Health Risk Assessment of Total Volatile Organic Compounds Concentration in Indoor Air: A Case Study of Hair Salon

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Abstract

The objective of this study was to conduct non-participant observation research and naturalistic observation in real-world settings. The study aimed to investigate the concentration of total volatile organic compounds (TVOCs) in hair salons and to assess the health risks associated with TVOCs in hair salons in the Nong Chok District, Bangkok. Total volatile organic compounds were measured on both weekdays and weekends using a total volatile organic compound measuring instrument (RAE SYSTEMS, model MiniRAE 3000+). The study results show that the highest average concentration of TVOCs at Site A occurred on Sunday, with a value of 0.315 ppm. At Site B, the concentration exceeded the Department of Health's standard threshold of 0.56 ppm on Wednesday, Friday, Saturday, and Sunday, with values of 0.664, 0.602, 2.388, and 0.875 ppm, respectively. There was no statistically significant difference between weekdays and weekends ($p > 0.05$). The Exposure Concentration Index (EC) was 0.007 ppm at Site A on Sunday and 0.055 ppm at Site B on Saturday. The Hazard Index (HI) is an indicator of the hazard level of a substance, representing the weekly average concentration of total volatile organic compounds (TVOCs). At Site A, the HI was 0.006, while at Site B, it was 0.047. An HI value less than or equal to 1 indicates that exposure to the substance does not pose non-carcinogenic adverse health effects.

Keywords: hair salon, indoor air pollution, health risk assessment, total volatile organic compounds

1. Introduction

Total Volatile Organic Compounds (TVOCs) are the sum of organic compounds that can evaporate into the air at room temperature. TVOCs consist of various highly volatile chemicals, most of which can have health effects such as respiratory irritation, headaches, and, in some cases, may cause cancer when exposed to high concentrations (Environmental Protection Agency (EPA), 2024; David, & Niculescu, 2021). These compounds are commonly found in products such as car paints, cleaning agents, perfumes, and construction and furniture materials (EPA, n.d.).

In Nong Chok District, Bangkok, urban growth, the expansion of housing estates, and an increasing population (Nong Chok District Office, 2022) have contributed to the growth of economic activities. This has led to the widespread use of products containing TVOCs in various establishments, such as nail salons, hair salons, and photocopy shops, where these products are used in large quantities and on a regular basis. This study is significant as it aims to measure and assess the levels of TVOCs in hair salons, which are high-risk sources of volatile organic compound (VOC) emissions due to the frequent use of chemical-containing products, such as perm solutions, hair straightening solutions, hair sprays, and hair dyes.

These products often contain VOCs such as formaldehyde, acetone, toluene, and benzene, which can be released into the indoor air of the salon (McNary, & Jackson, 2007; Zhang et al., 2019). The accumulation of TVOCs in the indoor air was assessed to determine whether it complied with the Department of Health's standard threshold of 0.56 ppm (Department of Health, 2022). This study not only focuses on measuring and analyzing chemical concentrations in the air at different time periods but also compares TVOC levels between regular working days and weekends. The accumulation of TVOCs in indoor air at hair salons may impact the health of both hairdressers and customers, particularly in salons with inadequate ventilation systems. Prolonged exposure to these compounds can lead to eye, nose, and respiratory irritation, and may

also increase the risk of long-term chronic diseases (Cohen et al., 2017; Madureira et al., 2015). Therefore, selecting specific hair salons for data collection is essential for assessing TVOC levels and identifying strategies to mitigate health risks for individuals in such environments.

The information obtained from this study will play an important role in developing guidelines and measures to reduce the risk of exposure to TVOCs. These measures may include improving ventilation systems, using personal protective equipment, selecting products with low TVOCs, or changing work processes to reduce the release of chemicals into the air. The results of the study can also serve as a foundation for developing appropriate environmental management plans and guiding the development of local and national health and environmental policies.

2. Objectives

1) To investigate the characteristics and concentrations of total volatile organic compounds (TVOCs) in hair salons.

2) To compare the concentration of VOCs between weekends and weekdays.

3) To assess the health risks associated with exposure to total volatile organic compounds (TVOCs) at hair salon sites in the Nong Chok District, a comprehensive study was conducted.

3. Materials and Methods

This study focuses on assessing the concentration of Total Volatile Organic Compounds (TVOCs) indoors in Nong Chok District, Bangkok. Two hair salons were selected, that regularly use TVOCs-emitting products.

3.1 TVOC Sampling

3.1.1 Indoor TVOC samples were monitored near the hairdressing station while they were in use during activities. The continuous real-time measurements were conducted by a photoionization detector (PID), Model: MiniRAE 3000+, RAE Systems, Honeywell Inc., Sunnyvale, CA, USA. TVOC concentrations were recorded every 1 second and were collected from 7 working days, from 9 am to 6 pm. The PID was equipped with a 10.6 eV lamp that had a sampling flow rate of 0.5 lmin−1 (Hori et al., 2015), a resolution of 0.1 ppm in the detected range of 0–15,000 ppm (Jia et al., 2019), and the average represented the TVOC concentration for that section (RAE System, 2018; Pongboonkhumlarp, & Jinsart, 2022).

3.1.2 Criteria for selecting hair salon sampling sites. The selected hair salons for sampling were required to conduct only hair coloring activities, excluding nail coloring services. Additionally, the salons had to have similar floor area sizes and fan or air conditioning systems to ensure a comparable environmental setting.

3.1.3 The measurement device was installed at a height of 140-160 centimeters, at breathing level, and near the point where the product was used. (see Figure 1). Each day of sampling started at 9:00 AM and ended at 5:00 PM. The average number of customers who undergo hair coloring or other chemical treatments is about 1 to 3 on weekdays and 5 to 7 on weekends. It was found that the number of customers at Site A was lower than at Site B.

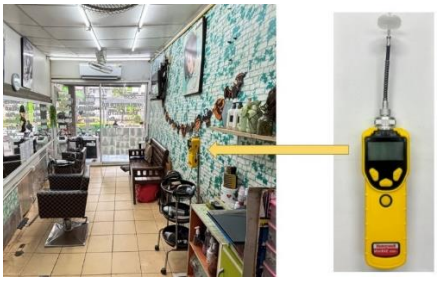

Figure 1 MiniRae3000+ and sample collection location.

3.2 Data Analysis and Risk Assessment

3.2.1 Comparison of Total Volatile Organic Compounds (TVOCs) Concentrations with Standard Thresholds.

TVOCs concentrations were calculated based on the daily average values from two sampling points. All data were averaged over an 8-hour period. Statistical analysis was conducted using SPSS. The distribution of TVOCs within the hair salon was analyzed using the non-parametric Kruskal–Wallis test (Pongboonkhumlarp, & Jinsart, 2022) and compared with the Department of Health's standard threshold of 0.56 ppm (Department of Health, 2022).

3.2.2 Exposure Concentration (EC)

To assess the potential risk level from exposure to Total Volatile Organic Compounds (TVOCs) in each area, the Exposure Concentration (EC) was calculated based on the principles of environmental risk assessment, using the following scientifically accepted equations (1) (U.S. EPA, 2011)

$$EC = \frac{C \times ET \times EF \times ED}{AT} \quad (1)$$

Where:

• C = Indoor air pollution concentration (ppm)
• ET = Exposure duration (hrs/day)
• EF = Exposure frequency ($day/year$)
• ED = Exposure duration ($year$)
• AT = Average exposure duration (day)

where C is concentration of TVOC as measured; ET is the exposure time as 8 h/day from the measured; EF is the exposure frequency as 250 days/year; ED is the exposure duration at 25 years for non-carcinogenic substances (U.S. EPA, 2013); AT is the average time (for non-carcinogens AT = ED × 365 days × 24 h/day) (Zhang et al., 2016; Pongboonkhumlarp, & Jinsart, 2022).

The EC index reflects the concentration of pollutants to which a person is exposed over a period of time to TVOCs, which can be used to assess health risks.

3.2.3 Hazard Quotient (HQ)

To assess the potential risk level from exposure to Total Volatile Organic Compounds (TVOCs) in each area, the Hazard Quotient (HQ) was calculated based on the principles of environmental risk assessment, using the following scientifically accepted equations (2) (U.S.EPA, 2008b; Pongboonkumlap, 2020)

$$HQ = \frac{EC}{Rfc} \quad (2)$$

Where:

EC is Daily Average Exposure Concentration

Rfc is TVOC reference concentration using standards in Kuwait, Malaysia, and Singapore, with an indoor standard concentration of 3 ppm (Abdul-Wahab et al., 2015; Pongboonkhumlarp, & Jinsart, 2022).

The HQ index is an indicator of the level of risk posed by exposure to a pollutant. If the HQ value is greater than 1.0, it indicates a potential health risk, and preventive measures are required.

3.2.4 Hazard Index (HI)

means the sum of more than one hazard quotient for multiple substances, multiple exposure pathways, or both. The Hazard Index is calculated separately for chronic, subchronic, and shorter duration exposures as the sum of the hazard quotients using Eq. (3) (U.S.EPA, 2014; Pongboonkumlap, 2020)

$$HI = \sum HQ \quad (3)$$

HI value less than or equal to 1 indicates that the exposure is not likely to result in adverse non-carcinogenic effects. In the case of HI value greater than 1, however, it does not necessarily suggest a likelihood of adverse health effects but still potentially poses a risk (U.S. EPA 2018b; Pongboonkhumlarp, & Jinsart, 2022).

4. Results and Discussion

In this study, the concentration of Total Volatile Organic Compounds (TVOCs), which are air pollutants that can affect human health and the environment, was analyzed. The TVOC concentration was measured using the Rae 3000+ instrument at two study sites, Site A and Site B, with data collected over 7 days to compare contamination levels between the two sites. In addition, the Exposure Concentration (EC) and Hazard Quotient (HQ) values were calculated as criteria to assess the potential risk of exposure to pollutants in each area. The mathematical formulas used to calculate both values are based on principles of environmental risk assessment and have been employed in many studies. The results of the study were presented in tables and graphs to illustrate the trends in pollution levels and risk rates in each area, including a detailed comparison between Site A and Site B.

4.1 Comparison of Total Volatile Organic Compounds (TVOCs) Concentrations with Standard Thresholds

Comparison of TVOC Concentrations Between Site A and Site B: The daily TVOC concentrations measured at each site are shown in Table 1. These values were detected by the Rae 3000+ instrument, which recorded the data daily from Monday to Sunday.

Table 1 TVOCs concentration (ppm) measured by Rae 3000+

Day	Site A (ppm)	Site B (ppm)	Standard Deviation
Monday	0.029	0.553	0.3705
Tuesday	0.106	0.169	0.0445
Wednesday	0.000	0.664	0.4695
Thursday	0.014	0.166	0.1075
Friday	0.030	0.602	0.4045
Saturday	0.242	2.388	1.5175
Sunday	0.315	1.582	0.8959
Average	0.120	0.875	0.5443

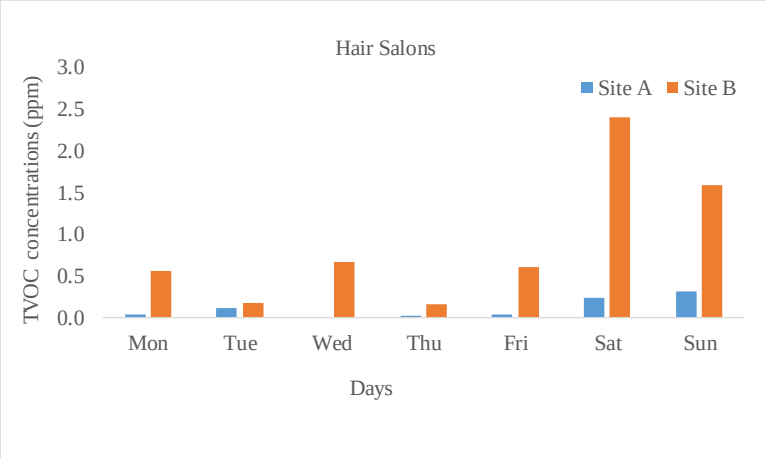

Figure 2 Salon average TVOC concentrations (ppm) of Site A and B.

TVOC concentrations at Site A remained below the standard threshold throughout the week. In contrast, Site B exceeded the Thai Department of Health's standard limit (0.56 ppm) on four out of seven days: Wednesday (0.664 ppm), Friday (0.602 ppm), Saturday (2.388 ppm), and Sunday (1.582 ppm). The standard deviation (SD) of daily TVOC concentrations reflects the variation between the two sampling points. Saturday had the highest SD (1.517 ppm), indicating a substantial difference in TVOC concentrations between the two locations, while Tuesday had the lowest SD (0.045 ppm), suggesting similar concentrations at both measurement points. The differences between the two sites can be attributed to their distinct characteristics,

such as the number of customers and the presence of a ventilation system. Site B lacks a ventilation system like Site A and has a higher customer count. Additionally, weekends typically see a higher number of customers compared to weekdays, leading to increased TVOC concentrations on weekends. Statistical analysis, including the Kruskal-Wallis test, was used to evaluate descriptive statistics (average values, SD)

The Kruskal-Wallis H test results showed that:

• Site A had a p-value of 0.0528, indicating no statistically significant difference at the 0.05 level.

• Site B had a p-value of 0.0528, also indicating no statistically significant difference at the 0.05 level.

This suggests that there was no significant difference in TVOC concentrations between weekdays and weekends according to the Kruskal-Wallis test. However, the p-value was close to 0.05, indicating a potential trend of difference, though the results were not statistically significant due to sample size limitations.

4.2 Exposure Concentration Index (EC)

The results of the EC index calculation from equation (1) are shown in Table 2, which is the value calculated from the TVOCs concentration data measured in the study area.

Table 2 Calculated EC values for each day

Day	Site A (ppm)	Site B (ppm)
Monday	0.001	0.013
Tuesday	0.002	0.004
Wednesday	0.000	0.015
Thursday	0.000	0.004
Friday	0.003	0.014
Saturday	0.006	0.055
Sunday	0.007	0.036
Average	0.003	0.020

This study analyzed the exposure concentration (EC) levels at Site A and Site B over seven consecutive days. TVOC concentrations were ranked in descending order to examine the distribution trends of pollutants each day. The average EC concentration at Site A was 0.003 ppm, while at Site B, it was 0.020 ppm. The EC concentrations were compared according to TVOC levels. Based on the ranked data, Saturday recorded the highest EC concentration at Site B (0.055 ppm), while Wednesday and Friday had similar values of 0.015 ppm and 0.014 ppm, respectively. Monday had the lowest EC concentration at 0.013 ppm. The analysis of EC levels showed a consistent trend with TVOC concentrations, with Site B exhibiting significantly higher values than Site A. Days with elevated TVOC concentrations, such as Saturday and Sunday, corresponded to increased EC levels. The distribution of EC values indicated a positive correlation between airborne pollutant concentrations and the measured EC levels.

4.3 Hazardous Index (HQ)

The HQ index values calculated from equation (2) for each day are shown in Table 3.

Table 3 Calculated HQ values for each day

Day	Site A (ppm)	Site B (ppm)
Monday	0.000	0.004
Tuesday	0.001	0.001
Wednesday	0.000	0.005
Thursday	0.000	0.001
Friday	0.001	0.005
Saturday	0.002	0.018
Sunday	0.002	0.012
Average	0.001	0.007

This study analyzed the Hazard Quotient (HQ) concentrations at Site A and Site B over a seven-day period. TVOC concentrations were ranked in descending order to assess trends and evaluate the potential health risks associated with volatile organic compounds (VOCs). The average HQ concentration at Site A was 0.001 ppm, while at Site B, it was 0.007 ppm. Based on the ranked data, Saturday recorded the highest HQ concentration at Site B (0.018 ppm), followed by Sunday (0.012 ppm). In contrast, Monday had the lowest HQ concentration at 0.004 ppm. The analysis indicated that HQ levels increased on days with higher TVOC concentrations, particularly on Saturday and Sunday. Site B showed HQ values exceeding the standard threshold on multiple days, which may be attributed to the accumulation of VOCs from indoor sources. Elevated HQ levels on certain days suggest a potential health risk from prolonged exposure to air pollutants.

4.4 Hazard Index (HI)

The HI index values calculated from equation (3) for each day are shown in Table 4.

Table 4 Calculate HI values for Site A and B.

Day	Site A (ppm)	Site B (ppm)
Monday	0.000	0.004
Tuesday	0.001	0.001
Wednesday	0.000	0.005
Thursday	0.000	0.001
Friday	0.001	0.005
Saturday	0.002	0.018
Sunday	0.002	0.012
Average	0.006	0.047

This study analyzed the Hazard Index (HI), an indicator of exposure risk to volatile organic compounds (TVOCs), in Site A and Site B over a seven-day period. TVOC concentrations were ranked in descending order, and the average HI concentration was calculated. The average HI at Site A was 0.001 ppm, while at Site B, it was 0.007 ppm. Based on the ranked data, Saturday recorded the highest HI concentration at Site B (0.018 ppm), followed by Sunday (0.012 ppm). The lowest HI concentration was observed on Monday (0.004 ppm).

The HI values were assessed according to the U.S. Environmental Protection Agency (U.S.EPA 2018a; Pongboonkhumlarp, & Jinsart, 2022). According to these guidelines: HI ≤ 1 suggests that exposure to TVOCs at this level is unlikely to cause non-carcinogenic health effects. HI > 1 does not necessarily imply immediate health effects but indicates a potential risk that requires further monitoring.

The findings from this study show that HI values on all measured days were below the threshold of 1, suggesting that TVOC exposure during the monitoring period was not at a high-risk level for adverse health effects. However, elevated TVOC concentrations on certain days, such as Saturday and Sunday, highlight the need for further investigation into the sources of TVOCs and ongoing monitoring.

5. Conclusion

This study investigated the concentration of Total Volatile Organic Compounds (TVOCs) in indoor air at hair salons in Nong Chok District, Bangkok. The results indicated that Site B exhibited higher TVOC concentrations than Site A, with values exceeding the Department of Health's standard threshold (0.56 ppm) (Department of Health, 2022) on four days: Wednesday (0.664 ppm), Friday (0.602 ppm), Saturday (2.388 ppm), and Sunday (1.582 ppm). The highest concentration was observed on Saturday, suggesting significant fluctuations in TVOC emissions depending on salon activities.

Health Risk Implications: Based on the Exposure Concentration (EC) and Hazard Quotient (HQ) values, the study assessed the potential health risks associated with TVOC exposure. The highest EC recorded was 0.055 ppm on Saturday at Site B, while the highest HQ value was 0.018. According to the Hazard Index (HI) framework, all recorded values were below 1, indicating that the exposure levels do not pose immediate non-carcinogenic health risks. However, prolonged exposure, particularly on days with elevated TVOC

levels, may still increase health risks. Short-term health effects of TVOC exposure include eye and respiratory irritation, headaches, dizziness, and nausea. Long-term exposure to high TVOC levels has been linked to chronic respiratory diseases, nervous system disorders, and potential carcinogenic effects due to the presence of hazardous compounds such as benzene, formaldehyde, and toluene.

Recommendations for Improving Air Quality: To mitigate health risks and maintain indoor air quality, the following intervention strategies are recommended:

1) Installation of Air Purifiers: High-efficiency air filtration systems, particularly activated carbon or HEPA filters, should be installed at multiple locations within the salon to capture and neutralize VOCs.

2) Ventilation Improvements: Increasing both natural and mechanical ventilation rates can help reduce TVOC accumulation. The installation of exhaust fans near workstations can significantly lower pollutant levels.

3) Use of Low-VOC Products: Hair salons should transition to low-VOC or VOC-free products, such as organic hair dyes and ammonia-free hair treatments.

4) Regular Monitoring of Air Quality: Routine TVOC monitoring should be conducted to ensure compliance with safety standards and to identify periods of elevated pollution levels.

5) Personal Protective Measures: Salon workers should wear masks and gloves during procedures involving chemical-based hair treatments to minimize exposure.

The findings of this study underscore the importance of air quality control in hair salons. While the TVOC concentrations did not reach immediately hazardous levels based on HI values, repeated exposure to elevated concentrations—especially on high-activity days—warrants further monitoring and preventive measures. The adoption of air purification systems, improved ventilation, and the use of low-VOC products would effectively reduce potential health risks associated with TVOC exposure and promote a safer working environment for both salon employees and customers.

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