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Load characteristics and inhalation risk assessment of benzene series (BTEX) pollutant in indoor air of Ghalyan and/ or cigarette cafes compared to smoking-free cafes

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ABSTRACT

To determine the concentration of benzene series (BTEX) compounds, 33 samples were collected from indoor air of Ghalyan cafés (GHC), cigarette cafés (CC) and smoking-free cafés (SFC) in Bushehr city, Iran, and analyzed using gas-chromatography - flame ionization detector (GC-FID). The results of this study indicated that the mean±SD values of ΣBTEX in GHC, CC and SFC cafés were 19.46 ± 6.07, 11.34 ± 5.21 and 2.26 ± 0.76 mg/m^3, respectively. The mean concentration of BTEX in the cafés with fruit-flavored tobacco was significantly higher than those in traditional cafés ($p < 0.05$). According to path analysis, the number of active waterpipe heads had the maximum impact on the production of pollutants inside the cafés. The results also indicated that the risk of exposure to BTEX in smoking cafés in Bushehr was very high; it can develop serious carcinogenic and noncarcinogenic risks.

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Indoor air; BTEX; Ghalyan; cigarette; risk assessment

Introduction

Recently, in academic and scientific communities, concerns over indoor air pollution have increased, and various researchers have directed their attention to investigating the effects of indoor air pollution on human health [1,2]. This interest is due to the fact that most people spend ~85% of their time inside buildings (houses and workplaces), and therefore are exposed to toxic substances via inhalation, skin contact or ingestion of air pollutants [3,4]. Every indoor environment is exclusively described by its specific ambient air, construction characteristics and its internal activities [5]. Among the internal environments, tobacco smoking cafés have extensive detrimental effects on the health of individuals residing in them because of the high and various concentrations of air pollutants which are observed in these indoors [6]. In these cafés, tobacco products are served in different forms. For example, one type of tobacco consumption is cigarette smoking, for which various brands are offered in these cafés for consumers. Tobacco consumption with Ghalyan is another form which is commonly offered in smoking cafés under different names including waterpipe, Hookah, Shisha, Sheesha and hubbly bubbly smoking. Ghalyan tobacco smoking involves passage of charcoal-heated air over raw/flavored tobacco and creation of smoke [7]. The produced smoke is bubbled inside a water bowl, and then it is inhaled by the consumer through an opening that is attached to the upper part of the bowl through a tube [8].

Various epidemiological and experimental studies have indicated that the environmental smoke of tobacco is a complex of thousands of gaseous and particular pollutants including tobacco consumption products, charcoal and the exhaled smoke by the smoker [9,10]. Among the gaseous pollutants, benzene, toluene, ethylbenzene and xylene (BTEX) constitute a group of hazardous pollutants which has been a hot topic of researches worldwide [1,10,11]. BTEX compounds have serious effects on human health including cancer, neurological disorders and symptoms such as weakness, loss of appetite, fatigue, confusion and nausea [12]. Benzene is the most toxic chemical in the BTEX family, and long-term exposure to this compound may increase the risk of incidence of leukemia and aplastic anemia in humans [13]. International Agency for Research on Cancer has introduced benzene as a definite carcinogenic to humans (Group 1) and ethylbenzene as possibly carcinogenic to humans (Group 2B). Schubert et al. [14]

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

Table 1. Occupational exposure limits for the BTEX concentration in indoor environments.

		Benzene	Toluene	Ethylbenzene	Xylene
Time-weighted average (TWA); mg/m^3	HSE (UK)	3.25	191	441	220
	HMEI (Iran)	1.60	75	87	434
	NIOSH	0.32	375	435	435
	ACGIH(2007)	1.60	75	87	434
Short-term exposure limit (STEL); mg/m^3	HSE (U.K.)	-	384	522	441
	HMEI (Iran)	8	-	-	651
	NIOSH	3.75	560	545	655
	ACGIH(2007)	8	-	-	651

conducted an experimental study in which they reported a high concentration of benzene (271 ± 8 µg per every session) for the mainstream of Ghalyan. They stated that this value is 6.2 times as large as that of cigarette. The high level of these pollutants in a confined space such as smoking cafés causes the development of a low-quality air in the indoor air of these cafés, and thus the people (including smokers, non-smokers, customers and employees) are at serious risks of low birth weight, periodontal diseases, lung cancer and other diseases associated with respiration [8]. In this regard, to preserve the health of exposed individuals, different organizations have regulated a wide range of occupational exposure limits for the BTEX concentration in indoor environments (Table 1). Nevertheless, WHO has not presented any allowable limit for exposure to benzene (due to its carcinogenicity) for the public so far [15].

Bushehr city is located in the south of Iran, in which there are numerous smoking cafés, where different types of tobacco including fruit-flavored and traditional tobaccos as well as cigarette are used. Nevertheless, unfortunately so far, no study has been conducted on the level of hazardous air pollutants in the indoor air of these cafés. Therefore, in the present study for the first time, BTEX concentration was examined in the indoor air of Ghalyan and cigarette cafés of this city. This study was designed and implemented with the following objectives: (1) investigating the concentration of BTEX compounds in the indoor air of Ghalyan cafés with fruit-flavored and traditional tobacco, (2) examining the concentration of BTEX compounds in the indoor air of cigarette cafés and comparing it with that of Ghalyan cafés, (3) exploring the effect of building characteristics and its different factors on the concentration of BTEX compounds in the indoor air of cafés and (4) assessing the risk of exposure to BTEX for the individuals via inhalation exposure inside these cafés.

Materials and methods

Design of the study and selection of sampling sites

In this study, the quality of the indoor air of tobacco cafés in Bushehr city located in the south of Iran was studied. For this purpose, 32 cafés were chosen, and the concentration of BTEX compounds in their indoor environment was examined between November 2018 and February 2019, of which, 15, 9 and 8 were cafés in which Ghalyan (hereafter referred to as GHC), only cigarette (hereafter referred to as CC) and eventually no tobacco (smoking-free cafés) as the control sample (hereafter referred to as SFC) were smoked, respectively. Of note, some of the cafés had been located in the basement, while some others were situated in the ground floor. Before initiating the sampling, at first, the necessary explanations were given to persuade the owners and managers of the chosen cafés to collaborate for taking samples from their indoor air. Once they were persuaded and signed the written informed consent form, sampling operations were initiated. For each of the cafés, background information including the area of the places, type of ventilation (natural (window opening), air conditioning, watercooler), rate of ventilation, the number of doors and windows, the number of ventilators, the number of active hookah heads, type of tobacco (fruit-flavored tobacco or traditional tobacco) and other information were recorded using a predesigned questionnaire.

The process of sampling the air

The sampling of the present study was performed according to NIOSH[1] 1501 [16] method. For this purpose, first, the equipment for suction and sampling including the pumps was calibrated before starting the sampling. Taking samples from BTEX compounds was performed in the indoor air of 31 studied cafés by an individual sampler pump (SKC) equipped with flow adjustment holders. In this method, charcoal tubes were utilized as an absorbent for collecting BTEX compounds. The sampling equipment was devised in the breathing region (located at 150 cm above the ground level). The sampling of the indoor air of the cafés was performed with a flow rate of 200 mL/min for 50 min continuously. Once the sampling plan was finished, the samples were immediately transferred to the laboratory according to the manufacturer's guidelines, stored at −20°C and eventually analyzed up to 72 h [17]. Taking samples from BTEX compounds was done during rush hours (5pm–9 pm) from each of the sampling stations twice, once during one of the weekdays (such as Monday) and another time at weekends (such as Thursday or

Friday) (due to the large number of Ghalyan consumers).

Preparation and analysis of the samples

According to NIOSH 1501 method [16], first, the two heads of the charcoal tube were appropriately broken and the charcoal inside each of them was poured into separate glass vials. Next, 2 mL of carbon disulfide (CS2) solvent was added to each of the vials. Thereafter, the lid of the vials was tightly closed and stirred on a shaker slowly for 30 min. The solvent-extracted samples were transferred to gas chromatography (GC) vials, and BTEX compounds were analyzed by GC device equipped with flame ionization detector (FID) detector and capillary column, whereby their values were determined. For this purpose, 1 µL of the prepared extraction solution was taken and injected into the capillary column. The temperature of the injection point and detector was adjusted at 250°C and 300°C, respectively. The oven temperature was also programmed such that it remained constant at 40°C for 10 min, and then reached 230°C at 10°C/min [17].

For quality control and quality assurance, a high-purity analytical BTEX standard was bought from Sigma-Aldrich (Austria) and was used for the preparation of calibration solutions. The devices were calibrated on a daily basis by calibration standards. To control the breakthrough, the front and rear parts of each of the charcoal tubes were analyzed separately, where none of the target pollutants (benzene, pollution, ethylbenzene and xylene) were observed in the rear part of the charcoal tubes. The method was validated using limit of detection (LOD), limit of quantification (LOQ) and relative standard deviation (RSD). LOD and LOQ were determined using the blank method. In this sense, the concentrations of 10 blank samples were measured in triplicate way, and LOD and LOQ were calculated using Equations (1) and (2).

$$LOD = Average(B) + [3 \times Standard\ Deviation(B)] \quad (1)$$

$$LOQ = Average(B) + [10 \times Standard\ Deviation(B)] \quad (2)$$

where B is the blank sample concentration.

Concentrations of BTEX compounds in blank samples ranged from 0.00 to 0.04, 0 to 0.06, 0 to 0.10 and 0.0 to 0.0 µg/m^3 for benzene, toluene, ethylbenzene and xylene, respectively. The LOD and LOQ were 0.02 and 0.05 µg/m^3 for benzene, 0.03 and 0.08 µg/m^3 for toluene, 0.04 and 0.12 µg/m^3 for ethylbenzene and 0.0 and 0.0 µg/m^3 for xylene, respectively. Also, to determine the extent of recovery of the analysis method, a certain value (10 µg) of each of the pollutants was injected into fresh charcoal tubes, and then extracted and analyzed similarly (similar to the field samples). The extent of recovery for the four compounds in the spiked samples was obtained as 88–103% with an SD < 10%. A method blank, a field blank and replication of samples for each batch of the samples were performed. Very trace amounts were observed for some of these compounds in the blank samples. These values were properly deducted from the values read in the samples.

Statistical analyses and risk assessment

The obtained data were analyzed by SPSS 20. Data normality was examined by Kolmogorov–Smirnov test (K–S test). The significance of the difference between the concentration of pollutants in the indoor air of smoking cafés and in that of SFC was tested by *t*-test. The significance level of the tests was considered as 0.05 and 0.01 (confidence intervals of 95% and 99%). Path analysis was performed to determine the factors significantly affecting the concentration of pollutants inside the GHC by Amos 21. Eventually, the assessment of the risk of exposure to BTEX compounds in GHC, CC and SFC was performed using Equations (1)–(5) and through the parameters presented in Table 2.

In these equations,

Table 2. Parameters used in the assessment of the risk of exposure to BTEX compounds in Ghalyan, cigarette and smoking-free cafés.

Parameters	Values	Unit
BTEX concentration (C_{BTEX})	-	mg/m^3
Rate of inhalation, adult (RI_a)	0.83	m^3/h
Exposure duration for adult (ED_a)	8	h/day
Body weight for adult (BW_a)	70	kg
Days of exposure per week (D)	6	day
Weeks of exposure (WE)	48	week
Years of exposure (YE)	30	year
Years in lifetime (YL)	70	year
Slope factor or carcinogenic potency slope (SF)	Benzene = 0.029	mg/kg-day
Reference dose (RfD): RfC[a] × 20 (assumed adult inhalation rate, m^3/day) ×1/BWa(kg)	Benzene = 0.00855	mg/kg-day
RfC: Inhalation reference concentration mg/m^3	Toluene = 1.4	
	Ethylbenzene = 0.286	
	Xylene = 0.029	

[a]Based on RfC_s for USEPA, IRIS (benzene = 0.03 mg/m^3, toluene = 5 mg/m^3, ethylbenzene = 1 mg/m^3, xylenes = 0.1 mg/m^3).

$$E = C_{BTEX} \times RI_a \times \frac{ED_a}{BW_a} \quad (1)$$

$$E_Y = C_{BTEX} \times RI_a \times ED_a \times \frac{D}{7} \times \frac{\frac{WE}{52}}{BW_a} \quad (2)$$

$$E_L = E \times \frac{D}{7} \times \frac{WE}{52} \times \frac{YE}{YL} \quad (3)$$

$$Risk = E_L\left(\frac{mg}{kg}.day\right) \times SF\left(\frac{mg}{kg}.day\right) \quad (4)$$

$$HQ = \frac{E_Y}{RfD} \quad (5)$$

where E stands for daily exposure (mg/kg·d), EY stands for yearly average daily dose received (mg/kg·d), EL stands for effective lifetime exposure (mg/kg·d), HQ stands for hazard quotient and RfD stands for reference dose (mg/m^3).

Results and discussion

The concentration of BTEX compounds in different cafés

The descriptive statistics of the concentration observed for BTEX compounds in the air samples taken from GHC, CC and SFC are given in Table 3. As can be seen, these pollutants have been detected in all of the samples collected from these cafés. This suggests that smoking tobacco is an important source for BTEX hazardous compounds in the indoor air of these cafés. The ΣBTEX lied within the range of 11.98–31.45 with a mean of 19.64 mg/m^3 in GHC, 2.45–15.32 with a mean of 11.34 mg/m^3 in CC and 0.88–3.51 with a mean of 2.26 mg/m^3 in SFC. The findings of the current work indicate the high concentration of BTEX in the indoor air of cafés, which can cause the development of considerable risks in public health. These results have been in line with other studies worldwide, which have reported elevated concentration of PM, CO and other pollutants including polycyclic aromatic hydrocarbons, black carbon nitrogen oxide, air nicotine and volatile organic compounds inside cafés [11,18].

The statistical analysis also showed that the concentration of ΣBTEX in the different cafés was in the order of GHC > CC > SFC. As can be observed in this order, higher BTEX concentration was found in the indoor air of Ghalyan cafés than in cigarette cafés. Smoking topography research has reported that smoking one cigarette involves ten to twelve 50-mL puffs, while smoking one 45- to 60-min session of Ghalyan can involve 100 puffs of around 500 mL, and therefore larger amounts of tobacco smoke are emitted across the indoor air of cafés in each puff [19,20]. In addition, cooling by water, flavorings, and sweeteners of tobacco in the waterpipe cause deeper and more puffs [21]. This extent of inhalation during a 45- to 60-min session of smoking waterpipe is very alarming because waterpipe smoke contains large amounts of combustion products including BTEX, heavy metals, PAHs, formaldehyde, etc. Based on an experimental study conducted by Thomas Eissenberg et al. [22], the volume of smoke produced and the values of the pollutants including carbon monoxide, tar and nicotine emitted from waterpipe were significantly larger than those of cigarette, which was in agreement with the findings of the present study. The benzene concentration lied within the range of 2.68–8.05 with a mean of 4.53 mg/m^3 in GHC, 0.71–4.09 with a mean of 2.77 mg/m^3 in CC and 0.26–0.69 with a mean of 0.52 mg/m^3 in SFC. The values observed for benzene in the indoor air of these cafés were compared with time-weighted average (TWA) values presented by different organizations, and it is deduced that the concentration of this pollutant in the indoor air of waterpipe and cigarette cafés has exceeded the recommended guideline. Concerning SFCs, benzene concentration did not exceed the allowable limit except for the guideline presented by NIOSH. Benzene has been introduced as a definite carcinogenic for the human, and exposure to this hazardous compound causes damage to hematopoietic cells of the bone marrow causing bone marrow cancer [23]. The toluene levels lied within the range of 2.58–7.42 with a mean of 4.44 mg/m^3, 0.42–3.51 with a mean of 2.56 mg/m^3 and 0.19–0.93 with a mean of 0.58 mg/m^3 in GHC, CC and SFC, respectively. Fortunately, toluene concentration inside the indoor air of the studied cafés did not exceed the allowable limit recommended by different organizations (Table 1). Acute exposure to toluene affects the central nervous system causing headache, losing control, convulsions, loss of consciousness and even death [24]. The ethylbenzene concentration lied within the range of 2.34–5.94 with a mean of 3.92 mg/m^3, 0.27–2.62 with a mean of 2.11 mg/m^3 and 0.12–0.68 with a mean of 0.39 mg/m^3 in GHC, CC and SFC, respectively. In a study carried out by Parra et al. on the indoor air of cafés in Spain, the mean concentration of ethylbenzene was reported as 1.06 µg/m^3, which was far lower than the values observed in this study [25]. Xylene concentration lied within the range of 4.38 ± 10.04 with a mean of 6.76, 1.05 ± 5.10 with a mean of 3.88 and 0.31–1.21 with a mean of 0.79 mg/m^3 in GHC, CC and SFC, respectively. Several researches believe that xylene causes various hematological disorders including leukocytosis, increased number of neutrophils, diminished number of erythrocytes, hematocrit and hemoglobin in animals, and anemia and reduction of white blood cells in humans. Nevertheless, it is not clear whether these hematological changes are exclusively attributed to xylene or not [26,27]. Generally, the values obtained in this study (all four compounds of BTEX) have been larger than those reported by

Table 3. Descriptive statistics for indoor BTEX concentrations (mg/m^3) in the compounds in smoking cafés if Bushehr.

			Benzene		Toluene		Ethylbenzene		Xylene		∑BTEX	
Café type		Session	Min-Max	Mean ± SD	Min-Max	Mean ± SD	Min-Max	Mean ± SD	Min-Max	Mean ± SD	Min-Max	Mean ± SD
GHC	**Fruit-flavoured tobacco**	**Weekday session**	3.77–9.65	4.75 ± 1.07	3.35–5.98	4.62 ± 0.89	2.98–5.23	4.06 ± 0.71	5.43–7.78	9.68 ± 1.70	15.53–25.94	19.96 ± 3.55
		Weekend session	4.98–9.12	6.68 ± 1.48	5.12–8.87	6.56 ± 1.17	4.76–7.12	5.85 ± 0.84	7.22–12.43	8.11 ± 1.23	22.08–37.54	28.79 ± 5.18
	Regular tobacco	**Weekday session**	2.37–3.39	2.76 ± 0.32	2.25–3.31	2.68 ± 0.31	1.98–2.91	2.34 ± 0.28	3.98–5.45	4.73 ± 0.57	10.58–15.04	12.53 ± 1.49
		Weekend Session	4.98–9.12	6.68 ± 1.14	2.81–3.83	3.52 ± 0.33	2.56–3.49	3.11 ± 0.32	4.77–6.74	5.71 ± 0.62	13.05–18.19	15.92 ± 1.66
CC		**Weekday session**	0.67–3.27	2.53 ± 1.33	0.39–2.89	2.36 ± 1.12	0.22–2.41	1.89 ± 0.9	0.89–4.19	3.37 ± 1.35	2.17–12.77	10.15 ± 4.70
		Weekend Session	0.77–4.24	3.03 ± 1.49	0.44–3.67	2.77 ± 1.29	0.31–2.81	2.33 ± 1.15	1.21–5.67	4.42 ± 1.77	2.73–16.39	612.54 ± 5.70
SFC		**Weekday session**	0.21–0.64	0.48 ± 0.18	0.17–0.98	0.61 ± 0.21	0.11–0.69	0.37 ± 0.13	0.34–1.12	0.76 ± 0.29	0.83–4.43	2.22 ± 0.81
		Weekend Session	0.33–0.72	0.56 ± 0.17	0.21–0.88	0.55 ± 0.16	0.13–0.67	0.39 ± 0.15	0.28–1.31	0.81 ± 0.23	0.95–3.58	2.31 ± 0.71

Fazlzadeh et al. for the waterpipe cafés in Ardabil City [11].

The effect of the number of active hookah heads, type of tobacco and the café location floor

In this study, the different variables of possible impact on indoor air quality including the number of active waterpipe heads, type of tobacco and location floor on the emission of BTEX compounds in the indoor air of the studied cafés were also evaluated. As can be seen in Table 3, BTEX concentration was higher in the cafés during weekend sessions compared with weekday sessions. Specifically, the mean±SD values of benzene concentration in the indoor air of WC, CC and SFC were 3.82 ± 1.28, 2.51 ± 1.33 and 0.48 ± 0.18 mg/m^3, respectively, during the weekday sessions. The weekend sessions presented the values of 5.23 ± 1.91, 3.02 ± 1.43 and 0.56 ± 0.17 mg/m^3, respectively. During the weekday sessions, the mean±SD values of toluene concentration were 3.71 ± 1.18, 2.36 ± 1.12 and 0.61 ± 0.21 mg/m^3, and during weekend sessions, the values were 5.14 ± 1.74, 2.77 ± 1.29 and 0.55 ± 0.17 mg/m^3 for WC, CC and SFC, respectively. During the weekday sessions, the mean±SD values of ethylbenzene concentration in WC, CC and SFC were 3.26 ± 1.01, 1.89 ± 0.91 and 0.37 ± 0.13 ng/m^3, and during weekend sessions, the values were 4.57 ± 1.51, 2.33 ± 1.15 and 0.39 ± 0.15 mg/m^3, respectively. Finally, during the weekday sessions, xylene concentrations in WC, CC and SFC were 5.69 ± 1.16, 3.37 ± 1.35 and 0.76 ± 0.26 mg/m^3, and in weekend sessions, they were 7.83 ± 2.37, 4.42 ± 1.77 and 0.82 ± 0.23 mg/m^3, respectively (Table 3). The results of path analysis suggested that among the influencing factors, the number of active waterpipe heads was found to be the most influential factor for BTEX emission in the indoor air of the cafés. With this analysis, modulus standardized effect size (MSES) for the number of active waterpipe heads was obtained as 0.46. The higher concentration of pollutants during the week in sessions can be justified based on the sparer time for individuals at the weekends, during which especially the youth come to these cafés to spend their leisure time. The higher BTEX levels during the weekend sessions can be attributed to the number of active waterpipe heads during the weekend sessions [28,29].

Concerning the type of tobacco, from 14 waterpipe cafés, 8 and 6 served fruit-flavored and traditional tobaccos, respectively. Significantly higher BTEX concentrations are found in indoor air of the cafés serving fruit-flavored tobacco compared to traditional tobacco-serving cafés. The mean±SD values of benzene, toluene, ethylbenzene and xylene concentration in waterpipe cafés serving fruit-flavored tobacco were 5.71 ± 1.25, 5.59 ± 0.97, 4.96 ± 0.71 and 8.12 ± 1.23 mg/m^3, respectively (Figures 1–4). On the other hand, in waterpipe cafés with traditional tobacco, the values were 3.17 ± 0.35, 3.10 ± 0.23, 2.72 ± 0.26 and 5.23 ± 0.58 mg/m^3, respectively (Figures 1–4). Possibly, the main source of production of air pollutants when smoking is the tobacco used for preparing the waterpipe. In comparison to cigarette smoke, more various and larger amounts of contaminants are produced in response to smoking waterpipe. Greater exposure to high-molecular-weight PAHs and benzene but less

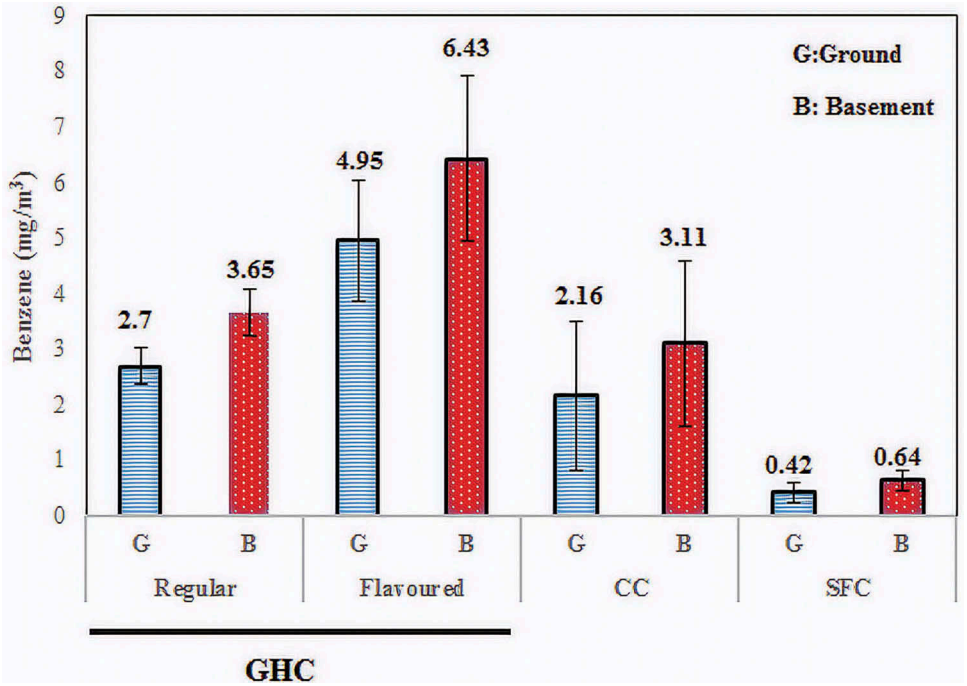

Figure 1. Average concentration of benzene in indoor air of smoking cafés according to the 'tobacco type' and 'the floor level'.

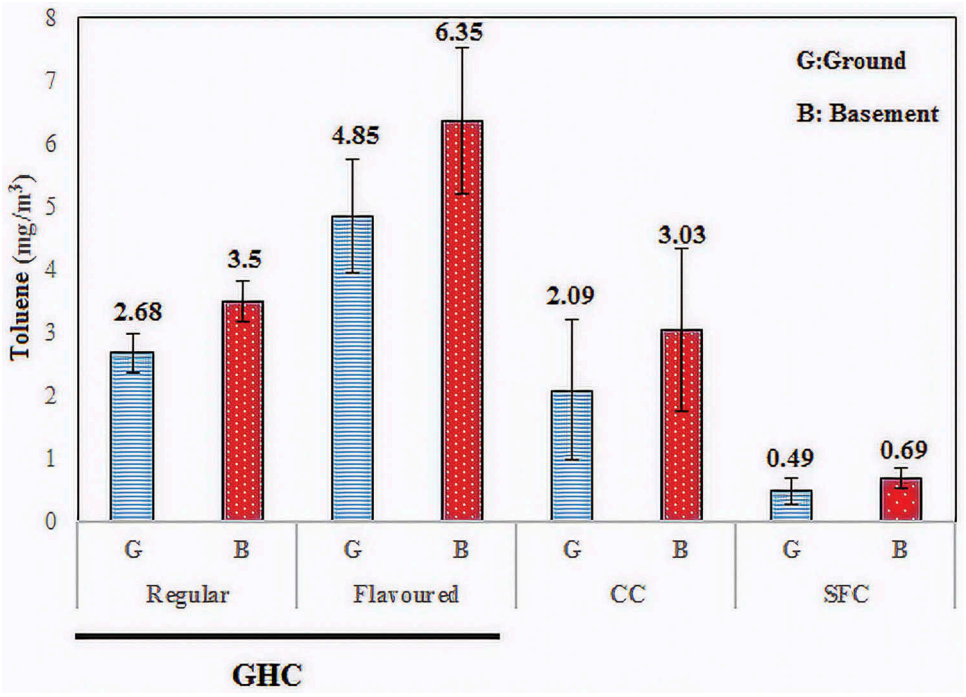

Figure 2. Average concentration of toluene in indoor air of smoking cafés according to the 'tobacco type' and 'the floor level'.

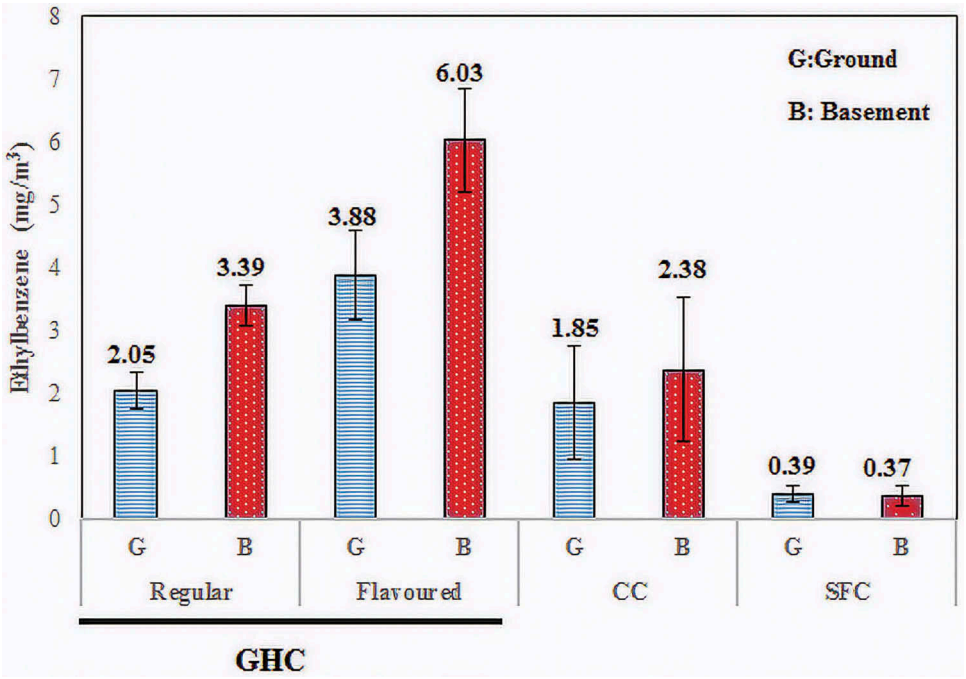

Figure 3. Average concentration of ethylbenzene in indoor air of smoking cafés according to the 'tobacco type' and 'the floor level'.

exposure to acrolein, propylene oxide, acrylonitrile, butadiene1,3, nitrosamines, ethylene oxide and low-molecular-weight PAHs have been reported in waterpipe cafés in comparison to cigarette cafés [30]. Different rates of production of air pollutants by various tobaccos have been observed in previous studies [22,31]. Based on path analysis, 'the type of tobacco' with MSES of 0.31 was the second influential factor in the emission of the pollutants chosen in this research, where in WCs in which fruit-flavored tobacco was served, the rate of production of pollutants was significantly higher than in WCs in which traditional tobacco was consumed.

The higher BTEX concentration in fruit-flavored cafés could be interpreted through the time required to smoke waterpipe with different types of tobacco.

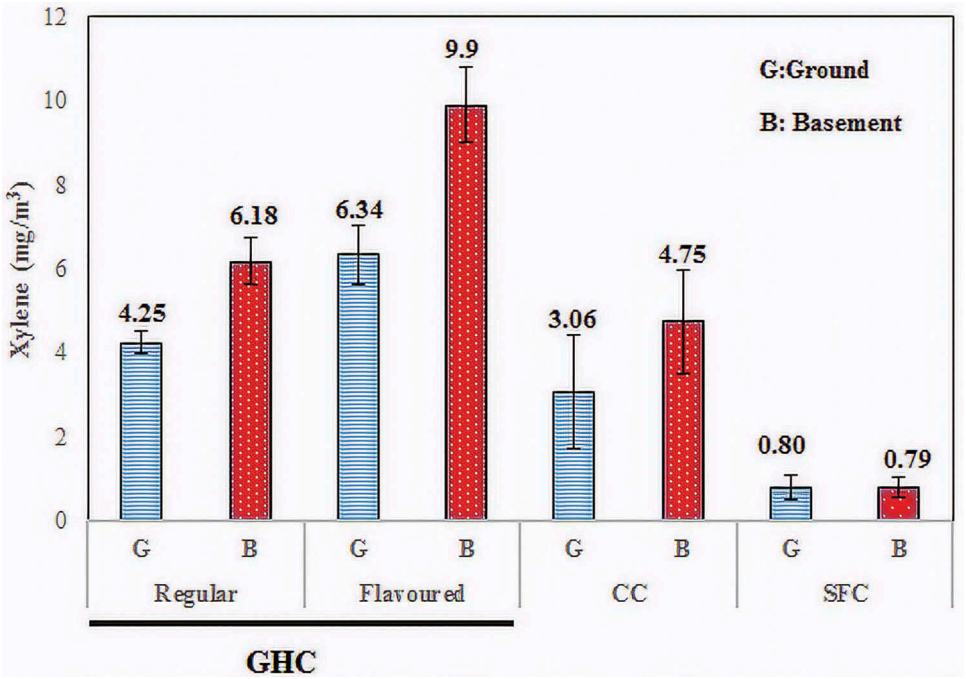

Figure 4. Average concentration of xylenes in indoor air of smoking cafés according to the 'tobacco type' and 'the floor level'.

Waterpipes containing flavored tobacco last at least 4 times longer to smoke than its traditional counterpart. This may be due to the soft and tasty smoke of flavored tobacco as well as the tendency of youth customers to spend more time on smoking this type of waterpipe [32].

In addition, fruit-flavored tobaccos contain large amounts of organic chemicals, aroma, essences and flavoring additives which are added to this type of tobaccos through the manufacturing process. The high concentration of BTEX in these cafés can be attributed to these chemical compounds (32). Similar results have been reported by previous studies in the production of CO and BTEX [11,13]. Further, the concentration of pollutants was significantly higher in the cafés located in the basement than those situated in the ground floor (Figures 1–4). According to the results of path analysis, MSES was 0.16 for the café location floor. Basements are usually confined places with no perforated walls and very restricted natural ventilation. Since ventilation is an influential factor in treating the air inside different places and cafés, the cafés located in the basement expectedly suffered larger amounts of pollutants. However, the basements are more favored by owners of the waterpipe cafés, especially in the city center where rent fees for ground floor settings are quite expensive.

Inhalation risk assessment

Although the mean concentration of toluene, ethylbenzene and xylene has been lower than the recommended allowable occupational exposure limits in some cases, most cigarette and waterpipe cafés run for 12 h per day and 7 days per week. Under these conditions, the risk of exposure to these pollutants for the exposed individuals cannot be neglected. According to the concentrations observed for each of the BTEX compounds, their risk was assessed, with its results presented in Table 4. These findings indicated that the HQ of benzene compound in GHC, CC and SFC cafés has been 39.72, 24.29 and 4.57, respectively. This value for xylene was 17.26, 10.97 and 2.01, respectively. As can be observed, benzene and xylene compounds have exceeded the HQ of 1 in all cafés (GHC, CC and SFC). HQ larger than 1 is unacceptable and has great potential for chronic noncarcinogenic effects on the target organs of the body [10,33]. Fortunately, HQ of toluene has not been larger than 1 in any of the cafés. Concerning ethylbenzene, HQ obtained has been lower than one except for GHC (HQ = 1.2). Given the type of tobacco, HQ was higher in the GHC with fruit-flavored tobacco than in traditional tobacco cafés, which is due to the higher concentration of these pollutants inside cafés serving food-flavored tobacco. Generally, HI (sum of HQs of individual compounds) inside GHC, CC and SFC was obtained as 58.23, 35.04 and 6.71, respectively, suggesting the fact that the individuals employed in these cafés are seriously at risk of exposure to these pollutants. Therefore, much increase in indoor air exchange rate is required to decrease BTEX concentration to a safe and healthy level [4].

The results also showed that the cancer risk (CR) obtained for benzene in GHC, CC and SFC was 3940×10^{-6}, 2409×10^{-6} and 452×10^{-6}, respectively. As can be observed, all of the cases have exceeded the

Table 4. Hazard quotient (HQ) and cancer risk (CR) of BTEX compounds in smoking cafés of Bushehr.

		Benzene		Toluene		Ethyl benzene		Xylene		
		CR	HQ	CR	HQ	CR	HQ	CR	HQ	HI
GHC	Total	3940×10^{-6}	39.72	-	0.23	-	1.02	-	17.26	58.23
	Fruit-flavored	5013×10^{-6}	50.08	-	0.29	-	1.31	-	20.97	72.65
	Regular	2776×10^{-6}	27.28	-	0.17	-	0.71	-	13.54	41.70
CC		2409×10^{-6}	24.29	-	0.13	-	0.55	-	10.07	35.04
SFC		452×10^{-6}	4.57	-	0.03	-	0.10	-	2.01	6.71

safe limit recommended by EPA (1×10^{-6}) [34], suggesting the high risk for employees of these cafés. In comparison to GHC with traditional tobacco, the CR is significantly higher in cafés with fruit-flavored tobacco (2776×10^{-6} vs. 5013×10^{-6}). Note that other carcinogenic compounds such as naphthylamines, PAHs and aldehydes may also exist in the indoor air of these cafés which have not been considered in this risk assessment [35]. High amounts of BTEX compounds in the indoor air of GHC with fruit-flavored tobacco of Bushehr city suggest that a large number of young people who mostly prefer to use fruit-flavored tobacco are exposed to adverse health effects.

Conclusion

Although the present study has been the first to investigate the concentration of BTEX compounds and assess the risk of exposure to them in the indoor air of GHC, CC and SFC in Bushehr City and had also some limitations, it offered valuable results. The results showed that the concentration of BTEX compounds in indoor air of tobacco cafés of this city is considerably high, such that it can pose a serious risk to the health of both employees and customers. The results of this study suggested that benzene concentration inside the cafés and GHC of this city has far exceeded the limits recommended by the health ministry for occupational exposure, developing high carcinogenicity and noncarcinogenicity risk for the staff. In addition, the individuals who use fruit-flavored Ghalyans are exposed to large amounts of these hazardous contaminants, and thus the risk of developing cancer and chronic noncancer diseases is higher in these individuals. Further, the cafés located in the basement, due to the poor ventilation system or its absence, accumulate large amounts of these pollutants, further jeopardizing the health of customers. Further, assessment of the risk caused by exposure to BTEX compounds in the indoor air of these cafés showed that the carcinogenicity and noncarcinogenicity risk values resulting from the indoor air of tobacco cafés have exceeded the safe limits recommended by EPA. Therefore, larger and further studies and monitoring should be conducted on these environments and suitable controlling policies should be regulated for this public health threat.

Note

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Disclosure statement

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