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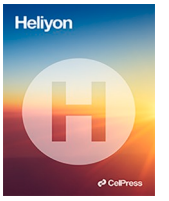

Assessing occupational exposure of airborne PMs and TVOCs in the nail salons in Tehran city, Iran

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ABSTRACT

There are concerns about the health of nail salon technicians due to the inherently harmful agents such as volatile organic compounds (VOCs) and released particles in the salons. For this reason, this study was conducted to investigate the occupational exposure of nail salon technicians to VOCs and particulate matters (PMs) in the nail salons in Tehran, Iran. In this cross-sectional study, indoor air quality and measurement continually Total VOCs and PMs in the various size of PM_1-PM_{10} using PhoCheck Tiger and particle counter device investigated, respectively. site observation, and an interview with the manager in 49 salons in Tehran. Data was analyzed using SPSS software (version 22). Mean concentrations of PM_1 with 2.56 μg/m^3 was the lowest amount and PM_{10} with 346.86μg/m^3 had the highest concentration. Also, the mean concentration of TVOCs was equal 2.61 ppm. The results of the regression model showed that there is a statistically significant between the number of services with airborne PMs ($PM_{2.5}$), (p-Value≤0.050). In salons only with nail activities, the concentration of PM_4 was less than the others, although this correlation was statistically significant just for PM_1 (p-Value = 0.010). By implementing effective local exhaust ventilation systems equipped with dust collectors and utilizing safe products, the emission of particles and chemical compounds within salons can be significantly reduced.

1. Introduction

Indoor air quality is a major global issue [1]. Small workhouses, similar to large industries, are usually associated with a mixture of volatile organic compounds(VOCs) [2]; It is also stated that pollutant concentrations in indoor environments are almost 2–5 times as high as in outdoor [3],due to low air exchange rates, and inefficient stoves [1].The official operation of nail salons began in 1980 [4] and globally marketed nail products has grown in the last two decades. There are concerns about the health of nail salon technicians working with vulnerable to several harmful materials [5], in long hours on the client's hand in a low distance of the nail technician's breathing zone and eyes [6,7].

Nowadays, airborne particulate matter is a serious health risk factor that affects humans and is used as an indicator of air quality [8]. PMs' impact on disease severity depends on their amount, composition, size, and exposure duration [1].Dust in Nail salons usually

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spreads in the indoor when utilization of rotary-powered devices for removing the former varnish and acrylic primer or shaping nails [9,10]. Concentrations of dust in the time of filing of nails with acrylic powder were over the standards of US and European [10], although the Food and Drug Administration (FDA) has banned the use of methyl acrylate in nail products, but it is still applied in nail salons [11]. Acrylates can put both the salon personnel and clients at risk allergic contact dermatitis (ACD) [12]. However, exposure for a technicians can be substantially greater than that for a client [13]. Furthermore, some VOCs with lower evaporation power such as acids, oxygenated compounds, and carbonyls may condense to form secondary organic aerosols which can affect the health [14]. Cardiovascular and respiratory symptoms observed in nail salon workers can increase due to capable of penetrating $PM_{2.5}$ and PM_{10} into the thoracic section [10,15]. About 100000 chemical compounds identified in nail products that just safety of a few percent of them have been checked [16], if there are regulations for cosmetic products which are mostly focused on the consumer [13]. The findings of Goldin et al. on the concentration of $PM_{2.5}$ and Total VOCs (TVOCs) in nail salons showed that the concentration of these contaminants is related to salon ventilation [17], Also, exposure to pollutants depends on the pattern and the level of exposure, even if there are inherent toxicological attributes for the compounds [13]. Lamplaugh et al. showed that the concentration of environmental and personal exposure to VOCs in six nail salons is comparable to these compounds in the oil and gas industry [18]. While the levels of chemicals in nail salons are generally considered to be within safe occupational exposure limits, such as the Threshold Limit Value (TLV), the additive or synergistic effects of these chemical compounds remain largely unknown. It's worth noting that these chemical compounds are often found in nail salons as mixtures and factors such as sensitization and the synergistic or additive effects of chemical compounds didn't consider in many of recommended occupational safety and health standards, Thus, there is challenging to promote health of technicians by adjustment of protocols that could be related to the toxic environment [19,20].

In Iran, there is no accurate statistic on the number of nail salons due to unlicensed salons and undocumented technicians in the industry, and also there is no standard for dealing with VOCs in hairdressers and local agencies have no program for their monitoring [21]. In order to control the safety of workers' occupational health and to make decisions about risk and hazard assessment, public health monitoring, and use of personal protective equipment (PPE) obtained information from the air analysis of work environments are important and vital for control [22]. To date, few studies have examined the elemental composition of PMs and VOCs in indoor and outdoor environments in Iran [8,23]. Furthermore, we have not found any research that has explored the presence of these pollutants in nail salons, which are common establishments that expose individuals to numerous chemicals. Consequently, further investigation is necessary to better understand the potential health risks of exposure to these pollutants in these environments. This study was conducted to investigate the occupational exposure of nail salon technicians to TVOCs and PMs in the nail salons sectors.

2. Methods

This cross-sectional study was conducted on nail salon technicians in Tehran. The majority of the participating salons were randomly selected and exclusively provided nail services. 49 nail salon technicians from 49 various salons participated in this study. The most of technicians were in the range of 18–30 years and the highest work experience was in the range of 3–6 years which shows that they are young.

2.1. Design of checklist

The criteria for participation in this study were salons that exclusively provide nail services A walkthrough survey and checklist were conducted for each salon, gathering information on various characteristics. This included assessing the type of ventilation system in place, the range of services offered, the personal protective equipment utilized by salon technicians, occupancy levels, and the ratio of salon area to employees. The survey aimed to comprehensively document these details for each salon [17]. Measurements were performed for a period of three months and exposure measurements were carried out during the work shift and contain TVOCs and PMs, in the personal breathing zone of the nail salons. This study has been approved by the Ethics Committee of Iran University of Medical Sciences under the reference number IR.IUMS.REC.1398.478.

2.2. Data collection

2.2.1. Measurement of PMs in the breathing zone of nail technicians

The concentration of dust particles is observed during filling. The highest concentration of dust particles is typically observed during filing activities, Afterward larger-sized particles tend to settle, while the finest dust particles can remain suspended the air for several hours [10]. The study employed various sensor types and incorporated the following features:

Concentration of particles was measured using a real-time particle counter device equipped with a temperature and humidity sensor (model TES 5200). This device is capable of measuring the concentration of airborne particles in six sizes of 1, 2.5, 4.0, 7.0, 10.0 μm and thoracic suspended particles (TSP), the flow rate was adjusted to 2.83 l min^{-1}, with tracing of the ambient air in 1s interval. In recent years, studies on particulate matter exposure using particle counter have become popular due to low cost, mobility, ease of use, measurement of particles in a short time, and showing a reliable estimation of actual exposure in both indoor and outdoor environments [24]. We recorded sampling from 10:00 a.m. to 6:00 p.m. for pollutant particle inlet with the set of sampling sensors device at the near in the height breathing zone of nail technicians who worked on the client's hand [25]. All measurements were taken on weekdays, excluding Fridays.

2.2.2. Measurements of TVOCs in the breathing zone of nail technicians

Types of organic chemicals that evaporate quickly at room temperature are called VOCs [26].The Concentrations of TVOCs were measured using a PhoCheck Tiger (IonScience) equipped with temperature and humidity sensors and also automatically reformed TVOCs according to RH [27] in the working zone air. The PhoCheck Tiger utilized a photoionization detector (PID), which detects organic compounds with an ionization potential of less than 10.6 eV. This device is designed to detect and measure the concentration of VOCs compounds in the environment. However, it does not have the capability to distinguish between different types of VOCs compounds. The reported concentrations are provided isobutylene-equivalent units. Measuring of gas ranged was from 0.001 ppm to 20000 ppm [28]. The device recorded the data manually every 10 min during the survey period. It estimated the composition of indoor air without individually detecting each organic compound. To ensure data quality, the PID was calibrated according to the manufacturer's manual every weekend using a specified concentration isobutylene standard gas.

2.2.3. Measurement of CO_2 concentration and air velocity in nail salons

Co_2 meter model TESTO, is a scale for indoor ventilation. The instruments were installed at position 1.5 m above the floor in the center salons, which has been device used frequently in previous studies [28,29]. Also, the indoor and recirculation airflow rates were measured with a Kata thermometer British-made (model Casella). Air samplings were typically conducted between 10:00 a.m. to 6:00 p.m. with a time interval of 20 min; data were recorded during the working hours of the nail salons.

2.3. Statistical analysis

Statistical analysis was computed for each parameter using SPSS software (version 22), Shapiro and Kolmogorov's tests were applied for normality. Pearson correlation coefficients were considered more than 0.2 as feature selection rules to choose the explanatory variables entered in the fitted multiple regression models. The relationships between environmental parameters such as TVOCs and PMs exposure with salon characteristics were assessed using multiple linear regression. Variance Inflation factor (VIF) used as a parameter to determine the collinearity between variables. VIF values > 10 were omitted [30]. Also, independent *t*-test used for comparing the means of the two groups. P-value of <0.05 was considered significant in all of the tests.

3. Results

3.1. Characteristics of the participants

Most of technicians, approximately 81.6 %, used masks during their work in the salon. The majority opted for surgical masks. However, it was observed that they rarely utilized aprons and glasses while on duty (Table 1). No installed local exhaust ventilation in the all salons.

3.2. Concentration of TVOCs, PMs and CO_2 in the breathing zone of nail salon technicians

Fig. 1 shows the concentration of inhalable particles and TVOCs. Average of concentrations PMs and TVOCs were different between the nail salons. Part Fig. 1-A illustrates the lowest concentration (mean = 2.56 μg/m^3) observed for PM_1, while the highest

Table 1
Characteristics of nail salon's technicians, N = 49.

Variable			Frequency (percent %)
Age (year)		18–30	39 (79.5)
		30–42	10 (20.5)
Work Experience (year)			18(36.7)
		3–6	25(51.0)
		6–9	6(12.3)
Education status		Diploma ≤	11(22.5)
		Bachelor	22(44.9)
		Master	16(32.6)
Type of PPE[a]	**Mask**	Yes	18(36.7)
		Intermittent	22(44.9)
		NO	9(18.4)
	Gloves	Yes	5(10.2)
		Intermittent	20(40.8)
		NO	24(49.0)
	Glasses	Yes	5(10.2)
		Intermittent	15(30.6)
		NO	29(59.2)
	Apron	Yes	9(18.3)
		Intermittent	12(24.6)
		NO	28(57.1)

[a] Personal Protective Equipment.

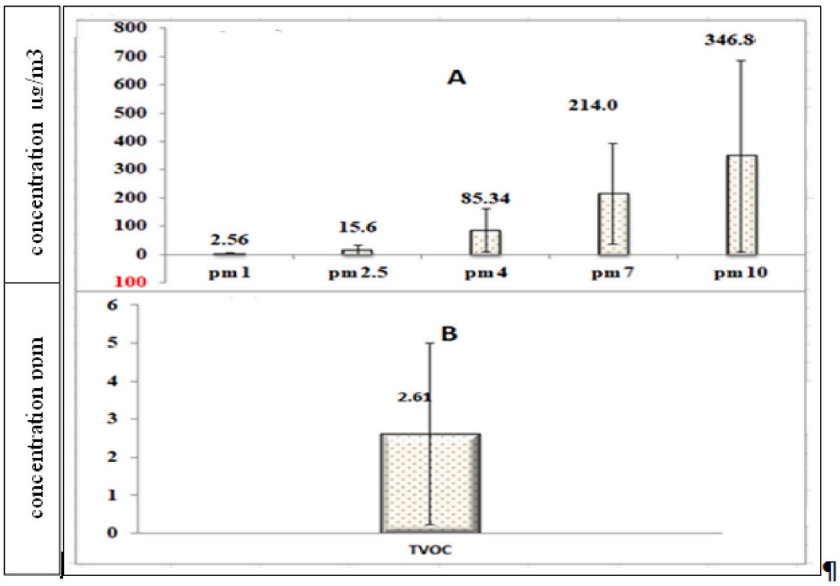

Fig. 1. Concentration of PMs (A) and TVOCs (B) in the breathing Zone of nail salons' technicians.

concentration (mean = 346.8 μg/m^3) was recorded for PM_{10}. Also, the mean concentrations of harmful particles such as $PM_{2.5}$ and PM_4 were equal to 15.6 and 85.34 μg/m^3, respectively. Fig. 1- B reveals that the mean TVOCs was equal to 2.61 ppm. The average concentration of CO_2 was 967.4 ppm, for admissible indoor air quality, indoor CO_2 concentration should be under 1000 ppm [31]. The measured indoor airflow velocity and relative humidity were 0.12 $\left(\frac{m}{s}\right)$ and 27.85 %, respectively. According to the air quality guidelines suggested by the World Health Organization (WHO), the recommended exposure level (REL) for a 24-h period is 20 μg/m^3 for PM_{10} and 10 μg/m3 for $PM_{2.5}$ [32], and permissible exposure limit (PEL) suggested by the American Conference of Governmental Industrial Hygienists (ACGIH) for exposure with the respiratory dust is equal to 3 mg/m^3 (21); therefore, in this study concentration of $PM_{2.5}$ and PM_{10} were upper than WHO guidelines, and total respiratory dust was lower than the ACGIH standard. The acceptable limit of TVOCs is 3 ppm [33]. In this study, concentration of TVOCs was lower than the acceptable limit.

3.3. *The correlation between concentrations of PMs and TVOCs with the environmental parameters*

The correlations between concentration of PMs and TVOCs with environmental parameters reveals in Table 2. The regression model showed that there is a statistically significant between the number of provided services to the customer with $PM_{2.5}$ (Beta = 0.29, p-Value = 0.038), PM_4 (Beta = 0.34, p-Value = 0.013), PM_7 (Beta = 0.30, p-Value = 0.046) and PM_{10} (Beta = 0.32, p-Value = 0.032.). Also, the results showed that the minimum tolerance was equal to 0.75 and the maximum amount of VIF was equal to 1.32, which

Table 2
Multiple linear regression-effect models for personal exposure to PMs and TVOCs.

Dependent variable	independent variable	Pearson's correlation		B	SE	Beta	p-Value	R^2adj	Collinearity statistic	
		R	p- Value						Tolerance	VIF
PM_1	Speed flow	−0.27	0.049*	−4.4	2.9	−0.21	0.134	0.10	1.05	0.94
	Service number	0.30	0.032*	0.11	0.06	0.25	0.074		1.05	0.94
$PM_{2.5}$	Speed flow	0. 32	0.022*	−37.27	19.7	−0.25	0.066	0.15	1.05	0.94
	Service number	0.35	0.013*	1.06	0.42	0.29	0.038*		1.05	0.94
PM_4	Speed flow	−0.30	0.031*	−150.4	88.9	−0.22	0.097	0.17	1.05	0.94
	Service number	0.40	0.004*	4.88	1.86	0.34	0.013*		1.05	0.94
PM_7	Speed flow	−0.33	0.019*	−345.7	221.6	−0.23	0.117	0.18	1.23	0.81
	Temperature	0.21	0.144	6.86	9.68	0.09	0.482		1.14	0.87
	Service number	0.22	0.123	9.73	4.74	0.30	0.046*		1.26	0.79
	Concentration Co_2	0.42	0.002*	0.09	0.09	0.08	0.588		1.23	0.79
	Occupancy	0.21	0.039*	2.01	3.32	0.09	0.549		1.32	0.75
PM_{10}	Speed flow	−0.28	0.047*	−560.8	396.0	−0.19	0.164	0.16	1.06	0.79
	Temperature	0.21	0.144	15.22	17.89	0.11	0.399		1.05	0.90
	Service number	0.39	0.004*	20.24	8.51	0.32	0.022*		1.09	0.89
TVOCs	Humidity	0.30	0.034*	0.10	0.05	0.26	0.070	0.06	1.01	0.98
	Ratio of salon area to employees	−0.29	0.057	−0.13	0.12	−0.17	0.226		1.01	0.98

Table 3
The results of PMs and TVOCs in salons equipped with modern and up-to-date technology in comparison to other salons.

Variable	dust collector	Non- dust collector	Test statistics	P-Value	natural ventilation usage	mechanical ventilation usage	Test statistics	P-Value	nail section is part of the hairdresser	Only specific nail salons	Test statistics	P-Value
	Mean ± SD	Mean ± SD			Mean ± SD	Mean ± SD			Mean ± SD	Mean ± SD		
PM_1	2.48 ± 2.30	2.61 ± 2.52	t = −0.19	0.848	3.38 ± 3.10	1.99 ± 1.60	t = −2.43	0.047*	3.75 ± 2.97	1.92 ± 1.72	t = −2.69	0.010*
$PM_{2.5}$	14.82 ± 82.57	16.18 ± 89.04	t = −0.27	0.887	20.01 ± 23.60	12.56 ± 9.30	t = −1.54	0.130	18.88 ± 16.82	13.88 ± 16.90	t = −0.98	0.333
PM_4	89.04 ± 92.16	82.57 ± 64.97	t = 0.28	0.774	102.64 ± 99.58	73.42 ± 53.58	t = −1.31	0.195	94.55 ± 62.50	80.49 ± 84.18	t = −0.60	0.548
PM_7	214.51 ± 163.64	213.63 ± 190.67	t = 0.01	0.987	222.98 ± 166.15	207.78 ± 188.03	t = 0.29	0.773	123.97 ± 102.99	224.70 ± 207.67	t = 0.69	0.591
PM_{10}	347.21 ± 286.83	346.5 ± 376.67	t = 0.08	0.994	245.96 ± 367.96	367.96 ± 387.73	t = 0.52	0.604	299.99 ± 154.15	371.76 ± 403.17	t = 0.89	0.377
TVOCs	–	–	–	–	2.84 ± 2.68	2.30 ± 1.77	t = −0.64	0.521	2.63 ± 1.95	2.53 ± 3.12	t = −0.16	0.870

indicates that there is no multicollinearity between the independent variables.

3.4. The concentration of PMs and TVOCs in salons equipped with modern and up-to-date technology compared to other salons

The results of Table 3 revealed that in salons that applied dust collector technology, the concentration of $PM_{2.5}$ was lower than the others, although this relationship wasn't statistically significant. Also, in the salons which used mechanical ventilation, the concentration of particles was lower than the salons with natural ventilation, however this relationship was significant only for the concentration of PM_1 (p-Value = 0.047). In salons that were specifically associated with nail activities, the concentration of PM4 was less than in salons that nail services are a part of activities in the hairdressers, although this correlation just for PM1 was statistically significant (p-Value = 0.010).

3.5. Compare the level of particles produced on weekdays versus weekends

Fig. 2 shows that the number of produced particles at the weekend is higher than the weekday especially deference in concentration of $PM_{2.5}$ - PM_7, which can be attributed to the high number of customers on the weekend.

4. Discussion

The nail salon technicians are exposed to a variety of pollutants in the workplace every day. Although, chronic exposure in a low amount is a pervasive topic within this industry, while maybe causes for health problems in nail technicians [34,35]. The aim of this study was to investigate the exposure of nail salon technicians to PMs and TVOCs and as well as effective factors in their exposure. As shown in the results, about 80 % of technicians were in range 18–30 age (Table 1), it means they are expected in the reproductive ages that expose to low air quality can cause to adverse effect in the pregnancy period [15]. Depending on the type of activity Such as manicures, pedicures, and nail implants, the concentration of PMs and TVOCs varied during the day. The results showed that the concentrations of $PM_{2.5}$ and PM_{10} in this study was lower and upper than the PEL of WHO (for 24 h), respectively. The mean concentration of TVOCs in our study was below the REL (3 ppm), however, 35 % of the salons were high, because of inefficient ventilation and the small space of the salons in relation to the number of services, is the key parameters in indoor air pollution [36]. In our study, this two-factors were found to be unsuitable. In Health Canada and European Commission Joint Research Centre determined the exposure level of TVOCs upper than 1.4 ppm as the discomfort level [37]. The mean concentration of TVOCs in our study was upper than the REL. Also, the EPA standard for breathing and the annual standard of Iran which is equal to 160 $\mu g/m^3$ [38]. The obtained results in this study with Phocheck tiger device for concentration of TVOCs are similar to the previous studies based on the other sampling strategies [11,39,40].

There are barriers for the nail technicians such as perceived work-related stressors, communication with key stakeholders, and training of safety at their workplace that role important to progress occupational health and safety from the nail salon workers [35]. The results of Table 1 show that a few numbers of salons are constantly using PPE. Also, they mostly utilized surgical or cloth masks that are not effective to protect against aerosolized particles or vapors. The use of cartridges mask or air supplier recommended for

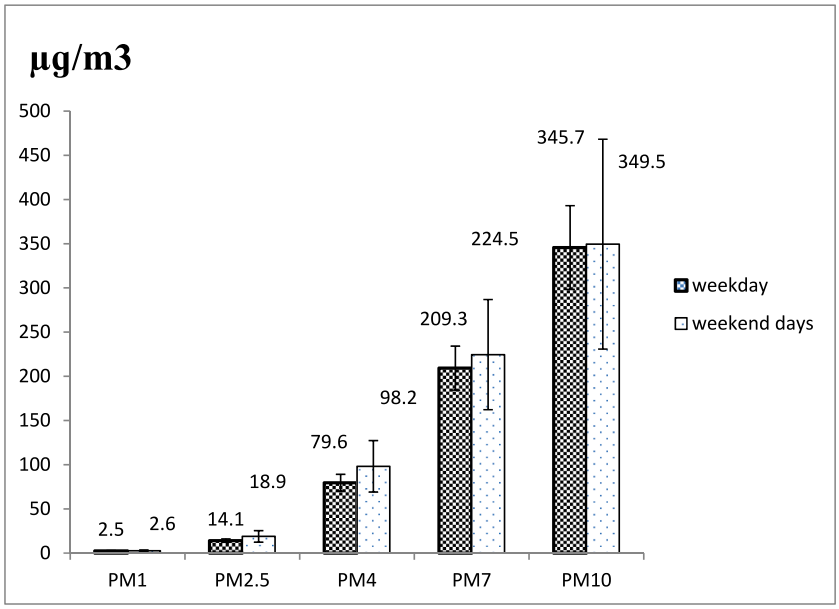

Fig. 2. The results of comparison the level of particles produced on weekdays versus weekends.

protection against the VOCs. Although they have the weak protection against particles, NIOSH recommended the use of N95 mask for protection against the particle [41]. The results of multiple linear regression model in Table 2 showed that there was a statistically significant correlation between the number of performed services with PM, while there wasn't statistically significant correlation between number of services with TVOCs concentration, although level of TVOCs was upper than others. Similar to our finding Goldin et al. (2014) revealed high levels of TVOCs for technicians while performing services to the customer however there wasn't a statistically significant relationship between them [17]. Also, in the salons with mechanical ventilation, the concentration of particles was lower than the salons with natural ventilation, but this relationship was significant only for PM_1 (p-Value = 0.047). Nazila Shakibaei et al. (2014) investigated the effect of local ventilation on the reduction of exposure of nail salon technicians to VOCs and particles; their results indicated the use of local ventilation systems has reduced at least 77 % of concentration VOCs and 69–90 % of particles [6].

High CO_2 concentration in our study indicates there was poor ventilation, thus the inefficiency in ventilating the greater particles than 1 μm. In our study' salons that were specifically associated with nail activities, the concentration of PM_4 was less than the others. Kopiec et al. (2018) surveyed the air pollution in hair salons. The personal and environmental samplings showed that the concentration of PM_4 inside the salons was several times higher than outside [42]. Therefore, salons that have different parts and provide different services can be a source of inhalable particles. For this reason, in our salons, which doing nail services specifically the concentration of PM_4 was lower. As regards, there aren't any chemical exposure standards befitting for nail salon products exposure. The appropriate strategy for developing standards is to support policymakers to test products before entering the market and writing the components of each product on the label, especially for materials with potential risk [43,44].

Our study had some limitations, such as each nail salon was assessed in only one day due to the lack of cooperation of the management. also, all surveys were done in the hot season of the year when ventilation usage is more common. The strengths of this study of nail salon Technicians consist of the simultaneous PMs and TVOCs measurements. In addition, the impact of influencing factors such as the ventilation, and the number of services to the customer have been investigated.

5. Conclusion

Higher concentrations of some of the harmful aerosol particles like $PM_{2.5}$ and PM_{10} equal to 15.6 and 85.34 $\mu g/m^3$, respectively and VOCs compared with the air quality guidelines such as WHO and the annual standard of Iran showed there are known hazards related to products that applied by nail technicians. In order to be responsible for primary prevention and mitigating occupational exposures is needed further studies to perceive the sources of hazard VOCs release such as formaldehyde and acrylate compounds in the occupation environments. Also using proper mechanical ventilations applying such as dust collectors with high engine speed can reduce the emission of particles and chemical compounds inside the salons.

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Vida Ebrahimi: Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation. **Rasoul Yarahmadi:** Writing – review & editing, Writing – original draft, Investigation. **Masoud Salehi:** Validation, Methodology, Formal analysis, Data curation. **Azadeh Ashtarinezhad:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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