



Impact of Filter on the Estimation of Quantitative Mixture Risk Caused by Some Chemical Constituents Generated from Popular Cigarette Brands in Iran

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Original Article

Abstract

Background: This study was conducted to evaluate the impact of filter on the eventual carcinogenic and non-carcinogenic risks caused by the main toxic constituents of popular cigarette brands in Iran.

Methods: At this laboratory study, the concentration of benzene, formaldehyde, arsenic, and cadmium in the mainstream smoke of 11 popular cigarette brands in Iran, on the without and with-filter modes was determined based on an established method. The hazard quotient (HQ), incremental lifetime cancer risk (ILCR), and mixture quantitative risk assessments (QRAs) were performed based on the QRA method recommended by United States Environmental Protection Agency (USEPA).

Findings: The mean of HQ due to benzene, formaldehyde, arsenic, and cadmium in without-filter cigarette smoke was from 3.96 to 3505. The findings indicated that the HQs related to benzene, formaldehyde, arsenic, and cadmium in cigarette smoke were decreased with filter by 48.3%, 25.3%, 37.6%, and 49.1%, respectively. The filter of cigarette decreased ILCR of benzene, formaldehyde, arsenic, and cadmium in cigarette smoke by 53.02%, 25.31%, 37.70%, and 61.01%, respectively. The mixture of non-carcinogenic and carcinogenic estimated risks due to inhalation of studied cigarettes smoke was very high and unacceptable.

Conclusion: The cigarette filter plays an essential role in reducing inhalation exposure to hazardous compounds in mainstream cigarette smoke; nevertheless, the average of overall mixture HQs and ILCRs estimated caused by studied compounds was higher than the acceptable value. It is recommended that future empirical studies investigate the impact of the type of fiber used in cigarette filter on reducing carcinogenic and non-carcinogenic risks caused by cigarette smoke.

Keywords: Tobacco products; Cigarette smoking; Volatile organic compounds

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Introduction

Cigarette smoking is one of the most important sources of exposure to toxic and chemical compounds, so that according to the World Health Organization (WHO) forecast by the year 2020, the cigarette will be the main leading cause of death of more than 10 million people per year globally.¹⁻³ Burning tobacco leaves generates cigarette smoke at very high temperatures (≈ 900 °C), which is composed of various toxicant particles and gas compounds.^{4,5}

Benzene is known to be a human carcinogen (leukemia), and chronic exposure to benzene causes damage to immune, nervous, and reproductive systems.⁶ Formaldehyde is a sensory irritating, neurotoxic, reproductive, and developmental toxic compound which can cause upper respiratory tract cancers (nasopharyngeal and sino-nasal) in human.⁷ Inorganic arsenic is considered to be a human carcinogen (lung cancer), and chronic exposure to this harmful compound causes cardiovascular and respiratory non-cancer effects in humans.^{8,9} The cadmium is considered a known human carcinogen, with the lung and the kidney as the identified target organs of chronic exposure to cadmium.^{10,11}

Different brands of cigarettes consist of various tobacco leaves, additives, paper quality, filter quality, and different dimension, that the type and concentration of harmful and potentially harmful compounds in the cigarette smoke of each brand will be different. The cigarette filter is a cost-effective way to reduce the concentration of tobacco-contaminated pollutants in cigarette smoke.^{12,13} Cigarette filter ventilation allows air to be down into the filter which can dilute the nicotine and tar of cigarette smoke.¹⁴⁻¹⁶ So far, a coherent study has not been conducted on the role of the filter in reducing the concentration of hazardous compounds in the cigarette smoke of Iranian popular brands.

Cigarette-related diseases do not depend on the single component, such as the concentration of harmful compounds in cigarette smoke; rather, these diseases rely on the interaction of complex components. In the process of quantitative risk assessment (QRA), multiple parts of the disease are investigated, and using scientific evidence describes the probability of incidence or prevalence of a health threat.¹⁷⁻¹⁹ The use of the QRA process to toxicant compounds in cigarette smoke provides an objective and comparable framework for the risks of carcinogenic and non-carcinogenic effects

due to cigarette smoking. The QRA has acceptable performance for comparison of human health risk between two or more tobacco products.^{12,17}

Considering the growing concern about the increase of cigarette smoking in Iran as a developing country, like in many countries, the obscurity of the role of filter in reducing the risk of hazardous compound in the cigarette smoke (benzene, formaldehyde, arsenic, and cadmium), and the effectiveness of the QRA process in predicting the risk of carcinogenicity and non-carcinogenicity of hazardous compounds of popular Iranian and foreign cigarette brands, this study was performed.

Methods

Study design

Sample selection: Based on market share information, eleven brands of cigarette commonly available in Iran (6 Iranian and five foreign brands) were selected and purchased from local retailers. Cigarette brands were labeled based on alphabetic terms (Iranian brands: A: Sina, B: Sattar, C: J one, D: Bahman low-yield, E: Bahman, F: Bistoon, and foreign brands: G: Magna, H: Montana, I: Marlboro, J: Winston, and K: Kent) and were stored in original packing at ambient temperature until sampling and analysis.

Sampling and analysis: In this laboratory study, the concentration of toxic compounds in cigarette smoke was measured in two mainstream modes: with filter and without-filter cigarette. In without-filter mode, the cigarette filter was removed from the cigarette using the cutter and cigarette without the filter was placed in the sampling path (Figure 1). The sampling of toxic compounds in cigarette smoke on mainstream mode was continued until the cessation of a cigarette burning.

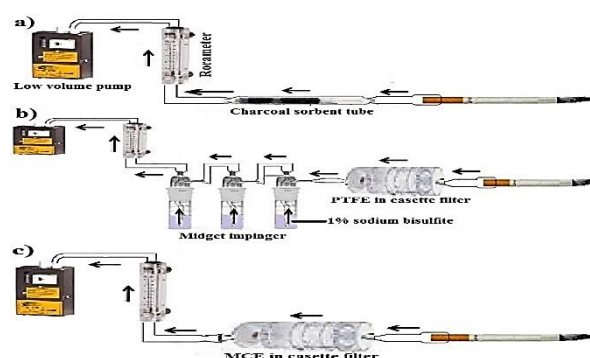


Figure 1. Simple present sampling set of a) benzene, b) formaldehyde, and c) arsenic and cadmium in mainstream cigarette smoke

Benzene in cigarette smoke was sampled based on National Institute for Occupational Safety and Health (NIOSH) 1501 method using charcoal sorbent tube (100/50, SKC Inc., USA) and low volume sampling pump at a flow rate of 0.170 l/min⁻¹ (model 222, SKC Inc., USA). The cigarette was connected to a charcoal tube in the sampling path (NIOSH 1501). Figure 1a shows a simple schematic presentation of the benzene sampling set. The benzene was analyzed using gas chromatography (GC) equipped with a flame ionization detector (FID) (Shimadzu, model 2010, USA).²⁰

Formaldehyde in cigarette smoke was sampled using three consecutive glass midget impingers (30 ml, model ACE 7533) containing 15 ml 1% sodium bisulfite (total: 45 ml) and personal sampling pump at a flow rate of 0.190 l/min⁻¹ (model 222, SKC Inc., USA). Also, it was used as a polytetrafluoroethylene (PTFE) filter to prevent the permeation of particle pollutants of cigarette smoke in midget impingers (based on NIOSH 3500 method). A schematic presentation of the formaldehyde sampling set was presented in figure 1b. The formaldehyde was analyzed by a spectrophotometer with an ultraviolet-visible (UV/Vis) detector (PerkinElmer, model Lambda 950, USA).²¹

The sampling of arsenic and cadmium in cigarette smoke was performed using a mixed cellulose ester (MCE) filter (pore size: 0.8 µm and diameter: 37 mm, SKC Inc., USA) and personal sampling pump at a flow rate of 2.0 l/min⁻¹ (model 222, SKC Inc., USA). The MCE filter was placed inside the cellulose backup pad and 37-mm diameter cassette (Figure 1c). The preparation of cadmium and arsenic was done by the ashing method and they were analyzed by an atomic absorption spectrometer (PerkinElmer, model Analyst 700, USA) equipped with cathode lamps set at 228.8 and 193.7 nm for cadmium and arsenic analysis, respectively.^{22,23}

Mixture QRAL: In this study, QRA methodology recommended by the United States Environmental Protection Agency (USEPA) has been used to evaluate the role of the filter in reducing adverse health effects due to cigarette smoke for two modes of with filter and without filter cigarette.²⁴ For this purpose, the QRA methodology involving four steps (hazard identification, toxicity assessment, exposure

assessment, and risk characterization) can be used for risk assessment of carcinogenicity and non-carcinogenicity of various toxic compounds.

Hazard identification: In the hazard identification step, the adverse health effects of the compounds studied due to the exposure to toxic compounds (e.g., carcinogen and non-carcinogen effects) will be investigated.

Toxicity assessment: The toxicity assessment step determined the toxic inherent of the compound. Also, in this step dose-response curve and toxicity information of compounds (for carcinogenic and non-carcinogenic effects: Reference Concentration and Inhalation Unit Risk, respectively) are considered.²⁵ The reference doses and IUR of benzene, formaldehyde, arsenic, and cadmium were shown in table 1.

Table 1. Reference concentration (RfC), inhalation unit risk (IUR), and absorption rate of studied toxic compounds of cigarette smoke in the respiratory system²⁵⁻²⁷

| Compound | RfC (µg/m ⁻³) | IUR (µg/m ⁻³) | ABS |
|-----------------------------|------------------------------|------------------------------|------|
| Benzene | 3.0 × 10 ⁻³ | 7.6 × 10 ⁻⁶ | 0.67 |
| Formaldehyde | 9.8 × 10 ⁻³ | 1.3 × 10 ⁻⁵ | 0.54 |
| Inorganic arsenic (fume) | 15.0 × 10 ⁻³ | 4.3 × 10 ⁻³ | 0.16 |
| Cadmium (fume) | 10.0 × 10 ⁻³ | 1.8 × 10 ⁻³ | 0.35 |

RfC: Reference concentration; IUR: Inhalation unit risk; ABS: Absorption rate of a compound in the respiratory system

Exposure assessment: In exposure assessment step, exposure levels, frequency, duration, and routes of personal exposure to toxic compound (s) are evaluated. Exposure assessment was calculated as the chronic daily intake (CDI), according to equation 1.²⁴

$$CDI = \frac{C \times CF \times TC \times ABS \times EF \times ED}{BW \times AT} \quad (\text{Equation 1})$$

Where CDI is the chronic daily intake of the toxic compound due to smoking cigarette (µg/m⁻³), C is concentration of toxic compound in each cigarette smoke (ng), CF is converting factor from ng to µg (10⁻³), TC is average number of smoking cigarette per day (for Iranian smoker population: 13.7),^{1,4,28} ABS is absorption rate of compound in respiratory system (Table 1), EF is exposure frequency or number of days with smoking cigarette per year (for Iranian smoker population: maximum days or 365),¹ ED is exposure duration (year) to toxic compounds of

cigarette smoke in lifetime (for Iranian smoker population: 55 years),²⁶ BW is average of body weight of smoker population (for Iranian smoker population: 75.1 kg),²⁶ and AT is average of lifetime or life expectancy (days) of smoker population, which for non-carcinogenic effects is calculated by multiplying the ED (herein: cigarette smoking years) by number of days per year (for Iranian smoker population: 55×365) and for carcinogenic effects is calculated by multiplying the average of population lifetime (years) by number of days per year (for Iranian smoker population: 75.9×365).^{4,25-27,29}

Risk characterization: In the risk characterization step, the risk-averse health effects due to chronic exposure to toxic compounds (such as carcinogens and non-carcinogens) are estimated based on the combination of toxicity with exposure of the compound. In this step, a scientific-based interpretation can be made based on those estimates of previous steps of QRA.³⁰

Non-carcinogenic QRA: We used the hazard quotient (HQ) to assess the non-carcinogenic effects of four toxic compounds (benzene, formaldehyde, arsenic, and cadmium) in cigarette smoke. The HQ was calculated based on CDI (Equation 1) and reference concentration (RfC) (Table 1) of each compound following equation 2. If the CDI is equal or lower than the reference dose, it is acceptable ($HQ \leq 1$); otherwise, there are potentially non-carcinogenic effects caused due to toxic compounds in cigarette smoke ($HQ > 1$).³¹

$$HQ = \frac{CDI}{RfC} \quad (\text{Equation 2})$$

Carcinogenic QRA: To evaluate the carcinogenic effects of studied compounds in cigarette smoke, the incremental lifetime cancer risk (ILCR) was calculated following equation 3. The ILCR has been calculated based on CDI (Equation 1) and IUR (Table 1). If the ILCR is lower than 10^{-5} , it is considered as "maybe" carcinogenic risk. If ILCR is in the range of 10^{-5} - 10^{-4} , it is considered as "possible" carcinogenic risk and if ILCR is higher than 10^{-4} , it is considered as "definite" carcinogenic risk.^{12,27,31}

$$ILCR = CDI \times IUR \quad (\text{Equation 3})$$

Mixture of non-carcinogenic and carcinogenic QRAs: The mixture of non-carcinogenic and carcinogenic QRA calculations were carried by

the methodology introduced by Pack et al.³² In this methodology to the prediction of non-carcinogenic and carcinogenic effects, the algebraic sum of the HQ and ILCR for each of the toxic compounds in cigarette smoke was used.

Ethical consideration: The project was approved by the Ethic Committee of Hamadan University of Medical Sciences, Hamadan, Iran (the approved code: IR.UMSHA.REC.1397.1010).

Data of study were entered in SPSS software (version 22, IBM Corporation, Armonk, NY, USA) and Excel software (version 2019) after collecting. Descriptive and analytical statistical tests such as one-way analysis of variance (ANOVA), paired t-test, independent t-test, Kruskal-Wallis test, chi-square test, and Pearson correlation coefficient with significant level of $P \leq 0.05$ were used to achieve the study objectives and investigate the effects of different variables on each other.

Results

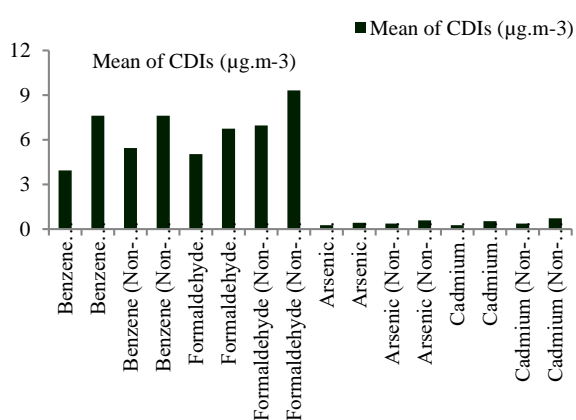
The concentration of toxic compounds: The results of sampling and analysis of the studied toxic compounds in the mainstream smoke of eleven domestic and foreign popular cigarette brands in Iran were presented in table 2. The concentration of all studied toxic compounds in the mainstream of eleven cigarette brands with filter mode was lower than without filter mode ($P = 0.012$). The highest and lowest filtration rates (difference of toxic compound concentration on cigarette smoke in two modes of with and without-filter in percent) of the toxic compounds by cigarette filter were related to the benzene and formaldehyde, respectively (50.56% and 25.23% absorption, respectively).

Exposure assessment of toxic compounds: In default exposure conditions, the CDI value varies according to concentration exposure and inhalation absorption rate of the toxic compound. Figure 2 depicts the results of the CDI index for carcinogenic and non-carcinogenic effects of the studied toxic compounds in the smoke of all examined cigarette brands, both with and without filter modes.

Carcinogenic and non-carcinogenic QRA: The mean and standard deviation (SD) of HQ (non-carcinogenic effects) and ILCR (carcinogenic effects) indices for studied toxic compounds in the mainstream smoke of studied cigarette brands were calculated as 886.7 ± 1239.0 and $53 \times 10^{-4} \pm 63 \times 10^{-4}$, respectively.

Table 2. Results of concentration of studied toxic compounds in the mainstream smoke of eleven cigarette brands (ng/cig⁻¹)

| Cigarette ID | With filter | | | | Without filter | | | |
|--------------|-------------|--------------|---------|---------|----------------|--------------|---------|---------|
| | Benzene | Formaldehyde | Arsenic | Cadmium | Benzene | Formaldehyde | Arsenic | Cadmium |
| A | 40500 | 78100 | 10575 | 4175 | 114500 | 85100 | 22285 | 10370 |
| B | 29900 | 55500 | 11715 | 3740 | 64100 | 72500 | 20120 | 11435 |
| C | 31800 | 72200 | 8737 | 8472 | 63200 | 91500 | 24470 | 13265 |
| D | 73000 | 56200 | 11550 | 9290 | 98900 | 84750 | 17475 | 13165 |
| E | 91200 | 99700 | 9542 | 4772 | 107900 | 112500 | 18065 | 12102 |
| F | 22003 | 80200 | 12077 | 3715 | 58100 | 89250 | 18240 | 4505 |
| G | 41600 | 100750 | 15250 | 3705 | 80646 | 123750 | 20245 | 12955 |
| H | 47961 | 95250 | 9870 | 6877 | 93260 | 108250 | 18865 | 11775 |
| I | 36600 | 86250 | 18170 | 9027 | 118200 | 110250 | 19780 | 12000 |
| J | 37100 | 12750 | 16320 | 6315 | 62500 | 75750 | 18430 | 12355 |
| K | 37600 | 40500 | 15845 | 3737 | 85300 | 86250 | 26200 | 11580 |
| Total | 44478 | 70672 | 12695 | 5802 | 86055 | 94531 | 20379 | 11409 |

**Figure 2.** The chronic daily intake (CDI) index based on with and without filter modes for carcinogenic and non-carcinogenic effects of studied toxic compounds in cigarette smoke

Results indicated that the HQ and ILCR indices were unacceptable for all examined cigarette brands. Results of HQ and ILCR indices based on cigarette brands are presented in tables 3

Table 3. The hazard quotient (HQ) index of non-carcinogenic effects due to studied toxic compounds in the mainstream smoke of 11 cigarette brands (acceptable: HQ < 1)

| Cigarette ID | With filter | | | | Without filter | | | |
|--------------|-------------|--------------|---------|---------|----------------|--------------|---------|---------|
| | Benzene | Formaldehyde | Arsenic | Cadmium | Benzene | Formaldehyde | Arsenic | Cadmium |
| A | 1650 | 785 | 2.05 | 26.65 | 4664 | 855 | 4.33 | 66.21 |
| B | 1218 | 557 | 2.27 | 23.87 | 2611 | 728 | 3.91 | 73.01 |
| C | 1295 | 725 | 1.70 | 54.09 | 2574 | 919 | 4.76 | 84.69 |
| D | 2974 | 564 | 2.24 | 59.31 | 4029 | 851 | 3.40 | 84.05 |
| E | 3715 | 1002 | 1.85 | 30.46 | 4395 | 1130 | 3.51 | 77.26 |
| F | 896 | 806 | 2.35 | 23.71 | 2367 | 897 | 3.54 | 28.76 |
| G | 1694 | 1012 | 2.96 | 23.65 | 3285 | 1243 | 3.93 | 82.71 |
| H | 1953 | 957 | 1.92 | 43.90 | 3799 | 1088 | 3.67 | 75.18 |
| I | 1491 | 866 | 3.53 | 57.63 | 4815 | 1108 | 3.84 | 76.61 |
| J | 1511 | 128 | 3.17 | 40.32 | 2546 | 761 | 3.58 | 78.88 |
| K | 1531 | 407 | 3.08 | 23.86 | 3475 | 866 | 5.09 | 73.93 |
| Mean | 1812 | 710 | 2.47 | 37.04 | 3505 | 950 | 3.96 | 72.84 |

and 4, respectively.

The results of mixture non-carcinogenic (HQ_{mix}) and carcinogenic (ILCR_{mix}) QRA in the present study showed that the risk of carcinogenic and non-carcinogenic effects due to inhalation of studied cigarettes smoke was very high and unacceptable (Figure 3).

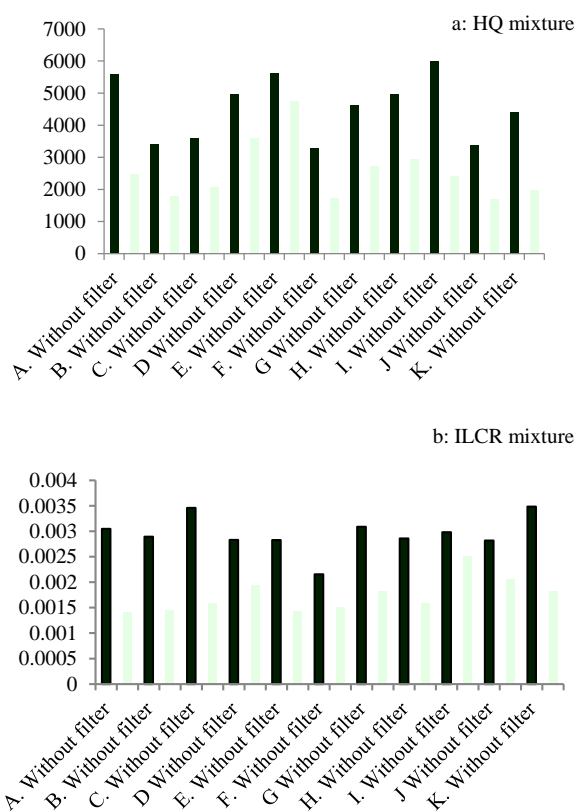
Discussion

This study was performed to assess the impact of filter on the quantitative potential non-cancer and cancer risks of inhalation exposure to some hazardous compounds in cigarette smoke.

As can be seen in table 2, the concentration of studied toxic compounds in the smoke of foreign cigarette brands (in without-filter mode) was higher than Iranian cigarette brands, such that, the highest mean concentration of benzene, formaldehyde, and arsenic was related to the Marlboro, Magna, and Marlboro cigarette brands (118200, 123750, and 26200 ng/cig⁻¹, respectively) which was higher than other cigarette brands.

Table 4. The incremental lifetime cancer risk (ILCR) index of carcinogenic effects due to studied toxic compounds in the mainstream smoke of 11 cigarette brands ($\times 10^{-5}$, maybe > 1, possible > 10, and definite carcinogenic > 100)

| Cigarette ID | With filter | | | | Without filter | | | |
|--------------|-------------|--------------|---------|---------|----------------|--------------|---------|---------|
| | Benzene | Formaldehyde | Arsenic | Cadmium | Benzene | Formaldehyde | Arsenic | Cadmium |
| A | 2.72 | 7.24 | 96.17 | 26.65 | 7.70 | 7.89 | 202.67 | 86.36 |
| B | 2.01 | 5.15 | 106.54 | 23.87 | 4.31 | 6.72 | 182.89 | 95.23 |
| C | 2.14 | 6.70 | 79.46 | 54.09 | 4.25 | 8.49 | 222.54 | 110.47 |
| D | 4.91 | 5.21 | 105.04 | 59.31 | 6.65 | 7.86 | 158.93 | 109.63 |
| E | 6.13 | 9.25 | 86.78 | 30.46 | 7.26 | 10.43 | 164.29 | 100.78 |
| F | 1.48 | 7.44 | 109.83 | 23.71 | 3.91 | 8.28 | 165.88 | 37.51 |
| G | 2.80 | 9.34 | 138.69 | 23.65 | 5.42 | 11.48 | 184.12 | 107.88 |
| H | 3.22 | 8.83 | 89.76 | 43.90 | 6.27 | 10.04 | 171.57 | 98.06 |
| I | 2.46 | 8.00 | 165.25 | 57.63 | 7.95 | 10.23 | 179.89 | 99.93 |
| J | 2.49 | 1.18 | 148.42 | 40.32 | 4.20 | 7.02 | 167.61 | 102.89 |
| K | 2.53 | 3.75 | 144.10 | 23.86 | 5.74 | 8.00 | 238.28 | 96.43 |
| Mean | 2.72 | 6.55 | 115.46 | 37.04 | 5.79 | 8.77 | 185.34 | 95.02 |

**Figure 3.** Results of mixture non-carcinogenic (a) and carcinogenic (b) quantitative risk assessment (QRA) of studied toxic compounds in smoke based on cigarette brands and with and without filter modes; HQ: Hazard quotient; ILCR: Incremental lifetime cancer risk

The results of a previous study showed that the concentration of zinc, copper, nickel, and cobalt elements in foreign cigarette brands was higher than Iranian brands, but according to the

results, the concentration of cadmium in Iranian cigarette brands was more than foreign brands.³³

The results of present study showed that the cigarette filter played an important role in reducing inhalation exposure to hazardous compounds in mainstream cigarette smoke, so that the filter reduced the concentration of benzene, formaldehyde, arsenic, and cadmium in mainstream smoke by 48.3%, 25.2%, 37.7%, and 49.2%, respectively (Table 2). A cigarette filter consists of at least one filter segment having at least one biodegradable fiber embedded therein, that is used to reduce hazardous mainstream smoke constituents.^{14,34} Also, previous studies based on patient smoker populations were illustrated that inhalation of the toxic compounds after smoking of cigarette without- filter was significantly higher than cigarettes with filter.^{14,31} The type of fiber used for the filter of the cigarettes studied was cellulose acetate, which can absorb nicotine, tar, heavy metals, and some of the hydrocarbon compounds.³⁵

In some previous studies, filter analysis methodology was used for determining exposure to toxic compounds in mainstream cigarette smoke.^{13,35-37} Filter analysis includes toxic compound analysis of spent cigarette filter after that cigarette is smoked by humans.³⁸ The filter analysis method also presents an estimate of the maximum quantity of smoke that enters the smoker's mouth. But, this method is limited by not being able to estimate mouth spill, post-puff smoke inhalation, non-inhaled smoke, and respiratory retention of smokers.^{39,40}

The CDI is directly affected by the smoker's

exposure scenario. The exposure factors can be divided as factors associated with smoker characteristics (e.g., body weight, exposure frequency, and exposure duration) and factors related to the type of cigarette (combustion chemistry, the concentration and absorption rate of toxic compounds). In the humans, smoking behavior has wide variations, so that this act involves very dynamic procedures, including puffing duration and smoking behavior and habit among individual smokers.⁴¹ So, CDI varies by smoking behaviors and habits per any smoker. Recently, in order to determine inhalation toxic compounds in cigarette smoke, the method proposed by the FTC/ISO (constant smoking conditions by puff machine) is used.^{37,42-44} On the other hand, people's smoke is different from each other, due to the difference in consumption of cigarette rod, individual human non-uniformity of cigarette puffing behavior, and nonlinearity of cigarette combustion chemistry.^{32,41} Therefore, FTC/ISO methods may be not suitable as the basis for actual determining of the concentration of smoke yields inhaled by smokers, due to the ignoring of human behavioral differences in smoking. Furthermore, Pack et al. reported that the mean number of cigarettes smoked per day and puffing volume were the main risk factors in risk assessment of toxic compounds in mainstream cigarette smoke.³²

The results showed that the highest mean CDIs for non-carcinogenic effects in with and without-filter modes were related to formaldehyde (6.96 and 9.31 $\mu\text{g}/\text{m}^3$, respectively) (Figure 2). Also, the highest mean CDI for carcinogenic effects in with-filter mode was due to formaldehyde (5.04 $\mu\text{g}/\text{m}^3$), and in without-filter mode was caused by benzene (7.62 $\mu\text{g}/\text{m}^3$) (Figure 2). Benzene and formaldehyde have high inhalation absorption coefficients (0.67 and 0.54, respectively) (Table 1), so that after inhalation, rapidly enter to systemic bloodstream. Therefore, CDIs of these compounds are higher than arsenic and cadmium.^{24,25}

Risk assessment results showed that benzene, formaldehyde, arsenic, and cadmium had high hazard potential for human health. All of the HQ values for studied compounds were estimated higher than 1, that this indicates unacceptable condition for chronic exposure.^{24,27} The results of this work illustrated that the filter had a significant impact on reduction of the

non-carcinogenic effects of the cigarette smoking, such that, it reduced 48.3%, 25.3%, 37.6%, and 49.1% of HQ values related to the benzene, formaldehyde, arsenic, and cadmium, respectively (Table 3). However, HQ values of studied compounds in with-filter cigarette smoke were still higher than 1. The results of previous studies based on machine-smoke indicate a high HQ value for benzene, formaldehyde, arsenic, and cadmium in the mainstream cigarette smoke in various countries,^{32,45,46} that is almost similar to the results of the present study. Marano et al., based on a review of arsenic biomarkers and probabilistic risk assessment process on data from the National Health and Nutrition Examination Survey (NHANES), reported that mean of HQ values (non-cancer hazard) and ILCRs estimates of tobacco consumers were within accepted ranges ($\text{HQ} < 1$ and $\text{ILCRs} \leq 10^{-4}$).⁹ Of course, given the role of biological systems in excretion of toxic compounds from the body, the concentration of toxic compounds associated with a cigarette in the biological matrix is lower than in mainstream cigarette smoke and thus, estimated risks will be lower.⁴⁷ It is noteworthy that the purpose of the present study was to investigate the role of the filter in reducing the carcinogenic and non-carcinogenic risks of cigarette smoking, and it does not emphasize the quantitative amounts of these risks.

The means of overall ILCRs estimated from all studied compounds in mainstream without-filter cigarette smoke were exceeded the minimum acceptable value (1×10^{-6}), so that, the ILCRs of benzene and formaldehyde were in the range of possible carcinogenic risk (5.79×10^{-5} and 8.77×10^{-5} , respectively) (Table 4) and ILCRs of arsenic and cadmium were in the range of definite carcinogenic risk (185.30×10^{-5} and 95.02×10^{-5} , respectively) (Table 4). Furthermore, in with-filter cigarette mode, the ILCRs of benzene, formaldehyde, arsenic, and cadmium in mainstream cigarette smoke were reduced compared to the without-filter mode, by 53.02%, 25.31%, 37.70%, and 61.01%, respectively (Table 4). A previous study on the Korean cigarette smokers based on comprehensive risk assessment reported that the ILCRs of benzene, formaldehyde, and cadmium in mainstream cigarette smoke were 8×10^{-5} , 1000×10^{-5} , and 8×10^{-5} , respectively, that these levels exceeded the

minimum level suggested by USEPA. Moreover, means of the HQs of benzene, formaldehyde, arsenic, and cadmium were reported 2.0, 3.6, 0.4, and 0.6, respectively,³² that were lower than the results of present study. In this study, the total amount of studied toxic compounds in the mainstream cigarette smoke was measured in with and without-filter cigarette modes, but in the study of Pack et al.,³² an automatic smoking machine was used (2 puff and 35 ml smoke suction during 2 seconds at any puff) and the concentration of the measured toxic compounds was lower than this study, and therefore, the CDIs and HQs of the toxic compounds in their study were lower than the present study.

When it is well known that humans are simultaneously exposed to multiple chemical compounds, there is a concern that the chemical may not be adequately protected by chemical risk assessment. The mixture carcinogenic and non-carcinogenic risks caused by exposure to multiple hazardous compounds usually are evaluated by aggregation of single ILCRs and HQs for any compound in the matrix.^{12,48} The average of overall mixture of estimated HQs and ILCRs caused by benzene, formaldehyde, arsenic, and cadmium in the mainstream without-filter cigarette smoke of 11 cigarette brands was more than the acceptable value (4533 and 3×10^{-3} , respectively). Furthermore, in a mixture risk assessment study on the South Korean smokers using an automatic smoke machine, it was reported that the cumulative HQs and ILCRs of Korean male smokers (range of HQs: 367-1225, ILCRs: 828×10^{-6} - 2510×10^{-6}) were higher than female smokers (HQs: 289-970, ILCRs: 440×10^{-6} - 1300×10^{-6}), that similar to results of this study, exceeded the minimum acceptable value.³²

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Posthuma et al. reported that the mixture risk assessment of chemical compounds had a covered wide range of potential regulatory applications, and use of the mixture risk assessment approaches in the condition of exposure to multiple chemical compounds was suggested.⁴⁸

Conclusion

The data of sampling of mainstream cigarette smoke presented herein has demonstrated that the cigarette filter plays an important role in reducing inhalation exposure to hazardous compounds in mainstream cigarette smoke, but yet, average of overall mixture HQs and ILCRs estimated caused by benzene, formaldehyde, arsenic, and cadmium in mainstream cigarette smoke of studied cigarette brands was more than the suggested acceptable value. It is recommended that future empirical studies investigate the impact of the type of fiber used in cigarette filter on reducing carcinogenic and non-carcinogenic risks caused by cigarette smoke.

Conflict of Interests

The Authors have no conflict of interest.

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Authors' Contribution

Conceive and design the study: JP, FGE and, MJA; Drafting of the manuscript: RR; Critical revision of the manuscript for important intellectual content: MJA and RR; Statistical analysis: FGE, JP and MJA. All authors approved final version of manuscript.

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بررسی تأثیر فیلتر در خطر کمی مخلوط ناشی از وجود برخی ترکیبات سمی در دود سیگارهای پرمصرف ایران

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مقاله پژوهشی

چکیده

مقدمه: این پژوهش با هدف ارزیابی تأثیر نقش فیلتر در خطر اثرات بهداشتی و سرطان‌زایی ناشی از برخی آلاینده‌های سمی موجود در دود سیگار برخی از برندهای پرمصرف در ایران انجام شد.

روش‌ها: در این مطالعه آزمایشگاهی، بر اساس روش‌های استاندارد، غلظت ترکیبات بنزن، فرمالدهید، آرسنیک و کادمیوم در جریان اصلی دود ۱۱ برند پرمصرف سیگار در ایران، در دو حالت سیگار با فیلتر و بدون فیلتر مورد سنجش قرار گرفت. بر اساس روش ارزیابی خطر کمی پیشنهاد شده از سوی سازمان حفاظت محیط زیست آمریکا، مقادیر نسبت خطر بهداشتی، خطر سرطان‌زایی مواجهه مادام‌العمر و همچنین، خطر مخلوط مواجهه با ترکیبات برآورد گردید.

یافته‌ها: میانگین خطر بهداشتی ناشی از بنزن، فرمالدهید، آرسنیک و کادمیوم در دود سیگارها در حالت بدون فیلتر در محدوده ۳/۹۶ تا ۳۵۰۵ بود. فیلتر سیگار موجب کاهش خطر اثرات بهداشتی ناشی از بنزن، فرمالدهید، آرسنیک و کادمیوم در دود سیگار به میزان به ترتیب ۴۸/۳، ۲۵/۳، ۳۷/۶ و ۹۱/۱ درصد شد. فیلتر سیگار منجر به کاهش خطر اثرات سرطان‌زایی مادام‌العمر ناشی از بنزن، فرمالدهید، آرسنیک و کادمیوم به میزان به ترتیب ۵۳/۲، ۲۵/۳۱، ۳۷/۷۰ و ۶۱/۰۱ درصد گردید. بر اساس یافته‌ها، خطر برآورد شده اثرات بهداشتی و اثرات سرطان‌زایی مخلوط ترکیبات موجود در دود سیگار بسیار بالاتر از حدود قابل قبول بود.

نتیجه‌گیری: فیلتر سیگار نقشی حیاتی در کاهش میزان مواجهه با آلاینده‌ها در جریان اصلی دود سیگارهای مورد مطالعه داشت. با این حال، میانگین کلی مخلوط خطر اثرات بهداشتی و اثرات سرطان‌زایی مادام‌العمر ترکیبات مورد بررسی بسیار بالاتر از محدوده قابل قبول می‌باشد. پیشنهاد می‌شود در تحقیقات تجربی آینده، به بررسی تأثیر نوع فیبرهای موجود در فیلتر سیگار بر کاهش خطر اثرات بهداشتی و سرطان‌زایی ترکیبات سمی موجود در دود سیگار پرداخته شود.

واژگان کلیدی: تولیدات تنباکو؛ سیگار کشیدن؛ محصولات آلی فرار

ارجاع: رحیم‌پور رزاق، گوهری انصاف فاطمه، پورالعجل جلال، عساری محمدجواد. بررسی تأثیر فیلتر در خطر کمی مخلوط ناشی از وجود برخی ترکیبات سمی در دود سیگارهای پرمصرف ایران. مجله اعتیاد و سلامت ۱۳۹۹؛ ۱۲ (۳): ۸۵-۱۷۵.

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