CASE STUDY

A Survey of Neurobehavioral Symptoms among Operational Workers Exposed to Mixture of an Organic Solvent (BTEX): a case study in an oil refinery

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ABSTRACT

Background: Benzene, toluene, ethyl benzene, and xylene (BTEX) are categorized as the hazardous airborne pollutants that widely consumed in various industries. Therefore, the aim of this study was the survey of the neurobehavioral symptoms among operational workers exposed to the mixture of an organic solvent (BTEX) in an oil refinery.

Methods: The present study was conducted on the personnel of a refinery located in the south of Iran in 2018. In total, 78 operational workers were selected as exposure group and 85 administrative staff as control group. BTEX compounds were sampled based on the methodology 1501 presented by NIOSH. In addition to, the demographical information of two groups were gathered by a questionnaire and Swedish Q16 questionnaire for long term solvent-exposed workers was applied to collect data on the neurobehavioral symptoms. Data analysis was performed using SPSS version 22 software.

Results: Based on the results of the chi square test, the frequency of the positive neuropsychiatric behavior symptoms in the exposure group was significantly higher than that in the control group. The results of spearman test demonstrated that there are the positively significant correlations between the frequency of the positive neuropsychiatric behavior symptoms and the measured values of benzene ($r = 0.402$, P value < 0.001) and toluene ($r = 0.577$, P value < 0.001) compounds.

Conclusion: The occupational exposure to BTEX compounds, particularly benzene and toluene, can cause the neurobehavioral symptoms in the exposed workers of the refinery.

Keywords: Neurobehavioral symptoms, organic solvent, benzene, toluene, xylene, ethylbenzene, oil refinery.

INTRODUCTION

Benzene, toluene, ethyl benzene, and xylene (BTEX) are categorized as the hazardous airborne pollutants that widely consumed in various industries such as electronic, steel, paint, petroleum and oil[1,2]. Poisoning to BTEX occurs when these compounds are entranced into the body through respiratory or dermal absorption. However, the respiratory absorption is the main uptake route of BTEX compound[3,4]. After the entrance, these compounds can be accumulated in the fatty tissue, nervous system, liver, and heart and cause the adverse health effects. Based on the exposure time, the effects were divided to the acute or chronic types. The acute effects such as dizziness and throat irritation occur after exposure to the high concentration of BTEX compounds at the short period of the time. However, the chronic effects such as memory loss and nausea occur after exposure to the low concentration of these compounds at the long period of the time[5,6]. Benzene has been classified as Group 1 in IARC classification (agents which are human carcinogenic). At the past studies, that has been shown that benzene can cause leukemia in the exposed workers[7,8]. Toluene, xylene, and ethyl benzene, as neurotoxic, can affected the central nervous system (CNS system).Chronic encephalopathy is an undesirable effect of the longtime exposure to the organic solvents. Signs of the exposure are initially reversible, but the increased exposure time cause irreversible effects, even when that is discontinued. The memory loss, unstable mood, irritability, end etc. are self-reported neurotoxic effects of Chronic encephalopathy due to exposure to the organic solvents[9,10,11]. Because of the industrial expansion, the number of people exposed to BTEX compounds increases daily. NIOSH estimates that higher than 8.9 million people in the United States are exposed to organic solvents. In Iran, there is no available accurate data on the number of the workers exposed to organic solvents[12,13]. There are many refineries in countries and a large number of workers are employed at these centers. Previous studies have shown that BTEX compounds are one of the most important contaminants in the workplace of the refineries. Many studies have been conducted on the blood induced effects due to the exposure with BTEX compounds in refineries and petrochemicals. Their findings indicate that there is a significant relationship between the air concentration of these compounds and the level of the blood changes in the exposed individuals[14-17]. A few Studies on the Neuro-behavioral effects of the exposure to BTEX compounds in various industries have shown that the exposure to these compounds has made the behavior changes in the exposed individuals[18,19]. Although, in recent years, different

studies have been carried out on the measurement and evaluation of the exposure to BTEX compounds in various industries, a few studies have been performed on the adverse effect in the workers exposed to the mixtures of the organic solvents. On the other hand, given to the uncertainties at the reported results, the aim of this study was the survey of the neurobehavioral symptoms among operational workers exposed to the mixture of an organic solvent (BTEX) in an oil refinery.

MATERIALS AND METHODS

The present study was conducted on the personnel of a refinery located in the south of Iran in 2018. The inclusion criteria included the work experience higher than five years, presence of neurological disease history, and non-use of psychiatric drugs and alcohol. People who did not possess these criteria were excluded. In total, 78 operational workers were selected as exposure group and 85 administrative staff as control group. BTEX compounds were sampled based on the methodology 1501 presented by NIOSH. The samples were collected using the activated carbon adsorbent tubes containing the coconut shell charcoal produced by Merck company from Germany. The characterizations of the charcoal particle included the mean size of nearly 670 × 6 millimeters, the purity higher than 99.5 percent, and the mesh size of 20/40 percent. a laboratory grade and high purity grade, was assembled with a flow of 0.2 liters per minute for 45 minutes. The flow rate and time duration of the sampling were 0.2 liters per minute and 45 minutes to eight hours, respectively. Then, the samples were transferred to a laboratory and analyzed using a gas chromatography analyzer with flame ionization detector (FID). In the next step, the demographical information of two groups were gathered by a questionnaire. As well as, Swedish Q16 questionnaire for long term solvent-exposed workers was applied to collect data on the neurobehavioral symptoms. In this questionnaire, four positive answers of the people aged below 28 years and six positive answers of the people aged over 28 years are determined as a known disease. This questionnaire is an appropriate tool to screen the neurobehavioral symptoms. Its information can be used for decision making and planning at clinical examinations and complementary psychological tests. Studies have been carried out that have used this tool to find the neurobehavioral symptoms among welders and confirmed its validity and reliability[20]. The questionnaire was translated into Persian and the participants were asked to answer the questions during the rest times. Data analysis was performed using SPSS version 22 software. The normality of data was examined by Kolmogorov – smirnov test. Independent t-test and chi square were applied to determine the differences of the variables. Spearman correlation test was also applied to specify the correlation between the variables.

RESULTS

The results of the Kolmogorov – Smirnov test showed that the distribution of the age, body mass index, and work experience are normal, while, other variables have abnormal distributions. Table 1 presents the descriptive statistics and comparison of individual's frequency between control and control groups based on the demographical and occupational characteristics. The mean and standard deviation values of the age and work experience in the exposure group were equal to 43.02±6.79 years and 7.51 ± 6.23 years, respectively. These values in the control group were equal to 43.23±7.49 years and 12.6±6.88, respectively. The results of independent sample test indicated that the mean values of the age and work experience are no significantly different in two groups. As well as, table 2 reports the descriptive statistics of positive neuro-behavioral symptoms in both case and control groups and the difference between them. Based on the results of the chi square test, the frequency of the positive neuropsychiatric behavior symptoms in the exposure group was significantly higher than that in the control group. As well as, figure 1 shows the correlations between the frequency of the positive neuropsychiatric behavior symptoms and the measured values of BTEX compounds (A. Benzene, B. Toluene, C. Xylene, and D. Ethylbenzene). The results of spearman test demonstrated that there are the positively significant correlations between the frequency of the positive neuropsychiatric behavior symptoms and the measured values of benzene ($r = 0.402$, P value < 0.001) and toluene ($r = 0.577$, P value < 0.001) compounds. However, the correlations between the frequency of the positive neuropsychiatric behavior symptoms and the measured values of xylene ($r = 0.146$, P value = 0.202) and ethylbenzene ($r = 0.105$, P value = 0.359) compounds were no meaningful.

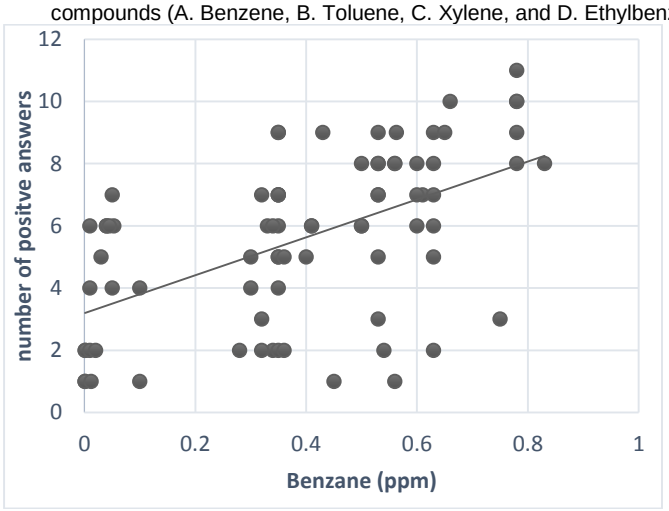
Table 1: The descriptive statistics and comparison of individual's frequency between control and control groups based on the demographical and occupational characteristics

Variables	Case group	Control group	P-Value
	Mean ±SD	Mean ± SD	
Age	43.02±6.79	43.23±7.49	0.99
Body mass index	24.19 ±4.55	24.72±4.72	0.59
Work experience	12.74±7.01	12.6±6.88	0.70

Table 2: The descriptive statistics of positive neuro-behavioral symptoms in both case and control groups and the difference between them

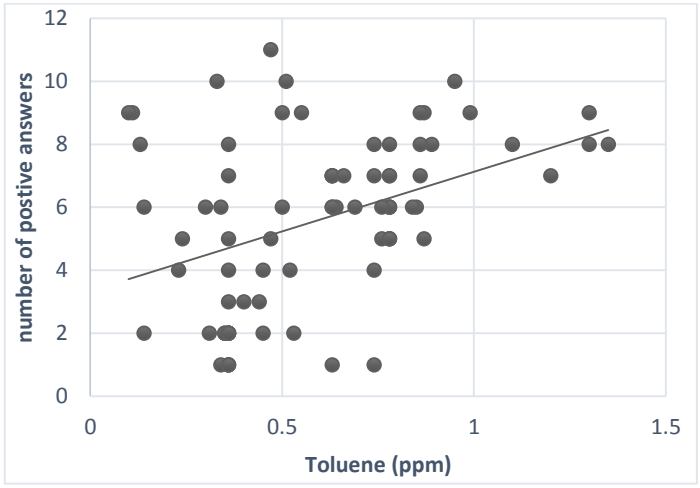
Question	Case group (N 78)		Case control (N 85)		P. value
	Positive	%	Positive	%	
1.Are you abnormally tired?	41	52.6	23	27.1	0.001
2.Do you have palpitations even when you don't exert yourself?	12	15.4	8	9.4	0.246
3.Do you often have a painful tingling in some part of your body?	16	20.5	12	14.1	0.280
4.Do you often feel irritated without any particular reason?	38	47.8	22	25.9	0.003
5.Do you often feel depressed without any particular reason?	21	26.9	18	21.02	0.390
6.Do you have problems with concentrating?	17	21.8	14	16.5	0.387
7.Do you have short memory?	13	16.7	8	9.4	0.167
8.Do you perspire without any particular reason?	6	7.7	3	3.5	0.245
9.Do you have problems with buttoning and unbuttoning?	9	11.5	4	4.7	0.108
10.Do you have generally find it hard to get the meaning from reading newspapers and books?	4	5.1	2	2.4	0.347
11.Have your relatives told you that you have a short memory?	8	10.3	3	4.7	0.175
12.Doyou sometimes feel an oppression of your chest?	17	35.1	12	14.1	0.002
13.Do you often have to make notes about what you must remember?	2	2.7	1	1.2	0.481
14.Do you often have to go back and check things you have done?	11	14.7	6	7.1	0.119
15.Do you have headache at least once a week?	44	56.4	36	42.4	0.073
16.Are you less interested in sex than what you think is normal?	6	7.7	2	2.4	0.115

Fig. 1: The correlations between the frequency of the positive neuropsychiatric behavior symptoms and the measured values of BTEX compounds (A. Benzene, B. Toluene, C. Xylene, and D. Ethylbenzene)



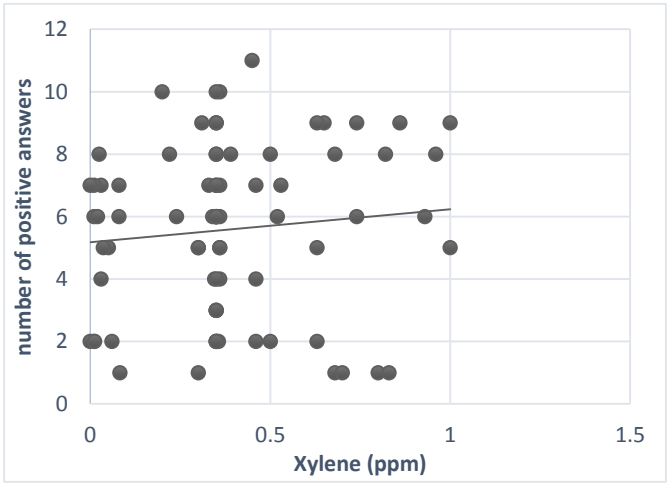
r = 0.402, P value < 0.001

A



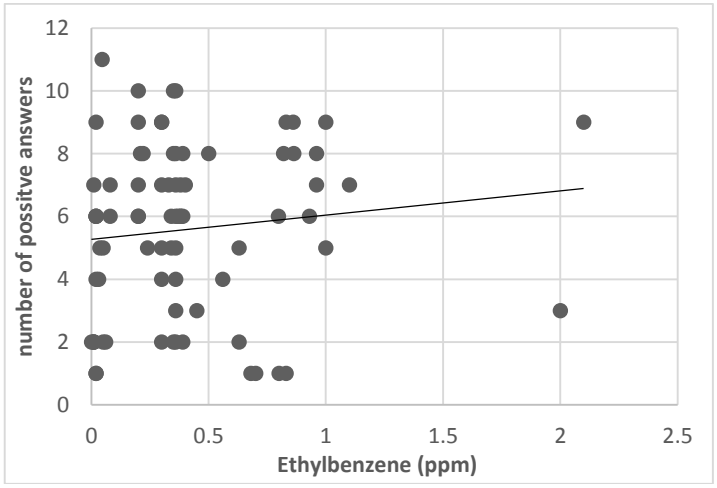
r = 0.577, P value < 0.001

B



r = 0.146, P value = 0.202

C



r = 0.105, P value = 0.359

D

DISCUSSION

The occupational exposure to BTEX compounds can cause the neurobehavioral symptoms. The results of the present study showed that the frequency of the positive neurobehavioral symptoms in the operating staff exposed to BTEX compounds were higher compared to those in the administrative staff no exposed to BTEX compounds. Based on the results, there are the positively significant correlations between the frequency of the positive neuropsychiatric behavior symptoms and the measured values of benzene and toluene compounds. However, these correlations were no meaningful for the xylene and ethylbenzene compounds. Given that confounding factors can affect the results, in the present study, people who had a neurobehavioral diseases and those who were consuming the certain medications, tobacco, and alcoholic beverages, were excluded. As well as, the age and work experience of two groups were nearly similar and there was no significant difference between them. Therefore, it can be resulted that the exposure to BTEX compounds have been affected the neurobehavioral symptoms of staff.

Some studies have been investigated the effects of the solvents and gases on neurological and behavioral symptoms. Rouch et al. performed a cross-sectional study on 113 employees of a printing house in two groups including 64 subjects exposed and 49 subjects non-exposed to toluene. The results showed that is a significant difference between the symptoms of mental fatigue in two groups at the error level of five percent[21]. Hasanzadeh et al. also investigated staff of a coloring industry as the group exposed to organic solvents and staff of a textile industry as group non-exposed. The results of the study indicated that the prevalence of mental fatigue in the exposed subjects was significantly higher compared to that in the non-exposed subjects[22]. In another study, Kauquianen also evaluated the fatigue incidence of the individuals exposed to organic solvents. Based on the results, there were a significant difference between the incidence of the fatigue in the case and control groups[23,24]. The results of the present study were consistent with the stated results of other studies. Therefore, it can be concluded that the chronic occupational exposure to organic solvents can cause the fatigue. So that, the results showed that most prevalence of neurobehavioral symptoms included the fatigue and depression, respectively. In the other words, these results may indicate a risk of developing chronic encephalopathy due to exposure to the solvents. Godderis et al. evaluated the neurobehavioral symptoms in the workers exposed to solvents using Q16 questionnaire. The results determined that the exposure to solvents can create more neurobehavioral symptoms[25]. The results of a study performed by Eemami et al. on the \ pharmaceutical laboratory workers also indicated that the exposure to the organic solvents can change the neurobehavioral symptoms[19]. However, the results of the present study showed that the exposure to benzene and toluene compound affect the neurobehavioral symptoms. While, exposure to xylene and ethylbenzene had no significant correlation with the positive the neurobehavioral symptoms. These results may be due to the fact that the exposure permissible limits of xylene and ethylbenzene compounds are greater than those of toluene and benzene compounds. While, the exposure concentrations were much lower than the exposure permissible limits of these two substances.

CONCLUSION

Based on the results, the occupational exposure to BTEX compounds, particularly benzene and toluene, can cause the neurobehavioral symptoms in the exposed workers of the refinery. Given the importance of the staff health and the prevention of the adverse effects due to the exposure to these compounds, the use of technical and engineering measures to reduce the exposure, especially in operating workers, is very necessary.

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Running title

exposed to mixture of an organic solvent (BTEX) and neurobehavioral symptoms

REFERENCES

1. Cipolla M, Izzotti A, Ansaldi F, Durando P, Piccardo M. Volatile organic compounds in anatomical pathology wards: comparative and qualitative assessment of indoor airborne pollution. International journal of environmental research and public health. 2017;14(6):609.
2. Zhang K, Xiu G, Zhou L, Bian Q, Duan Y, Fei D, et al. Vertical distribution of volatile organic compounds within the lower troposphere in late spring of Shanghai. Atmospheric Environment. 2018;186:150-7.
3. Jafari MJ, Khajevandi AA, Najarkola SAM, Yekaninejad MS, Pourhoseingholi MA, Omidi L, et al. Association of sick building syndrome with indoor air parameters. Tanaffos. 2015;14(1):55.
4. Mainka A, Kozielska B. Assessment of the BTEX concentrations and health risk in urban nursery schools in Gliwice, Poland. AIMS Environ Sci. 2016;3:199-219.
5. Wheeler AJ, Wong SL, Khoury C, Zhu J. Predictors of indoor BTEX concentrations in Canadian residences. Health reports. 2013;24(5):11-7.
6. Edokpolo B, Yu Q, Connell D. Health risk assessment of ambient air concentrations of benzene, toluene and xylene (BTX) in service station environments. International journal of environmental research and public health. 2014;11(6):6354-74.
7. Rousseau M-C, Straif K, Siemiatycki J. IARC carcinogen update. Environmental Health Perspectives. 2005;113(9):A580-A1.
8. Snyder R. Leukemia and benzene. International journal of environmental research and public health. 2012;9(8):2875-93.
9. Morakinyo OM, Mokgobu MI, Mukhola MS, Engelbrecht JC. Health risk assessment of exposure to ambient concentrations of benzene, toluene and xylene in Pretoria West, South Africa. African Journal of Science, Technology, Innovation and Development. 2017;9(4):489-96.
10. Viaene M. Overview of the neurotoxic effects in solvent-exposed workers. Arch Public Health. 2002;60:217-32.
11. Mousavi SM, Koohpaei A, hajizadeh R, yazdanirad s, moradirad r. Semi-quantitative risk assessment of occupational exposure area industrial wastewater Treatment unit in an oil refinery and chemical contaminants. Iran Occupational Health Journal. 2019;15(6):10-20.
12. Maryiantari ES, Martiana T, Sulistyorini L. Analyze the Level of Health Risks from Exposure to Toluene in Shoes Craftsman Workers. American Scientific Research Journal

for Engineering, Technology, and Sciences (ASRJETS). 2016;16(1):137-54.
13. Mousavi SM, Sharifiniya S, Yazdani Rad S, Esmaeilzadeh A, Hajizadeh R, MoradiRad R. The Relationship between shift work and its effects on the health of the operational staff in Abadan Oil Refining Company. Journal of Preventive Medicine. 2017;4(2):19-25.
14. Werder EJ, Gam KB, Engel LS, Kwok RK, Ekenga CC, Curry MD, et al. Predictors of blood volatile organic compound levels in Gulf coast residents. Journal of exposure science & environmental epidemiology. 2018;28(4):358.
15. Sutic I, Bulog A, Sutic I, Pavisic V, Mrakovcic-Sutic I. Changes in the concentration of BTEX (benzene, toluene, ethylbenzene, m/p-xylene and o-xylene) following environmental and occupational exposure to vapors. Changes. 2016;2(10).
16. Bolden AL, Kwiatkowski CF, Colborn T. New look at BTEX: are ambient levels a problem? Environmental science & technology. 2015;49(9):5261-76.
17. Edokpolo B, Yu QJ, Connell D. Health risk characterization for exposure to benzene in service stations and petroleum refineries environments using human adverse response data. Toxicology reports. 2015;2:917-27.
18. de Oliveira AR, Neto C, de Arruda A, Bezerra de Medeiros PC, de Andrade MJ, dos Santos NA. Chronic Organic Solvent Exposure Changes Visual Tracking in Men and Women. Frontiers in neuroscience. 2017;11:666.
19. Aminian O, Izadi N, Esmaeili A, Emami SM. Neurobehavioral Effects of Occupational Exposure to Organic Solvents among Pharmaceutical Laboratory Workers in Iran. International Journal of Health Studies. 2016;2(2).
20. Hassani H, Golbabaei F, Shirkhanloo H, Tehrani-Doust M. Relations of biomarkers of manganese exposure and neuropsychological effects among welders and ferroalloy smelters. Industrial health. 2016;54(1):79-86.
21. Rouch I, Wild P, Fontana J-M, Chouaniere D. Evaluation of the French version of EUROQUEST: a questionnaire for neurotoxic symptom`s. Neurotoxicology. 2003;24(4-5):541-6.
22. Firoozeh M, Kavousi A, Hasanzadeh S. Evaluation of Relationship between Occupational Exposure to Organic Solvent and Fatigue Workers at a Paint Factory in Saveh city. Iran Occupational Health. 2017;14(2):82-92.
23. Kaukiainen A, Hyvärinen HK, Akila R, Sainio M. Symptoms of chronic solvent encephalopathy: Euroquest questionnaire study. Neurotoxicology. 2009;30(6):1187-94.
24. Kaukiainen A, Akila R, Martikainen R, Sainio M. Symptom screening in detection of occupational solvent-related encephalopathy. International archives of occupational and environmental health. 2009;82(3):343.
25. Godderis L, Dours G, Laire G, Viaene M. Sleep apnoeas and neurobehavioral effects in solvent exposed workers. International journal of hygiene and environmental health. 2011;214(1):66-70.