original article

Effects of in-cabin decoration and deodorizer use on the interior concentrations of toluene and ethylbenzene in pride cars manufactured in Iran

Masoud Rismanchian, Massomeh Garsivaz, Hamidreza Porzamani[1], Mohhamad Reza Maracy[2], Mahnaz Shakerian, Shiva Souri

Departments of Occupational Health Engineering, School of Health, Isfahan University of Medical Sciences (IUMS), Isfahan, [1]Environment Research Center, Isfahan University of Medical Sciences, Isfahan, Iran and Department of Environmental Health Engineering, Student Research Center, School of Health, IUMS, Isfahan, [2]Department of Epidemiology and Biostatistics, School of Health, IUMS, Isfahan, Iran

Address for correspondence:
Dr. Masoud Rismanchian, School of Public Health, Isfahan University of Medical Sciences, Hezar Jerib Avenue, Isfahan, Iran.
E-mail: rismanchian@hlth.mui.ac.ir

ABSTRACT

Aim: The purpose of this study was to evaluate the concentrations of toluene and ethylbenzene inside the cars with an interior source related to in-cabin decoration and deodorizer use among Pride cars manufactured in Iran.

Materials and Methods: The vehicles under study were Pride cars manufactured in Iran. In-cabin sampling was conducted by a personal sampling pump drawing air through an active carbon sorbent tube. The samples were analyzed by a gas chromatograph equipped with mass spectrophotometer detector.

Results: In — cabin mean concentrations of toluene and ethylbenzene were 105.4 μg/m^3 and 19.09 μg/m^3, respectively. The effects of decoration and deodorizer use inside the cars on toluene and ethylbenzene in-cabin concentrations were also not significant.

Conclusion: Total means concentration of toluene inside the cars was higher than that of ethylbenzene. Models of the studied vehicles were not significantly affecting the concentrations of the target volatile organic compounds.

Key words: Decoration, deodorizer, ethylbenzene, toluene, vehicle

INTRODUCTION

Volatile organic compounds (VOCs) are considered as important groups of interior pollutants.[1]

Access this article online

Quick Response Code:

Website: www.ijehe.org

DOI: 10.4103/2277-9183.148277

The exposure to high level concentrations of VOCs can result in some important health effects such as neural inflammations, allergia, asthma and cancer symptoms.[2]

Toluene and ethylbenzene are two of these compounds largely found in both internal and external VOC emission sources.[3]

Central nervous system (CNS) disorders are of the most important effects of toluene (C_7H_8). The impacts on the respiratory, cardiovascular and renal systems has been proved.[4]

This article may be cited as:
Rismanchian M, Garsivaz M, Porzamani H, Maracy MR, Shakerian M, Souri S. Effects of in-cabin decoration and deodorizer use on the interior concentrations of toluene and ethylbenzene in pride cars manufactured in Iran. Int J Env Health Eng 2014;3:1-6.

The exposure to ethylbenzene (C_7H_8) may lead to the eyes and skin irritations as well as mucus tissue inflammation.

Chronic exposure to ethylbenzene can affect CNS as well as the respiratory and renal systems.[5] Ethylbenzene is classified as a potential carcinogen to humans (Group 2B) by the international agency for research on cancer.[6]

The exposure to VOCs occurs in workplaces[7,8] as well as residential areas[9,10] and urban environments.[11,12]

Now-a-days, the quality of indoor air has become of the interest of researchers because of the fact that people spend the majority of their time indoors.[13]

It is presumed that higher VOC levels can be found among the interior environments than the outsides. Monitoring of the interior places, therefore, can obtain more desirable results associated with the personal exposures to VOCs.[14]

One of the important interior environments is the cabin of vehicles where people are spending more time on commuting. With rapid growth of economy, privately owned cars are achieving more people popularity among in different societies.

Vehicle manufacturing companies report that an increasingly growth of their products marketing. Producing Pride cars in Iran was reported nearly up to 590,000 vehicles in 2012.[15]

The air contaminants inside the vehicles are possible to be produced by in — car compounds emission, fuel leaking and ambient outdoor air penetration into the vehicles.[16]

The studies indicate that toluene and ethylbenzene with known health effects are two of the VOCs found inside the cabin of the vehicles.[17,18]

Chertok *et al*. measured the passengers exposure to toluene and ethylbenzene inside the vehicles. As they reported, the average concentrations of toluene and ethylbenzene inside the 8 vehicles under study were 28.76 ppb and 4.38 ppb, respectively.[19] Som *et al*. revealed that in — cabin concentrations of toluene and ethylbenzene among public commuting cars under static conditions were 52.1 ± 21.2 μg/m^3 and 12.5 ± 4.3 μg/m^3, respectively.[20] Lau and Chan measured individuals' exposure to VOCs in public transportation vehicles (bus, taxi and subway) and found that the average concentrations of toluene and ethylbenzene among 12 tested taxi vehicles were 43.5 ± 12.6 μg/m^3 and 4.4 ± 1.6 μg/m^3, respectively.[21]

In another study conducted by Balanay and Lungu the exposure levels of 15 Jeepney drivers to toluene and ethylbenzene were reported 196.6 μg/m^3 and 17.9 μg/m^3, respectively.[22]

Zhang *et al*., studied on 822 vehicles parked in a covered garage and reported the concentrations of toluene and formaldehyde 1220 μg/m^3 and 80 μg/m^3, respectively.[16]

You *et al*., carried out another study on different kinds of chemical compounds as well as their quantity among both new and old vehicles under static conditions and found a 5 year old vehicle to have the concentrations of toluene and m, p xylene as 32.2 μg/m^3 and 10.2 μg/m^3, respectively.[23]

The results were obtained from the studies shows the importance of measuring the in-vehicle VOCs concentrations and assessing effective factors on exposure to these compounds. Noteworthy, Pride cars account for a major portion of the vehicles manufactured and utilized in Iran. The aims of the current study were to evaluate the concentrations of toluene and ethylbenzene inside Pride cars and to investigate the effect of decoration and deodorizer use on the in — cabin concentrations of the target compounds.

MATERIALS AND METHODS

Study plan

Toluene and ethylbenzene were considered as two pollutants to be investigated in this study because of their impacts on public health.[4,5]

The target compounds' presence inside the vehicles can be due to interior materials emission, fuel leakage and polluted ambient air penetration into the vehicles. Environmental sampling, therefore, was also carried out under the same condition that the study was performed to control the impact of the polluted ambient air on in — cabin concentrations of toluene and ethylbenzene. The samples were taken from the switched — off cars to eliminate the influence of fuel leakage on concentration of the compounds. Sampling was carried out in covered parking lots to reduce the influence of sunlight — induced heat. The public vehicles also were excluded from the study to control the effect of the cars application on the desired results. To achieve more precise results, the pride vehicles used in this study were classified into three different groups. 152 different models of Pride vehicles were evaluated totally in this study including KIA (Group I), Saba (Group II) 131, 141, LX 111, SX and Nasim (Group III). Environmental sampling was also carried out under the same condition that the study was performed to control the impact of the polluted ambient air on in — cabin concentrations of toluene and ethylbenzene.

Several samples were taken from fabric cars at the market offices to assess the initial in — vehicle concentrations of the target compounds exactly after being manufactured and before being utilized. Some other required information such as cabin decoration components and use of deodorizers was collected using a check list.

Measurement method

All samples were taken from the vehicles using low — flow rate sampling pump (Model 222-3 SKC Inc — England) drawing air through an active carbon tube (SKC. No 226-01).

The sampling was carried out based on the NIOSH sampling method NO. 1500-1501.[16,24]

Prior and after each sampling event, the sampling pump was calibrated using uniformity digital soap bubble flowmeter (Defender, Model 570 made in Bios Company, England). Temperature and humidity were measured through the study using temperature humidity meter (Model sinometer CTH-609).

The study was conducted in one of the covered parking lots of the Isfahan city, to eliminate the influence of solar radiation on the vehicles as well as the heat produced by sunlight.

After entering the cars into the parking lot and parking in a certain place, the vehicles were turned off and all their windows were closed. After 10 min, the suspended activated carbon sorbent tube inserted to the calibrated pump was sent into the cabin through back side window. The sampling, then, was performed in 20 min with a flow rate of 200 ml/min that was set based on the pretest.[16]

The samples were isolated completely and kept in the refrigerator until being desorbed and analyzed. To make the samples ready for analysis, the target compounds absorbed by an activated carbon sorbent tube were transferred to a vial and desorbed with 1 ml of carbon disulfide (Merck, Germany).

Samples analysis

The samples were analyzed using a gas chromatography (GC) (Agilent technology: 7890 Uniformity: USA) equipped with a mass spectrometer detector (Agilent technology: 5975 Concentration: USA) and sample distribution of split 1: 10. HP-5 ms column (30 m × 0.25 mm Id, 0.25 μm), was employed with helium (purity 99.995%) as carrier gas at a flow rate of 1 ml/min.

The column temperature program was 40°C for 5 min programmed with an increase of 5°C/min to the point where the temperature reaches 150°C and remains at this temperature for 2 min.

The known concentrations of each target VOCs were made using pure samples (Merck, Germany) and injected to GC-mass spectrophotometer (GC-MS) as the standard materials for calibration.

The samples were prepared and injected to GC-MS using an automated injection system (CTC Pal — Combi Pal).

The concentrations of contaminants to be existed in each sample were specified in terms of μg/m^3 based on the standard calibration curve corresponding to each sample and the sampling size.

Non — parametric kruskal — wallis test was utilized to compare the in — cabin concentrations of the tested compounds among the target vehicles and parameters under assessment.

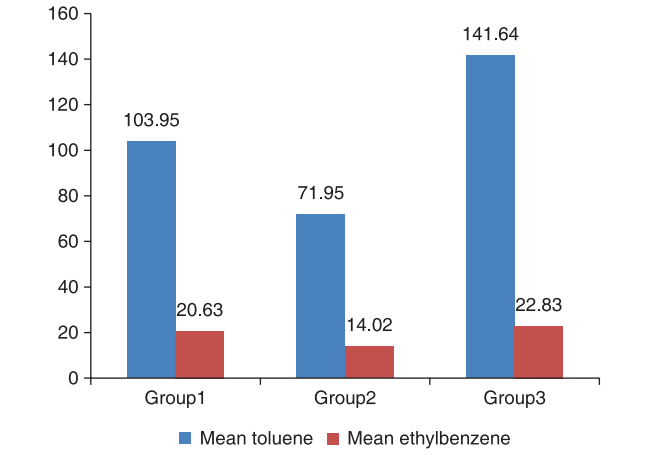
RESULTS

Table 1 represents the in — vehicle concentrations of toluene and ethylbenzene.

Figure 1 indicates toluene and ethylbenzene concentrations inside the vehicles based on three classified groups.

The results associated with in — vehicle concentration of toluene and ethylbenzene in relation to decoration and deodorizer application have been summarized in Table 2.

Based on non — parametric Kruskal — Wallis test, the in — vehicle concentrations of toluene and ethylbenzene among the three tested vehicle groups were not statistically significant, (P = 0.809 and 0.799 respectively).



Number of Group	Mean toluene	Mean ethylbenzene	*N*
Group1	103.95	20.63	50
Group2	71.95	14.02	52
Group3	141.64	22.83	50

Figure 1: Toluene and ethylbenzene concentrations in terms of the vehicle model

Table 1: The average in-vehicle concentrations of toluene and ethylbenzene

Compound	*N*	Mean (μg/m^3)	SD (μg/m^3)	Min-max (μg/m^3)
Toluene	152	105.4	270.5	10.56-1913.1
Ethylbenzene	152	19.09	33.97	7.6-245.04

SD: Standard deviation, Min: Minimum, Max: Maximum

DISCUSSION

The environmental air sampling and in–vehicle air sampling were carried out simultaneously. The target compounds concentrations collected by the environmental sampling were below GC-MS detection limit. The concentrations of toluene and ethylbenzene inside the cars, therefore, are more likely to be due to the interior sources emission. These results are consistent with the findings reported by Zhang *et al*.[16]

According to Table 1, the mean concentration of toluene inside the cars was higher than that of ethylbenzene. Karman *et al*.[25] and Batterman *et al*.,[26] measured the in — cabin concentrations of toluene and ethylbenzene and reported similar results. In another study conducted by Fedoruk and Kerger the concentrations of toluene inside the Chevrolet, Ford and Toyota cars were 38, 89.5 and 86.8 μg/m^3 and concentrations of ethylbenzene were respectively 7.5, 2.7 and 2.5 μg/m^3.[27] This can be due to using toluene as the important component of the solvents utilized in painting and surfacing of interior decoration inside the vehicles.[28]

Table 2: Toluene and ethylbenzene concentrations (mean, SD) in terms of the in-vehicle decoration and deodorizer use

Variable		Toluene (μg/m^3)		Ethylbenzene (μg/m^3)	
	N	Mean	SD	Mean	SD
In-cabin decoration					
No decoration	79	77.7	158.4	13.83	19.61
Seat covers	44	99.1	249.78	26.32	46.84
Dashboard covers	3	448.34	758.26	40	56.12
Seating and dashboard covers	6	17.09	13.92	9.83	5.46
Window screen	1	38.2	—	7.6	—
Seating covers and window screen	3	12.33	3.07	7.6	—
Hanging accessories	2	45.34	49.2	17.83	14.47
Deodorizer use					
No deodorizer	99	85.04	202.48	16.36	27.04
Spray	22	132.55	318.2	27.28	52.93
Oil-based deodorizer	13	41.36	39.41	15.8	19.46
Perfume	4	87.77	213.58	17.62	12.36

SD: Standard deviation

The cars classified in group III showed higher concentrations of toluene and ethylbenzene inside the vehicles compared with those of two other studied group [Figure 1].

According to kruskal — wallis test, however, the differences between three studied groups (group I, KIA group II, SABA and group III, SAIPA) were not statistically significant for both toluene and ethylbenzene. In this study, the mean concentrations of toluene and ethylbenzene inside KIA cars were 103.95 μg/m^3 and 20.63 μg/m^3, respectively, that show lower levels than the mean in– cabin concentrations of target compounds in a study performed by Jo WK and Park KH in South Korea which were 331 μg/m^3 and 42.8 μg/m^3, respectively. This inconsistency can be due to using tenax as sorbent in Jo and K-HP study, which is known for its high ability to absorb even very low level concentrations of VOCs.[29]

Zhang *et al*.,[16] and Harrison RM *et al*.,[30] reported higher VOCs concentrations in their studies due to the fact that these materials are more likely to be emitted from interior decoration used in new cars. In this study also the mean concentrations of toluene and ethylbenzene were higher among the fabric cars.

The factor that may have attributed to this difference is that the high — emitting materials widely used in the surface of the interior decoration of the vehicles emit VOCs specially when they are newly installed.[16]

Based on the collected data using a check-list, it was observed that in addition to the original interior cabin components, some extra components such as seat and dashboard covers, curtains and some other accessories were used by some drivers as well as deodorizers including sprays, fragrances and oil — based perfumes. Although some of the mentioned accessories were relatively effective on increasing the toluene and ethylbenzene in — cabin concentrations based on

Table 3: comparison of the mean concentrations of toluene and ethylbenzene in different studies

Study	Location	Average concentration of toluene inside the car (μg/m^3)	Average concentration of ethylbenzene inside the car (μg/m^3)	References
Current study	Isfahan, Iran	105.04	19.09	This study
Geiss *et al*.	Italy	98.8	11.7	[32]
Som *et al*.	Kolkata, India	186.7 ± 118.2	130.5 ± 76.4	[20]
Lau and Chan	Hong Kong, China	43.5 ± 12.6	4.4 ± 1.6	[21]
Fedoruk and Kerger	California, USA	169.6 ± 67.2	15.7 ± 11.7	[27]
Chan *et al*.	Guangzhou, China	108.5 ± 30.6	20.3 ± 6.9	[17]
Jo and Yu	Taegu, Korea	175	15.1	[34]
The Hong Kong indoor air quality objective	Hong Kong	1045	1090	[35]
The National indoor air quality standards	Chinese	200	—	[36]

the kruskal — wallis test, the effect was not significant, (P = 0.784, 0.546, 0.711 and 0.194 respectively).

However, in two other studies performed by Hsu and Huang HL [31] and Geiss *et al*.,[32] interior leather — used decoration and deodorizer use were respectively two important pollution sources to emit VOCs inside the cars.

The concentration levels of some samples were below the GC-MS detection limit in this study that may be due to the type of the utilized sorbent.

Using some other sorbents with higher ability to detect low — level concentrations can help to obtain more precise results.[33]

There was not any study conducted on interior air standard for BTEX in Iran. The results, therefore, have been compared with the standards applying in some other countries as well as the studies with similar objectives [Table 3].

The measured concentrations of toluene were lower than those of other similar studies and toluene concentrations were higher than ethylbenzene in all studies. The mean concentrations of both target compounds were lower than other studies, which can be due to the sampling location, different vehicles models, sampling size, the drivers conditions, the fuel type, climatic condition etc.

CONCLUSIONS

In the current study, the mean in — cabin concentrations of toluene and ethylbenzene were measured under the statistic condition. Since the samples were taken from switched — off cars and the results of the environmental sampling, simultaneously conducted in the same location and with the same conditions, showed that the environmental concentration were below the GC-MS detection limit, it can be claimed that the measured in — vehicle concentrations are related to the interior emission sources. It was also found that using some extra interior decorations and deodorizers was not significantly effective on the concentrations of the target compounds.

The results of this study indicate that the in-cabin emission sources can be attributed to the interior air pollution and there is an essential need to develop the required standards.

REFERENCES

1. Edwards RD, Jurvelin J, Koistinen K, Saarela K, Jantunen M. VOC source identification from personal and residential indoor, outdoor and workplace microenvironment samples in EXPOLIS-Helsinki, Finland. Atmospheric Environ 2001;35:4829e-41.
2. Sakai K, Norbäck D, Mi Y, Shibata E, Kamijima M, Yamada T, *et al*. A comparison of indoor air pollutants in Japan and Sweden: Formaldehyde, nitrogen dioxide, and chlorinated volatile organic compounds. Environ Res 2004;94:75-85.
3. Zalel A, Yuval, Broday DM. Revealing source signatures in ambient BTEX concentrations. Environ Pollut 2008;156:553-62.
4. Sarigiannis DA, Gotti A. Biology-based dose-response models for health risk assessment of chemical mixtures. Fresen Environmental Bulletin 2008;17:1439-51.
5. Jang JY, Droz PO, Kim S. Biological monitoring of workers exposed to ethylbenzene and co-exposed to xylene. Int Arch Occup Environ Health 2001;74:31-7.
6. Ramírez N, Cuadras A, Rovira E, Borrull F, Marcé RM. Chronic risk assessment of exposure to volatile organic compounds in the atmosphere near the largest Mediterranean industrial site. Environ Int 2012;39:200-9.
7. Manini P, De Palma G, Andreoli R, Poli D, Mozzoni P, Folesani G, *et al*. Environmental and biological monitoring of benzene exposure in a cohort of Italian taxi drivers. Toxicol Lett 2006;167:142-51.
8. Khoder MI. Formaldehyde and aromatic volatile hydrocarbons in the indoor air of Egyptian office buildings. Indoor Built Environ 2006;15:379-87.
9. Walgraeve C, Demeestere K, Dewulf J, Van Huffel K, Van Langenhove H. Diffusive sampling of 25 volatile organic compounds in indoor air: Uptake rate determination and application in Flemish homes for the elderly. Atmospheric Environ 2011;45:5828-36.
10. Lawson SJ, Galbally LE, Powell JC, Keywood MD, Molloy SB, Cheng M, *et al*. The effect of proximity to major roads on indoor air quality in typical Australian dwellings. Atmospheric Environ 2011;45:2252-9.
11. Geiss O, Giannopoulos G, Tirendi S, Barrero-Moreno J, Larsen BR, Kotzias D. The AIRMEX study-VOC measurements in public buildings and schools/kindergartens in eleven European cities: Statistical analysis of the data. Atmospheric Environ 2011;45:3676-84.
12. Guoa H, Lee SC, Li WM, Cao JJ. Source characterization of BTEX in indoor microenvironments in Hong Kong. Atmospheric Environ 2003;37:73-82.
13. Jia C, Batterman S, Godwin C. VOCs in industrial, urban and sub-urban neighborhoods, part 1: Indoor and outdoor concentrations, variation, and risk drivers. Atmospheric Environ 2008;42:2083e-100.
14. Topp R, Cyrys J, Gebefügi I, Schnelle-Kreis J, Richter K, Wichmann HE, *et al*. Indoor and outdoor air concentrations of BTEX and NO2: Correlation of repeated measurements. J Environ Monit 2004;6:807-12.
15. Available from: http://www.khabaronline.ir/detail/207985/.
16. Zhang GS, Li TT, Luo M, Liu JF, Liu ZR, Bai YH. Air pollution in the microenvironment of parked new cars. Build Environ 2008;43:315-9.
17. Chan LY, Lau WL, Wang XM, Tang JH. Preliminary measurements of aromatic VOCs in public transportation modes in Guangzhou, China. Environ Int 2003;29:429-35.
18. Chen X, Zhang G, Zhang Q, Chen H. Mass concentrations of BTEX inside air environment of buses in Changsha, China. Build Environ 2011;46:421-7.
19. Chertok M, Voukelatos A, Sheppeard V, Rissel C. Comparison of air pollution exposure for five commuting modes in Sydney — Car, train, bus, bicycle and walking. Health Promot J Austr 2004;15:5.
20. Som D, Dutta C, Chatterjee A, Mallick D, Jana TK, Sen S. Studies on commuters' exposure to BTEX in passenger cars in Kolkata, India. Sci Total Environ 2007;372:426-32.
21. Lau WL, Chan LY. Commuter exposure to aromatic VOCs in public transportation modes in Hong Kong. Sci Total Environ 2003;308:143-55.
22. Balanay JA, Lungu CT. Exposure of jeepney drivers in Manila, Philippines, to selected volatile organic compounds (VOCs). Ind Health 2009;47:33-42.
23. You KW, Ge YS, Hu B, Ning ZW, Zhao ST, Zhang YN, *et al*. Measurement of in-vehicle volatile organic compounds under static conditions. J Environ Sci (China) 2007;19:1208-13.
24. NIOSH: Method 1500-1501 in the NIOSH Manual of Analytical Methods. 4th ed. Cincinnati, OH: US Dept. of Health and Human Services, Center for Disease Control, NIOSH; 2003.

25. Karman D, Noseworthy L, Graham L, Oguz O. Motor vehicle related air toxic measurements along an urban street. In: International Symposium on the Measurement of Toxic and Related Pollutants Air and Waste Management Association, US EPA, Research Triangle Park; 2000.
26. Batterman SA, Peng CY, Braun J. Levels and composition of volatile organic compounds on commuting routes in Detroit, Michigan. Atmospheric Environ 2002;36:6015-30.
27. Fedoruk MJ, Kerger BD. Measurement of volatile organic compounds inside automobiles. J Expo Anal Environ Epidemiol 2003;13:31-41.
28. Chao CY, Chan GY. Quantification of indoor VOCs in twenty mechanically ventilated buildings in Hong Kong. Atmospheric Environ 2001;44:5895-913.
29. Jo WK, Park KH. Commuter exposure to volatile organic compounds under different driving conditions. Atmospheric Environ 1999;33:409-17.
30. Leung PL, Harrison RM. Roadside and in-vehicle concentrations of monoaromatic hydrocarbons. Atmospheric Environ 1999;44:191-204.
31. Hsu DJ, Huang HL. Concentrations of volatile organic compounds, carbon monoxide, carbon dioxide and particulate matter in buses on highways in Taiwan. Atmospheric Environ 2009;622:5723-30.
32. Geiss O, Tirendi S, Barrero-Moreno J, Kotzias D. Investigation of volatile organic compounds and phthalates present in the cabin air of used private cars. Environ Int 2009;35:1188-95.
33. Hinwood AL, Rodriguez C, Runnion T, Farrar D, Murray F, Horton A, *et al*. Risk factors for increased BTEX exposure in four Australian cities. Chemosphere 2007;66:533-41.
34. Jo WK, Yu CH. Public bus and taxicab drivers' work-time exposure to aromatic volatile organic compounds. Environ Res 2001;86:66-72.
35. Indoor Air Quality Management Group (IAQMG). Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places. Designed by the Information Services Department: The Government of the Hong Kong Special Administrative Region; 2002.
36. NBS.GB/T 18883-2002: Compilation of indoor environment quality and examining standard: Chinese National Bureau of Standards, Chinese Standard Publishing Company; 2003.

Source of Support: Isfahan University of Medical Sciences,
Conflict of Interest: None declared.