Jundishapur J Health Sci. 2026 July; 18(2) https://jjhs.ajums.ac.ir /
Published Online: 2026 July Research Article
10.22118/jjhs.2026.597582.1046

Evaluation of BTEX and VOCs Levels in the Indoor Air of Women's Beauty Salons in the West of Ahvaz

Abdolkazem Neisi [1,2], Gholamreza Goudarzi [1,2], Saeed Ghanbari [3], Maryam Nazari* [1,4]

1. Department of Environmental Health, School of Health, Air Pollution and Respiratory Diseases Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
2. Environmental Technologies Research Center, Medical Basic Sciences Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
3. Department of Biostatistics and Epidemiology, School of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
4. Department of Environmental Health, School of Health, Student Research Committee, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

*Corresponding Author: Department of Environmental Health, School of Health, Student Research Committee, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
Email: maryamnazari221@gmail.com

Article Info.

Received:2026/02/25 **Revised:** 2026/04/12 **Accepted:** 2026/04/30

Abstract

Background and Objective: This study aimed to determine the exposure of female beauty salon workers in western Ahvaz, Iran, to volatile organic compounds (VOCs) and BTEX, and to examine their potential health consequences.

Methods: For this study, 24 beauty salons across four districts of Ahvaz were selected. Air sampling was conducted during two periods (before and after daily operations) over four months in 2024–2025 using a portable PhoCheck instrument. A questionnaire was also administered to evaluate the personnel's respiratory and skin symptoms, as well as their health-related quality of life.

Findings: The results showed that the concentrations of VOCs and BTEX increased significantly after the salons began their activity. For example, in Azar (November–December), the concentration increased from 0.19 ppm before operations to 3.23 ppm afterward. In addition, workers frequently reported irritative symptoms, such as eye itching (77.1%), runny nose (46.9%), cough (43.8%), and shortness of breath (26.0%), which showed a significant positive correlation with the rising concentrations of these pollutants. Lack of proper ventilation was also associated with a considerable increase in pollutants. Although concentrations remained below occupational exposure limits, chronic and cumulative exposure may still pose long-term health risks to workers.

Conclusion: In accordance with the ALARA principle, continuous monitoring, the use of less hazardous materials, and improved ventilation in beauty salons are recommended to minimize exposure.

Keywords: Exposure assessment, Volatile organic compounds and BTEX, Indoor air of women's beauty salon.

Copyright © 2026, Jundishapur Journal of Health Sciences. This open-access article is available under the Creative Commons Attribution-NonCommercial 4.0 (CC BY-NC 4.0) International License, which allows for the copying and redistribution of the material onlyfor noncommercial purposes, provided that the original work is properly cited.

1. Introduction

The modern world is full of various sources of indoor pollution, some of which originate from health and beauty products that have numerous consumers. Although beauty salons constitute a widespread and high-traffic global industry, the occupational risks associated with chemical exposures in this sector remain under-researched (1). Beauty salon workers provide a wide range of services, including hair washing, cutting, drying, styling, coloring, and chemical treatments such as keratin straightening (2)(3). The products used in these environments are also diverse and include shampoo, oil, bleach, powder, hairspray, gel, cream, and nail polish (3)(4). Each of these chemical compounds, as well as hair treatment techniques, is capable of releasing a wide range of volatile organic components (VOCs) such as aromatics, esters, ketones, hydrocarbons, alcohols, phenols, and acids, some of these are classified as toxic and hazardous compounds. These pollutants can accumulate indoors and compromise air quality in beauty salons, particularly where mechanical ventilation and exhaust fans are lacking (5)(6).

The indoor air quality of beauty salons is highly complex and polluted due to the extensive presence of VOCs (7)(8). The staff and customers of these centers are daily exposed to high concentrations of numerous chemicals that are widely used in hair styling and nail care techniques. The salon personnel provide these services daily and continuously, and experience significant occupational exposure through dermal absorption and inhalation of vapors accumulated in the salon air during working hours (1)(8). The adverse effects caused by indoor air pollutants may appear in the short term or after a long period of time. Acute or repeated exposure to these compounds can cause symptoms such as eye, nose, and/or throat irritation, headache, impaired coordination, and general weakness, which are usually short-term and treatable. However, heart diseases, respiratory infections, and various cancers are more serious complications that may occur in the long term (7)(9). Also, short-term contact with high concentrations of VOCs can lead to mucosal irritation, dizziness, nausea, and exacerbation of asthma attacks. Some of these compounds even cause severe allergic reactions (10)(11). Chronic exposure to these pollutants is associated with the occurrence of diseases such as lung, liver, and kidney cancers, as well as neurological disorders, and some toxic VOCs impair the function of the central nervous system (12).

Given the above, conducting in-depth and systematic studies in this field seems necessary to better understand the health consequences resulting from exposure to various concentrations of pollutants, especially under acute and chronic exposure conditions. The most important VOCs and BTEX found in beauty salons include benzene, toluene, ethylbenzene, xylene, formaldehyde, acetaldehyde, and acetone (13). These mainly originate from straightening agents, dyes, solvents, and antioxidants, and are harmful to human health due to their chemical properties and high toxicity (14). Due to their high volatility, these compounds disperse into the air immediately after use and are absorbed through respiration. Also, due to their hydrophobic properties, they accumulate in fatty tissues, and short-term exposure to them causes dizziness, headache, and diarrhea, while chronic exposure has been associated with blood disorders, liver diseases, and leukemia (2)(3)(4). Chemicals such as benzene, formaldehyde, and acetaldehyde have been classified by the International Agency for Research on Cancer (IARC) in the group of definite human carcinogens. Prolonged exposure to these compounds may also cause serious, potentially irreversible health effects. Although some of these compounds have been banned in the global cosmetics market, they are still used in many cosmetic products (5). Despite these hazards, there are still no codified regulations under indoor air quality control law to protect the health of beauty salon personnel against exposure to VOCs and BTEX.

Although studies in Iran and elsewhere have investigated volatile organic compounds (VOCs) in beauty salons, most have focused on nail salons or a single city. To our knowledge, no study has simultaneously assessed BTEX compounds and other VOCs in women's beauty salons across different area types (high-traffic, low-traffic, residential, and industrial) and seasons (warm and cold) in western Ahvaz. Furthermore, the combined relationship between these pollutant concentrations, ventilation conditions, and self-reported health symptoms (ocular, respiratory, skin, and neurological) among salon personnel remains unexamined in this region. Therefore, this study aims to bridge this gap by simultaneously quantifying seven BTEX and VOC compounds pre- and post-operation across four months over two consecutive years and in four distinct urban areas. Combined with a questionnaire-based health survey of the staff, this comprehensive approach provides a clearer and more complete assessment of occupational exposure in women's beauty salons.

To address this gap, the present study investigated VOC and BTEX exposure across 24 women's beauty salons in four distinct urban zones (high-traffic, low-traffic, residential, and industrial) in western Ahvaz. Air sampling was conducted during pre- and post-operational periods across four months over two consecutive years, capturing both operational and seasonal variations. The simultaneous quantification of seven target compounds using a portable instrument enabled a thorough assessment of inhalation exposure. In addition, a questionnaire-based survey evaluated self-reported symptoms across five domains (respiratory, ocular, nasal, dermal, and neuropsychological) to examine health outcomes

associated with pollutant concentrations. Finally, salon ventilation status was recorded to determine its moderating effect on exposure levels, providing a comprehensive evaluation of occupational health risks in this sector.

1. Methods

The target population of this study was the indoor air of 24 women's beauty salons in the west of Ahvaz and the staff working in these salons. To measure the levels of VOCs and BTEX, a Tiger SELECT portable gas detector (ION Science, UK) with a 10.6 eV ultraviolet lamp was used (Table 1). This device is equipped with a 0.5-micron filter that draws air in at a flow rate of 200 mL/min, and the target compounds are detected by the ultraviolet lamp detector. The measurement range of the device is from 1 ppb to 20,000 ppm with a response time of less than 2 seconds. Before measuring the pollutant concentrations, the device was calibrated using a carbon blue filter from the manufacturer. The concentration of the target pollutants was measured in 24 women's beauty salons in the west of Ahvaz. Sampling was performed between 13:00 and 19:00, once a day, in two rounds: before the activity and after the start of activity and the provision of beauty services.

Sampling was carried out at a height of 1.5 m from the floor, at a distance of 1 m from the workers' breathing zone, and at a distance of at least 1 m from emission sources. Each reading was performed for 60 seconds in three consecutive replicates, and their average was recorded as the final concentration. The studied salons were located in four different points of the city (Figure 1), which are: 1- salons located in high-traffic areas and close to high-traffic zones, 2- salons located in low-traffic areas, 3- salons in low-traffic areas located in residential zones, and 4- salons close to industrial areas. The basis for the division of the areas was the role of two factors, namely vehicle traffic and industries, in the concentration of VOCs and BTEX. Sampling was performed in four months of the year, including Khordad and Tir 1404 (May–July 2025) and Azar and Dey 1403 (November 2024–January 2025). The required sample size was calculated using MedCalc software at a 95% confidence level and 10% precision, with a 10% dropout rate, yielding a target of 96 cases; ultimately, 87 valid samples were analyzed (15). Data were obtained from 96 questionnaires, and the investigated pollutants, including benzene, toluene, ethylbenzene, xylene, benzaldehyde, acetaldehyde, and acetone, were measured by direct reading in the indoor air of 24 beauty salons. Also, demographic data, self-reported symptoms, lifestyle (including smoking), and health-related quality of life of salon staff were investigated and collected as data in five domains—respiratory, ocular, nasal, skin, and neuro-psychological—and other groupings using a questionnaire (Appendices) during work and after work. Data analysis was performed using SPSS version 22.

Table 1. Specifications of the portable gas detector used in this study

Parameter	Value
Device	Tiger SELECT Gas Detector
Manufacturer	ION Science
Serial number	T-114852
Year of manufacture	2019
Calibration validity date	2026/02/16
Calibration cylinder	040008867037
Gas concentration	100 ppm Isobutylene

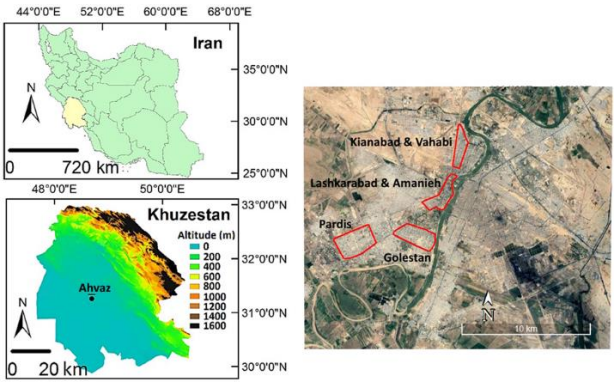


Figure 1. Aerial view of the sampling areas, including Kianabad–Vahhabi, Lashkarabad–Amaniyeh, Golestan, and Pardis in Ahvaz, Khuzestan.

Calibration

Before measuring the pollutant concentrations, the device was calibrated using the manufacturer's calibration cylinder (100 ppm isobutylene). The calibration validity date was 2026/02/16 and the device accuracy was ±2%. To control the effects of humidity and lamp contamination, calibration was performed with a carbon blue filter (manufacturer-made) and periodic cleaning of the lamp was carried out according to the manufacturer's instructions.

Response factors (RFs): The RFs used in this study were extracted from the manual of the PhoCheck PID device (Tiger SELECT, Ion Science). These RFs were determined under the same device settings (10.6 eV lamp) and the same operating conditions (temperature, pressure, and humidity) used in the field measurements. Therefore, the RFs are directly applicable to the field measurements of this study.

Correction factor: The correction factor (CF = 1/RF) was applied for each target compound based on isobutylene (the device standard). The numerical values of RF and CF for each compound are presented in Table 2.

Table 2. Response factors (RF) and correction factors (CF = 1/RF) for the target compounds

Compound	Response Factor (RF)	Correction Factor (CF = 1/RF)
Benzene	0.53	1.89
Toluene	0.51	1.96
Ethylbenzene	0.49	2.04
Xylene	0.46	2.17
Benzaldehyde	0.42	2.38
Acetaldehyde	0.38	2.63
Acetone	0.75	1.33

Quantification

The final concentration of each compound was calculated by multiplying the PID reading by the specific correction factor of that compound. It should be noted that in this study, the device was used to measure changes in the concentration of the specified pollutants before and after activity in an enclosed environment, rather than to determine the exact absolute concentration of total organic compounds. Therefore, the increasing trend was significant and fulfills the main objective of the study. Thus, the method of using the device is scientifically defensible.

Assessment of ventilation status: The ventilation status of each salon was evaluated through direct observation using a standardized checklist, with the presence or absence of an exhaust fan serving as the primary indicator of ventilation. For each salon, the presence or absence of an exhaust fan (ceiling or wall-mounted) and whether it was active or inactive during sampling were recorded. Salons with operating exhaust fans were defined as 'ventilated,' while those with non-operating or absent fans were designated as 'non-ventilated.' Consequently, 74% (n=18) and 26% (n=6) of the salons fell into the ventilated and non-ventilated categories, respectively. These data were utilized in the statistical models to examine the relationship between ventilation and pollutant levels.

Statistical Analysis

Data analysis was performed using SPSS version 22. The normality of the data was assessed using the Kolmogorov–Smirnov test, and in most cases, the variables had a normal distribution. Also, due to the large sample size, according to the Central Limit Theorem, the data were assumed to be normal. Homogeneity of variance was examined using Levene's test. The chi-square test was used to examine the relationship between categorical variables (such as ventilation status and type of work environment). The independent t-test was used to compare the mean pollutant concentrations between two independent groups (such as salons with and without ventilation), and the paired t-test was used to compare before and after activity within the same salon. One-way ANOVA was used to compare the mean pollutant concentrations across the four different areas (high-traffic, low-traffic, residential, industrial), and in case of significance, Tukey HSD post hoc test was used. In cases where normality was not confirmed, non-parametric equivalents were used: the Mann–Whitney U test instead of the independent t-test, the Wilcoxon signed-rank test instead of the paired t-test, and the Kruskal–Wallis test instead of one-way ANOVA. To account for repeated measurements in the same salons (24 salons × 4 months), the Friedman test was used as a non-parametric alternative. The statistical significance was set at $p < 0.05$.

2. Results

In this study, all 96 respondents were women (100%). The assessment of workplace ventilation status indicated that 74% of the work environments were equipped with ventilation and 26% lacked a ventilation system. Regarding the type of work environment, the highest frequency was attributed to residential areas (31.3%), followed by industrial areas (26%), high-traffic environments (24%), and low-traffic environments (18.8%). Also, in the distribution of job type, most respondents (72.9%) were in the keratin worker group and 27.1% worked in the nail worker group. The examination of the relationship between workplace variables using the chi-square test showed a statistically significant relationship between the presence of ventilation and the type of work environment ($p = 0.039$). Salons in industrial areas were significantly more equipped with ventilation systems than other areas. The relationship between the ventilation variable and job type was statistically significant ($p = 0.039$). In addition, smoking showed a significant relationship with the type of environment ($p = 0.047$), and the highest positive responses to this indicator were reported in industrial environments.

Analysis of the mean chemical pollutant concentrations across ventilation statuses and job types revealed that ventilation conditions play a crucial role in mitigating the pollution load. post-activity benzene concentrations measured in Azar were significantly higher in unventilated environments compared to ventilated ones ($p = 0.004$). A similar pattern was observed for toluene following work activity in Dey, where the lack of ventilation was associated with a significant elevation in its levels ($p = 0.041$). Table 3 presents the mean concentration of the pollutants measured over the 4 months in general. The lowest mean concentration among all measured compounds belonged to benzene (0.0981 ppm) and the highest concentration was reported for benzaldehyde (98 ppm). The permissible limit for acetaldehyde is ACGIH: 25 ppm TWA, STEL: 50 ppm.

Table 3. Mean concentrations of measured pollutants over four months

Pollutant	Minimum(ppm)	Maximum(ppm)	Mean(ppm)	Standard Deviation
Benzene	0.000	0.8400	0.0981	0.0879
Toluene	0.000	7.5500	1.6931	1.0478
Ethylbenzene	0.0100	36.6600	1.4072	0.9312
Xylene	0.000	6.6300	1.3429	0.6255
Benzaldehyde	0.0000	98.0000	0.7498	2.8390
Acetaldehyde	0.0400	25.3200	2.1302	0.8642
Acetone	0.0100	8.2400	1.5844	0.7139

Figure 2. Comparison of pre- and post-activity mean concentrations of indoor VOCs and BTEX—including benzene, toluene, ethylbenzene, xylene, benzaldehyde, acetaldehyde, and acetone—across four months (Azar, Dey, Khordad, and Tir), highlighting post-activity increases in benzene with a peak in Tir (summer)

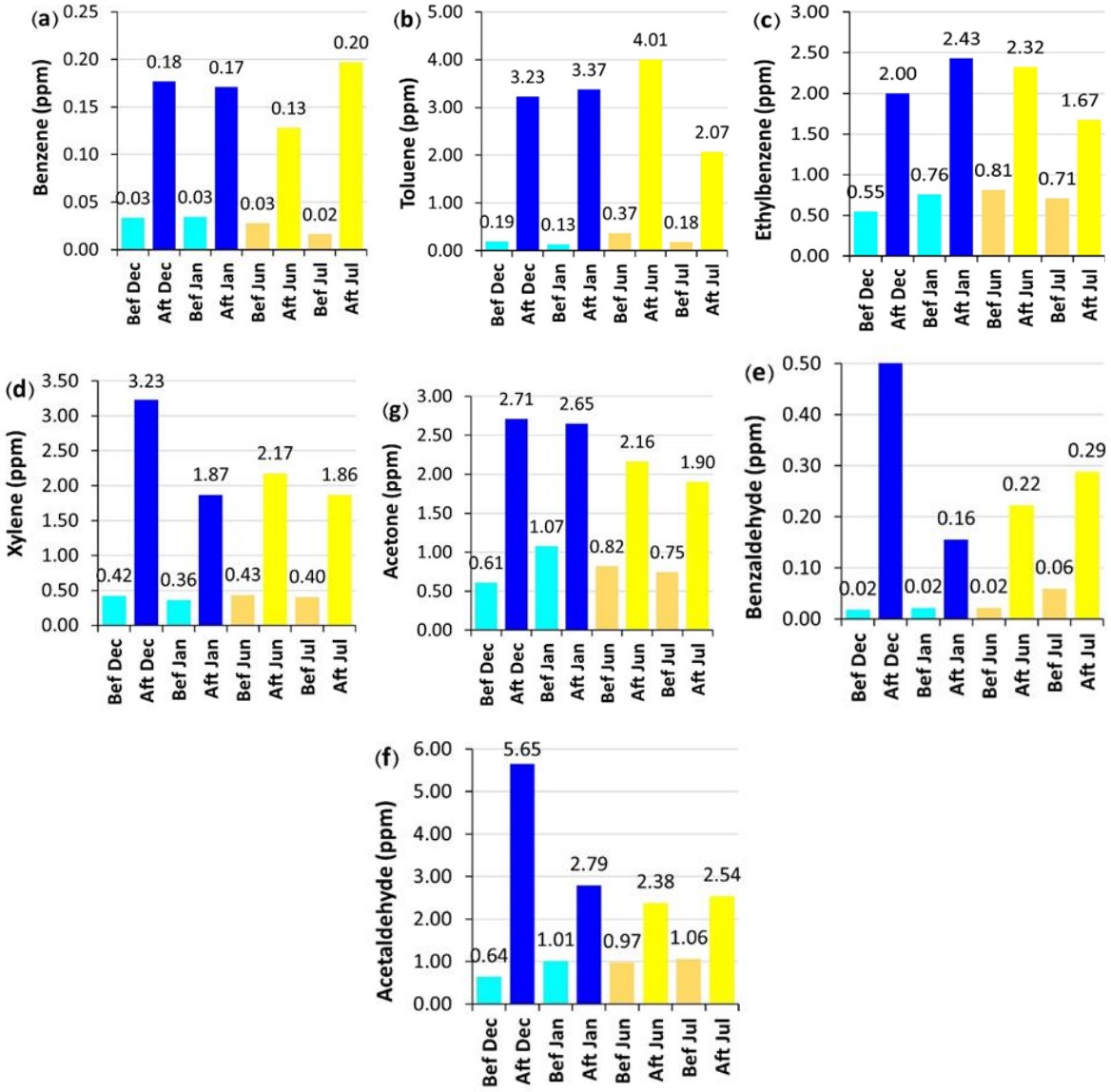


Figure 2. Mean concentrations of VOCs and BTEX measured before (Bef) and after (Aft) activity across different months: (a) Benzene, (b) Toluene, (c) Ethylbenzene, (d) Xylene, (e) Benzaldehyde, (f) Acetaldehyde, and (g) Acetone.

The concentration of toluene increased in the post-activity condition across all months, with the largest variation observed in Khordad (spring, warm season). A comparison of ethylbenzene

concentrations between the pre- and post-activity conditions revealed the most substantial mean change among all assessed pollutants, with its peak mean value recorded in Dey. The highest mean concentration of xylene was observed in Azar (cold season), while the maximum post-activity mean concentration of benzaldehyde also occurred in Azar during the cold season (5.21 ppm). The highest mean acetaldehyde concentration was related to Azar and Dey (cold season). The pattern of changes in the mean acetone was similar to that of acetaldehyde, being related to the months of Azar and Dey (cold season).

Table 4 presents the most frequently observed clinical symptoms among the salon workers. The highest symptom severity and prevalence were observed during work, predominantly affecting the ocular, nasal, and respiratory systems, respectively. Specifically, these included eye tearing and itching (77.1%), rhinorrhea (46.9%), cough (43.8%), shortness of breath (26.0%), and itching and eczema (22.9%). Conversely, anger, depression, and concentration difficulties (0%) indicated a complete absence of chronic neurological symptoms. Following the work shift, symptom rates decreased markedly (e.g., shortness of breath dropped to 3.1%), suggesting that these symptoms were primarily driven by occupational exposure.

Table 4. Prevalence of clinical symptoms among salon workers during work hours.

Clinical Symptom (N)	Prevalence (%)	Number of Workers (N)
Rhinorrhea and eye itching	77.1	96
Nasal discharge	46.9	96
Cough during work	43.8	96
Dyspnea	26.0	96
Frequent headaches	15.6	96
Itching and eczema	22.9	96
Clinical Symptom (N)	Prevalence (%)	Number of Workers (N)

Table 5 presents a comparison of the mean and maximum values of the pollutants with the permissible limits announced by reputable authorities (including OSHA, ACGIH, and NIOSH). The results show that most samples were within safe ranges. However, several notable cases were identified. Specifically, for ethylbenzene, one sample was recorded with a concentration higher than the permissible limit. Several measured values for benzaldehyde exceeded the short-term exposure limit (STEL), which is equivalent to 2 ppm. Furthermore, acetaldehyde levels approached the NIOSH permissible exposure limit (PEL) in one instance.

Table 5. Comparison of mean and maximum concentrations of pollutants with occupational exposure limits established by authoritative organizations (OSHA, ACGIH, and NIOSH).

Pollutant	Mean(ppm)	Maximum(ppm)	OSHA Limit(ppm)	ACGIH Limit(ppm)	NIOSH Limit(ppm)
Benzene	0.0981	0.8400	1 (TWA)	0.5 (TWA)	0.1 (TWA)
Toluene	1.6931	7.5500	100 (TWA)	20 (TWA)	100 (TWA)
Ethylbenzene	1.4072	36.6600	100 (TWA)	100 (TWA)	100 (TWA)
Xylene	1.3429	6.6300	100 (TWA)	100 (TWA)	100 (TWA)
Benzaldehyde	0.7498	98.0000	—	2 (STEL)	—
Acetaldehyde	2.1302	25.3200	—	25 (TWA)	—
Acetone	1.5844	8.2400	1000 (TWA)	250 (TWA)	—

The t-test was used to determine the relationship between the clinical symptoms of employees and the mean concentration of VOCs. A significant relationship was observed between the concentration of some pollutants and the symptoms of eye tearing and itching ($P = 0.031$, $p < 0.05$), runny nose ($P = 0.015$, $p < 0.05$), shortness of breath ($P = 0.047$, $p < 0.05$), and cough ($P = 0.025$, $p < 0.05$) among the salon staff. Statistical differences between pollutant concentrations and the groups that had eye tearing and itching showed a statistically significant relationship between the concentration of xylene, benzaldehyde, acetaldehyde, and acetone in Khordad, or ethylbenzene and acetaldehyde in Tir, and the pattern of eye tearing and itching in salon workers ($P = 0.031$, $p < 0.05$). Also, a statistically significant relationship was found between the concentration of ethylbenzene in Azar, xylene, benzaldehyde, and acetaldehyde in Dey, xylene, benzaldehyde, acetaldehyde, and acetone in Khordad, and benzaldehyde, acetaldehyde, and acetone in Tir, and the groups that had runny nose ($P = 0.015$, $p < 0.05$). Xylene in the two cold seasons of the year (autumn and winter) had a significant level with the cough pattern compared to the warm seasons (spring and summer) ($P = 0.047$, $p < 0.05$).

3. Discussion

The results of this study clearly show that the concentration of all measured pollutants increased significantly after salon activity. The increase in mean concentrations up to 5-fold (for example, benzaldehyde concentration rose from 0.0177 ppm to 5.2127 ppm) after work activity confirms the release of VOCs of occupational origin (keratin cosmetic materials and nail polish), direct release or evaporation of compounds from cosmetic products, chemical reactions resulting from the combination of materials, and the type of cosmetic activities. The results of the present study are consistent with those of previous studies that reported the presence of VOCs in the indoor air of beauty salons. For example, Sanja Kezic et al. in a systematic study in 2022 in the Netherlands, reviewing 23 studies from 14 countries, showed that beauty salon employees are simultaneously exposed to a wide range of hazardous chemicals, and different hair treatment methods along with the chemical products used play a major role in the accumulation of these pollutants in indoor air. Pollutant concentrations depend on salon characteristics—such as ventilation systems, customer volume, and product utilization—which frequently vary by country or clientele (16). In a 2014 study conducted in southern Italy, De Gennaro et al. performed a one-week monitoring campaign using diffusive samplers across 12 beauty salons to identify dominant VOCs and their primary emission sources (materials or activities). They also administered questionnaires to gather data on workplace characteristics and operational activities. Their findings revealed that VOC concentrations were primarily driven by the types of products used, whereas room size, ventilation efficiency, and customer volume exerted a comparatively minor influence (13).

Comparing the mean and maximum pollutant concentrations with permissible limits established by reputable authorities indicated that most samples fell within safe thresholds. However, a notable exception was ethylbenzene, where one sample exceeded the permissible limit. Furthermore, several benzaldehyde concentrations surpassed the short-term exposure limit (STEL) of 2 ppm, suggesting potential health risks associated with short-term exposure. In the case of acetaldehyde, one recorded concentration closely approached the NIOSH permissible exposure limit. These findings indicate that although conditions appear manageable, the occurrence of intermittent, high-concentration exposures highlights the need for continuous monitoring and special control measures for hazardous materials. A 2023 study in Tehran investigated the presence of BTEX compounds in the breathing zone of nail technicians in 49 beauty salons. In most cases, the BTEX concentration observed in this study was between or above the permissible values, which is consistent with the results of the present study (17). In a 2019 study conducted in Colorado, Lamplugh et al. measured indoor concentrations of formaldehyde, benzene, toluene, ethylbenzene, and xylene across six nail salons. Health questionnaires administered to 20 employees gathered data on demographic characteristics, work-related health symptoms, and the use of personal protective equipment. The findings revealed that 70% of the participating employees experienced at least one job-related health issue, with many reporting multiple symptoms. Furthermore, indoor formaldehyde levels across all six salons ranged from 5.32 to 20.6 $\mu g/m^3$. Indoor toluene concentration ranged from 26.7 to 816 $\mu g/m^3$, followed by benzene (3.13 to 51.8 $\mu g/m^3$), xylene (5.16 to 34.6 $\mu g/m^3$), and ethylbenzene (1.65 to 9.52 $\mu g/m^3$). The formaldehyde level measured in one salon exceeded the recommended exposure limit set by the National Institute for Occupational Safety and Health (3).

The results indicate a substantial difference in the mean concentrations of seven volatile organic compounds—namely benzene, toluene, ethylbenzene, xylene, benzaldehyde, acetaldehyde, and acetone—between pre-activity and post-activity conditions in the salons. An analysis of individual pollutants revealed that benzene concentrations increased moderately following salon activities, likely attributable to its presence in certain solvents and commercial products. Toluene exhibited a marked surge, which is well-supported by its widespread application in polishes and removers. Similarly, ethylbenzene showed a significant increase, probably originating from aromatic components in volatile solvents. Xylene displayed a moderate rise, indicating emissions from activities involving paints, thinners, and coating materials. In contrast, benzaldehyde maintained high levels both before and after salon operations, a trend likely linked to the use of essential oils and perfumes. Acetaldehyde also increased considerably, pointing to either chemical reaction by-products or direct product emissions. Finally, acetone demonstrated a sharp post-activity increase, as expected given its high volatility and extensive use in removers and cosmetic formulations.

Although mean concentrations remained well below occupational exposure limits set by OSHA and ACGIH, the significant post-activity increases warrant careful attention. Each detected pollutant presents specific health concerns: benzene is carcinogenic even at low levels, toluene poses potential neurological risks, xylene acts as a respiratory tract irritant, benzaldehyde causes olfactory and mucosal irritation, and acetaldehyde irritates the eyes and respiratory system. Furthermore, the high volatility and frequent use of acetone contribute to indoor

emissions. These chemical risks, combined with the reported employee symptoms—such as eye itching, rhinorrhea (runny nose), shortness of breath, cough, and headache—align closely with pollutant exposure. From an occupational health perspective, these findings underscore the critical need for continuous monitoring and effective control measures.

These results are also consistent with those of other studies. In a study by Janjani et al. in 2023 in Kermanshah, 30 indoor air samples of beauty salons were studied for the concentration of VOCs and BTEX. The results showed that toluene with a maximum concentration of 219.4 ($\mu g/m^3$) was the most abundant compound in beauty salons. Their study concluded that use of solvents and cosmetic products, improper heating systems, and the type of services are sources that probably play a role in the emission of BTEX in beauty salons (18).

In another similar study, Norouzian Baghani et al. evaluated the indoor air quality of 50 beauty salons in Ardabil, investigating the concentration of benzene, toluene, ethylbenzene, and xylene (BTEX). The results of their study showed that the mean benzene concentration (32.40 ± 26.38 $\mu g/m^3$) was higher than the levels recommended by Health Canada, ANSES, and HKSAR. Among the BTEX, ethylbenzene (62.38 ± 32.37 $\mu g/m^3$) had the highest concentration in the salons. the estimated cancer risk values for long-term exposure to benzene across different age groups—namely from birth to <6 years, 6 to <21 years, and 21 to <81 years—were 1.83×10^{-3}, 2.76×10^{-4}, and 1.50×10^{-4}, respectively. For ethylbenzene, the corresponding risk values across the same age groups were 4.90×10^{-4}, 7.30×10^{-5}, and 3.52×10^{-5}, respectively. Notably, all these values were significantly higher than the recommended safety thresholds (19).

Comparing the mean concentrations of chemical pollutants based on the presence or absence of ventilation demonstrated that ventilation conditions play a critical role in mitigating indoor pollution loads. Specifically, post-activity benzene concentrations in Azar were significantly higher in unventilated environments compared to ventilated ones ($p = 0.004$). A similar pattern was observed for post-activity toluene concentrations in Dey ($p = 0.041$). The results of the present study are consistent with the general results of all previous studies regarding the role of ventilation in reducing the concentration of chemical pollutants. For example, in an analytical cross-sectional study conducted in Gonabad in 2023, Ajorti et al. evaluated 10 women's beauty salons. Their findings demonstrated that stringent control and management of ventilation can effectively improve indoor air quality in such environments (20).

In another study conducted in Tehran, Hadei et al. evaluated 20 beauty salons and demonstrated that ventilation conditions play a pivotal role in reducing indoor VOC concentrations within these environments (6). Zhong et al. determined the levels of VOCs such as formaldehyde and methyl methacrylate (MMA) and other indoor air parameters in 17 nail salons in the autumn and winter seasons in three areas of Michigan. Their results indicated that cosmetic products serve as significant emission sources, with the widespread presence of MMA and toluene. Furthermore, 'informal' short-term sampling approaches can effectively assess chemical exposure in nail salons, yielding valuable data to protect susceptible and vulnerable populations. Implementing additional controls—such as restrictions on VOCs and enhanced ventilation systems—can substantially mitigate occupational and customer exposure risks 21).

The results showed a significant relationship between the concentration of some pollutants and the symptoms of eye tearing and itching ($P = 0.031$, $p < 0.05$), runny nose ($P = 0.015$, $p < 0.05$), shortness of breath ($P = 0.047$, $p < 0.05$), and cough ($P = 0.025$, $p < 0.05$) among salon staff. Specifically, elevated concentrations of ethylbenzene and xylene (ranging between 1 and 3 ppm) were recorded in some salons, levels known to induce eye and nasal irritation as well as neurological effects. This symptom pattern aligns consistently with typical exposures to VOCs and BTEX. From an occupational health perspective, these findings are largely attributable to specific job activities, such as keratin treatments and nail services, combined with inadequate ventilation—serving as a critical warning that highlights the urgent need for enhanced control measures and improved ventilation systems. Also, based on the results obtained from the questionnaire, the pattern of irritative symptoms during work (ocular, respiratory, skin) is consistent with the known effects (irritation of mucous membranes). These symptoms include eye tearing and itching (77.1%), runny nose (46.9%), cough (43.8%), shortness of breath (26%), and itching and eczema (22.9%), which indicates direct exposure to chemicals and pollutants. The results of the present study are consistent with those of previous studies. For instance, in a 2016 study conducted in Dammam, Saudi Arabia, Al-Marshad evaluated 14 beauty centers regarding both air quality and respiratory symptoms. The results demonstrated that indoor VOC concentrations exceeded outdoor levels, with ventilation playing a crucial role in mitigating these compounds; furthermore, a significantly higher prevalence of respiratory symptoms—specifically grade 2 dyspnea ($p=0.045$) and wheezing ($p=0.045$)—was observed among hair-section workers compared to those in

other areas. Similarly, our findings revealed a high prevalence of work-related symptoms among both keratin and nail technicians, including eye tearing and itching (77.1%), rhinorrhea (46.9%), cough (43.8%), dyspnea (26.0%), and pruritus/eczema (22.9%), collectively highlighting direct occupational exposure to hazardous chemicals (22). In a similar study, Ma et al. evaluated employees of several nail service salons in the eastern United States in terms of exposure to VOCs and BTEX. Their results showed that the most common health complaints included irritation of nose (21.4%), throat (11.6%), eye (17%), and skin (11.6%). Some participants experienced headache (8%) and dizziness (9.8%) after starting work in the nail salon. In addition, 15.5% of workers responded that their irritation worsened after starting work, and 15.6% experienced at least one miscarriage. Other symptoms that workers experienced at least one day a week included chronic cough, respiratory problems, nausea, shoulder pain, tendinitis, carpal tunnel syndrome, and arthritis, which is consistent with the results of the present study 23).

In another study, Pavilonis et al. evaluated indoor air quality of 10 nail salons located in New York City. The results showed that due to the nature of nail products and services, salon air can be filled with a combination of low levels of hazardous air pollutants. Studies conducted on nail technicians have usually shown an increase in work-related symptoms, such as headache and respiratory irritation, which is consistent with indoor air quality problems 24).

Novelty and Added Value of the Study

By simultaneously measuring seven BTEX and other VOCs during four months in each of two consecutive years, both before and after salon activities, this study provides a comprehensive assessment of occupational exposure in women's beauty salons across four urban settings in western Ahvaz: high-traffic, low-traffic, residential, and industrial areas. In contrast to many previous studies, which have focused on nail salons or a single city, this study examines spatial and seasonal variation in the same salons and assesses the relationships between pollutant concentrations, self-reported symptoms, and ventilation. The integration of these elements—spatial and seasonal comparisons, concurrent measurement of multiple pollutants, and a health questionnaire—distinguishes this study from previous research and extends the available evidence in this field.

Caution in Causal Interpretation

It should be noted that this study is cross-sectional, and therefore the observed associations between pollutant concentrations and self-reported symptoms cannot be interpreted as causal relationships. The study design does not allow determination of the direction of causality, and other confounding factors (such as age, work experience, smoking, and underlying health conditions) may play a role in the occurrence of symptoms. Also, exposure assessment was based on cross-sectional measurements and symptoms were assessed using a self-reported questionnaire without clinical examination; both approaches have limitations. Therefore, the findings of this study should be interpreted with caution, and to establish causal relationships, longitudinal studies with more precise assessments of exposure and health outcomes are needed.

4. Conclusion

This study demonstrates that although short-term exposure levels among women's beauty salon workers in western Ahvaz generally remained below international permissible limits (OSHA, ACGIH, NIOSH), the significant increase in BTEX and VOC concentrations during working hours—such as a sharp rise in benzaldehyde from 0.0177 ppm to 5.2127 ppm post-activity—indicates a cumulative and repeated exposure burden. Over the long term, this chronic exposure may lead to irreversible effects on the respiratory and visual systems.

Notably, the significant association between increased pollutant concentrations and a high prevalence of irritative symptoms—including eye itching (77.1%), runny nose (46.9%), cough (43.8%), and shortness of breath (26%)—demonstrates that quantitative exposure standards alone are insufficient to predict clinical effects. Instead, even sub-permissible levels, under conditions of chronic exposure and inadequate ventilation, can trigger adverse physiological reactions. This finding reveals a serious gap between the permissible numerical values and the actual irritation threshold in human tissues.

On the other hand, aggravating factors such as lack of ventilation (26% of salons), job type (73% keratin workers), and reduced ventilation in cold seasons indicate that exposure risks in this industry are driven not solely by routine occupational tasks, but also by workplace design and operational practices. Therefore, the main conclusion of the study is that exposure to VOCs in beauty salons is a hidden but influential occupational safety issue whose risk assessment should not be based solely on numerical standards, but should also include the temporal pattern of exposure, environmental conditions, and clinical signs of salon workers. Finally, In contrast to conventional approaches that focus solely on reducing pollutant concentrations, this study demonstrates that combined environmental and behavioral interventions—such as installing effective local ventilation systems, using personal protective equipment like masks, and providing employee

training—yield a synergistic effect in alleviating symptoms. Because the success of any single measure in isolation is limited, adopting a systemic approach is essential for formulating effective health protocols in this industry.

Future research should address the following areas: 1. Conducting longitudinal studies with more precise assessments of exposure and health outcomes to establish causal relationships; 2. Utilizing standardized health-related quality of life (HRQoL) tools, such as the SF-36 or WHOQOL-BREF, to evaluate employees' quality of life; 3. Incorporating outdoor or background air measurements alongside a control group to better differentiate exposure sources; and 4. Systematically documenting specific beauty services, customer density, and working hours to characterize occupational exposure more accurately.

Footnotes

Acknowledgments: This article is derived from Maryam Nazari's master's thesis which was carried out with the support of Ahvaz Jundishapur University of Medical Sciences (APRD-0303).

Authors' Contribution: A. N. developed the study concept and design. M. N. acquired the data and wrote the original draft of the manuscript. G. G. and S. G. analyzed and interpreted the data. All authors contributed to the intellectual content, manuscript editing and read and approved the final manuscript.

Conflict of Interests Statement: The authors declare no conflict of interest.

Ethical Approval: The study was approved by the Ethical Committee of Ahvaz Jundishapur University of Medical Sciences (code: IR.AJUMS.REC.1403.342).

Funding/Support: The financial support of Ahvaz Jundishapur University of Medical Sciences (Grant no APRD-0303), is gratefully acknowledged.

Reference

1. Acharya SR, Moon DH, Shin YC. Assessment of VOCs, PM10, and Formaldehyde Exposure in the Hair Salons of South Korea. 2020 Dec 10;5(4):1103–8. DOI: 10.18502/jehsd.v5i4.4958

2. Choi YH, Lee JY, Moon KW. Exposure to volatile organic compounds and polycyclic aromatic hydrocarbons is associated with the risk of non-alcoholic fatty liver disease in Korean adolescents: Korea National Environmental Health Survey (KoNEHS) 2015-2017. 2023 Feb 2. DOI: 10.1016/j.ecoenv.2023.114508.

3. Lamplugh A, Harries M, Xiang F, Trinh J, Hecobian A, Montoya LD. Occupational exposure to volatile organic compounds and health risks in Colorado nail salons. Environ Pollut. 2019 Jun;249:518-526. DOI: 10.1016/j.envpol.2019.03.086.

4. Shuai J, Kim S, Ryu H, Park J, Lee CK, Kim GB, Ultra VU Jr, Yang W. Health risk assessment of volatile organic compounds exposure near Daegu dyeing industrial complex in South Korea. BMC Public Health. 2018 Apr 20;18(1):528. DOI: 10.1186/s12889-018-5454-1.

5. Han I, Seo JY, Barr DB, Panuwet P, Yakimavets V, D'Souza PE, An-Han H, Afshar M, Chao YY. 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 Public Health. 2022 Sep 29;19(19):12411. DOI: 10.3390/ijerph191912411.

6. Hadei M, Hopke PK, Shahsavani A, Moradi M, Yarahmadi M, Emam B, Rastkari N. Indoor concentrations of VOCs in beauty salons; association with cosmetic practices and health risk assessment. J Occup Med Toxicol. 2018 Sep 27;13(30). DOI: 10.1186/s12995-018-0213-x.

7. Tsai WT. An overview of health hazards of volatile organic compounds regulated as indoor air pollutants. Rev Environ Health. 2019 Mar 26;34(1):81-89. DOI: 10.1515/reveh-2018-0046.

8. Ronda E, Hollund BE, Moen BE. Airborne exposure to chemical substances in hairdresser salons. Environ Monit Assess. 2009 Jun;153(1-4):83-93. DOI: 10.1007/s10661-008-0338-y.

9. Kim KH, Jahan SA, Lee JT. Exposure to formaldehyde and its potential human health hazards. J Environ Sci Health C Environ Carcinog Ecotoxicol Rev. 2011 Oct;29(4):277-99. DOI: 10.1080/10590501.2011.629972.

10. Song SK, Shon ZH, Kang YH, Kim KH, Han SB, Kang M, Bang JH, Oh I. Source apportionment of VOCs and their impact on air quality and health in the megacity of Seoul. Environ Pollut. 2019 Apr;247:763-774. DOI: 10.1016/j.envpol.2019.01.102.

11. Perumalla Venkata R, Subramanyam R. Evaluation of the deleterious health effects of consumption of repeatedly heated vegetable oil. Toxicol Rep. 2016 Aug 16(3):636-643. DOI: 10.1016/j.toxrep.2016.08.003.

12. Soni V, Singh P, Shree V, Goel V. Effects of VOCs on human health. In: Air Pollution and Control: Springer; 2017. p. 119-142. DOI: 10.1007/978-981-10-7185-0_8.

13. de Gennaro G, de Gennaro L, Mazzone A, Porcelli F, Tutino M. Indoor air quality in hair salons: Screening of volatile organic compounds and indicators based on health risk assessment. Atmospheric Environment. 2014;83:119-26. DOI: 10.1016/j.atmosenv.2013.10.056.

14. Zhong Z, Li G. Current trends in sample preparation for cosmetic analysis. J Sep Sci. 2017 Jan;40(1):152-169. DOI: 10.1002/jssc.201600367.

15. Henault P, Lemaire R, Salzedo A, Bover J, Provot G. A methodological approach for quantifying aerial formaldehyde released by some hair treatments-modeling a hair-salon environment. J Air Waste Manag Assoc. 2021 Jun;71(6):754-760. DOI: 10.1080/10962247.2021.1893238.

16. Kezic S, Nunez R, Babić Ž, Hallmann S, Havmose MS, Johansen JD, John SM, Macan M, Symanzik C, Uter W, Weinert P, Turk R, Macan J, van der Molen HF. Occupational Exposure of Hairdressers to Airborne Hazardous Chemicals: A Scoping Review. Int J Environ Res Public Health. 2022 Mar 31;19(7):4176. DOI: 10.3390/ijerph19074176.

17. Ebrahimi V, Yarahmadi R, Salehi M, Ashtarinezhad A. Exposure assessment to BTEX in the air of nail salons in Tehran city, Iran. Heliyon. 2023 Jul 13;9(7):e18195. DOI: 10.1016/j.heliyon.2023.e18195.

18. Janjani H, Yunesian M, Yaghmaeian K, Aghaei M, Yousefian F, Alizadeh B, Fazlzadeh M. BTEX in indoor air of barbershops and beauty salons: Characterization, source apportionment and health risk assessment. Chemosphere. 2023 Dec;345:140518. DOI: 10.1016/j.chemosphere.

19. Baghani AN, Rostami R, Arfaeinia H, Hazrati S, Fazlzadeh M, Delikhoon M. BTEX in indoor air of beauty salons: Risk assessment, levels and factors influencing their concentrations. Ecotoxicol Environ Saf. 2018 Sep 15;159:102-108. DOI: 10.1016/j.ecoenv.2018.04.044.

20. Ojrati A, Qasemi M, Zarei A. Human Health Risk Assessment of Formaldehyde in the Indoor Air of Women's Beauty Salons in Gonabad City. Journal of Health. 2023;14(1):7-21. DOR: 20.1001.1.23829710.1402.14.1.1.6. [In persion]

21. Zhong L, Batterman S, Milando CW. VOC sources and exposures in nail salons: a pilot study in Michigan, USA. Int Arch Occup Environ Health. 2019 Jan;92(1):141-153. DOI: 10.1007/s00420-018-1353-0.

22. Almarshad S. Assessing Indoor Air Pollution within Different Areas of Female Beauty Centers and Exploring Their Relation to Various Respiratory Symptoms. Pollution. 2016;2(3):357–364. DOI: 10.7508/pj.2016.03.009.

23. Ma GX, Wei Z, Husni R, Do P, Zhou K, Rhee J, Tan Y, Navder K, Yeh MC. Characterizing Occupational Health Risks and Chemical Exposures Among Asian Nail Salon Workers on the East Coast of the United States. J Community Health. 2019 Dec;44(6):1168-1179. DOI: 10.1007/s10900-019-00702-0.

24. Pavilonis B, Roelofs C, Blair C. Assessing indoor air quality in New York City nail salons. J Occup Environ Hyg. 2018 May;15(5):422-429. DOI: 10.1080/15459624.2018.1447117.