31] For example, long-term exposure to different levels of pollutant concentration can raise cancer risk.[32] In addition, the use of fossil fuels in various industries[33] can result in the release of a variety of substances into the atmosphere.[34] The concentration of xylene in the worker's breathing zone was found to be lower in this study than in the other VOC concentrations investigated. The average concentration of benzene, on the other hand, was higher than in the other pollutants. Among the three employment groups surveyed, the average concentration of benzene in the operator's group breathing zone significantly greater than the TLV-TWA indicated by ACGIH. At the same time, other pollutant concentrations were lower than the TLV. It can consider VOCs vapor pressure as the leading cause for the distribution of substances in the workspace.[35] Oil and its related industries have a strategic and vital role in the country. According to the IRAC statistic report, people's number employed in petroleum is 400000 to 500000. Many employees in these industries imply the importance of further investigation on the subject of harmful

Table 6: Health risk assessment results according to pollutants concentrations

Job group	Pollutants	HR	ER	Risk rating	Ranking
Operators	Benzene	5	5	5	Very high
	Toluene	3	1	1.73	Low
	Ethyl benzene	3	1	1.73	Low
	Xylene	3	1	1.73	Low
Head shifts	Benzene	5	4	4.47	High
	Toluene	3	1	1.73	Low
	Ethyl benzene	3	1	1.73	Low
	Xylene	3	1	1.73	Low
Supervisors	Benzene	5	3	3.87	High
	Toluene	3	1	1.73	Low
	Ethyl benzene	3	1	1.73	Low
	Xylene	3	1	1.73	Low

HR: Hazard rating, E: Exposure, ER: E rating

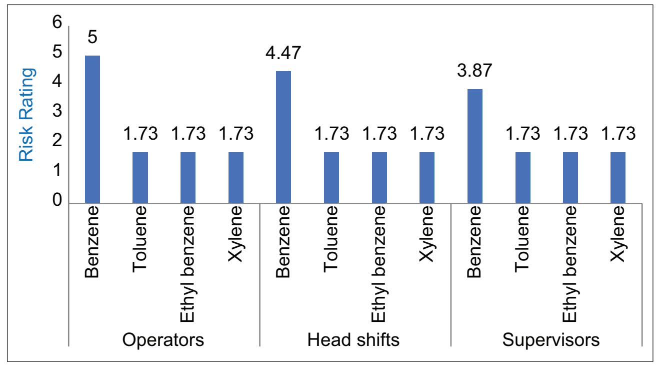

Figure 2: Job group's risk rating

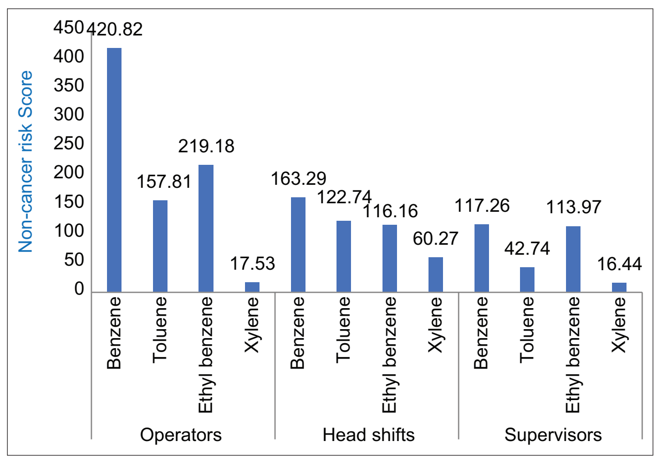

Figure 3: Job group's Noncancer risk (HQ). HQ: Hazard quotient

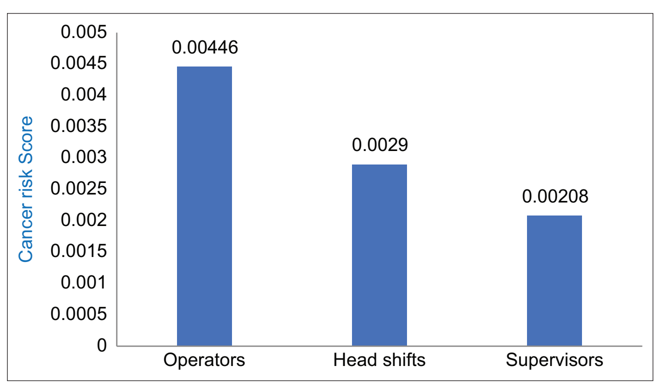

Figure 4: Job group's cancer risk due to benzene

[Downloaded free from http://www.ijehe.org on Sunday, January 15, 2023, IP: 178.173.131.240]

Table 7: Benzene, toluene, ethylbenzene, and xylene's lifetime cancer risk and noncancer risk assessments

Job group	Pollutants	EC (mg/m^3)	Noncancer risk (HQ)	CSFi $(mg/kg/day)^{-1}$	CDI (mg/kg/day)	Cancer risk
Operators	Benzene	12.62	420.82	2.73×10^{-2}	0.163	4.46×10^{-3}
	Toluene	4.73	157.81	-	-	-
	Ethyl benzene	6.58	219.18	-	-	-
	Xylene	0.53	17.53	-	-	-
Head shifts	Benzene	4.90	163.29	2.73×10^{-2}	0.106	2.90×10^{-3}
	Toluene	3.68	122.74	-	-	-
	Ethyl benzene	3.48	116.16	-	-	-
	Xylene	1.81	60.27	-	-	-
Supervisors	Benzene	3.52	117.26	2.73×10^{-2}	0.076	2.08×10^{-3}
	Toluene	1.28	42.74	-	-	-
	Ethyl benzene	3.42	113.97	-	-	-
	Xylene	0.49	16.44	-	-	-

E: Exposure, EC: E concentration, CDI: Chronic daily intake, HQ: Hazard quotient, CSFi: Inhalation cancer slope factor

factors in the workplaces,[36] including chemical factors. This research results show that benzene's risk rating was 5, showing a very high and high rank of risk. On the other hand, the benzene-related risk is higher than other pollutants among the noted substances. Rinsky shows the relationship between benzene and leukemia in different concentrations[37] Coline *et al*. showed that benzene can result in leukemia even in trivial amounts. Thus, we suggest corrective actions and adequate training to reduce exposure time to hazardous pollutants. Based on the toxicity of benzene vapors and the high concentration of pollutants, the first option is to eliminate this compound, but in terms of the process, it is impossible to eliminate benzene from gasoline because the BTEXs are important compounds used to increase engine efficiency.[38] Nowadays, Floren is introduced as a substance to substitute the BTEX compounds in gasoline to significantly increase engine efficiency. The addition of this substance to gasoline significantly decreases gasoline pollutants, including benzene.[18] Of course, research about this substance is in the early stages and has not found a complete application yet.[38] As a result, to substitute this substance with fewer dangerous ones to reduce hazard rate and exposure time. Furthermore, we propose a respiratory protection program to manage very high risk and a four-year periodical evaluation to control low risk.[39] We recommend a four-year periodical evaluation for low-risk levels because the risk for toluene, ethyl benzene, and xylene was 3, indicating a low rank of danger. Furthermore, from the results mentioned in Tables 6 and 7, it can be inferred that among the three job groups studied, the health risk for the operators is higher than the other groups. It is necessary to mention that workers' exposure time to pollutants is different, so operators have the highest exposure per week with an average of 84 h. In contrast, head shifts and supervisors have the lowest exposure to pollutants, with 40 h per week. Thus, exposure time can justify obtained risk ranks for different jobs. Estimation of carcinogenic risk of chemical substances in gas stations showed that operators have the highest risk with a risk score of 4.46×10^{-3}, and supervisors have the lowest risk of cancer affliction with a risk score of 2.08×10^{-3}, in other words, 4.46 and 2.08 cancer per 1000, i.e., higher than the acceptable limit of 10-6. Therefore, cancer risk due to exposure to dangerous substances should not be more than 1.1 people per 100,000.[40] The average cancer risk of benzene was higher than 10-6 in the study of Harati *et al*.(2020)[40] also Tunsaringkarn *et al*.(2012).[41] In addition, Yimrungruang *et al*.(2008) stated that Benzene is one of the VOCs that has the potential to cause cancer.[40] As a result, long-term VOC exposure may cause changes in complete blood counts.[27,42] The noncancer risk for BTEX in this study was higher than the acceptable level (HQ 1). Individual habits and nonoccupational lifestyle, on the other hand, can cause cancer. However, some risk factors, including individual habits and nonoccupational lifestyle, can cause cancer.

Conclusion

We consider cancer risk analysis for benzene in our study because there was no appropriate method available for other pollutants. According to ACGIH and IARC substances Carcinogenesis classification, benzene is classified as a definitive human carcinogen. This research demonstrated that risk assessment and cancer risk analysis approaches utilized during the design phase can lead to methods to improve workplace conditions and provide valuable data for decision-making, prioritizing hazards, and maintaining programs. However, we can significantly decrease the risk of exposure to these compounds using control measures such as reducing work shift time, installing the vapors recycling system, periodic maintenance of fuel distribution equipment, and designing a particular chamber for the worker.

Financial support and sponsorship

This investigation has received support from the Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Department of Health Safety Environment Ahvaz National Iranian Oil Products, Distribution Company, and Oil Industries' Commissioning and Operation Company (OICO) R and D Department. The authors further thank the people who participated in this study.

[Downloaded free from http://www.ijehe.org on Sunday, January 15, 2023, IP: 178.173.131.240]

Ethics Code

The research Ethics Committee approved this study of Tehran University Medical of Sciences, Tehran, Iran (No: 32610). Informed consent was obtained from all participants, and each one received a code to be unknown.

Conflicts of interest

There are no conflicts of interest.

References

1. Rekhadevi PV, Mahboob M, Rahman MF, Grover P. Determination of genetic damage and urinary metabolites in fuel filling station attendants. Environ Mol Mutagen 2011;52:310-8.
2. Golbabaie F, Eskandari D, Rezazade Azari M, Jahangiri M, Rahimi M, Shahtaheri J. Health risk assessment of chemical pollutants in a petrochemical complex. Iran Occup Health 2012;9:11-21.
3. Leigh JP, Markowitz SB, Fahs M, Shin C, Landrigan PJ. Occupational injury and illness in the United States. Estimates of costs, morbidity, and mortality. Arch Intern Med 1997;157:1557-68.
4. Eisaei HR, Ahmadi Dehrashid SS, Khani MR, Hashemi SM. Assessment and control of VOCs emitted from gas stations in Tehran, Iran. Pollution. 2015;1:363-71.
5. Davis WT, Buonicore AJ. Air Pollution Engineering Manual. New York: Wiley; 2000.
6. Caprino L, Togna GI. Potential health effects of gasoline and its constituents: A review of current literature (1990-1997) on toxicological data. Environ Health Perspect 1998;106:115-25.
7. Rahimi F. Study of the effect of fuel consumption and geographic conditions on Tehran's air pollution. J Air Pollut Health 2020.5:71-88.
8. Enterline PE. Review of new evidence regarding the relationship of gasoline exposure to kidney cancer and leukemia. Environ Health Perspect 1993;101 Suppl 6:101-3.
9. ATSDR U. Toxicological Profile for Benzene. Atlanta, GA: US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry; 2007. p. 1-5.
10. Moolla R, Curtis CJ, Knight J. Occupational exposure of diesel station workers to BTEX compounds at a bus depot. Int J Environ Res Public Health 2015;12:4101-15.
11. Edokpolo B, Yu QJ, Connell D. Health risk assessment of ambient air concentrations of benzene, toluene and xylene (BTX) in service station environments. Int J Environ Res Public Health 2014;11:6354-74.
12. Lerner JC, Sanchez EY, Sambeth JE, Porta AA. Characterization and health risk assessment of VOCs in occupational environments in Buenos Aires, Argentina. Atmos Environ 2012;55:440 7.
13. Zhang L, Eastmond DA, Smith MT. The nature of chromosomal aberrations detected in humans exposed to benzene. Crit Rev Toxicol 2002;32:1-42.
14. Lynge E, Andersen A, Nilsson R, Barlow L, Pukkala E, Nordlinder R, *et al.* Risk of cancer and exposure to gasoline vapors. Am J Epidemiol 1997;145:449-58.
15. Tiwari V, Hanai Y, Masunaga S. Ambient levels of volatile organic compounds in the vicinity of petrochemical industrial area of Yokohama, Japan. Air Qual Atmos Health 2010;3:65-75.
16. Jafari H, Ebrahimi S. A study on risk assessment of benzene as one of the VOCs air pollution. Int J Environ Res 2007;1:214-17.
17. Rekhadevi PV, Rahman MF, Mahboob M, Grover P. Genotoxicity in filling station attendants exposed to petroleum hydrocarbons. Ann Occup Hyg 2010;54:944-54.
18. Jiang Z, Zheng X, Zhai H, Wang Y, Wang Q, Yang Z. Seasonal and diurnal characteristics of carbonyls in the urban atmosphere of Changsha, a Mountainous city in South-Central China. Environ Pollut 2019;253:259-67.
19. Wang SM, Wu TN, Juang YJ, Dai YT, Tsai PJ, Chen CY. Developing a semi-quantitative occupational risk prediction model for chemical exposures and its application to a national chemical exposure databank. Int J Environ Res Public Health 2013;10:3157-71.
20. Carrieri M, Bonfiglio E, Scapellato ML, Maccà I, Tranfo G, Faranda P, *et al.* Comparison of exposure assessment methods in occupational exposure to benzene in gasoline filling-station attendants. Toxicol Lett 2006;162:146-52.
21. Jahangiri M, Motovagheh M. Health risk assessment of harmful chemicals: Case study in a petrochemical industry. Iran Occup Health. 2011;7:4-0.
22. Mahdi J, Somaieh J, Masood Shafii M, Hossein M, Vahdat Faraji T, Mohamad J. Health risk assessment of occupational exposure to BTEX compounds in petrol refueling stations in Mashhad. J. Neyshabur Univ. Med. Sci.2014;1:19-27.
23. Lin YC, Lai CY, Chu CP. Air pollution diffusion simulation and seasonal spatial risk analysis for industrial areas. Environ Res 2021;194:110693.
24. Yari S, Fallah Asadi A, Varmazyar S. Assessment of semi-quantitative health risks of exposure to harmful chemical agents in the context of carcinogenesis in the latex glove manufacturing industry. Asian Pac J Cancer Prev 2016;17:205-11.
25. Guénel P, Imbernon E, Chevalier A, Crinquand-Calastreng A, Goldberg M. Leukemia in relation to occupational exposures to benzene and other agents: A case-control study nested in a cohort of gas and electric utility workers. Am J Ind Med 2002;42:87-97.
26. Masekameni MD, Moolla R, Gulumian M, Brouwer D. Risk assessment of benzene, toluene, ethyl benzene, and xylene concentrations from the combustion of coal in a controlled laboratory environment. Int J Environ Res Public Health 2018;16:95.
27. Harati B, Shahtaheri SJ, Yousefi HA, Harati A, Askari A, Abdolmohamadi N. Cancer risk assessment for workers exposed to pollution source, a petrochemical company, Iran. Iran J Public Health 2020;49:1330-8.
28. Cao Q, Yu Q, Connell DW. Health risk characterisation for environmental pollutants with a new concept of overall risk probability. J Hazard Mater 2011;187:480-7.
29. Rinsky RA. Benzene and leukemia: An epidemiologic risk assessment. Environ Health Perspect 1989;82:189-91.
30. Collins JJ, Ireland BK, Easterday PA, Nair RS, Braun J. Evaluation of lymphopenia among workers with low-level benzene exposure and the utility of routine data collection. J Occup Environ Med 1997;39:232-7.
31. White PA, Claxton LD. Mutagens in contaminated soil: A review. Mutat Res 2004;567:227-345.
32. Chen X, Zhang LW, Huang JJ, Song FJ, Zhang LP, Qian ZM, *et al.* Long-term exposure to urban air pollution and lung cancer mortality: A 12-year cohort study in Northern China. Sci Total Environ 2016;571:855-61.
33. Olufemi AC, Mji A, Mukhola MS. Assessment of secondary school students' awareness, knowledge and attitudes to environmental pollution issues in the mining regions of South Africa: Implications for instruction and learning. Environ Educ Res 2016;22:43-61.
34. Shepardson DP, Choi S, Niyogi D, Niyogi D, Charusombat U. Seventh grade students' mental models of the greenhouse effect. Environ Educ Res 2011;17:1-17.
35. Baghani AN, Rostami R, Arfaeinia H, Hazrati S, Fazlzadeh M, Delikhoon M. BTEX in indoor air of beauty salons: Risk assessment, levels and factors influencing their concentrations. Ecotoxicol Environ Saf 2018;159:102-8.
36. Thepaksorn P, Koizumi A, Harada K, Siriwong W, Neitzel RL. Occupational noise exposure and hearing defects among sawmill workers in the south of Thailand. Int J Occup Saf Ergon 2019;25:458-66.
37. Liu CS, Tsai JH, Kuo SW. Comparisons of complete blood counts and urinary benzene metabolites after exposure to benzene. Mid Taiwan J Med 2000;5:235-42.
38. Heydari M, Omidvari M, Fam I. Presenting of a material exposure health risk assessment model in oil and gas industries (case study: Pars Economic and Energy Region). Health Saf Work 2014;3:11-22.
39. Manpower M. Semi Quantitative Method to Assess Occupational Exposure to Harmful Chemicals. Singapore: Ministry of Manpower,Occupational Safety and Health Divisin;2005. Available from: https://www wshc sg/files/wshc/upload/cms/file/2014/A Semiquantitative Method toAssess Occupational Exposure to Harmful

[Downloaded free from http://www.ijehe.org on Sunday, January 15, 2023, IP: 178.173.131.240]

Chepdf. [Last accessed on 2021 Oct 10].

40. Baghani AN, Sorooshian A, Heydari M, Sheikhi R, Golbaz S, Ashournejad Q, *et al.* A case study of BTEX characteristics and health effects by major point sources of pollution during winter in Iran. Environ Pollut 2019;247:607-17.
41. Tunsaringkarn T, Prueksasit T, Kitwattanavong M, Siriwong W, Sematong S, Zapuang K, *et al*. Cancer risk analysis of benzene, formaldehyde and acetaldehyde on gasoline station workers. J Environ Eng Ecol Sci 2012;1:1-6.
42. Kipen HM, Cody RP, Goldstein BD. Use of longitudinal analysis of peripheral blood counts to validate historical reconstructions of benzene exposure. Environ Health Perspect 1989;82:199-206.