RISK ASSESSMENT OF BENZENE, TOLUENE, ETHYLBENZENE, AND XYLENES (BTEX) IN PAINT PLANTS OF TWO AUTOMOTIVE INDUSTRIES IN IRAN BY USING THE COSHH GUIDELINE

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Abstract
Objectives: The purpose of this study was to assess the risk Benzene, Toluene, Ethylbenzene, and Xylenes in the paint plants of two automotive industries in Iran by using the COSHH guideline and by measuring the ambient concentration of these chemicals.
Method: This cross sectional study was conducted in two phases, in phase one the BTEX ambient concentration was measured in three unites of paint plants according to the method advised by OSHA12. In the second phase, the COSHH data collection forms were used for a qualitative risk assessment and were distributed among 90 randomly selected workers (45 in each industry).
Results: In both industries, maximum risk rating was for benzene followed by toluene, which showed moderate to high risk level for these two chemicals in both industries. Mean ambient concentration of benzene and toluene were 34.9 and 4.4 times of Iranian standard Threshold Limit Value in industry no 1, and 9.5 and 1.9 times of Iranian standard Threshold Limit Value in industry no 2, respectively. The level of concentration of BTEX and the risk rating in industry number 1 was significantly more than that of industry number 2.
Conclusion: This study revealed the need for control of Benzene and Toluene in work place, and also showed that the COSHH risk assessment showed a similar result to the actual measuring of the same substances.

Keywords: Risk assessment, BTEX, COSHH, hazardous substances, ambient concentration

Introduction:

The production and use of chemicals are increasing worldwide. Output of chemicals increased approximately 10-fold between 1970 and 2010, globally. Exposures to toxic chemicals are one of the main environmental factors contributing to the global burden of diseases. The potential public health risks related to exposure to hazardous chemicals is serious, especially in developing countries, and is magnified by fewer resources for chemical risk management and the projected growth in the production and use of chemicals 1).

Exposure to hazardous chemicals in different industries is the main source of occupational diseases for the workers 2). Exposure to hazardous chemicals in the workplace is not only affected by the mechanical controls, but also by other measures such as administrative and behavioral measures like systems of work, supervision and training. Good measures and practices should be used by employer and employees to control the risk, minimize the exposure and protect the health of workers and non-workers, who are at risk of exposure.

Control of Substances Hazardous to Health Regulations 2002 (COSHH) was initially used to help duty holders comply with the COSHH regulations in Great Britain 3). COSHH Essentials is a system of workplace risk management for use by proprietors of small and medium sized enterprises 4), and sets basic measures that must be taken by employers, and sometimes employees to ensure controlling exposure to hazardous substances and to prevent adverse effect on health 5), and impose a commitment for the health and safety of employees upon employers. All health authorities should ensure that the highest standards of occupational health are provided 6). This risk assessment includes health, environmental and safety aspects, which enable an appropriate balance between these factors to minimize the exposure to hazardous chemicals 7).

Performance of risk assessment of hazardous chemical is an important process in management of hazards of chemicals. Risk assessment is a process to calculate or estimate the risk of an agent to a targeted organism, system or population following exposure to that agent and includes hazard identification, hazard characterization, exposure assessment, and risk characterization 8). Exposure standards show the ambient concentration of a particular substance or mixture that must not be exceeded 9).

Benzene, toluene, ethylbenzene, and xylenes frequently occur together. These four chemicals are volatile and have good solvent properties. Toxicokinetic studies in humans and animals indicate that these chemicals are well absorbed, distribute to lipid-rich and highly vascular tissues such as the brain, bone marrow, and body fat due to their lipophilicity, and are rapidly eliminated from the body. The available knowledge on toxic or carcinogenic responses to the whole mixtures of BTEX is insufficient. All four components can produce neurological impairment; in addition benzene can cause hematological effects which are associated with aplastic anemia and development of acute myelogenous leukemia. Results of different studies showed that joint neurotoxic action is expected to be additive at BTEX concentrations below approximately 20 ppm of each component. Exposure to relatively high concentrations of BTEX is expected to increase the potential for neurotoxicity and decrease the potential for hematotoxicity/carcinogenicity due to competitive metabolic interactions among the mixture components 10).

The purpose of this study was to assess the risk of hazardous chemicals, BTEX in the paint plants of two automotive industries in Iran by using the COSHH guideline and also by measuring the ambient concentration of these chemicals.

I.

Methodology

This cross sectional study was conducted in paint plants of two automotive industries in Iran by using the COSHH guideline and measurement of the actual ambient concentration of these chemicals. The study was conducted in two phases, in phase one the BTEX concentration in the air of 3 unites of paint plants (inlet liners, PVC compound and sealer spray and input color) was measured in two automotive industries. In the second phase, the COSHH risk assessment form 11) was distributed among 90 randomly selected workers of painting plant in the two automotive industries (45 in each industry).

In the first phase, measuring the ambient concentration of BTEX was done according to the method advised by OSHA12 12). In this method measuring employee exposure to BTEX that represent average 8-hour exposure is determined from a single 8-hour sample. The method was based on absorption of BTEX in an active charcoal tube. Glass Tubes with 6 mm external diameter and 4 mm internal diameter and 70 mm height, containing activated charcoal holder with restrictive Orifice (separated by a 2-mm portion of urethane foam) and sampling universal pupm model SKC with low dB were used for sample collection. Both sides of the tubes were filled with two layers of actived charcol 20/40 mesh, the front side contained 100 mg and the rear side contained 50 mg activated charcol. A 3-mm portion of urethane foam was placed between the outlet end of the tube and the back-up section. A plug of silanized glass wool was placed in front of the adsorbing section. The sample was extracted from front side charcoal, and rear side of sorbent tubes was used separately, as control for the emission of the pollutant. The sampling tube was from SKC, USA Company. The sampling pump was calibrated by a rotameter for 40 ml/minute before the study. To measure the real BTEX exposure duration in a shift work long duration, the pump dB was reduced 6 times and the duration of measurement increased to 250 minutes. The sampling number, the pump number, the time of and duration of sampling, the humidity, the wet and dry temperature, and the date of sampling was labeled on each tube. The charcoal in the tube was transferred to a small, stoppered vial, and the analyte was desorbed with 1000 µl of carbon disulfide, and was kept for 30 minutes. The extraction and analysing was done before 10 days of sampling. There was a control tube for each sample.

An aliquot of the desorbed sample was injected into a Gas Chromatography (GC) detection. The GC device, equipped with a flame ionization detector (FID) , was made in Japan (GC Chrompack CP 9001). The GC device was set on a time schedule of 60º C for two minutes, then increase in temprature 10 C per minute till the temprature reaches to 230 C and set for two minutes at the same temprature, and then the temprature reduced to 60 C . The total run time was around 10 minutes.

Calculating the sample size was based on the correction for pressure and temperature for SKC pump as follow:

Sample (ml)= R*K*(P1/760)*[298/(T+273)]

R: The observed number on rotameter

K: the calibration coefficient

P1: The air pressure at the time of sampling (mmHg)

T1: The temperature at the time of sampling (˚C)

In the second stage the COSHH data collection form was used for a qualitative risk assessment. General information regarding different hazardous substances, demographic information of the workers, the level and routs of exposure, evaluating the hazardous substances controlling system including the engineering and personal controlling systems, the efficacy of safety trainings, the risk and ways of exposure and the medical records of the workers, was elicited by a form which consisted of six section. Information about work practices and procedures including the type of the job of a worker, the duration of exposure and also the safety training in the industry was collected in the first section. Information related to the hazardous substances resulting from the painting procedure, and the sources of pollution including the existing pollution sources like gases, steam, dust and particles, and the possibility of exposure and routs of exposure was collected in the second section of the data collection form. In the third section, information related to the safety measure like storage, transport, and packaging and labeling of the hazardous chemicals was collected and compared to the standard procedure based on MSDS forms for each chemical that in this article, BTEX are the major concern. Also the emergency kits and equipment at the time of accidents like eye-wash, safety shower and the first aid kits and their work condition was assessed. The forth section of the questionnaire was related to the industrial controlling measures for the hazardous substances including general ventilation and local exhaust ventilation systems and other personal protective equipment. In this section the efficacy and the maintenance information related to this safety equipment and the result of technical inspection were enquired from the industries. In the fifth section the concentration of hazardous chemicals, resulted from the above mentioned measurement were collected and registered in the data collection form. In the sixth section of the data collection form, the information related to medical care facilities and medical records of the workers were collected.

Based on the above mentioned information, a semi-quantitative hazardous risk assessment for four substances BTEX was done.

Measures

Determining the risk level included 5 stages:

Stage 1: Obtaining information about hazardous substances which was collected through the first part of the data collection form

Stage 2: Inspecting workplace and evaluate exposure based on the above mentioned data collection form.

Stage 3: Determining the hazard ratio, which was done based on the information obtained from MSDS.

Stage 4: Determining the exposure ratio which was determined based on the below formula:

n is the number of exposure factors and the exposure indicators are defined in a Likert system of 5 values from 1 which means the lowest exposure to 5 which is the highest exposure.

Stage 5: Determining the Risk Rating (RR)

Based on the above calculated Hazard Rating (HR) and Exposure Rating (ER) and the below formula:

Then, the risk level was determined based on the risk rating, the risk rating 0-1.7 was considered as insignificant, 1.7-2.8 as low, 2.8-3.5 as moderate, 3.5- 4.5 as high and 4.5-5 as very high

Data analysis

All analyses were performed using statistical package for social sciences (SPSS) version 16.0 for windows (IBM Corporation, New York, United States) and Mann-Withney U test was used to compare the results in the two industries.

Ethical issues

Participants were explained that the data are considered as confidential and their identity will not be revealed and the data will not be used except for the research purpose. All participants gave verbal consent to participate in the study.

Results

Table 1 shows the mean BTEX risk rating in the two automotive industries. In both industries, maximum risk rating was for benzene (3.7 and 3.4 respectively) followed by toluene (3.5 and 3.3 respectively), which showed moderate to high risk level for these two chemicals in both industries, however the level of concentration of each BTEX substances in industry number 1 was significantly more than that of industry number 2 ($P<0.005$).

Table 1: Mean risk rating and risk level of BTEX in the painting plants of the tow automotive industries

Hazardous chemicals	Mean risk rating in industry 1	Mean risk level in industry 2	Mean risk rating in industry 2	
Benzene*	3.7 ± 0.2	High	3.4 ± 0.3	Moderate
Toluene*	3.5 ± 0.3	High	3.3 ± 0.3	Moderate
Ethyl-benzene*	2.7 ± 0.4	Low	1.9 ± 0.3	Low
Xylene*	2.6 ± 0.4	Low	2.0 ± 0.3	Low

* All risk rating was significantly higher in industry number 1 (Mannwitney U test)

The result of measuring the actual concentration of each BTEX substances is shown table 2. Mean ambient concentration of benzene and toluene in both industries was very high and much higher than Iranian standard Threshold Limit Value (TLV) (34.9 and 4.4 times in industry no 1, respectively and 9.5 and 1.9 times in industry no 2, respectively), the level of concentration of BTEX in industry number 1 was significantly more than that of industry number 2 ($P<0.005$).

Table 2: Mean ambient concentration of BTEX and ratio of ambient concentration of BTEX to Iranian standard TLV in the painting plants of the two automotive industries

	Industry no 1		Industry no 2	
Hazardous chemicals	Mean atmospheric concentration (ppm[5]) ± SD	Ratio of ambient concentration of BTEX to Iranian standard TLV**	Mean atmospheric concentration (ppm) ± SD	Ratio of ambient concentration of BTEX to Iranian standard TLV**
Benzene*	19.9 ± 4.8	34.9	5.4 ± 2.3	9.5
Toluene*	216.7 ± 119.6	4.4	101.9 ± 27.4	1.9
Ethyl-benzene*	75.0 ± 6.4	0.46	68.3 ± 6.5	0.8
Xylene*	39.2 ± 21.1	0.26	13.4 ± 7.8	0.2

*All ambient concentration was significantly higher in industry number 1 (Mannwitney U test)

** TLV for benzene is equal to 0.5 ppm, toluene is equal to 0.50 ppm, ethyl-benzene is equal to 100 ppm and for Xylene is equal to 100 ppm, Iranian standard.

Discussion

Assessment and evaluation of the level of risk of hazardous substances to the workers is an incumbent responsibility of employers and health authorities in each industry. A proper system and guideline is needed to help the employer to identify, measure and priorities the risk level of each hazardous substances for each worker in a practical and easy to apply ways. The COSHH provide such a mean for employees to easily assess the situation and control the risk to their employees and others who may be exposed to the risk. This study was an attempt to assess the risk of fours hazardous substances BTEX by using COSHH and actual measurement of the ambient concentration of these substances in two painting plant of two automotive industries in Iran.

This study showed that the level of benzene and toluene in industry number 1 was high and in industry number 2 was moderate. The measurement of ambient concentration of these substances also showed that the mean concentration of benzene was significantly higher in industry number one which is consistence with the risk level and risk rank by using COSHH and showed the strength of COSHH as an easy to apply measure for assessing and prioritizing the risk of hazardous chemicals. The finding of Lee et al. on evaluation of the COSHH Essentials model with a mixture of organic chemicals at a medium-sized paint producer suggested that the COSHH essentials model worked reasonably well for the volatile organic chemicals at the plant, however, it was difficult to override the reproductive hazard even though it was meant to be possible in principle 13). Study of Siriruttanapruk and Burge on the impact of the COSHH regulations on workers with occupational asthma in UK showed that COSHH was successful in increasing awareness of health related risk of hazardous chemicals and training them the required skills to control exposure to hazardous chemicals among employers 14).

This study showed that the concentration of ambient benzene was 19.9 ppm and 5.4 ppm and the concentration of ambient toluene was 216.7 ppm and 101.9 ppm in two industries, respectively, which is a very high concentration. In a study in Thailand the mean concentration of benzene was 92.7 ppb, toluene 195.3 ppb, Ethyl benzene 6.25 ppb and xylene 11.6 ppb, in gas stations. The study in Thailand, showed that exposure to this amount of benzene and toluene was significantly associated with fatigue, and also, the mean lifetime cancer risks for workers exposed to this concentration of benzene and ethylbenzene for 30 years were estimated at 1.75×10^{-4} and 9.55×10^{-7} 15). Therefore, exposure to the higher level of benzene and toluene in this study can raise a much higher risk of cancer for the workers on these two industries.

A study by Chaudhary and Kumar in Firouz Abad India, which monitored BTEX concentrations in ambient air showed that the mean concentration of benzene (ranging from 0.197 ppm to 0.207 ppm), toluene (0.198 ppm to 0.209 ppm), ethyl benzene (0.195 ppm to

[5] 1ppm = 1000ppb

0.285 ppm) and xylene (0.195 ppm to 0.205 ppm) and the BTEX concentrations ranged from 0.0127 ppm to 0.013 ppm in industrial areas and 0.675 ppm to 0.784 ppm in refueling pump station, which is much lowered from concentration of these chemicals in this study 16).

In a study on BTEX personal exposure monitoring in four Australian cities, it was shown that the level of exposure of the usual citizens to these four chemicals was much below the standard and the most elevated exposure measurement recorded for each of the BTEX constituents was; 23.8 ppb for benzene, 2120 ppb for toluene, 119 ppb for ethylbenzene and 697 ppb for xylene, respectively, and also it was shown that the elevated concentrations were associated with non-occupational activities such as the use of lacquer thinners, resins and house paints and exposure to spilt petrol 17). The level of exposure of citizens in these four main Australian cities was nearly 1000 times less than the level of exposure of the workers in these two industries.

This study showed that the level of benzene and toluene was 35 and 4.4 times, and 9.5 and 1.9 times more than TLV Iranian standard in the two industries, respectively. In a study on a sample of 8 Italian handicraft car painting shops, the exposure levels to solvents, was measured using three classic exposure monitoring methods, namely environmental sampling with charcoal tubes, personal sampling with diffusive charcoal samplers, and urinary determination of unmetabolised solvents and the result of this study showed that benzene was found in all shops, at levels around or higher than the 8-h time-weighted average limit (8-h TLV-TWA) 18).

The best way to control the risk of BTEX is to reduce the exposure to the emission of these chemicals in the ambient air of the working place, which can be done by using protective equipment and using proper respiratory masks. This study showed that 77.8% of exposure to BTEX was respiratory and skin exposure, which should be controlled via using personal protecting equipment like respiratory masks, proper clothing and gloves. Garrod and Rajan-Sithamparanadarajah explained COSHH can simply be adapted to produce specific control advice, but where it is not possible or practical to use control advice, the control bands of COSHH can suggest adequate respiratory protective equipment using ‘protection factors’ 19).

The low number of sampling unites and measuring the ambient concentration in a short duration of time were the study limitations which may have distorted the accuracy of results in term of its magnitude.

Conclusion:

This study revealed the urgent need for control of hazardous substances of Benzene and Toluene in work place, and also showed that the COSHH evaluation of risk of hazardous substance showed a similar result to actual measuring of the same substances, which is much more complicated and costly.

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