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Evaluation of Exposure to BTEX in Hookah Smokers and Carcinogenic and Non- Carcinogenic Risk Assessment

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ABSTRACT

To investigate the demographic characteristics, concentration of Benzene, Toluene, Ethyl benzene and Xylenes (BTEX) in output smoke and health risk assessment in hookah smokers in hookah cafés, Iran. We checked hookah cafés in the different parts of Hamadan city and analyzed location and social station of each cafés in 2016. Finally, 20 cafés selected and five samples on each cafés (total of 100 samples). BTEX compounds were sampled in output smoke from mouth smokers using charcoal and analyzed by GC- MS according to NIOSH1501 method. The quantitative risk assessment of exposure to BTEX as recommended by the United State Environmental Protection Agency method was used. The smokers' demographic characteristics collected using a self-designed questionnaire. The average concentrations of benzene, toluene, ethyl benzene, o, m-Xylene and p- Xylene were 6.45, 7.02, 10.07, 7.21 and 8.36 mg/m^3, respectively. The mean cancer risk for benzene was estimated as 529 × 10-5 and mean non-carcinogenic risks for toluene, ethyl benzene and o, m-Xylene and p–Xylene (TEXs) were 17.57, 5.03, 24.03 and 27.88, respectively. Hookah smoking is prevalent among youths and smokers are exposed to benzene level higher than the threshold limit value recommended by ACGIH. Cancer risk for benzene and non-carcinogenic risk for TEXs were much higher than recommended limits. Thus, in order to prevent diseases stemming from hookah smoking, urgent and increased notification about its adverse health effects and intensified regulatory laws are needed to decrease hookah smoking in hookah cafés.

Key words: BTEX Compounds; Hookah Smoke; Risk Assessment; Addiction

INTRODUCTION

Volatile organic compounds (VOCs) are some of the most dangerous air pollutants. These compounds are known as air-borne carbon compounds which evaporate quickly and spread in the atmosphere and having the highest emission rates after suspended particles in the environment [1, 2]. VOCs are released from various sources and can lead to detrimental effects to health, prosperity and human performance [3]. These compounds are absorbed into the human body through different routes, however, inhalation is the main route absorption of these compounds due to high vapor pressure of these compounds [4].

BTEX (Benzene, Toluene, Ethyl benzene, and Xylenes) compounds are of aromatic hydrocarbons comprising and are considered as an index of VOCs. These compounds are mostly found in the air of cities and industrial regions and are categorized as toxic and priority pollutants [5]. BTEX in the atmosphere reacts with other chemical compounds such as nitrogen oxide to produce photochemical smog containing ozone and other toxic compounds [6]. Benzene is a known as a human carcinogen (IARC: group1 and ACGIH: skin A1), that can cause aplastic anemia, acute myelogenous leukemia and lymphoma [7, 8]. Toluene and xylenes are more soluble in lipid than benzene thus can cause increased adverse neurological effect upon exposure. Several studies have illustrated that chronic and acute exposure to toluene and xylenes may result in colon and rectal cancer and anemia [9, 10]. Ethyl benzene has been categorized as a group 2B carcinogen (Possibly carcinogenic to human) by the IARC [7]. However, ethyl benzene can cause adverse effects to the central nervous and respiratory systems and hearing loss [11]

Hookah smoking has a long history. Its geographical and historical backgrounds have been studied by Martinasek *et al.* in 2011 [12]. An alternative to cigarette smoking that has been employed for at least four centuries especially in Africa and Asia, hookah smoking is also known as Narghile, Argileh, Hubble-bubble, Shisha, Goza or Water-pipe [13]. Hookah

smoking has a higher social and cultural acceptance than cigarette smoking and most people (57%) believe that this kind of smoking is less harmful and less addictive than other kinds of smoking, such that in recent times the use of hookah is reaching epidemic proportions [14, 15]. In general, coal heating causes incomplete combustion in flavored and moist tobacco (called Muessel) which produces smoke after passing through water, and then enters into the lung of smokers [14]. Fig. 1 shows the components and how the hookah works [16]. The smoke produced from the hookah contains carbon monoxide, nicotine, tar, heavy metals, acetaldehyde, nitrous amine and BTEX [17, 18]. Hookah smoking in cafes is the main source of exposure of both smokers and the general public to compounds such as BTEX [19]. Recent studies have suggested that hookah smoking can increase the risk of lung and nasopharyngeal cancers, teratogenic disorders, oral dysplasia and pulmonary diseases [14, 20].

Risk assessment involves quality and quantity estimating of probability occurrence and severity of adverse health effect caused by human exposure to hazards in the environment [21]. The process assessing of lifetime risk cancer include four stages: hazard identification, dose- response assessment, exposure assessment and risk characterization. The USEPA of the Integrate Risk Information System (IRIS) chemical file supply information on the hazard identification and dose- response assessment steps [22]. To complete the risk assessment process need to develop estimates of exposure and integrated these with dose- response characteristics to develop estimates of risk [23]. In order to estimate carcinogenic and non-carcinogenic effects caused by environmental exposure to hazardous contaminants the method proposed by the US Environmental Protection Agency (USEPA) is used [24, 25].

Due to the prevalence of hookah smoking in the general population and the lack of access to a study on the personal exposure of hookah smokers to BTEX compounds and As well as a according to lack of risk assessment of carcinogens and non-carcinogens of these compounds in the hookah smokers, the objective of this study was investigate demographic characteristics, concentration of BTEX in output smoke from flavored hookah smoker mouth and health risk assessment using presented method by USEPA in hookah smokers in hookah cafés of Hamadan, Iran in 2016.

MATERIALS AND METHODS

Study site and number samples

In order to evaluate the exposure of hookah smokers to BTEX, hookah cafés were studied in Hamadan city, central Iran in the summer of 2016. Twenty out of 110 cafes were selected using systematic random sampling method and all selected hookah cafés had the following similar properties: they were covered and had restricted places for hookah smoking. In each of the selected hookah café, five samples of the output smoke from smoker mouth during fruit flavored hookah smoking (total 100 samples) were collected. The smokers' demographic characteristics and general information such as body weight, age, education level, duration of smoking in any time, frequency of smoke per day, history of hookah smoking and attitudes of smokers about adverse health effects from hookah toward cigarette were collected using a self-designed questionnaire.

Fig. 1: components and how the hookah works. Bowl: Holds tobacco charcoal burned on top during smoking. Plate: Ash tray. Body: Body is a hallow tube with gasket at bottom, gasket has opening for hose and seals connecting of body with water jar. Water jar: Smoking from tobacco passes through jar, gaining moisture and lowering temperature before it reaches hose. Hose: Slender tube that allow smoke to be drown, its end is typically fitted a designed metal, wooden or plastic mouthpiece [16]

Sampling of BTEX:

In this study, sampling, transport, storage and preparation process of the samples were in accordance with NIOSH method 1501. First of all, a charcoal adsorption tube (100- 50mg) from (SKC, USA) connected to a pocket pump low flow meter (SKC, Model 220, USA) were used to sampling from output smoke from smoker mouth. A digital flow calibrator (SKC Accuflow) was used to calibrate the flow rate of pump (200ml/min). In this stage, sorbent tube was attached to location of suction on the hookah hose and requested from smoker which after sucking smoke, your exhaled air blowing to sorbent tube for a period of 30min. Therefore, the sampling time was 30min. The interference effect due to other hookah smokers was minimized by separating of subject from other

smokers in the cafe. The variables affecting the concentration of these compounds such as temperature, humidity and pressure atmospheric were determined during sampling. In order to reach real figures of BTEX compounds as far as possible, the sampling was done at different times of selected days. After sampling, two sides of the absorbents were closed by plastic caps.

Storage, preparation and analysis samples:

Collected samples were transformed to the lab and kept at 5°C until preparation stage (max: 5days). Benzene, toluene, ethyl benzene and xylene isomers in front and back section of charcoal were extracted in separate vials with 1ml carbon disulfide (CS_2) (Merck Company) and occasional agitation in ultrasonic bath (Soltec 2200 MH model) for 30min, finally, was injected 1µlit to GC-MS. A Gas Chromatography (GC) machine (Model CP 3800-Varian, USA) equipped with Mass- Spectrometry was used for qualitative and quantitative measurement. Separation of the compounds was achieved with capillary column 25m× 0.22mm× 2.5µm. The operation condition was: hydrogen 2.5ml/min, air flow 25ml/min, and detector temperature 280°C. This column temperature was programmed at 30°C for 12min, and then increased to 180°C at a rate 20°C/min, and finally kept at constant temperature of 180°C for 0.5min. The results were calculated in mg/m^3 unit over 30min average [26, 27].

Quality Assurance and Quality Control:

Blank sample was used to minimizing systematic errors in transport, storage, preparation and analysis process and reduction interference effects of BTEX compound in indoor air of cafés. In order to quantify the concentration of the BTEX in the main and blank samples, first, was made stock standard solution (1000mg/l) and by using seven working solutions, was plotted calibration curve. Recovery factor of GC- MS determined by spiked sample standards and average recovery for BTEX compounds was determined 95%. The final concentration of BTEX in the main sample calculated by using the equation below:

$$C = \frac{(C_F + C_B) - (B_F + B_B)}{R \times V} \quad \text{(Eq.1)}$$

Where, C: concentration in output smoke from smoker mouth (mg/m^3), CF: concentration in front section of sorbent (µgr/ml), CB: concentration in back section of sorbent (µgr/ml), BF: concentration in front section of blank sorbent (µgr/ml), BB: concentration in back section of blank sorbent (µgr/ml), R: Recovery factor, V: Volume of air sampled (lit).

Health Risk Calculation

The assessment of carcinogen risk toxics applied of Life time Cancer Risk index (LCR). Cancer risk for benzene is calculated by using the equation below:

$$LCR = CDI \times PF \quad \text{(Eq. 2)}$$

Where, the PF is Potency Factor: Body response to intake per unit of toxin in a lifetime, this indicates of increased cancer risk from oral and inhalation exposure to a dose of 1mg/kg-day in life. The USEPA developed the IRIS system to provide the values of PS for benzene as 0.029mg/kg-day [28].

CDI (Chronic Daily Intake): in mg/kg/day calculated by using the equation below:

$$CDI = \frac{C \times IR \times ED \times EF \times LE}{BW \times ATL \times NY} \quad \text{(Eq.3)}$$

Where, C: contaminant concentration in exhaled air (mg/m^3), IR: Inhalation Rate (0.875 m3/h), ED: Exposure Duration (h/week: duration of smoking in any time [h]× frequency smoke per day×7), EF: Exposure Frequency (week/year: 51), LE: Length of Exposure (history of smoking: years), BW: Body Weight (kg), ATL: Average Time of Lifetime (years: 70), NY: Number of day per Year (days: 365) [29].

The LCR in the range of between $10^{-5} – 10^{-6}$ and lower than is considered as "acceptable" by the world Health Organization and in lower amount than 10-6 considered as "recommended" by USEPA [30].

In this study, non- carcinogenic risk for Toluene, Ethyl benzene and Xylene isomers (TEXs) were estimated by using inhalation reference concentration. Reference dose represent the continuous daily intake of a particle substance that should without risk of adverse health effect in lifetime [31]. Reference dose for toluene (not classifiable, group D), ethyl benzene (not classifiable, group D) and xylene isomers (not classifiable, group D) used were 400, 2000 and 300µg/m^3 respectively [29]. Term of Hazard Quotient (HQ) indicated the non-carcinogenic risk. According to concentration of TEXs in smoker exhaled air (C: µg/m^3) and reference dose was calculated the HQ by using the equation below:

$$HQ = \frac{C}{RFC} \quad \text{(Eq.4)}$$

If HQ>1 indicated that the TEXs concentration in output smoke from smoker mouth during fruit flavored hookah smoking exceed benchmark concentration and if the HQ was ≤1 no adverse health effect was expected [24].

Statistical Analysis:

Data analysis was performed using SPSS statistical software for windows (version 16.0). Pearson correlation coefficient test was used to investigate the relationship between duration of smoking in any time, frequency of smoking per day and history of hookah smoking. The ANOVA fisher's test was used to investigate the relationship between education level and frequency of smoking per day, history of hookah smoking and attitudes of smokers about adverse health effects from hookah toward cigarette. Crosstab test was used to investigate the relationship between education level and attitudes of smokers about adverse health effects from hookah toward cigarette. For all the tests permissible error (α) of 0.05 is considered.

RESULTS

Generally, the average age of hookah smokers was 24.7 years. Majority (53%) of the subjects, engaged in hookah smoking more than once a day. Average history of hookah smoking in the subjects was 6.5 years. The demographic data for hookah smokers is shown in Table 1.

Table 1: The demographic characteristic of hookah smokers studied

	Mean	SD	Maximum	Minimum	Variance
Age (years)	24.720	4.6798	37.0	18.0	21.901
Body Weight (kg)	70.600	5.64971	81.00	59.00	31.919
duration of smoking in any time (min)	35.100	9.01682	60.00	20.00	81.303
frequency smoke per day	1.500	.67420	4.00	1.00	.455
history of hookah smoking (year)	5.620	3.44592	15.00	1.00	11.874

There was a negative significant relationship between history of hookah smoking and frequency of smoking per day (R2= -0.42, P-Value= 0.03). Duration of smoking was not statistically different from history of hookah smoking and frequency of smoking per day (P-Value= 0.074 and P-value= 0.087 respectively). The majority (92%) of subjects obtained bachelor degrees. The education level of subjects is shown in Fig. 2.

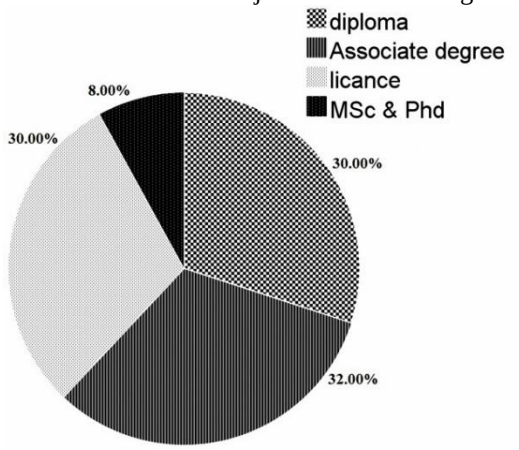

Fig. 2: Distribution of Education level of hookah smokers

There was a significant difference between education level and frequency of smoking per day, such that by higher education level reduced the frequency of hookah smoking per day (P-Value< 0.01). The highest and lowest history of hookah smoking was reported subjects with MSc and PhD and diploma educational levels, respectively (P-Value= 0.000). Distribution of subjects based on their attitudes about adverse health effects from hookah toward cigarette is shown in Fig.3. There was a negative significant relationship between attitudes about adverse health effects and frequency of smoking per day (R^2= -0.61, P-Value=0.02). Duration and history of hookah smoking were not statistically different from hookah smoker attitudes about adverse health effects from hookah toward cigarette (P-Value= 0.10 and P-value= 0.13 respectively).

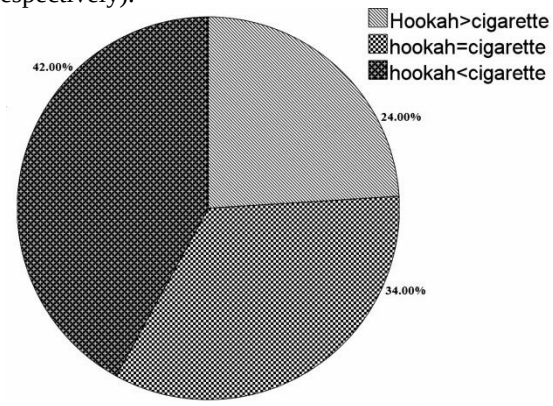

Fig. 3: Distribution of attitudes about health adverse effects from hookah toward cigarette

The mean concentration of benzene in output smoke during hookah smoking in sampling time of 30min, was more than the Threshold Limit Value (TLV) recommended by ACGIH but the concentration of other compounds was less than the standard limits [32]. The result of the concentration of BTEX compounds in output smoke from hookah smoking is shown in Table 2.

In all samples, BTEX concentration in the back section was lower than 10% of the front section sorbent (no phenomenal break through). The results of health risk assessment for subjects that is Life time Cancer Risk (carcinogenic effects) for benzene and Hazard Quotient (non-carcinogenic effects) for toluene, ethyl benzene and xylene isomers is shown in Table 3.

Table 2: BTEX concentration in output smoke from smoker mouth during hookah smoker (mg/m^3)

	TLV: ACGIH [33]*	Mean	SD	Maximum	Minimum	Variance
Benzene	1.600	6.453	0.373	6.861	5.961	0.140
Toluene	75.370	7.028	11.158	36.476	0.156	124.523
ethyl benzene	434.23	10.078	15.515	72.400	0.196	240.742
O&M-Xylene	434.19	7.210	21.341	97.496	0.009	455.476
P- Xylene	434.19	8.364	20.274	73.508	0.025	411.050

*Threshold Limit Value recommended by ACGIH (mg/m^3)

Table 3: Life time Cancer Risk and Hazard Quotient related BTEX concentration in hookah smokers

	LCR	HQ			
	Benzene	**Toluene**	**Ethyl benzene**	**O,M-Xylene**	**P-Xylene**
Minimum	738×10^{-6}	0.389	0.098	0.031	0.083
Percentile 10	150×10^{-5}	0.524	0.291	0.048	0.119
Percentile 25	209×10^{-5}	1.653	0.992	0.218	0.159
Percentile 50	354×10^{-5}	4.245	2.068	2.300	0.332
Mean	529×10^{-5}	17.570	5.039	24.033	27.882
Percentile 75	829×10^{-5}	17.660	6.035	8.000	8.670
Maximum	189×10^{-4}	91.890	36.200	324.980	245.026

DISCUSSION

The purpose of the present study was to investigate demographic characteristics, BTEX concentration of in output smoke from smoker's mouth during fruit flavored hookah smoking and health risk assessment in hookah smokers.

The mean age of subjects was 24.7 years and this could be indicative of an increased prevalence of hookah smoking in young people (Table 1). According to social- culture condition in Iran, after adolescence, people engage in social activities and experience higher freedom than before (especially for men). On the other hand, because of availability and social backgrounds, some youths aged 17-20 years old, at leisure time prefer going to cafés for hookah smoking. However, most often, parents are unaware of their children's going to the café [34, 35]. These youths repeat hookah smoking due to increased economical and personal independence they are hookah smoking is openly. Open hookah smoking can be continued until the age of 30-35 years and sometimes to end of lifetime. Increase prevalence of hookah smoking at a young age has been reported in other studies [12].

In the present study, fifty- three percent of subjects engaged in hookah smoking more than once a daily basis, such that this problem is more common in younger subjects. The most frequent hookah smokers are young adults who, at their leisure time go into cafes for hookah smoking, which creates a feeling of euphoria and increased desire for hookah smoking during this period. Over time, there is a relative decrease in intensity of the feeling of euphoria followed by reduced frequency of smoking per day. According to present nicotine in hookah smoke, there is a possibility of addiction to hookah smoke in the early period of youth [20]. The results showed that seeking to increase the educational level, reduces the frequency of smoking per day (Fig.2). This could be due to a higher history of hookah smoking in smokers with higher educational level relative to a reduced intensity in the feeling of euphoria followed by increased age. According to the results of this study, smokers with higher educational level are more aware of the adverse health effects caused by hookah smoking, and believe that these effects caused by hookah smoking are not less in cigarette smoking. Thus this could be effective in reducing the frequency of smoking per day in these subjects. A study by Essenberg *et al.* showed that the hookah smokers compared to cigarette smokers are exposed to higher level of monoxide carbon, similar level of nicotine and much higher amount of smoke [36].

All subjects in this study were male. The results of investigation into hookah smoking among Iranian women (south of Iran) showed prevalence among housekeepers (141 per thousand) and even recently from in banquets. This indicates that in addition to men, women are exposed to adverse health effects caused by toxins in hookah smoke [37].

Among BTEX compounds in the output smoke from hookah smokers, benzene concentration was higher than the recommended levels by ACGIH (Table 2). However, the limits recommended by ACGIH are related to exposure to contaminants in the workplace for an 8-hour shift, 5 days per week and 50weeks per year regardless of non-occupational exposures. However so far there is no recommended limit of exposure to BTEX indoors by authoritative international organizations [33]. Given that often

recommended limit values for occupational exposure are higher than indoor exposure, therefore, control measures to reduce exposure to contaminant indoor should be intensified compared to occupational environment and as much as possible minimize deliberate exposure to contaminants such as hookah smoke [38]. A study based on measuring concentration of BTEX compounds in indoor air of water-pipe cafes in Ardebil (north west of Iran) show that concentration of benzene (4.96mg/m^3) is higher than the limit recommended by ACGIH while the concentration of Toluene, Ethyl benzene and Xylene isomers (4.86, 4.38 and 6.69mg/m^3, respectively) was less than recommended the limit by ACGIH (Table 2). In addition ventilation systems used in cafés do not have significant impact on reducing the concentration of BTEX [39]. In a study performed by Fromme *et al*. in Germany, it was found that exposure to benzene in water-pipe smokers was more than in other people (15.0 and 0.11 µgr/m3, respectively) and water-pipe smoking increases the concentration of pollution in air and exposure may pose a health risk for water-pipe smokers [40].

The average cancer risk (LCR) caused by exposure to benzene in smokers was 529 times higher than the acceptable and recommended risk values recommended by WHO and USEPA (Table 3). Hazrati *et al*. reported that cancer risk caused by benzene in indoor air in water-pipe cafés was 431 times higher than acceptable and recommended risk values by the WHO and USEPA [39]. Guo *et al.* study showed that the cancer risk caused by benzene in smoker home and nonsmoker home was 30.24 and 6.56, respectively [41]. Therefore, smokers should be informed and alerted to the increased leukemia risk caused by benzene in hookah smoke.

Despite that the concentration of TEXs in output smoke from hookah smokers was lower than is recommended by ACGIH, the non-carcinogenic risk (HQ) are greater (Table 3). The mean non-carcinogenic risk for contemporary exposure to this compounds was 74.51 times higher than the recommended risk value, making this a warning for hookah smokers that is, the high risk of non-carcinogenic effects caused by these compounds (such as adverse effects on the central nervous, homological, auditory and respiratory systems [9, 42, 43].

Hookah smoking is prevalent among youths and smokers are exposed to benzene level higher than the threshold limit value recommended by ACGIH. Cancer risk for benzene and non-carcinogenic risk for TEXs were much more than the recommended limits (Table 1). In order to determine the exact evaluation of the adverse health effects caused by hookah smoke, it is suggested that future studies be done on the basis of identification and health risk assessment for other contaminants in hookah smoke. It is also suggested that future studies investigate demographic characteristics of men and women hookah smokers according to locality, culture and social differences in Iran and other parts of the world in order to exactly identify the population exposed to hookah smoke and to undertake preventive measures.

Finally, in order to prevent diseases stemming from hookah smoking, urgent increased notification about t adverse health effects and intensifying regulatory laws to decrease hookah smoking consumption in cafés are required.

ETHICAL ISSUES

All participants gave written informed consent to this study. Study documents were approved by UMSHA research ethic committee.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

AUTHORS' CONTRIBUTION

MS and RR originated the study, developed study protocol and guided the data analysis. JM and MS supervised all aspects of the study implementation. RR and JM assisted in the study implemented and data collection in each study site. RR drafted the manuscript. All authors reviewed drafts of the manuscript and approved the version to be published.

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