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Exposure assessment to BTEX in the air of nail salons in Tehran city, Iran

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ABSTRACT

The nail salon industry has grown considerably, but there are serious concerns about the health risks associated with working in this field. Therefore, the purpose of this study was to investigate the exposure of nail technicians to BTEX. A cross-sectional study was conducted on 49 salons, and NIOSH Method 1501 was used to measure the concentration of BTEX in the breathing zone of technicians. The EPA method was used to assess health risks. Statistical analysis was conducted using SPSS software. The mean concentrations of toluene were (82.65 ± 198.84μg/m^3)μg/m^3, followed by benzene (10.58 ± 9.62μg/m^3), p-xylenes (20.77 ± 37.79μg/m^3), o-xylene (13.79 ± 25.70μg/m^3), and ethylbenzene (29.35 ± 58.26μg/m^3) , that lower than the permissible exposure limits suggested by NIOSH. Among the BTEX, toluene (82.65 ± 198.84μg/m^3) has the most concentration in the nail salons. It was also discovered through multiple linear regression analysis that humidity had a significant effect on increasing the concentration of toluene (Beta = 0.50, P-value = 0.001) and ethylbenzene (Beta = 0.16, P = 0.049), while there was a considerable association between the number of services performed and benzene concentration (Beta = 0.34, P = 0.010).

The average inhalation lifetime cancer risk for benzene ($4.9 \times 10^{-5} \pm 4.5 \times 10^{-5}$) was higher than the recommended value set by the US EPA. Although the concentrations of BTEX were lower than the maximum permissible limits, the results of the cancer risk assessment for benzene showed that working in nail salons with poor ventilation is hazardous. Therefore, exposure can be minimized by ensuring appropriate ventilation in the workplace and using safe products.

1. Introduction

The nail salon industry has experienced significant growth in both the number of salons and nail technicians over the past 20 years [1,2]. As of 2017, there were 56389 nail salons and 439,751 nail technicians working in the United States [3]; And by 2030, it predicts a 33% growth for nail technicians, which is several times higher than the average worker growth projected for all occupations [4]. The training schools and technicians' growth, coupled with the increasing demand for a diverse range of services in Iran, have amplified the growth and value of this job [5]. Notably, a significant fraction of workers in this industry are women of childbearing age [3,6]. Raising concerns about workplace air pollution and employee health amidst this booming business [7]. Survey studies showed that nail

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technicians are exposed to the chemical in nail products has been linked to carcinogens and endocrine disruptors, skin irritation, and allergic and teratogenic agents [8,9]. For example, toxic compounds such as formaldehyde, phthalates, acrylates, toluene, acetone, acetonitrile, and isopropyl acetate. Nail technicians are exposed to other volatile organic compounds (VOCs) (such as benzene, xylene) and semi-volatile compounds through the frequent use of nail products and nail shaping, and manicuring close to the respiratory tract [10,11].

Various chemicals in workplaces, especially when ventilation is poor, nail technicians caused to adverse effects outcomes [7,12], including eye and skin irritations, cancer and reproductive defects [13], cognitive function decreased, chronic pulmonary obstruction, asthma [14], abruption placenta, and gestational diabetes [3,15]. Today, some manufacturers claim that their varnishes are green products and dibutyl phthalate- and toluene-free [13]. In the beauty industry, technicians who perform nail treatments may be at risk of exposure to bloodborne pathogens, which are microorganisms that can cause disease and are transmitted through contact with infected blood or other bodily fluids [16]. Furthermore, individuals performing nail services experience ergonomic vulnerabilities due to the need for awkward posturing when focusing on the client's fingernails [16,17]. Additionally, there is a lack of information regarding the harmful effects of cosmetics on health, leading many female users who are typically attracted to advertising networks due to the nature of their work to use these products without adequate awareness of their side effects [18]. Owing to the serious risks of exposure to compounds, recent guidelines are insufficient for worker's protection [14].

Environmental and health organizations are raising concerns about the release of strong chemical odors from nail products which can be dangerous for health [19]. Most artificial nails require repair every three to five weeks using manual or electrical equipment, that emit chemical substances into the indoor air. This poses a significant occupational exposure risk to salon workers who may inhale nail dust containing hazardous substances [20].

Few studies have examined the presence of chemical compounds like toluene, methyl methacrylate, and formaldehyde inside nail salons located in other countries [10,21,22]. There has been limited research conducted on the potential health hazards associated with exposure to VOCs in the beauty salons in Iran. In 2019, Mahbobeh Moradi et al. measured BTEX concentrations in both indoor and outdoor beauty salons and surveyed the urinary BTEX concentrations of beauty technicians.

They found that urinary BTEX concentrations in the beauty technicians were significantly higher than in the control group and also average indoor concentrations of BTEX were higher than those in the outdoor [23]. Another study, measured inside and outside BTEX and formaldehyde concentrations in beauty salons and surveyed environmental and occupational factors in air pollution. They found that indoor concentrations of each composition were higher than outdoor pollutants. The results of the risk assessment showed that there is a risk of cancer in technicians due to exposure to benzene and formaldehyde. Some environmental and occupational factors affected the concentration of pollutants [24]. Norouzian et al. (2018) investigated the concentration of BTEX in indoor beauty salons. Also, the structural and occupational factors of the salons were studied. The results of this study show that among the BTEX, ethylbenzene has the most concentrations in the salons. Some of the factors such as the number of services in the salons, and the type of ventilation system, affect the concentration of benzene [25]. As far as we have researched, no data have been available on BTEX compositions in nail salons in Iran. Today, nail salons operate separately from beauty salons.

Our study was exclusively conducted in nail salons. This profession is progressing in Iran, and due to the lack of enough studies in this field, the objective of this study was focused on estimate the exposure of technicians in nail salons to BTEX found in nail products, polish removers, polishes, and other matters. We also aimed to provide a preliminary assessment of ventilation status and other factors that can affect exposures.

2. Methods

2.1. Selection of nail salons

This cross-sectional study was performed in 49 nail salons. In November 2019 to January 2020, a study was conducted in Tehran, Iran, where a total of 49 nail salons were selected randomly using a sampling method. The aim was to evaluate the participation of salon technicians in the study, with a focus on salons that provide exclusively nail services. In case any of the selected salons declined to participate, they were replaced by other salons. It's also worth noting that this study was approved by the ethics committee of Iran University of Medical Sciences with the reference number No.IR.IUMS.REC.1398.478.

A questionnaire was initially designed to evaluate the characteristics of the nail salons selected for the study. The aim was to determine factors affecting the levels of indoor chemical pollution, including the type of ventilation (mechanical or natural) and whether they were turned on or off, the separation of the nail section from other sections, types of building materials used, as well as the number of waiting customers and salon workers. These characteristics were recorded at the beginning of sampling and continued to be monitored at 30-min intervals throughout the study.

2.2. Sampling and measurements

CO_2 concentration, wind speed, relative humidity, and temperature were measured at 30 minutes intervals during sampling. However, the concentration of BTEX was measured over a longer period of time (60–306 minutes). Personal breathing zone samples were collected from the nail technician using a flow rate of 200 $\pm$ 5% (L per minute) during BTEX sampling according to method number 1501 NIOSH [25,26]. Sampling was performed using a pump (model 110-100 MODLE Air lite SKC) with Charcoal sorbent tubes (SKC). The pump flowrate was calibrated before sampling using a soap bubble glass flow meter. CO_2 level, temperature and relative humidity was measured using TESTO 535 CO_2 meter [27], as well as airflow velocity by Kata thermometer brand Casella with the average temperature of the cooling 53.5 °C in a height of 1.5 m above the ground and a minimum distance of 0.5 m from the walls. After sampling, the sorbent tubes were capped and tubes were stored in a cold box at 4 °C and taken to the laboratory.

2.3. Preparation and decomposition sample

After collection, the samples were stored at −20 °C for a maximum of 72 h. Then, the front and back sections of the charcoal tube were separately extracted in 1 ml of carbon disulfide (CS2). The samples were then gently desorbed by shaking for 30 minutes or more [25]. Calibration curves were generated using six points based on standard solutions ranging from 20 ppb to 100 ppm. Quantitative /Qualitative analysis of elicited BTEX compounds was accomplished with the Gas Chromatography-mass spectrometry (included an Agilent series 7890A GC linked to an Agilent MSD 5975C quadrupole mass spectrometer). GC was fitted with HP-5 MS capillary column (30 m × 0.25 mm i.d, 0.25 μm film thickness).

The flow rate of the carrier gas (helium) was maintained at 1.0 mL/min in a steady flow mode. The oven temperature was programmed as follows: the initial temperature: 40 °C for 4 minutes, then increased and held to 100 °C at 5 °C/min for 1 min and finally increased to 250 °C at 50 °C/min.

Full scan mass spectra (50–550 m/z) were recorded for the detection BTEX compound for validating the retention times of BTEX compound and selected ion monitoring (SIM) mode ($m/z = 78$ for benzene, $m/z = 91$ toluene, ethylbenzene 91 for o-xylene and p-xylene 106). QC and QA measures were done based on former study by Norouzian et al. [25]. QA methods involved the use of field blanks for each sampling in every salon. These blanks underwent the same analytical procedures as real samples, and their concentrations were subtracted from those of the actual samples. The front and back sections of the tubes were analyzed separately in order to check the breakthrough of the sorbent tubes. Concentrations of BTEX compounds in blank samples ranged from 0.00 to 0.07, 0.00–0.11, 0.00–0.05 and 0.00–0.00 μg/m^3 for benzene, toluene, ethylbenzene, and xylene isomers, respectively. LOD was defined using the blank method. The concentration of blank samples was measured in triplicate and LOD was computed. The LOD and LOQ for them were 0.03 and 0.09 μg/m^3, 0.04 and 0.13 μg/m^3, 0.02 and 0.06 μg/m^3 and 0.0 μg/m^3, respectively.

2.4. Risk assessment

2.4.1. Benzene carcinogenic risk assessment

According to IARC and EPA classifications, benzene in the group BTEX is a definite human carcinogen (category A) [28]. Therefore, the carcinogenic risk of exposure to benzene is assessed for nail salon workers based in the formula 1 [25]:

$$\text{Cancer risk} = \text{CDI*CSF} \tag{1}$$

CDI is chronic daily intake (mg/kg/day) through Inhalation and CSF is inhalation cancer slope factor (mg/kg/day)$^{-1}$ equal to 0.029 (mg/kg/day)$^{-1}$ [26]. CDI calculated based in the formula 2 [14,25]:

$$\text{CDI} = \frac{\text{CA} * \text{IR} * \text{ET} * \text{EF} * \text{ED}}{\text{BW} * \text{AT} * 365} \tag{2}$$

CA: Concentration of the desired compound in the salon nail air ($\frac{mg}{m^3}$)

IR: The inhalation rate for worker nail salons ($\frac{m^3}{h}$)

ET: The exposure time with the pollutant ($\frac{h}{day}$) that is equal to 8 h per day

EF:The exposure frequency ($\frac{days}{yr}$) (with an average of 300 days a year)

ED: The exposure duration in the year that minimum and maximum equal to 25 and 35 years, respectively.

BW: Body weight of nail salon workers (kg)

AT: AT is the average lifetime (70 year*365year^{-1})

BW and IR were calculated based on the age of workers reported according to the demographic information in the study, anthropometric measurements and body composition reference [14,29]. In this study, 93% of the working-age were between 20 and 39 years. According to anthropometric table, the BW and the IR for Asian women in the age group of 20–39 are the weight of 58.3 kg [29] and 0.5 $\left(\frac{m^3}{h}\right)$, respectively.

2.4.2. Non-carcinogenic risk assessment of BTEX compounds

The non-carcinogenic risk of other BTEX compounds is calculated using the EPA method, which is shown in the formula 3 [25]:

$$\text{HQ (hazard quotient)} = \frac{\text{CDI}}{\text{RFC}} \tag{3}$$

An HQ value greater than 1 indicates an unacceptable risk of non-carcinogenic effects, while an HQ value that is less than or equal to 1 indicates an acceptable risk [25]. RFC values set by EPA for BTEX compounds are toluene 5, ethylbenzene 1 and xylene 0.1 mg /m^3 [30]. Which after Unit conversion in terms of mg/kg-day is equal to 1.43, 0.29 and 0.029, respectively [26].

2.5. Statistical analysis

Statistical analysis was performed using SPSS software (version 22). Kolmogorov-Smirnov or Shapiro-Wilk tests were used to evaluate normality of the data. Independent Samples *t*-test were applied to compare means. Multiple linear regression analysis was used to choose the finest subset of the explanatory variables for each one of the BETX variable. Pearson correlation coefficients greater than 0.2 was considered as feature selection rule to choose the explanatory variables entered in the fitted multiple regression models.

Variance inflation factor (VIF) has been generally utilized to determine the collinearity in this study. VIF higher than 10 indicates severe collinearity [31]. P values less than 0.05 were considered significant in all of the tests.

3. Results

3.1. General characteristics of nail salons

Table 1 presents the physical characteristics of the salons, which includes the frequency or mean of ventilation conditions, air ambient, and dimensions. Among the studied salons, 83.7% (41) had at least one window for natural ventilation. Out of these, 28.6% (14) salons had open windows. While 63.4% (31) participating salons had a HVAC system (Split and Centrifugal fan), the others had fan on the window 14.3% (7).

3.2. Concentrations of BTEX in the nail salons

BTEX concentrations (mean, unit: (μg/m^3) in each nail salon and ambient condition are listed in Supplemental table S1. Table 2 reveals the chemical compounds of the nail salons and their permissible limits of exposure. Mean concentrations of benzene, toluene, ethylbenzene, p-xylene and o-xylene in the technicians breathing zone in salons were 10.58 ± 9.62, 82.65 ± 198.84, 29.35 ± 58.26, 20.77 ± 37.79, and 13.79 ± 25.70 μg/m^3, respectively. Owing to results, exposure to BTEX compounds is less than the permissible exposure limits in OSHA and EU-OSHA, the recommended exposure limits (REL) in NIOSH and RFC (EPA) organizations [32–36]. Furthermore, the mean distance of nail salons from the nearest highways or garages was 750 m.

BTEX levels from several published studies that measured exposure are also shown in Table 3. In most cases, the BTEX concentrations observed in this study were between or higher than those reported in this table [21,23,25].

Table 1
The general characteristics of the sampled nail salons.

Variable	groups	Subgroups	status	**Frequency (percent) or mean(±SD)**
Ventilation	natural	window	open	14 (28.6%)
			close	27 (55.1%)
			Without window	8 (16.3%)
		door	Open	2 (4.1%)
			close	47 (95.9%)
	mechanical	Fan on the window	on	7 (14.3%)
			off	–
			Not installed	42 (85.7%)
		Centrifugal fan	on	15 (30.7%)
			off	–
			Not installed	34 (69.3%)
		Split	On	16 (32.7%)
			off	2 (4.1%)
			Not installed	32 (65.2%)
ambient conditions	temperature $\left(\frac{\dot{C}}{30\ min}\right)^*$	–	–	23.77 (±2.57)
	relative humidity $\left(\frac{\%}{30\ \text{min}}\right)^{**}$	–	–	27.85 (±5.85)
	concentrationCO2	–	–	967.49 (±286.14)
	air flow velocity $\left(\frac{m}{s}\right)$	–	–	0.12 (±0.11)
Dimensions salon	high (m)	–	–	2.84 (±0.15)
	area (m^2)	–	–	52.67 (±15.04)
	area per employee $\left(\frac{\text{m}^2}{\text{person}}\right)$	–	–	8.91 (±2.99)
Day of sampling of salons(frequency)	Week day	34		
	Weekend day	15		
Number of services(frequency)	One service	4		
	Two services	12		
	>Two services	33		
Wall material (frequency)	Plaster	43		
	Ceramic	6		

*mean temperature per 30 min **percent relative humidity per 30 min.

Table 2
Concentration of BTEX compounds in nail salons and permissible exposure limits provided by occupational health agencies.

Concentration BTEX $\left(\frac{\mu g}{m^3}\right)$ (8 h)		Q1	Mean (±SD)	Q3	EU-OSHA		NIOSH $\left(\frac{mg}{m^3}\right)$		OSHA $\left(\frac{mg}{m^3}\right)$		RFC[a] (EPA) $\left(\frac{mg}{m^3}\right)$
					STEL	TWA	STEL	TWA	STEL	TWA	IRIS[b]
Benzene		4.48	10.58 (±9.62)	13.92	12.8	3.25	3.19	0.319	15.95	3.19	0.03
Toluene		8.40	82.65 (±198.84)	31.50	384	192	560	375	1131	745	5.0
Ethyl benzene		0.00	29.35 (±58.2)	26.80	884	442	545	435	–	435	1.0
Xylene	**p-xylene**	0.00	20.77 (±37.79)	25.50	442	221	655	435	–	435	0.1
	o-xylene	0.00	13.97 (±25.70)	15.30							

[a] RFC: Reference Concentrations for non-cancer effects and unit risks for cancers.
[b] IRIS: Integrated Risk Information System is an environmental assessment program operated by EPA.

3.3. The relationships between each BTEX compound concentration and environmental parameters

Table 4 displays the results of the multiple linear regression, indicating that humidity has a significant effect on increasing the concentration of toluene (Beta = 0.50, p-value = 0.001) and ethylbenzene (Beta = 0.16, p-value = 0.049).

For example, an increase of one unit in the humidity variable of nail salons is associated with a 50% increase in the concentration of toluene. The larger Beta value indicates a better prediction of the response variable. Additionally, the number of services provided by the nail salon showed a significant relationship with benzene concentrations (Beta = 0.34, p-value = 0.010). The VIF values for this index had a maximum value of 1.49 in this table, indicating slight collinearity.

The minimum and maximum adjusted R square value between the response variables of toluene and ortho-xylene with the predictor variable suggested r^2 adj = 0.42 and r^2adj = 0.12, respectively. In interpreting these findings, it is shown that by Increase one unit SE relating to the score of the predictor variables, the score of response variables, Beta equivalent the SE unit increases.

An independent samples *t*-test model was utilized to investigate and contrast the outcomes for each BTEX compound with respect to the type of wall material, as well as for each BTEX compound in relation to the day of sampling (Table 5).

According to the results presented in the table, there was no statistically significant difference between the levels of these compounds found in both types of wall materials (Plaster and Ceramic). However, Fig. 1 indicates that there may be a difference in the concentrations of toluene and ethylbenzene with the wall materials.

The correlation between days of sampling with each of BTEX compound was not statistically significant ($P > 0.05$). There was a significant difference between the salons with exclusively nail services with other sections of the salon in the concentration of benzene (P-value = 0.042). Among the BTEX compounds, there wasn't a significant Statistical difference between the type of mechanical ventilation, except for toluene with the fan installed on the window (P-value = 0.002).

3.4. The carcinogenic and non-carcinogenic risk assessment of exposure to BTEX

The results of Carcinogenic and non-carcinogenic risk assessment of exposure to BTEX shows in Table 6.The mean of LTCR for benzene is equal to ($4.9 \times 10^{-5} \pm 4.5 \times 10^{-5}$) and mean of HQ for xylene is upper than toluene and ethylbenzene.

3.5. Personal protective equipment

According to Table 7, which shows the percentage of used personal protective equipment (PPE) by technicians, PPE was utilized while working in nail salons. A Self-report of 49 technicians, 18.4% of technicians stated that they never wear masks during their work shift and just 20.4% of them always use the mask. Moreover, 49% of nail technicians never use gloves while 8.2% of them used them in all their work shifts.

4. Discussion

This study examined the presence of BTEX compounds in the breathing zone of nail technicians. According to Table 2, the average concentration of BTEX compounds in salons was found to be below PEL set by OSHA as well asREL advised by NIOSH and RFC (EPA). The study found that among BTEX compounds, toluene had the highest concentration. This is consistent with previous studies conducted by Mahbobeh Moradi et al. [26] and Lamplugh, A et al. [14] which also reported higher concentrations of toluene compared to other BTEX compounds. Toluene is commonly emitted from products such as nail polishes, glue, and varnishes, and can cause irritation to the eyes, ears, nose, and headaches [14,37].

The concentration of BTEX in this study was found to be higher than that reported in the studies conducted in nail salons by Victor M. Alave [38] and DM. Ceballos [39]. This difference in concentration may be attributed to variations in salon products, occupancy levels, and ventilation rates [25]. However, it was observed that the value of LTCR for benzene exceeded the recommended limit proposed by ACGIH and WHO. Therefore, there is a potential risk of carcinogenesis due to exposure to benzene, but it is not significant. Moreover, the average HR for TEX (toluene, ethylbenzene, and xylene) was less than 1, and the sum of HR for TEX compounds was 0.25, indicating a negligible non-cancer risk. These findings are consistent with previous research studies [14,25].

The results of this study are consistent with previous research, which has shown a significant positive relationship between

Table 3
Comparing the results of BTEX concentrations in the present study and other studies.

Author/year of publication	Workplace/ Country	Exposure measurement condition	Ventilation System	Concentration of Benzene	Concentration of Toluene	Concentration of Ethyl benzene	Concentration of xylene
present study/ 2019–2020	nail salons/ Iran	Personal sampling measurements range of the 60–306 min	Fan on the window (on) = 14.3% Centrifugal fan (on) = 30.7% Split (on) = 32.7%	Mean ± SD 10.58 ± 9.62 (IQR 4.48–13.92) μg/m^3	Mean ± SD 82.65 ± 198.84 (IQR8.40–31.50) μg/m^3	Mean ± SD 29.35 ± 58.2 (IQR 0.00–26.80) μg/m^3	**p-xylene** Mean ± SD 20.77 ± 37.79 (IQR 0.00–25.50) **o-xylene** Mean ± SD 13.97 ± 25.70 (IQR 0.00–15.30) μg/m^3
Moradi/2019	Beauty salons/ Iran	environmental sampling for 30 min at a height of 1.5 m in the working areas	not reported	mean 4.9 (IQR 3.4–5.7) μg/m^3	mean 118.7 (IQR 70.2–138.9) μg/m^3	Mean 7.5 (IQR 5.6–8.3) μg/m^3	m-xylene mean 16.7 (IQR 12.8–20.8) μg/m^3 o-xylene median 7.5 (IQR 5.6–9.3) μg/m^3
Lamplugh/2019	nail salons/ Colorado	Personal exposure VOC measurementsfor 8 continuous hours each day	All salons were equipped with mechanical ventilation systems	range 3.13–51.8 μg/m^3	range 26.7–816	range 1.65–9.52	range 5.16–34.6
Norouzian Baghani/2018	Beauty salons/ Iran	environmental sampling for fifty min at breathing zone (150 cm)	not reported	mean ± SD 32.40 ± 26.38	mean ± SD 16.10 ± 14.34	mean ± SD 62.38 ± 32.37	Mean ± SD 13.82 ± 11.6

Table 4
Multiple linear regression results for operational status and Ambient conditions on concentrations of BTEX in the nail salons

Dependent Variable	independent variable	Pearson's correlation		B	SE	Beta	p-value	R^2adj	Collinearity statistic	
		r	p-value						Tolerance	VIF
Benzene	Service number	0.41	0.002	0.48	0.25	0.27	0.049*	0.19	0.776	1.28
	Relative humidity	0.43	0.003	0.46	0.26	0. 28	0.080		0.667	1.49
	Co_2 concentration	0.21	0.144	0.002	0.005	0.04	0.746		0.832	1.20
Toluene	Fan on window	−0.41	0.002	−207.98	62.35	−0.37	0.002*	0.42	0.971	1.03
	Relative humidity	0.52	0.000	16.43	4.28	0.48	0.000*		0.751	1.33
	Service number	0.37	0.008	3.62	4.50	0.1	0.426		0.768	1.30
	centrifuge	0.21	0.144	11.62	48.48	0.02	0.812		0.926	1.08
Ethylbenzene	Relative humidity	0.41	0.003	3.37	1.50	0.33	0.030*	0.16	0.751	1.32
	Service number	0.36	0.010	2.43	1.54	0.23	0.132		0.773	1.30
	Co_2 concentration	0.20	0.153	−18.21	16.90	−0.14	0.287		0.941	1.06
Para-xylene	Relative humidity	0.41	0.002	1.86	1.05	0.28	0.083	0.14	0.667	1.49
	Service number	0.33	0.019	1.25	1.03	0.18	0.234		0.776	1.28
	Co_2 concentration	0.24	0.095	0.01	0.01	0.09	0.539		0.831	1.20
Ortho-xylene	Relative humidity	0.37	0.003	1.20	0.67	0.27	0.084	0.12	0.764	1.30
	Service number	0.39	0.019	0.75	0.71	0.16	0.301		0.773	1.02
	Split	−0.20	0.177	−3.57	3.76	−0.13	0.348		0.96	1.03

* Significant relationship between independent variables and the concentration of compounds.

Table 5
Independent-Samples T Test results for comparing mean BTEX concentrations of different variables.

variable	various classify		p-value			
		Benzene	Toluene	Ethyl benzene	Para xylene	Orto xylene
specific nail salons	Yes NO	0.042	0.921	0.747	0.464	0.241
Sampling day	Weekday Weekends	0.520	0.751	0.998	0.608	0.605
wall material	plaster Ceramic	0.421	0.625	0.527	0.648	0.749

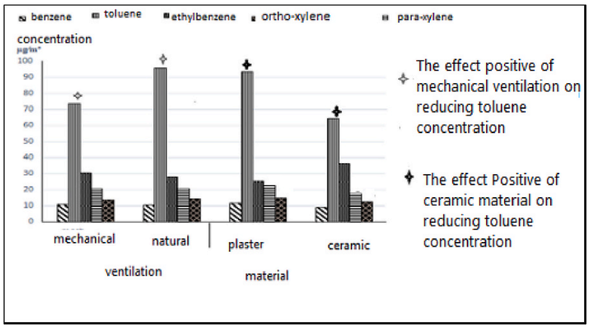

Fig. 1. Average concentration of airborne BTEX compound base on ventilation statues and structural.

Table 6
Carcinogenic and non-carcinogenic risk assessment of exposure to BTEX compounds in nail salons.

Unit		Pollutant				Risk limit
HQ or LTCR[a]		benzene	toluene	Ethylbenzene	xylene	
LTCR	mean	4.9×10^{-5}	–	–	–	
	SD	4.5×10^{-5}	–	–	–	1×10^{-6}
	Max	1.5×10^{-4}	–	–	–	
HQ	Mean	–	9.3×10^{-3}	1.1×10^{-2}	2.4×10^{-1}	1
	SD	–	2.2×10^{-2}	2.1×10^{-2}	4.8×10^{-1}	1
	Max	–	0.12	0.12	2.47	1

[a] HQ: hazard quotient; LTCR: lifetime cancer risk.

Table 7
Self-report Percentage of use of PPE in employees of the participating nail salon

variable	type	Never use	10–20%	30–50%	60–80%	90–100%
PPE	mask	18.4	20.4	24.5	16.3	20.4
	gloves	49.0	26.5	14.3	2.0	8.2

humidity and the concentrations of toluene and ethylbenzene compounds [40,41]. However, Quach et al. (2011) found no significant relationship between relative humidity and the concentrations of VOCs in nail salons [2]. Based on previous studies, it appears that the effect of humidity on BTEX concentration may vary depending on the specific materials used in the building and the types of BTEX compounds present [41]. The previous studies investigated air quality and salon ventilation in the nail salons compared with the mean concentration of CO2 [10,38,42]. In Supplemental Table S1 shows that the mean concentration of CO2 in 19 salons (38.7%) was higher than the standard value of 1000 ppm recommended by American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) [27].

Previous studies have shown the positive effect of local ventilation in reducing VOC compounds [43,44], As per our study, we observed a positive effect of air movement equipment in reducing the concentration of toluene. There was just a significant relationship between the low concentration of toluene with the fan on the window. Also, a comparison of concentration reduction between natural and mechanical ventilation shows that natural ventilation (open window or door) can't alone do as well for decline BTEX, Circulated the air because these compounds quickly released from nail products and outspread in the atmosphere (Fig. 1). Norouzian et al. conducted a study in beauty salons and found that natural ventilation was not as effective as mechanical ventilation in terms of exchanging air to reduce the concentration of chemical compounds [25]. According to Table 4, a significant relationship was found between the number of services and the concentration of benzene (Beta = 0.34, p = 0.010). Probably because benzene is higher volatile than toluene, and toluene tends to adhere to the surface [45]. Goldin et al. reported that the concentration of VOC was high while working on the client's hand, although those concentrations were not significantly related to the number of services [46]. Similar to the previous study, there was no significant statistical correlation between concentrations of BTEX compounds and wall materials [25]. Fig. 1 shows that ceramic salons have a lower concentration of toluene, although this relationship was not significant. The difference in concentration may be attributed to the fact that most salons in Iran with plaster walls have their walls covered with oil paint or wallpaper, which are also sources of BTEX emission [47,48]. Nevertheless, it is possible that the present study still holds value in providing novel information or insights to the field, despite previous studies being conducted in the same location and season [42].

In a study conducted by Missia et al., which surveyed indoor exposure from building materials, their results indicated a significant correlation between the concentration of formaldehyde and acetone with indoor emission sources of buildings, while BTEX showed only a weak correlation with these materials [49].

Table 7 illustrates that nearly 38.8% of the technicians used masks for less than or equal to 10% of their working time, indicating a lack of attention to safety culture in the salons. The study also revealed that most technicians preferred surgical and cloth masks, believing that they provided sufficient protection against both particles and chemical vapors, although air-purifying respirators are recommended for protecting against vapors of VOCs [38]. Moreover, about half of the technicians reported using gloves only sometimes during their work hours. It is worth noting that dermatitis is commonly related to exposure to acrylates, and therefore nitrile gloves are recommended to prevent this condition [50].

5. Limitations

There were a few limitations to the study that need to be addressed. Firstly, it was not feasible to measure the air exchange rate (AER) in the salons, which made it difficult to assess the efficiency of ventilation. Additionally, there was a lack of availability of nail technicians and some reluctance to participate in the study, which may have affected the overall findings. At the end, due to budget constraints, we were unable to measure the outdoor concentration.

6. Conclusions

The study found that all of the nail products tested could release BTEX compounds, particularly toluene. Although the concentration of BTEX compounds measured in the study was below PEL, it is important to note that there is no safe level of exposure for salon technicians, who are predominantly women of childbearing age. Therefore, it is crucial to take measures to minimize exposure to these potentially harmful substances in order to protect the health and well-being of salon workers. Furthermore, there appears to be a significant correlation between the number of services performed and the concentration of benzene present. Thus, growth in training policies, and improve conditions within their workplaces, could be useful. In future researches, it could be beneficial to conduct laboratory analyses of the nail products commonly used in salons and to measure and detect biomarkers that may predict potential adverse health effects among nail technicians. This could provide a more comprehensive understanding of the potential risks associated with working in this industry and help inform strategies for mitigating these risks.

Author contribution statement

Vida Ebrahimi: Conceived and designed the experiments, analyzed and interpreted the data, materials, contributed reagents,

materials, analysis tools or data, wrote the paper.

Rasoul Yarahmadi: Wrote the paper, Analysis tools or data.

Masoud Salehi: Materials, Analyzed and interpreted the datammc1.

Azadeh Ashtarinezhad: Conceived and designed the experiments, analyzed and interpreted the data, materials, contributed reagents, materials, analysis tools or data, wrote the paper.

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

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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References

[1] T.B. Huynh, et al., Factors influencing health and safety practices among Vietnamese nail salon technicians and owners: a qualitative study, Am. J. Ind. Med. 62 (3) (2019) 244–252.
[2] T. Quach, et al., Characterizing workplace exposures in Vietnamese women working in California nail salons, Am. J. Publ. Health 101 (S1) (2011) S271–S276.
[3] J.Y. Seo, et al., Worrying about getting Sick in the future": lived Experience of health Seeking and healthcare utilization among Korean immigrant nail salon workers, Journal of Racial and Ethnic Health Disparities (2019) 1–11.
[4] I. Han, et al., Evaluating indoor air phthalates and volatile organic compounds in nail salons in the greater New York city area: a pilot study, Int. J. Environ. Res. Publ. Health 19 (19) (2022), 12411.
[5] M. Karami, S. Karami, N. Elahinia, Personality or quality: influencing factors in customers' intention to revisit beauty salons in Iran, Int. J. Manag. Account. Econ. 8 (5) (2021).
[6] L. Zhong, S. Batterman, C.W. Milando, VOC sources and exposures in nail salons: a pilot study in Michigan, USA, Int. Arch. Occup. Environ. Health 92 (1) (2019) 141–153.
[7] L. Ward, et al., Interventions targeting health and wellbeing among nail salon workers: a scoping review, Annals of Work Exposures and Health 66 (7) (2022) 827–837.
[8] T. Quach, et al., A preliminary survey of Vietnamese nail salon workers in Alameda County, California, J. Community Health 33 (5) (2008) 336–343.
[9] B. Pavilonis, et al., Assessing Indoor Air Quality in New York City Nail Salons Assessing Indoor Air Quality in New York City Nail Salons, 2018.
[10] C. Nguyen, Indoor Air Quality of Nail Salons in the Greater Los Angeles Area: Assessment of Chemical and Particulate Matter Exposures and Ventilation, UCLA, 2016.
[11] B. Pavilonis, C. Roelofs, C. Blair, Assessing indoor air quality in New York City nail salons, J. Occup. Environ. Hyg. 15 (5) (2018) 422–429.
[12] S.-A. Park, S. Gwak, S. Choi, Assessment of occupational symptoms and chemical exposures for nail salon technicians in Daegu City, Korea, Journal of Preventive Medicine and Public Health 47 (3) (2014) 169.
[13] G.X. Ma, et al., Characterizing occupational health risks and chemical exposures among Asian nail salon workers on the East Coast of the United States, J. Community Health 44 (6) (2019) 1168–1179.
[14] A. Lamplugh, et al., Occupational exposure to volatile organic compounds and health risks in Colorado nail salons, Environ. Pollut. 249 (2019) 518–526.
[15] T. Quach, et al., Adverse birth outcomes and maternal complications in licensed cosmetologists and manicurists in California, Int. Arch. Occup. Environ. Health 88 (7) (2015) 823–833.
[16] J.V. Dang, M.-A.S. Rosemberg, A.B. Le, Perceived work exposures and expressed intervention needs among Michigan nail salon workers, Int. Arch. Occup. Environ. Health 94 (8) (2021) 2001–2013.
[17] F. Abareshi, S. Rastaghi, M. Fallahi, Nail Job and Women's Health: Assessment of Ergonomics and Occupational Hazards, Work, 2022, pp. 1–8 (Preprint).
[18] M. Tagesse, et al., Non-combustible source indoor air pollutants concentration in beauty salons and associated self-reported health problems among the beauty salon workers, Risk Manag. Healthc. Pol. (2021) 1363–1372.
[19] C. Roelofs, T. Do, Exposure Assessment in Nail Salons: an Indoor Air Approach, 2012, ISRN Public Health, 2012.
[20] M. Gjølstad, S. Thorud, P. Molander, Occupational exposure to airborne solvents during nail sculpturing, J. Environ. Monit. 8 (5) (2006) 537–542.
[21] A. Lamplugh, et al., VOC emissions from nail salon products and their effective removal using affordable adsorbents and synthetic jets, Build. Environ. 168 (2020), 106499.
[22] T. Heaton, et al., Laboratory estimation of occupational exposures to volatile organic compounds during nail polish application, Workplace Health & Saf. 67 (6) (2019) 288–293.
[23] M. Moradi, et al., Exposure to BTEX in beauty salons: biomonitoring, urinary excretion, clinical symptoms, and health risk assessments, Environ. Monit. Assess. 191 (2019) 1–10.
[24] M. Hadei, et al., Indoor concentrations of VOCs in beauty salons; association with cosmetic practices and health risk assessment, J. Occup. Med. Toxicol. 13 (2018) 1–9.
[25] A.N. Baghani, et al., BTEX in indoor air of beauty salons: risk assessment, levels and factors influencing their concentrations, Ecotoxicol. Environ. Saf. 159 (2018) 102–108.
[26] M. Moradi, et al., Exposure to BTEX in beauty salons: biomonitoring, urinary excretion, clinical symptoms, and health risk assessments, Environ. Monit. Assess. 191 (5) (2019) 286.

[27] A. Tsigonia, et al., Indoor air in beauty salons and occupational health exposure of cosmetologists to chemical substances, Int. J. Environ. Res. Publ. Health 7 (1) (2010) 314–324.
[28] E. Durmusoglu, F. Taspinar, A. Karademir, Health risk assessment of BTEX emissions in the landfill environment, J. Hazard Mater. 176 (1–3) (2010) 870–877.
[29] C.D. Fryar, et al., Anthropometric Reference Data for Children and Adults, United States, 2016.
[30] IRIS, USEPA (Electronic Data Base), Integrated Risk Information System, 2009.
[31] S.T. Ahmed, R.S. Mehsen, T.H. Hadi, A Structural Model Fuzzy Multiple Regression Analysis to Cloud Computing Security Issues, 2019.
[32] M.E. Barsan, NIOSH Pocket Guide to Chemical Hazards, 2007.
[33] ECC, Commission Directive 2000/39/EC of 8 June 2000 establishing a first list of indicative occupational exposure limit values in implementation of Council Directive 98/24, O. Journal 142 (2000) 47.
[34] E. Union, Directive 2004/37/EC of the European Parliament and of the Council of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work, Off. J. Eur. Union 158 (2004) 50–76.
[35] E. Union, Commission Directive 2006/15/EC of 7 February 2006 Establishing a Second List of Indicative Occupational Exposure Limit Values in Implementation of Council Directive 98/24/EC and Amending Directives 91/322/EEC and 2000/39/EC, OJ EU, 2006.
[36] U. Epa, Integrated Risk Information System (IRIS) Database, EPA, Washington, DC, 1996.
[37] A.R. Ford, Overexposed, Underinformed": Nail Salon Workers and Hazards to Their Health/A Review of the Literature, National Network on Environments and Women's Health, Toronto, ON, 2014.
[38] V.M. Alaves, et al., Characterization of indoor air contaminants in a randomly selected set of commercial nail salons in Salt Lake County, Utah, USA, Int. J. Environ. Health Res. 23 (5) (2013) 419–433.
[39] D.M. Ceballos, et al., Environmental and biological monitoring of volatile organic chemicals among nail technicians, in: ISEE Conference Abstracts, 2018.
[40] S.T. Mirmohammadi, et al., Evaluating occupational exposure to para-phenylenediamine (ppd), in: THE INHALED AIR AND ENVIRONMENTAL FACTORS AFFECTING WOMEN HAIRDRESSERS IN SARI, 2018.
[41] M.H. Dehghani, et al., Exposure and risk assessment of BTEX in indoor air of gyms in Tehran, Iran, Microchem. J. 150 (2019), 104135.
[42] D.M. Ceballos, et al., Biological and environmental exposure monitoring of volatile organic compounds among nail technicians in the Greater Boston area, Indoor Air 29 (4) (2019) 539–550.
[43] N. Shakibaei, Reducing Workers' Exposures to Chemicals and Dust in Nail Salons Using Local Exhaust Ventilation Systems, 2014.
[44] K. Logachev, et al., Improving dust capture efficiency with local exhaust hoods in manicure shops, Build. Environ. 181 (2020), 107124.
[45] J. Mohammed, et al., Adsorption of benzene and toluene onto KOH activated coconut shell based carbon treated with NH3, Int. Biodeterior. Biodegrad. 102 (2015) 245–255.
[46] L.J. Goldin, et al., Indoor air quality survey of nail salons in Boston, J. Immigr. Minority Health 16 (3) (2014) 508–514.
[47] R. Harrison, et al., WHO Guidelines for Indoor Air Quality: Selected Pollutants, 1, World Health Organization, 2010.
[48] M. Hadei, et al., Indoor and outdoor concentrations of BTEX and formaldehyde in Tehran, Iran: effects of building characteristics and health risk assessment, Environ. Sci. Pollut. Res. 25 (2018) 27423–27437.
[49] D.A. Missia, et al., Indoor exposure from building materials: a field study, Atmos. Environ. 44 (35) (2010) 4388–4395.
[50] H. White, et al., Identifying health and safety concerns in Southeast Asian immigrant nail salon workers, Arch. Environ. Occup. Health 70 (4) (2015) 196–203.