Health Risk Assessment of Occupational Exposure of Refinery Unit Site Workers to BTEX in an Oil Refinery Company

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Abstract

Background: Specific improvements in the risk assessment of chemicals have been recently considered by many national and international expert groups. This study aimed to identify the highest occupational exposure levels in Abadan Oil Refining Company, Iran, to benzene, toluene, ethylbenzene, and xylene (BTEX) in 2020.

Methods: This is a cross-sectional, descriptive and analytical study carried out in several units (ten units) in Abadan Oil Refining Company. Air sampling and BTEX analysis were conducted according to NIOSH method number 1501. To determine the risk of exposure to BTEX pollutants, we used the method proposed by the Department of Occupational Safety and Health of Malaysia. Then, the hazard rate, exposure rate, and health risk level caused by exposure to chemicals were determined. SPSS 20 software was used to analyze the data.

Results: The results showed the employees studied in this research were exposed to the pollutants of BTEX during their work. Comparing total BTEX concentrations with the recommended standard level showed that BTEX concentrations in Abadan Oil Refining Company Workers' breathing zone were lower than the TLV-TWA recommended by ACGIH; also, the findings of this risk assessment study showed benzene had the highest risk ranking in seven operating units and a low risk ranking in three other units. Moreover, toluene, ethylbenzene, and xylene had a very low risk in all operating units.

Conclusion: Corrective and preventive measures should be taken to eliminate or minimize the exposure rate due to the significant effects of benzene exposure.

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Introduction

Benzene, toluene, ethylbenzene, and xylene (BTEX) are considered as predominant pollutants in areas near large cities and have adverse effects on both humans and the environment.[1,2] Research has shown that BTEX compounds are at the highest volatile organic compound (VOC) concentrations.[3] Benzene and ethylbenzene, which are categorized as carcinogenic to people by the International Agency for Research on Cancer (IARC), are dangerous compounds in the BTEX Group (Group 1). These exposures are associated with an increased risk of leukemia and hematopoietic cancers.[4-7] The monoaromatic BTEX hydrocarbons are the sources of a variety of adverse health effects such as asthma, fatigue, dizziness, and nose, throat and eye irritation. Additionally, nausea and other similar non-specific symptoms have also been associated with BTEX.[8,

[9] Benzene and ethylbenzene are the most dangerous BTEX group compounds classified as carcinogenic to humans by the IARC. Exposure to these substances is associated with increased risks of leukemia and hematopoietic cancers.[10-13]

The IARC has been classified benzene as "carcinogenic to humans" (Group 1) based on sufficient evidence that this compound causes acute myeloid leukemia. In contrast, toluene has been classified within Group 3 (not classifiable as to its carcinogenicity to humans).[14, 15] Toluene is widely used in the aromatic solvents industry.[16] This compound is comprised of major components of adhesives, paints, industrial varnishes, polishers, oil cleaners, fuel additives, which all are thinners.[17] Toluene can also affect the reproductive system and CNS.[18] This chemical material has an adverse health effect and can affect the central nervous system. Ethylbenzene and xylene can have neurological effects.[19, 20] Xylene exposure has been correlated with an increased risk of oligomenorrhea.[21] There are plenty of potentially BTEX sources in the air, such as smoking tobacco, gasoline, and diesel combustion in the motor and petrochemical industries.[22-24]

The solvents and organic compounds used in the BTEX have similar physical and chemical properties, with their main characteristic being their high evaporation rate.[25] Workers are exposed to BTEX when working with various thinners, paints, and lacquers for work processes, and washing parts and equipment through inhalation, peeling, and eating, which is the most important way to inhale.[26] VOC levels and their metabolites are highly correlated by corresponding air levels in occupational studies.[27, 28]

According to a study, employees in the oil and gas industry are exposed to a variety of chemicals, which are commonly found in low concentrations in everyday activities. During maintenance operations, there could be more interactions, which normally happen in less than one complete turn. Moreover, skin-to-skin exposures may involve high during the year in organizational activities, although such exposures have not been documented.[29] Long-term exposure to petroleum products involves negative impacts on the respiratory systems of certain employees, causing symptoms such as breathlessness, coughing, and wheezing.[30] The levels of VOCs and their metabolites in breath, blood, and urine appear to be closely related to the corresponding air levels in occupational studies.[31, 32]

The Australian Commission on Safety and Quality in Health Care produced the semi-quantitative method of risk assessment of hazardous chemicals in 1994, which later was published by the Australian Government Publishing Service.[33] The Malaysian Ministry of Human Resources Department of Occupational Safety and Health proposed a more comprehensive version of this approach in 2000.[34] Later, the Occupational Safety and Health Division of Singapore adopted it as a tool for assessing chemical risk in the region.[35] Occupational Health and Safety Assessment Series (OHSAS) 18001 defines risk assessment as an evaluation process of risks posed by hazards in the workplace, taking regulating measures into account and deciding on their acceptability.[36]

Risk evaluation is a key component of the Health, Safety, and Environmental (HSE) Management System to identify, evaluate, and control risk factors that affect the health and safety of employees in the workplace.[37] Chemical risk assessment is used to classify possible chemical hazards, evaluate the exposure of employees to hazardous chemical substances, and calculate the risk of unintended negative effects on people from interaction with hazardous chemical substances.[38, 39]

Without a proper method for classifying the potential risks, costs and resources can be spent on the management of less important risks rather than high-risk jobs.[40] To make proper decisions about control and safety measures against chemical complications, it is also essential to assess health risks.[41, 42] In other words, the chemical health risk assessment will help conduct a thorough assessment of your employees' exposure to hazardous health factors and make decisions about control steps, treatment, and education for employees.[43] BTEX compounds have the highest concentration of volatile organic compounds and thus control measures for these compounds should be prioritized.[44] This study aimed to identify the highest occupational exposure level in Abadan Oil Refining Company to BTEX compounds and assess the risks caused by them.

Methods

The number of BTEX compounds in the air of the respiratory area of employees in operating units was calculated by creating related exposure groups based on a group of personnel with similar behavior and work environment according to organizational charts (similar exposure groups=SEGs). To assess the exposure of operational unit employees, we selected 40 individual samples of air from the respiratory zone and used in an 8-hour morning shift. This was done followed by identifying similar occupational groups and collecting information related to the procedure, maintenance, occupational groups, and tasks.

The Singapore Department of Occupational Health has assessed the risk of occupational exposure to BTEX compounds. Besides, employees with a minimum of one year's experience were studied. Air sampling and BTEX analysis were carried out according to NIOSH method No. 1501. SPSS 20 was used to analyze the obtained results. Moreover, the method used by the Singapore Health Department

Table 1: Determination of hazard rate based on toxic effects or carcinogenicity property

Hazard rate	Hazard/effect classification description	
1	- No adverse effects on health - Carcinogenicity A5 (ACGIH) - It is not a toxic and harmful substance.	
2	- Undesirable effects on the skin and mucosa (without high intensity) - Carcinogenicity A5 (ACGIH) - Creating sensitivity and stimulating the skin	
3	- Carcinogenicity and mutagenesis in humans or animals (sufficient information has not yet been provided) Carcinogenicity A3 (ACGIH) - Group 2B (IARC) - Corrosive substance (5>PH>3 or 11>PH>9) - Respiratory stimulation as a component of harmful substances	Toluene, Ethylbenzene, Xylene
4	- Possibility of carcinogenicity, mutagenesis, and genetic disorders (based on studies on laboratory organisms) - Carcinogenicity A2 (ACGIH) - Group A2 (IARC) - Group B (NTP) - Very corrosive substance (2>PH>0 or 14>PH>5.11) - Toxic substance	
5	- Carcinogenic, mutagenesis, and cause of genetic disorders in infants - Carcinogenicity A1 (ACGIH) - Group 1 (IARC) - Group A (NTP) - Very toxic substance	Benzene

NTP: National Toxicology Program; ACGIH: American Conference of Governmental Industrial Hygienists; and IARC: International Agency for Research on Cancer

to assess the health effects of exposure to hazardous chemicals was adopted in this study.

Sampling and Analysis of BTEX

Eighty air samples were collected from 40 workers (two samples from each worker). The NIOSH 1501 method was followed for the sampling. According to this method, the samples were collected with activated charcoal and a low flow rate SKC pump (EX 44–224). For the sampling and performing the tests, the activated SKC tubes were calibrated by pumping a rotary meter (226-01). Samples were collected from the workers' breathing area over 8 h after preparing the absorbent and sampling pump. This study used an adsorbent every 4 h, adjusted the pump flow at 0.2 ml/min, and used controller specimens. After collecting the samples using a Chemicals recycling sample, carbon disulfide solution was used and working standard solution concentrations of 5, 1, and 30 µg/ml were tested. The work standard solution was injected into a GC-FID, using a 5ml syringe. The first step was to inject the main sample into the GC-FID. The sample volume was then determined via the calibration curve.[45]

Health Risk Assessment

The method proposed by the Malaysian Department of Occupational Safety and Health was used to determine harmful chemical exposure risks, and procedure that was followed in this study is described below.

(A) Hazard Rate Determination

According to the method recommended by the Malaysian Department of Occupational Health,[46] the hazard rate (HR) or risk factor of various substances is determined according to the factors presented in Table 1. Data used in this method include information provided by organizations related to chemical hazards such as the IARC and NTP, as well as ACGIH classification of chemicals in terms of health risks. The potential risks of chemicals can also be determined based on the classifications presented by these organizations.

(B) Determination of Exposure rate

Exposure rate (ER) is measured by determining actual exposure levels (when air monitoring results are available) or by determining the exposure index (EI) when the results of air monitoring are unavailable. The first method was used in this study to determine the ER. To this end, EI was calculated, and the ER was determined based on the following formula.

$$E = \frac{F \times D \times M}{W}$$

where E is the weekly exposure rate in mg/ppm, F is weekly exposure frequency, M is the rate of exposure in mg/ppm, D is the average duration of each exposure in hours, and W is the average working hours a week.[47] Finally, ER was obtained by dividing the weekly exposure rate (E) by the acceptable PEL contact limit and the degree of ER exposure (Table 2).

EI is ranked from 1 to 5 in numerical scales in terms of the severity of exposure, with 1 and 5

Table 2: Determining the degree of exposure based on the measured density

E/PEL	ER
<0.1	1
0.1–0.5	2
0.5-1	3
1-2	4
2<	5

Table 3: Determining the risk rate[47]

Ranking	Rating	Risk rate
Very low (Inconsiderable)	1	0-1.7
Low	2	1.7-2.8
Average	3	2.8-3.5
High	4	3.5-4.5
Very high	5	4.5-5

representing the lowest and highest exposure severities, respectively.

(C) Determination of Risk Rate

After determining the exposure rate and Hazard rate, the risk rate is obtained according to the following equation.

$$RR = \sqrt{HR \times ER}$$

where HR is hazard rate and ER is the exposure rate. The reason for taking the square root of the results is to get a number in the range of 1 to 5. The determined risk of each duty and its ranking is presented in Table 3.

Results

In this study, the workers' exposure to chemical pollutants was measured after selecting the related occupational exposure groups. According to the results in all units, BTEX concentrations to the recommended standard level showed that BTEX concentrations to the counseled respiration zone were lower than TLV-TWA recommended by ACGIH (Table 4). Employees are required to work 40 hours a week. Shift employees were exposed to BTEX compounds 30 days a week, in two half-hour shifts in the morning and two half-hour shifts in the evening, for a total of 2 hours in 8 working hours. Overall, using the method suggested by the Singapore Department of Occupational Health showed that Benzene posed the greatest risk.

Table 5 shows that benzene has a very Highrisk ranking (4.5–5). In operating units, among other BTEX compounds, Production, Distillation 85, Distillation 70, Distillation 75, Distillation 80, and Control Center are the units with the highest risks. Meanwhile, in Distillation 200, Catalyst conversion, and Distillation 60 units, benzene has a low ranking. Employees in the Distillation75, Distillation 200, Catalyst conversion, and Distillation 60 units did not have toluene in their respiratory tracts. Also, it had a very low level (0–1.7) of risk in the other units. Only the employees of the Control Center and the Catalyst conversion units were exposed to ethylbenzene, which had a very low level (0–1.7) of risk. The Xylene compound was also found only in the Control Center and Distillation 200 staff's respiratory areas, although with a very low level (0–1.7) of risk.

Discussion

This study was conducted in several units (ten units) in Abadan Oil Refining Company, and this study was carried out with the participation of skilled personnel with experience and familiarity with daily processes in the operational units of Abadan Oil Refining Company. The results showed the employees studied in this research were exposed to the pollutants of BTEX during their work. Comparing total BTEX concentrations with the recommended standard level showed that BTEX concentrations in Abadan Oil Refining Company Workers' breathing zone were lower than the TLV-TWA recommended by ACGIH. A tool provided by the Singapore Health Department was used to determine the health risks linked to occupational exposure. The risk degree, the degree of employees' exposure to chemicals, and the level of health risk were then measured after identifying contaminants including benzene, toluene, ethylbenzene, and xylene (BTEX). To this end, the average weight-time exposure was used because the results of sampling and air monitoring were available and obtainable every week.

The findings of this risk assessment study showed benzene had the highest risk ranking in seven operating units and a low risk ranking in three other units. Also, benzene is a harmful pollutant due to its high acute and chronic toxicity. Hence, much effort is needed to measure, control, and lower the negative health impacts of this pollutant. As can be seen from Table 5, toluene, ethylbenzene, and xylene had very low risk in all operating units.

Several studies, such as those by Harati[49] and Ding and Bao,[50] have also pointed to the adverse effects of BTEX. Harati et al. showed that exposure to benzene could increase the risk, and risk assessment analysis

Table 4: Summary of Benzene, toluene, ethylbenzene, and xylene (BTEX) concentrations in the breathing air zone

Pollutant name	OEL-TWA (ppm) in Iran	ACGIH TWA (ppm)	Average concentrations
Benzene	0.5	0.5	0.3176
Toluene	20	20	O.4011
Ethylbenzene	20	20	0.6645
Xylene	100	100	0.1034

Table 5: Exposure Rate (ER), Hazard Rate (HR), Risk Level (Rl), and Risk Rate (RR)

Unit	Pollutant name	HR	ER	RL	RR	The proposed program of periodic exposure assessment.[48]
station15	Benzene	5	2	5	Very high	At least once every three months
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Production	Benzene	5	2	5	Very high	At least once every three months
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Distillation 85	Benzene	5	2	5	Very high	At least once every three months
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Distillation 70	Benzene	5	2	5	Very high	At least once every three months
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Distillation75	Benzene	5	2	5	Very high	At least once every three months
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Distillation 80	Benzene	5	2	5	Very high	At least once every three months
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Control Center	Benzene	5	2	5	Very high	At least once every three months
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Distillation 200	Benzene	5	1	2.5	Low	At least once a year
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Catalyst conversion	Benzene	5	1	2.5	Low	At least once a year
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years
Distillation 60	Benzene	5	1	2.5	Low	At least once a year
	Toluene	3	1	1.5	Very low	At least once every two years
	Ethylbenzene	3	1	1.5	Very low	At least once every two years
	Xylene	3	1	1.5	Very low	At least once every two years

can provide valuable information on the control procedures in the petrochemical industry. Jahangiri and Parsarad performed a chemical risk assessment in a petrochemical unit. In their study, because of applying effective controls, epichlorohydrin had the highest risk and toluene had the lowest risk.[51] Jalali et al. carried out a report in Mashhad on the risk assessment of BTEX compounds in fuel stations. According to their results, the highest risk values were found in ethylbenzene and benzene.[52]

Therefore, control measures should always be taken into consideration. Different occupations can be ranked in terms of risk exposure by using the information on the dangers of chemicals and the results in assessing the health risks posed by exposure to chemicals. This ranking can prioritize control actions resources and reduce the exposure risk to acceptable levels. Overall, taking exposure control measures, including technical control, engineering, and management measures, continuous monitoring of the work environment, and risk reassessment after the interventions necessary to minimize the pollutants are suggested in this regard. Since benzene has the highest risk level of the three chemicals, it is necessary to conduct control methods and health risk mitigation. In terms of control intervention, the priority must be minimizing the exposure by changing working methods and ventilation systems, as well as using adequate protective equipment. According to the EPA, the easiest way to regulate benzene in petroleum products is to eliminate benzene and substitute it with a material that is less harmful.[53]

BTEX compounds have the highest concentration of organic volatile compounds,[54] suggesting the necessity to control measures for these compounds. While BTEX compounds are not components of the raw materials used by Abadan Oil Refining Company, their presence can lead to material leakage from the equipment of the units. However, the findings of this study revealed that benzene had a high level of risk. Therefore, it is important to implement controlling measures. Employees must be controlled regularly, and chemical cartridge masks must be used to control hazardous organic matters such as BTEX compounds.[55, 56] Other useful measures in this regard are employee respiratory protection,[57] workplace rotation,[58] and exposure time reduction.[59]

This rating will aid us in correcting a mission, obligation, or measuring whether a matter poses a significant health danger. If the evaluation indicates that corrective measures are required to reduce the risk in BTEX compounds, the industry should take effective corrective actions.

Conclusion

Employees in oil refineries are often exposed to BTEX compounds, which luckily occurs at low concentrations. Based on the significant effects of BTEX, corrective and preventive measures should be taken to minimize or decrease exposure rates. Moreover, benzene regulation steps take precedence over the other three compounds. According to the findings of the risk assessment conducted in this report, control and preventive steps should be taken at three levels of engineering, management, and use of adequate personal protective equipment. It is also recommended to perform a risk assessment every three months to determine and control benzene concentration and health risks.

Limitations

One of the drawbacks of this study is the lack of data on risk assessment from previous years, which could have been used to compare the findings with those of the current study.

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Conflicts of interest*:* None declared.

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