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Investigation of Heavy Metal Pollution in the Indoor Air of Traditional Coffee Houses in Tehran, Iran (2020)

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Abstract

Background: Exposure to heavy metals in coffee house air poses notable occupational health risks. This study aimed to quantify heavy metal and particulate pollution levels in Tehran's traditional coffee houses.

Materials and Methods: In this study of 57 Tehran coffee houses, samples were collected using personal sampling pumps and 0.8 µm cellulose ester filters following National Institute for Occupational Safety & Health (NIOSH-7300) guidelines. Heavy metal levels were determined using ICP-AES analysis.

Results: The results showed that iron and magnesium metals had the lowest concentration of metals in the air within coffee houses, with an average of 10-8 µg/m3, whereas manganese metals had the highest concentration, with an average of 4.507 10-5 µg/m3. Two of the 57 locations under study had greater Threshold Limit Values (TLVs) than the others, whereas other locations had lower TLV mixtures, and these two locations had mixed TLVs of 1.315 and 1.282, respectively. 96.49 percent of the 57 measured locations had a mixed TLV below the standard and 3.51 percent above it. According to the findings of the current study, there are eight heavy metals present in Traditional coffee houses air, ranging in concentration from more to less of Fe, Mg > Pb > Ag > Cu > Ca >Na >Mn.

Conclusions: The health of coffee house employees may suffer adverse effects from chronic exposure to these elements. To protect the health of Traditional Coffee Houses employees, it is essential to incorporate engineering controls for indoor air quality, monitor ventilation systems, and ensure compliance with safety regulations.

Keywords: Air Pollution, Heavy Metals, Health

Introduction

Humans depend on air as a necessary resource all the time, although it is intangible and out of our immediate reach [1, 2] Air pollution is one of the issues brought on by population increases, urbanization, and lifestyle changes [3]. Air pollution is a factor in one out of every eight fatalities worldwide. The larynx, throat, and other respiratory organs of the body are harmed by air pollution, which generates an environment that is conducive to infections and carcinogens [4]. According to the World Health Organization, illnesses linked to air pollution cause over 800,000 early deaths each year [4]. Reduced life expectancy, impaired vision, eye burns, respiratory illnesses, lower performance in daily tasks, exacerbated heart disease, increased drug usage, early mortality, and harm to the environment are all effects of air pollution [5]. By interacting with airborne particles, heavy metals have the potential to disperse far. Urbanization and industrialization are mostly responsible for the rise in the amount of these metals in the environment due to human activity [6]. Significant pollutants frequently discovered in big cities' air include heavy metals like arsenic, iron, zinc, lead, cadmium, chromium, copper, manganese, and nickel [7]. In big cities, people spend more than 90% of their time in enclosed places and settings, 6% in open areas, and a tiny fraction in their vehicles. This subject highlights the significance of focusing on evaluating indoor air pollution and its effects on human health. Therefore, it is crucial to investigate the air quality of enclosed spaces [3]. Clients are welcome in coffee houses, one of closed environments where they can get coffee, tea, water pipe smoke (hookah), and traditional meals.

Waterpipe smoke is utilized in all of them to serve clients [8]. The findings of the 2015 study "Waterpipe smoke: source of toxic and carcinogenic VOCs, phenols, and heavy metals?" by Schubert and colleagues found that high concentrations of the hazardous metals nickel, cadmium, lead, and chromium are present in both coal and waterpipe tobacco [9]. According to Global statistics, hookah smoking is becoming a common social habit. Adults in Asian and African communities, particularly in the Middle East and Arab countries, have been discovered to consume a lot of water pipes in recent years. According to a 2013 survey by Dehdari et al., 29% of students at the Tehran University of Medical Sciences smoked hookah [10]. From the perspective of occupational health, exposure to heavy metals bound to aerosol particles is particularly significant. Workplace exposure to heavy metals by inhalation causes issues with the central and peripheral nervous systems, the digestive system, the kidney system, the hematological system, the cardiovascular system, enzyme diseases, different forms of cancer like lung, trachea, and blood cancer, and other organs [11, 12]. Although there have been numerous research studies on coffee houses, none have shown the extent to which coffee house employees are exposed to heavy metals in the air at work from the perspective of occupational health. To determine the extent of contamination of heavy metals bound with suspended particles in the air inside traditional coffee houses in Tehran, the present study was conducted, taking into account the significance of examining the air quality in the closed environment of traditional coffee houses on the health of the workers in this profession.

Materials and Methods

This descriptive cross-sectional study was conducted in Tehran's Traditional Coffee Houses in 2019-2020. Only permitted places that offered and used hookah were included in the current study. When the number of the population is unknown, the following formula was used to calculate the sample size for air sampling of heavy metal content in traditional coffee houses [13].

Formula 1.

$$n = \frac{\sigma^2 (z_{1-\frac{\alpha}{2}} + z_{1-\beta})}{d^2} = \frac{10.5 \times 0.7^2}{0.3^2} = 57.16 = 57$$

$\alpha = 0.05$

$\beta = 0.1$

$SD = 0.7$

$\bar{X} = 0.9$

$d = 0.3$

After obtaining permission and cooperation with the relevant union, the concentration of metals in the indoor air of traditional coffee houses in Tehran was sampled and measured by the active sampling method. This involves using 37 mm cellulose ester filters with a pore size of 0.8 micrometers and an SKC model personal sampling pump with one to four liters per minute volume. The personal sampling pump was calibrated using a 500 ml soap bubble flow meter. After sampling, the flow of the pump was checked again by the soap bubble flow meter to ensure the accuracy of the performance and validity of the samples. The data from the NIOSH-7300 method suggests that 2.4 liters per minute of sampling were collected at 57 traditional coffee houses in Tehran. The Indoor air in the traditional coffee houses was collected by turning on the personal sampling pump and sampling in the breathing zone of the employees (where the filter and holder were located at a height of 1.5 meters). All the filters were placed in a desiccator containing silica gel for 24 hours before sampling and after the end of the sampling period to remove possible moisture and were delivered to the laboratory by the researcher. The amount of metals in the samples was measured using the Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES Agilent 5100) laboratory. In this study, only metals (AL), Cd, Co, Cr, Cu, Fe, Mg, Mo, Mn, Na, Ni, Pb, Sn, Ti, Zn, K, As, Se, Ca, and Ag were determined due to the kind of metals contained in hookah smoke composition, their significance in toxicology, and the management of study costs. After measuring the ambient temperature and air pressure of Tehran, the results of metal sampling in the extracted solutions of the laboratory were measured in terms of micrograms per liter in the conditions of Tehran city (height above sea level). And the standard pressure was corrected. These results were then converted to concentrations in micrograms per cubic meter of air under standard conditions for temperature and pressure. A total of 57 hookah supply stations were chosen for sampling and measurement based on the available information and findings from earlier research.

Determining the Amount of Heavy Metals Bound to Suspended Particles in the Indoor Air Traditional Coffee Houses: It is possible to measure the concentration levels of heavy metals in the indoor air of traditional coffee houses in Tehran by using active sampling technique and SKC model personal sampling pump with an operating flow rate of 2.4 liters per minute (the total capacity of the personal sampling pump was 4 liters per minute), with filters of 37 Millimeter cellulose ester was used by NIOSH-7300 method and placing the filter and its holder at the height of 1.5 meters from the ground (breathing air range of traditional coffee house employees). [13]

Air temperature, air humidity, air flow rate, building volume, number of active hookahs, window area, type of ventilation system, type of hookah tobacco, number of people, and the proportion of active hookahs to coffee floor area are additional factors that can affect the concentration of metals. The filters (samples and blanks) were transported to the lab after sampling. Ultimately, the materials were ready for examination by applying the acid digestion procedure. In this manner, the blank and sample filters were taken out of their holders and placed in a fresh container. The beakers were filled with five milliliters of digestive acid (one volume of HNO_3 to three volumes of HCl), their openings were covered with a watch glass, and the beakers were allowed to sit at room temperature for thirty minutes. 0.5 mL of the solution was left at the bottom of the container after we heated the samples to 120 °C on the stove Then, step 3 was carried out after adding two milliliters of digestive acid to the beaker. This was continued until the solution became clear. After that, the watch's glass was taken off and filled with distilled water.

We raised the oven's temperature to 150 degrees Celsius and let the solution boil until it reached the maximum dryness point (0.5 mL) in volume. 3–5 milliliters of diluted acid were used to dissolve the remaining solution. After that, the solutions were put into 25 ml volumetric flasks and filled with distilled water to the full capacity. Then, the samples' potential metal content was ascertained using an inductively coupled plasma-atomic emission spectrometer (ICP-AES Agilent 5100) to identify metals. The amounts of Al, Cd, Co, Cr, Cu, Fe, Mg, Mo, Mn, Na, Ni, Pb, Sn, Ti, Zn, K, As, Se, Ca, and Ag were determined based on the types of metals discovered in hookah smoking and the significance of metals in terms of toxicity. The microgram concentrations per cubic meter of air at standard pressure and temperature were then calculated from the data [14]. Finally, formula 1 was used to determine the metals concentration in traditional coffee houses' air.

Formula 2.

$$C\ (mg/m3) = \frac{(C_s \times V_s) - (C_b \times V_b)}{V}$$

C: Metal Concentration (mg/m3)
C s: Sample Concentration (µg/ml)
Vs: Sample Volume (ml)
C b: Blank Concentration (µg/ml)
V b: Blank Volume (ml)
V: The volume of sampled air (Liter)

In cases where we are confronted with a mixture of pollutants, including airborne particles, and these particles have similar effects on the body, the density of their mixture is used to assess the exposure and compare it with permissible threshold values from the perspective of occupational health and according to occupational exposure limits (OELs). Based on this, formula 2 was used to determine the study subjects' actual exposure density to a combination of heavy metals [15].

Formula 3.

$$\frac{C_1}{TLV_1} + \frac{C_2}{TLV_2} + \cdots + \frac{C_n}{TLV_n} \leq 1$$

C = pollutant concentration in air (mg/m^3)
TLV: threshold limit value of pollutant (mg/m^3)

Values less than one, in this case, denote normal conditions, whereas values higher than one signify pollutant densities above the permissible limit.

Data Analysis Method: The study's data were statistically analyzed using the SPSS Version 22 software. The test of computing the mean, the standard deviation, and the confidence interval of 95% were used to compare the concentration of bound metals with dispersed particles. A non-parametric Wilcoxon test with a 95% confidence interval was performed to compare the average TLV of mixed metals with the normal range.

Results

The average amount of metal attached to airborne particles in Tehran's traditional coffee houses is displayed in Table 1 below. The findings show that manganese had the highest concentration of metals, with an average of 4.507×10^{-2} and a standard deviation of 10^{-8}. In contrast, iron and magnesium metals have the lowest concentrations, with an average of 10^{-8} and a standard deviation of 10^{-9}.

Table 1. The average concentration of metals bonded with airborne particles in the Tehran traditional coffee houses' indoor air (µg/m^3)

Metal	Mean	Std. Deviation	95% Confidence Interval	
			Min	Max
Cu	4.1702×10^{-3}	3.1484×10^{-3}	-4.183×10^{-3}	1.252×10^{-2}
Fe	$<10^{-8}$	$<10^{-9}$	-2.114×10^{-2}	$<10^{-7}$
Mg	$<10^{-8}$	$<10^{-9}$	$<10^{-7}$	$<10^{-7}$
Mn	4.507×10^{-2}	$<10^{-8}$	8.509×10^{-4}	8.929×10^{-2}
Na	4.033×10^{-2}	$<10^{-8}$	5.513×10^{-3}	7.515×10^{-2}
Pb	2.05×10^{-5}	1.545×10^{-4}	-2.05×10^{-5}	6.15×10^{-5}
Ca	6.154×10^{-3}	1.572×10^{-2}	1.981×10^{-3}	1.032×10^{-2}
Ag	4.55×10^{-4}	1.871×10^{-2}	1.16×10^{-5}	8.985×10^{-4}

It should be noted that the average value for several samples was less than the device's detection limit due to the atomic absorption device's limitations. The results of comparing the average concentration of each metal in the air inside coffee houses with the threshold limit value of that metal using Wilcoxon's one-sample non-parametric test at a significance level of 0.05 showed that there is a significant difference between the average concentration of each metal in the air inside coffee houses and the threshold limit value (TLV) of that metal. In other words, the average amount of metal in the assessed Traditional Coffee Houses is below the permissible level for each metal (Table 2).

Table 2. One-Sample-Wilcoxon test to compare the average metal concentration in the indoor air of Traditional Coffee Houses with the threshold limit value (TLV) of each metal

Metal	Number	Mean (mg/m^3)	TLV (mg/m^3)(14)	P_{value}
Ag	57	4.55×10^{-4}	0.1	0.001
Cu		4.1702×10^{-3}	1	
Fe		$<10^{-8}$	5	
Mg		$<10^{-8}$	10	
Mn		4.507×10^{-2}	0.02	
Na		4.033×10^{-2}	1	
Pb		2.05×10^{-2}	0.05	
Ca		6.154×10^{-3}	2	

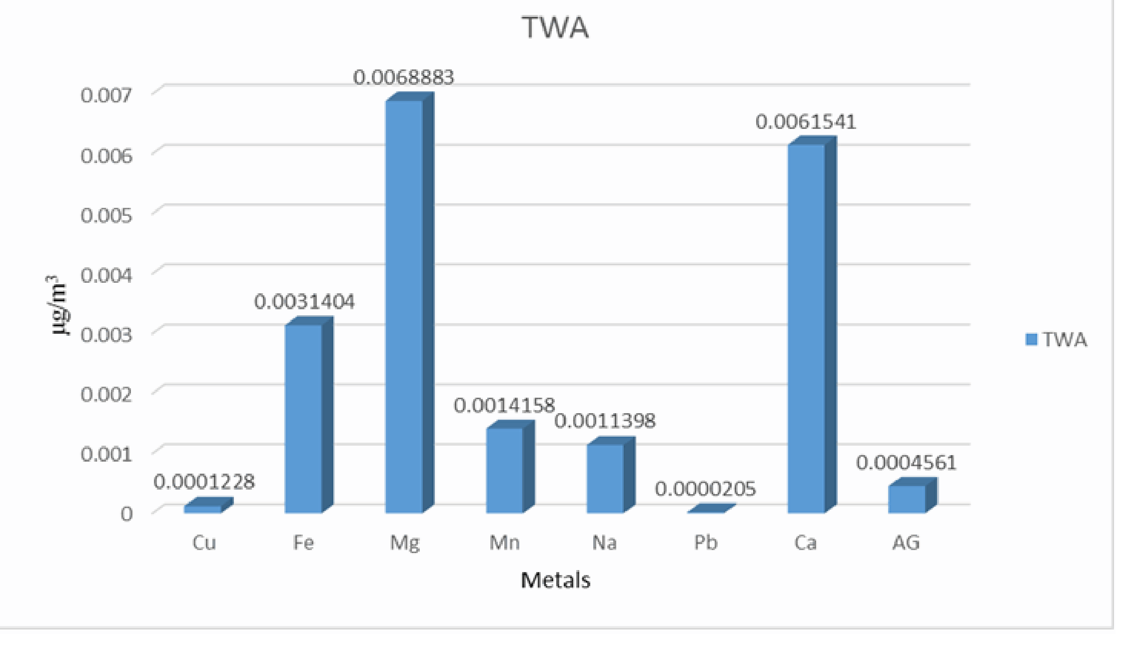

Fig. 1. TWA values for metals in Tehran's traditional coffee houses in micrograms per cubic meter.
This image shows the concentrations of copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), lead (Pb), sodium (Na), calcium (Ca), and silver (Ag) within the indoor air of Tehran's traditional coffee houses, measured in micrograms per cubic meter.

Formula 3 was used to determine the actual exposure density to a mixture of metals present in the traditional coffee houses under study.

In the 57 places investigated, location No. 2, a hookah cafe with a mixed TLV of 1.315, and location No. 72, a tea shop with a mixed TLV of 1.282, had a density of mixed metals that was higher than the permitted threshold, while other places had lower permissible threshold densities.

The average metal concentration and a few physical parameters of traditional coffee houses were correlated using Spearman's rank correlation test with a 95% confidence interval (Table 3).

Table 3. Spearman's Rank Correlation Coefficients between the Average Concentration of Metals and Some Physical Characteristics of Tehran's Traditional Coffee Houses.

Metal	Correlation Coefficient (R) And Probability Value (P)	Door area (m^2)	Window (s) area (m^2)	Active hookah (n)	person's number(n)	Number of active hookah/ floor area	Room volume (m^3)	Indoor air temperature (◦c)	Indoor ratio humidity (%)
Cu	Correlation Coefficient (R)	0.218	-0.079	-0.118	-0.004	-0.138	0.187	0.208	-0.069
	And Probability Value (P)	0.103	0.561	0.383	0.976	0.304	0.164	0.121	0.610
Fe	Correlation Coefficient (R)	0.131	-0.162	-0.020	0.017	-0.011	0.025	0.040	0.006
	And Probability Value (P)	0.331	0.230	0.883	0.900	0.936	0.852	0.768	0.964
Mg	Correlation Coefficient (R)	-0.122	0.211	0.004	0.144	-0.064	0.091	0.142	0.347
	And Probability Value (P)	0.364	0.115	0.978	0.285	0.635	0.501	0.293	0.008
Mn	Correlation Coefficient (R)	-0.087	0.089	0.053	0.213	-0.059	0.092	-0.012	-0.033
	And Probability Value (P)	0.521	0.508	0.695	0.112	0.661	0.496	0.927	0.810
Na	Correlation Coefficient (R)	-0.017	0.139	0.089	0.112	0.085	-0.061	-0.062	0.362
	And Probability Value (P)	0.897	0.304	0.510	0.406	0.530	0.652	0.647	0.006
Pb	Correlation Coefficient (R)	-0.144	-0.079	0.219	0.228	0.204	0.001	-0.159	0.171
	And Probability Value (P)	0.285	0.561	0.101	0.089	0.129	1.00	0.238	0.204
Ca	Correlation Coefficient (R)	-0.382	0.324	0.085	0.064	0.124	-0.102	0.023	0.270
	And Probability Value (P)	0.003	0.014	0.532	0.636	0.357	0.450	0.867	0.042
Ag	Correlation Coefficient (R)	-0.185	0.191	-0.064	0.214	-0.285	0.292	0.174	-0.075
	And Probability Value (P)	0.168	0.154	0.635	0.111	0.032	0.027	0.197	0.581

A positive correlation coefficient denotes a direct association, while a negative one denotes an inverse relationship between two variables. The P-value indicates whether or not the correlation coefficient is generalizable to the population. Furthermore, the quantity of air speed was calculated by taking the Kata thermometer's temperature and entering it into the calculation. Out of 57 locations, 12 had airflow speed measurements, all of which were less than 1 m/s. It was not measured in the other locations because it was so subtle.

Discussion

This study aimed to determine the amount of metal bound to aerosol particles in Tehran's traditional coffee houses. The measurements' results, as shown in Table 1, indicated that the coffee houses' air contains eight heavy metals in the following amounts from less to more: Fe, Mg< Pb< Ag< Cu< Ca< Na< Mn. Additionally, it was discovered that all of the metal concentrations were below Iran's legal occupational exposure limits. With a concentration of 4.507 × 10-2 ±10-8 µg/m3, manganese had the highest amount of metals, while iron and magnesium had the lowest amount, at 10-8 ± 10-9 micrograms per cubic meter. The results showed that the average metal concentration values detected in the air of traditional coffee houses are lower than the TLV for each metal ($P < 0.05$) after comparing the average metal concentration values with the threshold limit value (TLV) published by ACGIH [16]. The findings of the current study are consistent with those of the 2020 study by Rostami et al. in Ardabil city, which revealed that the average concentration of metals Ag, Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Sn, Sr, V, and Zn and their maximum values did not exceed the permissible limits of the workplace [17]. In a 2020 study by Celia A. Alves et al., the results of a short but comprehensive air sampling in a university cafeteria showed that the cancer risk from inhaling metals and PAHs was negligible [18]. To determine the level of heavy metals in tobacco and the hookah water used in coffee houses in Sanandaj City, Ramezani et al. conducted a study in 2017. Their study revealed that zinc (11.05 micrograms per gram) and arsenic (1.35 micrograms per gram) had the highest and lowest quantities of heavy metals, respectively. According to the results, As, Cd, Pb, Cu, and Zn were in order of average importance among the metals, which is similar to Ramezani's work [19]. According to the findings of a 2008 study by Bolt et al. in German bars, clubs, and restaurants, the average concentration of cadmium was between 3 and 10 nanograms per cubic meter [20]. The findings of a study conducted in 2020 by Joneidi Jafari et al. on the amount of heavy metals revealed a substantial difference in the amount of heavy metals present in burned and unburned tobacco. Iron and mercury had the highest and lowest metal concentrations, respectively. The study's findings demonstrated that exposure to hazardous metals in tobacco, charcoal, and hookah smoke can be the primary reason for concern for this substance [21]. In a study on samples of cigarettes and aromatic hookah tobacco conducted by Zazoui et al. in 2020, their findings revealed that manganese and selenium had the greatest and lowest quantities in cigarette and hookah tobacco, respectively [22]. The amount of metals found in the blood and urine samples of the workers was examined by Khoshakhlagh et al. in 2023, and their findings revealed that the mean and standard deviation of the concentrations of lead, arsenic, and thallium were 3.77±2.22, 8.50±4.34 and 4.22±2.69 µg/liter, respectively. The average blood levels of hookah users were significantly higher than those of the control group in terms of urinary lead, arsenic, and thallium [23]. The mixed TLV values in 57 locations (traditional coffee houses) revealed that in two locations, the mixed TLV values were above the threshold, while in the remaining 55 locations, they fell below the mixed TLV standard. In other words, the mixed TLV values for the 57 measurement traditional coffee houses were lower than the standard in 96.49% of the cases and higher than the standard (above one) in 3.51%. The higher TLV values of mixed metals in these two traditional coffee houses can be due to the higher concentration of manganese metal in the air of these two traditional coffee houses compared to other traditional coffee houses. Exposure to a mixture of heavy metals can be very important for coffee shop workers in the long run. Manganese metal values were also higher than other metals in Jens Schuber et al.'s 2015 study [24]. The density of mixed metals was higher than the permitted threshold in Place No. 2, a hookah cafe with a mixed TLV of 1.315 that was on the first floor, and in Place No. 72, a teahouse with a mixed TLV of 1.282 that was on the basement floor. Other traditional coffee houses had mixed metal densities below the permitted threshold. Due to the higher quantities of manganese metal in the air in these two locations compared to other locations, the TLV values of mixed metals are higher in both of them. While Jan G. Hengstler and colleagues' study on simultaneous exposure to lead, cadmium, and cobalt in battery workers, galvanizing, and recycling of electrical appliances revealed that even if the exposure level to the concentration of single metals is much lower than the permissible limits, there can be genotoxic effects of heavy metals. In this case, exposure to a mixture of heavy metals can be very important in long-term exposure [25]. The study by Hermann Fromme and colleagues in 2009 showed that the concentration levels of heavy metals such as lead, arsenic, cadmium and thallium were in the range of nanograms per cubic meter in the air of rooms where hookah was used [26]. According to the findings of the current study, Pb metal had the lowest TWA value and Mg metal had the highest TWA value among metals. Table 3's Spearman's rank correlation coefficients between the typical concentration of metals found in traditional coffee houses' indoor air and a few of their physical characteristics reveal that, in 87.5% of cases, there is a positive correlation between the metals and the variable number of clients. Additionally, there was a 62.5% positive association between the five variables with which metals were associated, including the number of active hookahs, the floor space per active hookah, the window area, the indoor air temperature, and the indoor air humidity. The findings of a 2021 study by Arfai Nia et al. similarly revealed a negative correlation between the concentration of metals, the location of coffee houses, and the number of operational hookahs [17]. In the 2021 study by Roohollah Rostami et al., all average metal concentrations measured in the indoor air of coffee houses were below the time-weighted average (TWA) limit set by the American Conference of Governmental Industrial Hygienists (ACGIH)(15). Metals' correlation coefficients with the variable number of clients at the traditional coffee houses were positively correlated in 87.5% of the cases and negatively correlated in 12.5%. In 75% of cases, there was a positive association between metals and the room volume and door area variables.

Despite the vast number of unlicensed coffee shops in Tehran, accessing them was one of this study's difficulties.

Conclusion

The current investigation demonstrated the presence of heavy metals in coffee shops' indoor air, with the average values of these elements ranging from higher to lower and including Fe, Mg > Pb > Ag > Cu > Ca >Na >Mn. This revealed that among the 57 coffee shops, manganese metal was present in higher concentrations than the other metals. The analyzed coffee shops typically employed two to five people. Mixed TLV values were used to assess the exposure of the coffee shop staff to the metals in the working air, and of the 57 coffee shops, only two had mixed TLV values that were greater than the standard (one) and were lower in 55 coffee houses. Due to their chronic exposure to air pollutants inside coffee houses and the fact that they work every day of the week, including on weekends and holidays, these individuals may experience side effects such as long-term liver and kidney damage, obstructive lung diseases, blood diseases, etc., on their health. Therefore, rigorous consideration must be given to the implementation of technical and engineering controls for breathing air monitoring, periodic inspections, and monitoring the status of the ventilation system and the necessity that they are in correct functioning order by the supervisory organizations.

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Conflict of interest

None declared.

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Ethical Considerations

The ethical committee at the Iran University of Medical Sciences approved the current study.

Code of Ethics

The code of ethics, IR.IUMS.REC 1397.627 was followed in conducting this study.

Authors' Contributions

Mehdi Ahmadian: Material preparation and data collection were performed. Rasoul Yarahmadi: Material preparation and data collection were performed. Masoud Salehi: data analysis was performed. Neda Mehrparvar: The first draft of the manuscript was written. Azadeh Ashtarinezhad: conception, design and supervision was performed. All authors read and approved the final manuscript.

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