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Risk assessment of occupational exposure to BTEX in the National Oil Distribution Company in Iran

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Original Article

Abstract

BACKGROUND: This study evaluated the quantitative, carcinogenic and non-carcinogenic risk of exposure to BTEX using lifetime cancer risk (LCR) and hazard quotient (HQ) in the National Company for Distribution of Petroleum Products in Iran.

METHODS: In this risk assessment method, the data were collected in different parts of the company. In order to determine the concentration of BTEX, sampling was carried out in different parts using activated carbon. A Gas Chromatography–Flame Ionization Detector (GC-FID) was used for analysis. Analysis and sampling was conducted according to the NIOSH 1500 method. For carcinogenic risk assessment, LCR was calculated. For non-carcinogenic risk assessment, HQ was calculated.

RESULTS: The carcinogenetic risk of benzene was definite for loading and deep handling units, and safety officer, and was probable for sealing, inspection gate, security, and loading 1 and deep handling units. The carcinogenic risk of ethylbenzene was definite for quality control and loading 1 units, was probable for deep handling and loading 2 units, and safety officer, and was possible for sealing, inspection gates, and security units. The non-carcinogenic risk of toluene was acceptable for deep handling, sealing, inspection gates, and sealing units, but was unacceptable for safety officer, quality control, and loading 1 and loading 2 units. The non-carcinogenic risk of xylene was acceptable for the inspection gate unit, but was unacceptable for security, sealing, safety officer, quality control, and deep handling, loading 1, and loading 2 units.

CONCLUSION: This risk assessment method used was a comprehensive and quantitative method, so it determined the risk accurately. Commensurate with the risk level of each part of the company, the appropriate corrective actions must be carried out.

KEYWORDS: Risk Assessment, Hydrocarbons, Petroleum Industry, Occupational Exposure

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Introduction

Exposure to volatile organic compounds (VOCs) has been a serious concern of the scientific community in the past decades.[1-3] The chemical diversity of the VOCs has adverse impact on human health ranging from carcinogenic to non-carcinogenic effect.[4-7]

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Benzene, toluene, ethylbenzene, and xylene (BTEX) are VOCs. Benzene and ethylbenzene are well known carcinogens.[8,9] Benzene can also affect the hematopoietic system, the central nervous system (CNS), and the reproductive system.[10-12] Toluene can also affect the reproductive system and CNS.[13] Neurotoxicity studies showed that benzene exposure is mostly associated with headache.[14,15]

In oil products distribution companies, due to leakage of petroleum products in different parts of the site, operators and workers in different parts are exposed to BTEX compounds and concentration exposure to benzene in quality control and loading sections are considerable. To estimate the health impact of variation in levels of VOCs, indicators of risk assessment used included the lifetime cancer risk (LCR) and hazard quotient (HQ).[16-19]

In study of Tunsaringkarn et al., in order to assess carcinogenic risk of workers exposed to benzene in diesel stations, the Environmental Protection Agency (EPA) risk assessment method by calculation of LCR and HQ was implemented.[13] Finally, they concluded that exposure to BTEX compounds increased carcinogenic risk among the workers.[13] Guo et al. conducted a study for risk assessment of exposure to VOCs using the United States Environmental Protection Agency (US-EPA) method.[16] Tunsaringkarn et al. recommended the US-EPA method for risk assessment of VOCs in the weather conditions of Bangkok.[13] They used a Gas Chromatography–Flame Ionization Detector (GC-FID) at gas stations and reported that the risks of benzene were definitive.[13] The results of the study by Ramirez et al. in petro-chemical residential areas showed that the risk of ethylbenzene was present in all three investigated sites.[7] The results of Ramirez et al.[7] showed that the risk of toluene was less than the amount recommended by the World Health Organization (WHO).[1] The study by Lee et al.[20] in photocopy centers in Taiwan showed that the risk of toluene was lower than that reported by Andersson et al.[1] The findings of Ramirez et al.[7] showed that the risk of xylene was lower than that reported by Andresson et al.[1] Colman Lerner et al. evaluated the risks of exposure to VOCs in urban air and used the US-EPA method in order to carry out risk assessment in Argentina.[4] They found that benzene in repairing and the laboratory had a definite and possible risk, respectively.[4] According to previous studies, LCR values of more than 10^{-4}, between 10^{-4} and 10^{-5}, and between 10^{-5} and 10^{-6} were, respectively, classified as the risk of outages, probable risk, and possible risk.[4]

In chemical industries dependent on petroleum, BTEX is released because of high vapor pressure of these compounds; and many people are exposed to these compounds in industrial and non-industrial environments. In this regard, respiratory exposure is the most important contact point of humans with this group of chemical compounds. In general, the adverse health effects caused by chronic exposure to VOCs can be divided into two categories of carcinogenic and non-carcinogenic. From among the adverse non-carcinogenic effects allergy effects, stimulating, liver and kidney disorders, and neurological and respiratory disorders can be noted. Cancers of the lungs, blood, liver, kidney, and biliary tract are cancers that can be caused by human exposure to VOCs. The International Agency for Research on Cancer (IARC) classified benzene as a definite carcinogen (Group 1), ethylbenzene as possibly carcinogenic (Group 2B), and toluene and xylene as not classifiable as to their carcinogenicity to humans (Group 3).

Today, many international organizations, including the World Health Organization (WHO), US-EPA, the United States Food and Drug Administration (US FDA), consider the use of quantitative risk assessment as the basis for legislation on chemical compounds. In order to estimate the cancer risk of carcinogenic hydrocarbons, LCR is used and defined as a possible indicator in the increasing risk of cancer caused by specific exposure. In addition, in order to estimate the risks of exposure to non-carcinogenic hydrocarbons the HQ is used. HQ expresses the level of exposure to a substance at which that substance does not have any harmful effects. From this statement it can be concluded that quantitative risk assessment is very important for VOCs such as BTEX. Moreover, according to the legal requirements of labor protection, a quantitative risk assessment should be conducted in the chemical industries dependent on the type of petroleum and oil broadcasting companies.

This study was conducted to determine occupational exposure to BTEX compounds, estimate the LCR, and perform non-carcinogenic assessment of these chemical compounds using the HQ in the some Oil Distribution Companies in Iran.

Materials and Methods

This cross-sectional study was conducted on individuals in charge in different parts of a company, and the data were collected through measurement. Sampling was conducted according to the NIOSH 1501 method. According to this method, samples were collected using activated charcoal and a low flow rate pump.

The activated charcoal tubes were prepared for sampling and sampling pump was calibrated through a rotameter. After preparing the absorbent and sampling pump, samples were collected from the breathing zone of workers for 8 hours. In this study, an adsorbent was used every 4 hours, the pump flow was adjusted at 200 ml per minute, and the control specimens were used. Preparation of collected samples was performed using chemical recovery extraction method. Sample perpetration was performed using carbon disulfide solution and 5, 1, and 30 micrograms per ml concentration of working standard solutions were used.

Using a 5 microliter syringe, the working standard solution was injected into a GC-FID. In the next step, the main sample was injected into the GC-FID, after that, the amount of samples was determined through the calibration curve. One of the HQ factors was estimated by determining the amount of the sample through the calibration curve; and another factor was inhalation reference concentrations (RfCs), which was determined using IRIS; for chronic daily intake (CDI) formula, the amount of the sample and other factors were determined via interviewing and measurement.

The US-EPA recommended formula for calculating HQ is proportion of measured concentration divide by RFC. Furthermore, for the determination of LCR, CDI and slope factor (SF) were used. Since, based on the division of the IARC, benzene and ethylbenzene are among the group 1 and group 2B carcinogens, respectively, LCR was used in order to determine the carcinogenic risk of benzene and ethylbenzene. To determine LCR, first, the terms of the factors for CDI (Equation 1) must be determined.

$$CDI=\frac{C*IR*ED*EF*LE}{BW*ATL*NY} \qquad \text{(Equation 1)}$$

In this formula, C is the pollutant concentration in inhalation in work shift in milligrams per cubic meter, IR is the respiration rate in terms of cubic meters per hour, ED is the duration of exposure in terms of hours per week, EF is the frequency of exposure in terms of weeks per year, BW is body weight in kilograms, ATL is the average lifespan of a person, and NY is the number of days per year.

After the CDI was determined, the SF of benzene had to be determined. The SF of benzene was 0.0273 which was provided by the Risk Assessment Information System

(RAIS) and the SF of ethylbenzene was 0.0087 which was provided by the California Office of Environment Health Hazard Assessment (OEHHA). LCR was determined according to the formula of LCR = CDI * SF. LCR of higher than 10^{-4}, 10^{-4}-10^{-5}, and less than 10^{-5} was considered to be a definite risk, a possible carcinogenic risk, and a probable risk of carcinogenesis, respectively. In order to determine the HQ, reference concentration was determined. The inhalation reference concentrations (RfCs) values are provided by the Integrated Risk Information System (IRIS) database. The RFC for toluene and xylene is 5 and 217 mg per cubic meter, respectively. The information of BTEX compounds for carcinogenic and non-carcinogenic risk assessment is presented in table 1.

After determination of RFC, the HQ was determined using the equation HQ = C/RFC. Risk classification was determined for non-carcinogens. Thus, if the HQ was less than or equal to 1, risk was considered acceptable, and if the HQ was more than 1, risk was considered unacceptable.

Table 1. The information of BTEX for carcinogenic and non-carcinogenic risk assessment

Substance	Variable	Provided by
Benzene	Slope factor : 0.0273	RAIS
Toluene	RFC: 5	IRIS
Ethylbenzene	Slope factor: 0.0087	OEHHA
Xylene	RFC: 0.217	IRIS

RAIS: Risk Assessment Information System; IRIS: Integrated Risk Information System database; OEHHA: the California Office of Environment Health Hazard Assessment

Results

The LCR of benzene for the quality control, loading 2, and safety officers was higher than 10^{-4} which was a definite risk. Moreover, for sealing, deep handling, loading 1, inspection gates, and security, it was between 10^{-4} and 10^{-5}, which was probable risk. The LCR of ethylbenzene for quality control and loading 1 was higher than 10^{-4} which was a definite risk, and for the loading 2, deep handling, and safety officer the risk was 10^{-4}-10^{-5} which was considered as a probable risk.

Moreover, for security, inspection gate, and sealing, it was less than 10^{-5} which was a possible risk. The results of carcinogenic risk assessment due to exposure to benzene and ethylbenzene in various employers are shown in table 2.

The HQ of toluene for the quality control, loading 1, loading 2, and safety officers was greater than 1, which was considered unacceptable. The HQ of toluene for sealing, deep handling, loading 1, inspection gates, and security was less than 1, which was considered an acceptable risk. The HQ of xylene for quality control, loading 1, loading 2, sealing, security, and the safety officer was greater than 1, which was considered as an unacceptable risk. In addition, the HQ of xylene for inspection was less than 1 that was considered as an acceptable risk.

The results of non-carcinogenic risk assessment due to exposure to toluene and xylene in various employers are illustrated in table 3.

Table 2. The carcinogenic risk of benzene and ethylbenzene in various worksites

Site	Benzene		Ethylbenzene	
	Risk	Risk classification	Risk	Risk classification
Security	$7.6*10^{-5}$	Probable risk	$1*10^{-6}$	Risk possible
Inspection gate	$1.8*10^{-4}$	Probable risk	$1.11*10^{-6}$	Risk possible
Sealing	$7.2*10^{-4}$	Probable risk	$1.23*10^{-6}$	Risk possible
Safety officer	0.14	Probable risk	$1*10^{-5}$	Probable risk
Quality control	0.45	Probable risk	$3.5*10^{-3}$	Definite risk
Deep handling	$1.1*10^{-4}$	Probable risk	$1.37*10^{-5}$	Probable risk
Loading 1	$1.6*10^{-4}$	Probable risk	$1*10^{-3}$	Definite risk
Loading 2	0.17	Definite risk	$1.9*10^{-5}$	Probable risk

Table 3. The non-carcinogenic risk of toluene and xylene in various worksites

Site	Toluene		Xylene	
	Risk	Risk classification	Risk	Risk classification
Security	0.04	Acceptable risk	1.40	Unacceptable risk
Inspection gate	0.04	Acceptable risk	0.34	Acceptable risk
Sealing	0.27	Acceptable risk	7.20	Unacceptable risk
Safety officer	31.50	Unacceptable risk	760.00	Unacceptable risk
Quality control	62.50	Unacceptable risk	26.30	Unacceptable risk
Deep handling	0.13	Acceptable risk	1.60	Unacceptable risk
Loading 1	6.89	Unacceptable risk	4.80	Unacceptable risk
Loading 2	16.20	Unacceptable risk	160.00	Unacceptable risk

After calculating the risk, the various divisions of the company were ranked in terms of the risk of benzene as quality control, load 2, safety officer, sealing, inspection gates, loading 1, and deep handling. Furthermore, they were ranked in terms of the risk of ethylbenzene as quality control, loading 1, loading 2, deep handling, safety officer, sealing, inspection gates, and security. Various parts of the company were ranked as quality control, safety officer, loading 2, loading 1, sealing, deep handling, inspection gates, and security in terms of the risk of toluene.

Different parts of the company were prioritized in terms of the risk of xylene as safety officer, loading 2, quality control, sealing, loading 1, deep handling, security, and inspection gates. The cumulative risk of toluene and xylene was calculated by hazard index (HI) method. Thus, the cumulative risk was 88.8 for quality control, 791.5 for safety officers, 176.2 for loading 2, 11.6 for loading 1, 7.33 for sealing, 1.73 for deep handling, 1.44 for security, and 0.38 for inspection gates. However, the cumulative effect of benzene and ethylbenzene has not been established yet. After calculating the cumulative risk, ranked risks of various parts were calculated. The highest risk was related to the quality control and the lowest risk was related to the inspection gate. In any shift, 12 people worked at loading 1, and 12 at loading 2, 4 in deep handling, and 2 in sealing, 3 in the laboratory, 4 in security, and 2 at the inspection gate. Each shift lasted 8 hours, and the company personnel worked in three shifts. Table 4 shows the results of carcinogenic and non-carcinogenic risks due to exposure to BTEX at various worksites.

The results of cumulative risk of exposure to BTEX at different worksites are presented in table 5.

Discussion

Protecting health workers in the oil-depend industries is very important, as these workers are exposed to carcinogens and non-carcinogenic compounds. One of the most

Table 4. The carcinogenic and non-carcinogenic risks due to workers exposure to BTEX in various worksites

Benzene		Ethylbenzene		Toluene		Xylene	
Quality control	0.045	Quality control	3.50×10^{-3}	Quality control	62.50	Safety officer	760.0
Loading 2	0.017	Loading 1	1.00×10^{-3}	Safety officer	31.50	Loading 2	160.0
Safety officer	0.014	Loading 2	1.90×10^{-5}	Loading 2	16.20	Quality control	26.3
Sealing	7.2×10^{-4}	Deep handling	1.37×10^{-5}	Loading 1	6.89	Sealing	7.2
Inspection gate	1.8×10^{-4}	Safety officer	1.00×10^{-5}	Sealing	0.27	Loading 1	4.8
Loading 1	1.6×10^{-4}	Sealing	1.23×10^{-6}	Deep handling	0.13	Deep handling	1.6
Deep handling	1.1×10^{-4}	Inspection gate	1.11×10^{-6}	Inspection gate	0.04	Security	1.4
Security	7.6×10^{-5}	Security	1.00×10^{-6}	Security	0.04	Inspection gate	0.3

Table 5. Cumulative risk of exposure to BTEX in different worksites

Site	Cumulative risk ($HI = \sum HQ$)
Quality control	62.5 + 26.3 = 88.8
Safety officer	760 + 31.5 = 791.5
Loading 2	160 + 16.2 = 176.2
Loading 1	6.89 + 4.8 = 11.69
Sealing	7.2 + 0.13 = 7.33
Deep handling	1.6 + 0.13 = 1.73
Security	1.4 + 0.04 = 1.44
Inspection gate	0.34 + 0.04 = 0.38

important industries for exposure to chemicals is in oil products distribution companies. Risk assessment is effective in preventing, and appropriate risk assessment is a legal requirement in safety management and risk control systems. In oil distribution companies, due to volatile chemicals, many people expose to benzene, toluene, ethylbenzene, and xylene. In oil distribution companies, the main route of human exposure to chemical compounds is through respiratory exposure. Today, quantitative risk assessment is very important; thus, many international organizations, including the US FDA, US-EPA, and the WHO, consider using a quantitative risk assessment as the basis for legislation on chemical substances.

In this study, quantitative risk assessment of occupational exposure to BTEX was conducted in the Petroleum Distribution Company based on the US-EPA instruction. For chemicals in groups 1 and 2 in the IARC category, a carcinogenic risk assessment method should be used. The LCR index was used in the present study. In addition, for the quantitative risk assessment of non-carcinogenic compounds, HQ was used for groups 3 and 4 of the classification of the IARC. In which, benzene, ethylbenzene, toluene, and xylene are classified as group 1, 2, and 3, respectively. This risk assessment method is a comprehensive approach, because it considers many factors that can affect the exposure, such as exposure time, frequency of exposure, history of the individual, respiration rate, body weight, and concentration of pollutants. The results of this study can be used to classify different parts of the company to reduce the risk, and rank them to control the engineering and management. Risk classification allows people to obtain a good understanding of risk. By risk assessment, the various divisions of the company were classified. In this way, HI was used for non-carcinogenic hydrocarbons, which represented cumulative risk, determined by the total HQ of non-cancerous pollutants. In this study, the cumulative risk was calculated. The cumulative effect of toluene and xylene has been proven, but for benzene and ethylbenzene the investigation continues. The risks of benzene, ethylbenzene, and toluene were higher in quality control than other parts of the company. In the quality control of petroleum products distribution companies, because of maintenance products, pure chemicals, and inadequate ventilation, exposure to BTEX is high. In loading 2, fuel was loaded, while in loading 1, oil and diesel fuel were loaded which produce less VOCs than petrol; thus, loading 2 showed higher risks. Security and inspection gate operators had less exposure than the quality control operators and safety officers. According to the cumulative risk of toluene and xylene, quality control operators, safety officers, and loading 2, loading 1, sealing, deep handling, security, and inspection gate operators were at high risk, respectively. LCR of benzene was definite and probable. The LCR of ethylbenzene was definite, probable, and possible. The risk level for benzene in most parts was higher than ethylbenzene. The HQ of Xylene for all areas, except the inspection gate, was unacceptable. However, the HQ of toluene was unacceptable for quality control, loading 2, safety officer, and loading 1, but was acceptable for the other parts. In a study that was conducted by Colman Lerner et al. in 2012 in Argentina, the risk of benzene was certain and possible in repair workers and laboratory personnel, respectively.[4] In a study by Tanasorn Tunsaringkarn et al. in Thailand in 2012 at a petrol station, the risk of benzene was a definite risk.[13] The result of the study by Ramirez et al. in petrochemical plants showed that the risk of ethylbenzene was possible in all 3 studied sites.[7] The result of the study by Ramirez et al. showed that the risk of toluene in petrochemical residents was less than the amount recommended by the WHO.[7] In the study by Lee et al., the risk of toluene was lower than the reference value.[20] The study by Ramirez et al. showed that the risk of xylene in petrochemical sites was lower than the reference value.[7] The studied company operated in three shifts, operators changed per shift, and the duration of work was 8 hours per shift. In this study, everyone was examined, and measurements and calculations were performed for each shift. In order to reduce the level of risk in quality control operators, who had the highest risk level, engineering controls (such as the designing of ventilation systems) and management controls should be used. Management control, such as reducing exposure time can be effective on the reduction of the level of risk.

Conclusion

The exposure to pollutants in the studied company was due to the spillage of chemical materials, as well as the loss of oil tankers and pollution caused by them. The method of risk assessment used in the present study is comprehensive and the obtained results can be used for correcting and controlling the prioritization of resources in order to reduce the level of risk. The health risk assessment conducted at this site indicated that employees were at risk of carcinogenic compounds. The highest carcinogenic risk was related to benzene in the quality control unit and the highest non-carcinogenic risk was related to xylene in the safety officer. Except for the gateway inspection unit, the remaining parts were unacceptable in terms of non-carcinogenic risk. The carcinogenic risk in the quality control and loading 1 units was definitive, and the highest risk of carcinogenicity was in these units.

Conflict of Interests

Authors have no conflict of interests.

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