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Working Conditions and Health Risk Assessment in Hair Salons

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ABSTRACT: Objective:The aim of this study was to assess the chemical and physical work conditions in hair salons and to analyze health risk of exposure to VOCs for the hairdressers of hair salons. **Methods:** This study was carried out at 4 selected hair salons close to universities in Surat Thani province, Thailand. VOCs were collected by area sampling using charcoal tubes (9 samples per salon). The air samples were analyzed using GC/FID. The noise levels, illumination, and temperature were measured by using sound level meter, lux meter, and WBGT, respectively. **Results:** Toluene, cyclohexanone, xylene, and hexane were the most frequently found across the hair salons. All of the VOCs concentration was highest in the mixing area. All of hair salons had cancer risk exceeding 1×10^{-6} and HI > 1.0, indicating that indoor air pollution may affect hairdresser's health. The average VOCs concentrations after installation of local exhaust ventilation and open the door for 30 minutes before closing the hair salon, was significantly lower than before and after installation of the local exhaust ventilation. The WBGT indoors varied within 22 to 28°C, sound pressure levels within 71 to 76 dBA, and illumination within 70 to 400 lux. The noise levels and temperature in the hair salons were satisfactory on the scale of the Ministry of Labor (Thailand). **Conclusions:**Installing and using proper ventilation in hair salon are recommended to eliminate health effects. Hairdresser worked in poor lighting that should be improved to appropriate levels (>1000 lux).

KEYWORDS: Volatile organic compounds, hairdresser, illumination, temperature, noise

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Introduction

In Thailand, hair salon is a growing business with revenue over 56 million Thai baht in 2017 and its employment increased 85% from 2010 to 2017. Moreover, there is approximately 1 hairdresser for every 300 of the population, and there are 121,635 salons.[1] At the present time, very few published research studied about chemical exposure levels in hairdressing salons in Thailand. The only 1 study investigated the formaldehyde exposure of hairdressers in salons. Those results indicated that 19 salons had higher concentration than NIOSH standards, and 31 hairdressers were exposed to unacceptable risk levels according to US EPA.[2] Hairdressers are exposed to occupational health hazards from chemical and physical factors in their work. Normal services in a hair salon include cutting, cleaning, styling, bleaching, coloring, waving, or straightening of the hair. These activities involve a wide variety of chemicals in the hair care products. These chemicals can cause indoor air quality (IAQ) problems and relate to the sick building syndrome (SBS).[3-5] Genotoxic effects and cancer have been linked to chemical exposure of hairdressers.[6-9] The International Agency for Research on Cancer (IARC) classified dichloromethane as a probable human carcinogen (Group 2A).[10] Toluene is suspected to be teratogenic and can affect reproductive and central nervous systems.[11] Some chemical exposures can lead to occupational skin and respiratory disorders. The use of persulfates during hair bleaching is associated with increased risk of asthma, laryngitis, rhinitis, and dermatitis.[12-21] Volatile organic compounds (VOCs) in hair spray may cause cardiovascular effects.[22]

The physical environmental factors, such as temperature, illumination, and sound in hair salons, may cumulatively increase the health risks. Hairdressers normally use hairdryers and work very close to these sources of high temperature air and noise. In addition to inadequate and inappropriate illumination, high temperature and noise inherent in the working conditions can lead to fatigue, reduce work efficiency, and increased accidents in hair salons.[23,24] In Thailand, the Ministry of Labor has set standards for thermal, illumination, and sound in the workplace. The thermal standards use WBGT limits for light, medium, and heavy work set at 34°C, 32°C, and 30°C, respectively. The minimum illumination level in the workplace should be between 300 and 500 lux, and the sound level should not exceed 85 dBA.[25]

Working conditions in hair salons, especially indoor air quality, is important because it is a closed space and poor ventilation. Therefore, the pollutants are accumulated inside the hair salons. Hollund and Moen[26] reported that the VOCs concentration is significantly lower in the hair salons with local exhaust ventilation than in the salons with no ventilation. Chang et al[27] found that hair salons in Taipei had various ventilation systems with exhaust fans, air conditioners, heat-recovery ventilators, or by opening the windows. In addition, they reported that air pollutants were accumulated in the working area more than washing area, technical area, and reception area.

To the best of the authors' knowledge, the working conditions in hair salons in Thailand had never been reported. Therefore, in order to assess whether there were potential health risks due to the exposure of indoor air pollutants for both hairdressers and customers, the purpose of this study was to assess the chemical and physical work conditions in hair salons and to analyze health risk of exposure to VOCs for the hairdressers of hair salons.

Materials and Methods

The sampling of sites

This study was performed at 4 hair salons around the Prince of Songkla University and the Suratthani Rajabhat University in Surat Thani province, from February 2019 to April 2019 during the summer season in Thailand. The hair salons selected were outside the city center to avoid impacts of outdoor pollution. There were 14 hair salons around the University, but only 4 of these had higher customer counts than the salons in other neighborhoods and the hair salon owners accepted to participate, so these were selected as the study samples. All these hair salons were located in multi-story buildings on the first floor, while the upper floors were residential apartments. Generally, the interior of the hair salon had tile floor, painted concrete walls, painted concrete ceiling, and sliding aluminum-framed glass doors. There were usually a few wooden desks, wooden cabinets and leather chairs.

Air sampling method

BTEXs (benzene, toluene, ethylbenzene, xylene, and styrene), cyclohexanone, hexane, IPA, MIBK, trichloroethylene, dichloromethane, MEK, chloroform, butyl acetate, ethanol, and butanol were sampled and analyzed according to the NIOSH method 1501, 1300, 1500, 1400, 1300, 1022, 1005, 2500, 1003, 1450, 1400, and 1405, respectively.

Air sampling design

At each hair salon, the sampling sites were located at 3 different places, including center of the room where customer received hair care product, mixing area where hair care products were stored and mixed, and customer waiting area where no hair care product was performed. A soap bubble flow meter was used for calibration of flow rates. The pump was calibrated before and after each sampling. Samples were collected at breathing zones of hairdressers (at a height of 1.5 m above the floor). The air samples were collected with an activated charcoal tube (Zefon, 6 × 70 mm) at a flow rate of 0.05 L/min for approximately 8 hours (from 09:00 to 17:00.) with a GilAir5 pump (Gillian, USA). Each salon was done in 3 samples per day and collected 3 days. This gives 9 samples per salon. The overall sample (4 salon) was 36 (n = 36). Charcoal tubes were kept at 4°C during transportation to the laboratory, and were stored in a refrigerator until further analysis.

When this study started (February 2019) salon D had no local exhaust ventilation but hair salon owner planned to install local exhaust ventilation in March 2019. Therefore, airborne volatile organic compounds in the mixing area of hair salon D were measured in 3 different ventilation conditions; before installation of local exhaust ventilation, after installation of local exhaust ventilation, and after installation of local exhaust ventilation with open the door for 30 minutes before closing the hair salon. A total of 3 charcoal tubes per day were used in a background air sampling done 1 hour before operation (from 08:00 to 09:00.), 1 tube was used in the morning for 4 hours (from 09:00 to 13:00), and 1 tube was used in the afternoon for 4 hours (from 13:00 to 17:00). Each ventilation condition was done in 3 samples per day and collected 3 days. This gives 9 samples per ventilation condition. The overall sample (3 conditions) was 27 (n = 27). The same procedure as above was followed throughout the experiments. Lee et al[28] concluded that area sampling results could be representative of personal exposure because room volume was limited areas (105-168 m^3). In addition, Leino et al[24] divided hair salon into 2 groups including small (volume 42-168 m^3) and large (volume 233-837 m^3) hair salon. The 4 hair salons in this study varied in size from 50 to 94 m^3 (small salons) and samples were collected at breathing zones of hairdressers (at a height of 1.5 m above the floor) and also near the hairdressers.

Air sampling and analytical methods

The TWA of volatile organic compounds was calculated by the following equation:

$$TWA = \frac{(C\ T)+(C\ T)+(C\ T)}{T+T+T} \quad (1)$$

Where, TWA is Time Weight Average (μg/m^3), C represents concentration (μg/m^3), and T is time of exposure (h).

Sample preparation and analysis

The front and back sorbent sections of the charcoal tubes were placed in separate vials. Carbon disulfide 2 mL was added to each vial and stand for 30 minutes. The extracted samples were transferred into GC vials and analyzed by GC/FID. GC/MS was used to confirm the results from GC/FID.

Quality control and quality assurance (QC/QA)

The front and back sorbent sections of the charcoal tubes were analyzed separately for checking breakthrough and there was no evidence of chemical compounds in the back section of the charcoal tube. The method was validated using limit of detection (LOD). LOD was determined using the blank method. The concentration of 10 blank samples were measured in triplicate and LOD was calculated (LOD = mean + 3 × standard deviation). Ten blank samples were collected and the concentration of volatile organic compounds were limited to 0.00 to 0.042 μg/m^3 for toluene, 0.00 to 0.135 μg/m^3 for xylene, 0.00 to 0.216 μg/m^3 for ethylbenzene, 0.00 to 0.042 μg/m^3 for cyclohexanone, 0.00 to 0.054 μg/m^3 for MIBK, 0.00 to 0.125 μg/m^3 for hexane, 0.00 to 0.033 μg/m^3 for IPA, 0.00 to 0.156 μg/m^3 for trichloroethylene, 0.00 to 0.137 μg/m^3 for dichloromethane, 0.00 to 0.128 μg/m^3 for MEK, 0.00 to 0.242 μg/m^3 for chloroform, 0.00 to 0.185 μg/m^3 for butyl acetate, 0.00 to 0.035 μg/m^3 for ethanol, and 0.00 to 0.047 μg/m^3 for butanol. The LODs were 0.03, 0.06, 0.09, 0.02, 0.03, 0.07, 0.01, 0.05, 0.07, 0.06, 0.09, 0.08, 0.01, and 0.02 μg/m^3 for toluene, xylene, ethylbenzene, cyclohexanone, MIBK, hexane, IPA, trichloroethylene, dichloromethane, MEK, chloroform, butyl acetate, ethanol, and butanol, respectively. The mean recovery was 94% (91%-100%) for the volatile organic compounds and standard deviations (SDs) of these compounds were less than 5%. Calibration curves were carried out in 6 levels (0.01-60 ppm) of standard solutions and R^2 values were 0.998 for xylene, chloroform, hexane, MIBK, and dichloromethane, and also 0.999 for toluene, cyclohexanone, ethylbenzene, IPA, trichloroethylene, MEK, butyl acetate, ethanol, and butanol.

Health risk assessment

The main exposure route of hairdresser was inhalation. The carcinogenic and non-carcinogenic risks of volatile organic compounds for full time hairdressers in hair salons were calculated based on the following equation.

$$\text{CDI} = \left(\text{CA x IR x ET x EF x ED}\right) / \left(\quad \text{x AT x BW}\right) \tag{2}$$

Where CDI represents chronic daily intake (mg/kg-day), CA denotes the concentration of volatile organic compounds in hair salons (mg/m^3), IR is the inhalation rate (m^3/h), ET is exposure time (h/day), EF and ED are exposure frequency (day/year), and exposure duration (year). In addition, AT and BW are average lifetime (years) and body weight (kg). An average lifetime for carcinogenic and non-carcinogenic assessment was 70 and 30 years, respectively.

Cancer risk estimates for volatile organic compounds were expressed in terms of the probability of developing cancer from a lifetime of continuous exposure to volatile organic compounds. The lifetime cancer risk was calculated using equation (3).

$$\text{Cancer risk} = \text{CDI x CSF} \tag{3}$$

CSF is cancer slope factor (mg/kg/day)$^{-1}$. CSF for ethylbenzene, dichloromethane, chloroform, and trichloroethylene are 0.00385, 0.014, 0.081, and 0.013, respectively.[29,30] Hence, if cancer risk $>1 \times 10^{-6}$ is indicated carcinogenic effects of concern. In addition, if cancer risk $\leqslant 1 \times 10^{-6}$ is considered acceptable.[31] According to Nabizadeh et al,[32] if the cancer risk exceeds 1×10^{-4}, range from 1×10^{-5} to 1×10^{-4}, is between 1×10^{-5} and 1×10^{-6}, or is less than 1×10^{-6}, it indicates as definite, probable, possible, and negligible risk, respectively.

The non-carcinogenic of volatile organic compounds were calculated by hazard quotient (HQ) which is ratio of CDI and reference concentration (RfC, mg/kg/day) as followed equations.

$$\text{HQ} = \text{CDI} / \text{RfC} \tag{4}$$

Inhalation reference concentration for toluene, xylene, ethylbenzene, hexane, IPA, ethyl acetate, MIBK, acetone, trichloroethylene, dichloromethane, MEK, and chloroform are 5, 0.01, 1, 7, 2, 0.7, 30, 310, 0.02, 6, 30, and 1, respectively.[29,30] Inhalation reference concentration for cyclohexanone, butyl acetate, ethanol, and butanol are not existed. HQ $\leqslant$ 1.0 is considered acceptable; HQ $>$ 1.0 is adverse non-carcinogenic effects of concern.

The non-cancer health impacts were expressed as the hazard index (HI), which is calculated by summing all of the HQ at a specific location.

$$\text{HI} = \sum \text{HQ} \tag{5}$$

Where; if HI $\leqslant$ 1.0 is means acceptable hazard. If HQ $>$ 1.0 is likely to be associated with adverse health effect.

Physical measurements

The physical measurements during work hours were sound pressure level, illumination, and temperature, determined during 1 day in each salon. Sound pressure was measured with a sound level meter (3M, USA) during the use of a hairdryer (n = 20/salon). Sound level meter was placed at 1.25 m elevation above the floor near hairdresser. Lux meter (Extech, USA) was used to measure illumination at mixing point and at hairdresser work sites every 1 hour from 9.00 to 17.00 (n = 8/salon). The Wet Bulb Globe Temperature (WBGT) (QUESTemp 34, 3M) recorded dry bulb, wet bulb, globe temperature, and relative humidity, at 15 minutes intervals in the salon from 09:00 to 17:00 (n = 32/salon), at 1.25 m elevation above the floor. The device automatically calculates and records WBGT indoor as: WBGT (indoor) = (0.7 × wet bulb) + (0.3 × globe temperature).

Statistical analysis

All determinations were done in triplicates. The Statistical Package for Social Sciences (SPSS) was used for the analyses. Normality of data distribution was assessed by Kolmogorov-Smirnov test. The data of VOCs concentration were checked with variables (sampling site: center of the room, mixing area, waiting area; sampling time: before operation, morning, afternoon; installation of local exhaust ventilation: before or after) to recognize normal distribution. If the P-value obtained from the Kolmogorov-Smirnov test exceeded .05, the ANOVA test was performed for further analysis. If the P-value was less than

Table 1. Characteristics of the 4 hair salons.

PHYSICAL CHARACTERISTICS	SALON A	SALON B	SALON C	SALON D
Room volume (m^3)	51.5	50.9	93.8	86.0
Number of customers per day	7-10	8-10	10-15	15-18
Type of door entrance	Closed	Opened	Closed	Closed
Type of window	No window	No window	No window	No window
Number of fan	1	2	0	3
Number of air conditioner	1	0	1	0
Number of local exhaust ventilation	1	1	2	0
Working hours (h/d)	11	14	12	13

.05, the Mann-Whitney *U* test was used for further analysis. The data were reported as mean ± standard deviation (SD) and were analyzed by comparing the means of VOCs concentrations between 2 groups using Mann-Whitney *U* test, with statistical significance assigned if $P < .05$.

Results and Discussion

General descriptions of the hair salons

The room volume of the hair salons were 50.9 to 93.8 × m^3. Hair salons A and B were the same size, while hair salon C was the largest. Three of the 4 salons had local exhaust ventilation (A, B, and C) and fan (A, B, and D) but none had windows. Half of the salons had split type of air conditioner (A and C) with limited air exchange rate. Only salon B opened the door during work hours. Hair salon D had the most customers, 15 to 18 per day. The work hours of hairdressers are normally 11 to 14 hours per day, and the owner usually works alone (Table 1). Normal services in a hair salon include cutting, washing, styling, bleaching, coloring, waving, or straightening of the hair.

Chemical measurements

VOCs concentrations in different sampling locations and different salons. Table 2 shows the average concentrations of volatile organic compounds in center of the room, mixing area and customer waiting area, for the 4 hair salons (A, B, C, and D). The 16 volatile organic compounds found in mixing area were toluene (A: 367.0 ± 72.9; B: 360.7 ± 29.5; C: 345.3 ± 7.6; D: 412.3 ± 29.3 μg/m^3), cyclohexanone (A: 212.7 ± 19.4; B: 207.0 ± 16.1; C: 203.0 ± 16.2; D: 1664.0 ± 115.5 μg/m^3), xylene (A: 446.7 ± 22.0; B: 393.3 ± 8.5; C: 410.0 ± 17.0; D: 714.0 ± 15.8 μg/m^3), ethylbenzene (A: 168.3 ± 12.1; B: 159.0 ± 11.6; C: 150.7 ± 1.4; D: 155.3 ± 4.0 μg/m^3), hexane (A: 188.7 ± 13.7; B: 197.7 ± 7.6; C: 189.3 ± 11.7; D: 228.0 ± 30.6 μg/m^3), isopropanol: IPA (A: 1149.7 ± 92.4; D: 386.7 ± 16.1 μg/m^3), ethyl acetate (A: 440.7 ± 13.0 μg/m^3), methyl isobutyl ketone: MIBK (A: 315.7 ± 19.1; C: 320.0 ± 14.9; D: 729.7 ± 20.3 μg/m^3), acetone (A: 131.3 ± 42.1; B: 154.0 ± 14.1 μg/m^3), trichloroethylene (D: 4861.0 ± 119.2 μg/m^3), dichloromethane (A: 959.0 ± 32.8; D: 423.3 ± 16.4 μg/m^3), methyl ethyl ketone: MEK (B: 263.3 ± 17.1; D: 416.7 ± 16.6 μg/m^3), chloroform (D: 849.0 ± 23.8 μg/m^3), butyl acetate (D: 536.7 ± 25.6 μg/m^3), ethanol (D: 478.7 ± 21.0 μg/m^3), and butanol (D: 248.3 ± 25.1 μg/m^3). These average concentrations were below the permissible level set by the ACGIH (toluene: 188; cyclohexanone: 100; xylene: 434; ethylbenzene: 434; hexane: 176; IPA: 983; ethyl acetate: 1400; MIBK: 205; acetone: 1780; trichloroethylene: 269; dichloromethane: 174; MEK: 590; chloroform: 49; butyl acetate: 713; ethanol: 1880; butanol: 152 mg/m^3). The most frequently detected VOCs across the hair salons were toluene (A: 367.0 ± 72.9; B: 360.7 ± 29.5; C: 345.3 ± 7.6; D: 412.3 ± 29.3 μg/m^3), cyclohexanone (A: 212.7 ± 19.4; B: 207.0 ± 16.1; C: 203.0 ± 16.2; D: 1664.0 ± 115.5 μg/m^3), xylene (A: 446.7 ± 22.0; B: 393.3 ± 8.5; C: 410.0 ± 17.0; D: 714.0 ± 15.8 μg/m^3), ethylbenzene (A: 168.3 ± 12.1; B: 159.0 ± 11.6; C: 150.7 ± 1.4; D: 155.3 ± 4.0 μg/m^3), and hexane (A: 188.7 ± 13.7; B: 197.7 ± 7.6; C: 189.3 ± 11.7; D: 228.0 ± 30.6 μg/m^3) due to their use in hair care products.

Hair products can be released many components such as VOCs into the air of hair salons. This matches prior reports in Canada, Spain, and Norway of high toluene concentration in hair salon air.[3,4,26] In contrast, the predominant of VOCs in salon in Iran was ethyl benzene.[29] The toluene concentration in this study was higher than in earlier reports due to various factors, such as room volume, number of customers, ventilation system, temperature, relative humidity, types of hair products, and interior materials. Toluene, cyclohexanone, xylene, ethylbenzene, and hexane are the major VOCs that had high concentrations during hair dying and hair straightening in the salon. This result corresponding to the previous studies in which the chemical exposure in the hair salons was highest for several compounds when hair dying was performed.[4,27,29]

Dichloromethane and IPA were found in salons A and D. Trichloroethylene, chloroform, butyl acetate, ethanol, and butanol were found only in salon D due to type of hair dying and hair straightening was different from other salons. Salon C showed

Table 2. The average of volatile organic compounds concentration (μg/m³) in hair salons (n=36).

COMPOUNDS	ACGIH (MG/M³)	SALON A (N=9)			SALON B (N=9)			SALON C (N=9)			SALON D (N=9)		
		CENTER OF THE ROOM	MIXING AREA	WAITING AREA	CENTER OF THE ROOM	MIXING AREA	WAITING AREA	CENTER OF THE ROOM	MIXING AREA	WAITING AREA	CENTER OF THE ROOM	MIXING AREA	WAITING AREA
Toluene	188	325.3 ± 20.1	367.0 ± 72.9	337.0 ± 27.4	336.7 ± 18.4	360.7 ± 29.5	315.7 ± 17.1	345.3 ± 7.6	345.3 ± 7.6	233.0 ± 10.7*	362.3 ± 11.7	412.3 ± 29.3	239.3 ± 10.3*
Cyclohexanone	100	122.0 ± 35.9*	212.7 ± 19.4	47.7 ± 7.3*	51.3 ± 16.1*	207.0 ± 16.1	86.3 ± 9.5*	131.7 ± 16.6*	203.0 ± 16.2	92.0 ± 10.8*	657.7 ± 32.6*	1664.0 ± 115.5	150.7 ± 14.5*
Xylene	434	400.0 ± 14.9	446.7 ± 22.0	240.0 ± 21.0*	231.0 ± 12.0*	393.3 ± 8.5	227.3 ± 7.7*	377.7 ± 10.7	410.0 ± 17.0	235.7 ± 21.0*	425.7 ± 15.8*	714.0 ± 15.8	385.0 ± 17.1*
Ethylbenzene	434	138.3 ± 16.9	168.3 ± 12.1	146.3 ± 17.2	155.3 ± 5.8	159.0 ± 11.6	140.0 ± 8.6	134.3 ± 10.2	150.7 ± 1.4	86.7 ± 11.6*	150.7 ± 3.6	155.3 ± 4.0	135.3 ± 8.3*
Hexane	176	241.7 ± 12.8*	188.7 ± 13.7	ND	172.7 ± 10.7*	197.7 ± 7.6	ND	138.7 ± 13.0*	189.3 ± 11.7	78.7 ± 16.1*	154.3 ± 12.5*	228.0 ± 30.6	92.7 ± 7.2*
IPA	983	778.0 ± 13.0*	1149.7 ± 92.4	430.3 ± 37.2*	ND	ND	ND	ND	ND	ND	278.7 ± 15.2*	386.7 ± 16.1	ND
Ethyl acetate	1400	359.3 ± 22.1*	440.7 ± 13.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MIBK	205	ND	315.7 ± 19.1	ND	ND	ND	ND	ND	320.0 ± 14.9	ND	369.0 ± 22.3*	729.7 ± 20.3	ND
Acetone	1780	93.0 ± 6.3	131.3 ± 42.1	ND	ND	154.0 ± 14.1	ND	ND	ND	ND	ND	ND	ND
Trichloroethylene	269	ND	ND	ND	ND	ND	ND	ND	ND	ND	1603.0 ± 127.5*	4861.0 ± 119.2	529.3 ± 21.2*
Dichloromethane	174	ND	959.0 ± 32.8	ND	ND	ND	ND	ND	ND	ND	ND	423.3 ± 16.4	ND
MEK	590	ND	ND	ND	ND	263.3 ± 17.1	ND	ND	ND	ND	ND	416.7 ± 16.6	ND
Chloroform	49	ND	ND	ND	ND	ND	ND	ND	ND	ND	50.0 ± 21.3*	849.0 ± 23.8	ND
Butyl acetate	713	ND	ND	ND	ND	ND	ND	ND	ND	ND	227.0 ± 21.1*	536.7 ± 25.6	ND
Ethanol	1880	ND	ND	ND	ND	ND	ND	ND	ND	ND	284.0 ± 14.9*	478.7 ± 21.0	ND
Butanol	152	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	248.3 ± 25.1	ND

Abbreviation: ND, not detected.
*Significantly different from mixing area ($P < .05$; Mann-Whitney U test).

the lowest overall concentration of VOCs while salon D had the highest concentration. The concentrations of toluene, cyclohexanone, xylene, MIBK, and MEK were lower in the salons with local exhaust ventilation (Salon A, B, C) than in the salons without ventilation (Salon D). This result is similar with previous study.[26] The hair salons had various ventilation systems with fans, air conditioners, local exhaust ventilation, or by opening the door. Salon C had low VOC concentrations because of its large dimensions, 2 local exhaust ventilators, and air conditioner. Large volume alone without adequate ventilation should be worse than small volume with good ventilation. Also salon D was voluminous, but without local exhaust ventilation or air conditioner, and it also had large number of customers per day. It had the highest concentrations of most VOCs measured. This use of local exhaust ventilation and air conditioner clearly improved indoor air quality.

The VOCs concentrations from mixing area were significantly higher than at center of the room (working area) or at customer waiting area ($P < .05$). The mixing area had the highest VOCs concentration because that is where the hairdressers stored and mixed chemicals for dyeing, bleaching, or straightening hair. In addition, hairdressers opened the packages of hair care products at mixing area when not in use. Therefore, VOCs can be released readily from the hair care products and diffused in the air. This result is different to prior report in which the VOCs concentration at working area in hair salons in Taipei were higher than mixing area and customer waiting area.[27] Numerous factors could explain these differences, including room volume, number of customers, ventilation system, temperature, relative humidity, types of hair products, and interior materials. The customer waiting area also had VOCs concentration levels that may contribute to health risks.

VOCs concentrations in different sampling times and different ventilations. Table 3 presents the concentration of VOCs before operation, in the morning, in the afternoon, and as time-weighted-average (TWA) at mixing area in hair salon D, in 3 different ventilation conditions. Before and after the installation of local exhaust ventilation, the initial VOCs concentration was significantly more than in the morning and in the afternoon, by approximately 2- and 1.5-fold. The VOCs concentration decreased as hair salon opened in the morning. The results correspond to previous reports in which the VOCs concentrations were high before operation. This suggests accumulation of VOCs when ventilation is inadequate, as the doors of a hair salon generally are closed overnight. However, business hours started and air-conditioners or local exhaust ventilation were operated, VOC concentrations declined markedly.[33,34] Furthermore, the VOCs concentrations in the afternoon were more than in the morning. The result is similar to earlier reports in which the concentrations of VOCs were increased in the afternoon as customers came in the hair salons. This indicates that the accumulations of VOCs occurred during business hours.[27,29]

After installation of local exhaust ventilation and open the door for 30 minutes before closing the hair salon, the initial VOCs concentration was significantly less than in the morning and in the afternoon. All the average VOCs concentrations after the installation of local exhaust ventilation were significantly less than before the installation by approximately 1.5- to 2-fold ($P < .05$). Moreover, the average VOCs concentrations after the installation of the local exhaust ventilation and open the door for 30 minutes before closing the hair salon, were significantly less than before the installation by approximately 3- to 4-fold ($P < .05$). Similar finding is reported that VOCs concentration was lower in salons that had natural ventilation (open doors or windows),[3,35] but the natural ventilation cannot support adequately air exchange to decrease VOCs concentration.[29] Local exhaust ventilation was used to capture the airborne contaminants such as VOCs at their source. Therefore, install local exhaust ventilation and open the door for 30 minutes before closing the hair salon was reduced the VOCs concentration and enhanced the indoor air quality in the hair salon.

Health risk assessment

The results of hairdresser health risk assessment are summarized in Table 4. The results for the cancer risk assessment indicate that all hair salons in this study exceeded the suggested value by US EPA ($>1 \times 10^{-6}$). According to Nabizadeh et al (2020), ethyl benzene in 4 hair salons were probable cancer risk (1×10^{-5}-1×10^{-4}). Ethyl benzene in this study probable cancer risk (1×10^{-5} to 1×10^{-4}) is similar to previous study.[32] Furthermore, dichloromethane (A: 1.2×10^{-3}; D: 5.5×10^{-4}), chloroform (D: 6.4×10^{-3}), and trichloroethylene (D: 5.8×10^{-3}) were definite cancer risk ($>1 \times 10^{-4}$). To the best of our knowledge, there are no studies investigating cancer risk for trichloroethylene, dichloromethane, and chloroform in hair salon.

Regarding non-cancer risk, the HI for all hair salons ranged from a high of 68.16 at hair salon D to a low of 9.13 at hair salon C. The HI for all hair salons exceeded 1.0, and trichloroethylene and xylene contributed most to the total risk. The HQ for xylene in 4 hair salons ranged from 9.075 to 15.408. The similar finding is reported by Baghani et al[29] the HQ of xylene was more than 1. The HQ for trichloroethylene in hair salon D was 52.45. The HQ for other chemicals was below the reference levels ($\leqslant 1.0$).

All of the hairdressers were women working more than 8 hours per day with chemicals. The hair salons were small with poor ventilation, the doors were normally kept closed, and none had windows. The hairdressers complained about skin irritation and bad odors during preparation and application of hair care products. These VOC exposures including ethyl benzene, dichloromethane, chloroform, trichloroethylene, and xylene might constitute a health risk in combination, despite each separately appearing innocuous. Therefore, installing local

Table 3. The average of volatile organic compounds concentration (μg/m^3) in hair salon D before and after installation of local exhaust ventilation (n = 27).

COMPOUNDS	BEFORE INSTALLATION OF LOCAL EXHAUST VENTILATION (N = 9)				AFTER INSTALLATION OF LOCAL EXHAUST VENTILATION (N = 9)				AFTER INSTALLED LOCAL EXHAUST VENTILATION WITH OPEN THE DOOR FOR 30 MIN BEFORE CLOSING THE HAIR SALON (N = 9)			
	BEFORE OPERATION	MORNING	AFTER NOON	TWA	BEFORE OPERATION	MORNING	AFTER NOON	TWA	BEFORE OPERATION	MORNING	AFTER NOON	TWA
Toluene	675.3 ± 26.5	374.3 ± 19.8*	424.7 ± 11.8*	430.3 ± 12.2	452.3 ± 21.3	271.3 ± 14.8*	333.3 ± 16.1*	318.7 ± 9.8**	84.0 ± 8.6	208.0 ± 8.5*	272.3 ± 7.7*	222.7 ± 5.7**
Cyclohexanone	3741.7 ± 131.5	1590.7 ± 106.5*	2255.3 ± 112.9*	2125.0 ± 90.2	2448.3 ± 55.9	1132.3 ± 112.0*	1653.0 ± 57.4*	1509.3 ± 66.5**	226.0 ± 10.0	433.3 ± 9.6*	554.3 ± 11.6*	464.3 ± 6.9**
Xylene	1651.0 ± 74.1	683.3 ± 16.5*	821.0 ± 22.0*	852.0 ± 23.5	980.3 ± 69.0	353.3 ± 13.0*	447.3 ± 11.4*	465.0 ± 11.4**	126.0 ± 8.8	228.3 ± 8.1*	314.7 ± 11.2*	255.7 ± 5.2**
Ethylbenzene	324.3 ± 8.5	160.3 ± 15.2*	212.3 ± 10.7*	201.3 ± 5.4	223.7 ± 19.0	104.3 ± 6.9*	155.0 ± 6.3*	140.0 ± 4.1**	50.3 ± 5.5	86.0 ± 11.2*	138.7 ± 2.3*	105.3 ± 4.9**
Hexane	422.7 ± 17.5	230.0 ± 14.4*	294.0 ± 10.8*	279.7 ± 7.4	245.0 ± 6.8	113.3 ± 11.5*	184.7 ± 6.7*	160.0 ± 7.6**	48.7 ± 4.0	104.3 ± 7.2*	146.7 ± 7.7*	117.0 ± 5.4**
IPA	616.0 ± 20.1	359.3 ± 13.7*	415.3 ± 10.0*	412.7 ± 7.5	334.3 ± 6.3	163.3 ± 10.1*	251.0 ± 10.3*	221.0 ± 7.7**	58.7 ± 5.4	109.0 ± 14.2*	167.0 ± 9.7*	129.3 ± 10.0**
MIBK	1330.3 ± 36.8	675.7 ± 19.3*	736.3 ± 13.4*	775.3 ± 12.2	739.7 ± 13.4	314.0 ± 10.5*	376.3 ± 9.1*	389.3 ± 2.3**	116.7 ± 10.3	244.7 ± 10.4*	306.0 ± 6.3*	257.7 ± 5.1**
Trichloroethylene	7128.0 ± 120.3	4456.0 ± 86.1*	5352.3 ± 102.7*	5151.3 ± 15.9	3569.3 ± 92.1	1920.7 ± 76.9*	2456.3 ± 96.8*	2342.0 ± 19.2**	262.3 ± 7.2	465.3 ± 5.4*	554.0 ± 10.2*	482.3 ± 4.0**
Dichloromethane	740.7 ± 16.3	372.7 ± 9.9*	458.3 ± 12.5*	451.7 ± 4.1	413.3 ± 7.8	226.3 ± 9.1*	306.7 ± 9.5*	282.7 ± 3.1**	87.7 ± 4.5	144.3 ± 10.4*	184.3 ± 7.4*	155.7 ± 1.0**
MEK	816.7 ± 15.2	411.0 ± 12.5*	498.7 ± 12.5*	495.0 ± 6.4	465.7 ± 5.8	266.0 ± 12.3*	333.0 ± 7.2*	318.3 ± 7.8**	78.0 ± 3.2	146.7 ± 9.5*	178.0 ± 3.2*	153.3 ± 3.6**
Chloroform	1512.0 ± 20.3	794.3 ± 16.5*	855.7 ± 14.8*	901.3 ± 8.0	842.0 ± 8.5	319.0 ± 13.2*	359.3 ± 3.4*	395.0 ± 3.6**	134.3 ± 7.7	233.7 ± 7.5*	276.0 ± 9.3*	241.7 ± 5.4**
Butyl acetate	1002.0 ± 33.0	481.3 ± 13.7*	635.3 ± 16.3*	607.7 ± 7.2	485.3 ± 10.1	274.7 ± 10.3*	326.3 ± 9.5*	321.0 ± 5.6**	63.7 ± 10.3	124.0 ± 8.2*	181.3 ± 15.0*	142.7 ± 9.0**
Ethanol	872.3 ± 10.9	450.7 ± 20.3*	548.0 ± 16.4*	541.0 ± 13.2	405.3 ± 10.3	222.3 ± 10.5*	278.7 ± 11.3*	267.7 ± 6.3**	64.7 ± 5.5	121.0 ± 10.3*	166.7 ± 11.2*	133.3 ± 9.6**
Butanol	441.7 ± 14.7	239.3 ± 11.2*	317.7 ± 15.2*	297.0 ± 9.3	264.0 ± 9.7	107.3 ± 7.6*	174.7 ± 6.7*	154.3 ± 5.2**	38.7 ± 3.1	75.3 ± 11.2*	105.3 ± 5.4*	84.3 ± 7.6**

*Significantly different from before operation ($P < .05$; Mann-Whitney *U* test).
**Significantly different from TWA of before installation of local exhaust ventilation ($P < .05$; Mann-Whitney *U* test).

Table 4. Summarized results of health risk assessment of hairdressers.

	SALON A	SALON B	SALON C	SALON D
Body weight (kg)	42	47	45	50
Exposure time (h/d)	11	14	12	13
Exposure duration (y)	30	30	30	30
Exposure frequency (d/y)	365	365	365	365
Inhalation rate (m^3/h)	0.83	0.83	0.83	0.83
Cancer risk				
Ethyl benzene	6.0×10^{-5}	6.5×10^{-5}	5.5×10^{-5}	5.5×10^{-5}
Dichloromethane	1.2×10^{-3}	—	—	5.5×10^{-4}
Chloroform	—	—	—	6.4×10^{-3}
Trichloroethylene	—	—	—	5.8×10^{-3}
Non-cancer risk (HQ)				
Toluene	0.016	0.018	0.015	0.018
Xylene	9.710	9.724	9.075	15.408
Ethylbenzene	0.036	0.039	0.033	0.033
Hexane	0.006	0.007	0.006	0.007
IPA	0.125	—	—	0.042
Ethyl acetate	0.137	—	—	—
MIBK	0.002	—	0.002	0.005
Acetone	0.00009	0.00012	—	—
Trichloroethylene	—	—	—	52.450
Dichloromethane	0.035	—	—	0.015
MEK	—	0.002	—	0.003
Chloroform	—	—	—	0.183
HI	10.07	9.79	9.13	68.16

exhaust ventilation in a hair salon especially mixing areas and open the door for 30 minutes before closing the hair salon, and also hairdressers using respirators, are essential for removing chemicals that accumulate in the mixing areas, and could eliminate health hazards.

Physical measurements

The results of the physical measurements in the hair salons are shown in Table 5. The outdoors temperatures were approximately 34°C during the summer time period in Surat Thani province. Hair salon C was the coolest. WBGT indoor levels did not exceed the reference level for hair salons (<32°C). Salon D had the highest relative humidity. WBGT levels in all hair salons were suitable, because of air conditioner and fan use. The mean illumination levels in salons A, B, and D were below the standard (<300 lux), according to the standard values recommended by the Ministry of Labor (300-500 lux): this is similar to prior report.[23,24] Hair dying demands accurate observation of the hair color, so hairdressers should be improved to appropriate level (>1000 lux). The mean sound pressure levels during hairdryer use were below the reference level in all salons (<85 dBA). Nonetheless, the noise interferes with communications between hairdresser and customer.

A limitation of this study is the small number of hair salons monitored, and this might not be representative of all Thai hair salons. However, the results may be used as a basis for preventive work in hair salons. It is important to note that the hairdressers might be affected by hair fashions. Nowadays, dying and straightening of the hair is a fashion emitting various chemical substances. In the future this might change, and there can be differences between countries.

Table 5. Physical conditions in the 4 hair salons.

PARAMETER	SALON A		SALON B		SALON C		SALON D	
	AVERAGE ± SD	RANGE	AVERAGE ± SD	RANGE	AVERAGE ± SD	RANGE	AVERAGE ± SD	RANGE
Air temperature (°C) (n = 32)	29.0 ± 0.15	28.9-29.2	31.7 ± 0.3	31.4-32.1	25.3 ± 0.2	25.1-25.6	31.4 ± 0.10	31.3-31.5
WBGT (indoor) (°C)	24.7 ± 0.3	24.4-24.9	28.2 ± 0.2	28.0-28.4	22.0 ± 0.4	21.5-22.4	28.2 ± 0.3	27.8-28.4
(Standard level < 32°C, n = 32)								
Relative humidity (%)	55.3 ± 4.1	50-58	66.3 ± 2.6	63-68	59.7 ± 5.2	53-64	70.0 ± 3.1	66-72
(Standard level 50%-65%, n = 32)								
Illumination—mixing point (lux)	232 ± 125.6	169-264	225 ± 48.6	146-273	319 ± 151.1	274-323	129 ± 20.6	108-133
(Standard level = 300 lux, n = 8)								
Illumination—hairdresser work site (lux)	77 ± 57.3	51-89	258 ± 139.5	166-266	398 ± 155.3	355-406	119 ± 11.2	93-127
(Standard level = 300 lux, n = 8)								
Sound pressure level (dBA)	75.2 ± 2.7	63.1-81.1	75.8 ± 1.7	56.3-84.2	71.4 ± 1.1	62.0-74.3	74.8 ± 0.1	65.3-79.8
(Standard level < 85 dBA, hair dryer: n = 20)								

Conclusion

This study investigated the chemical and physical factors in 4 hair salons, in Thailand. Work tasks and hair products used, ventilation systems, and hair salon size (volume), can determine the relevant VOC concentrations. Hairdressers were exposed to low levels of VOCs, some of which are probable human carcinogens or can affect reproductive function. All of hair salons had cancer risk exceeding 1×10^{-6} for ethyl benzene and HI more than 1.0. Hair salons were accumulations of VOCs, especially in the mixing area. The exposure levels were lower in hair salons with local exhaust ventilation than without ventilation. Furthermore, the VOCs concentrations were found to be lesser after installation of local exhaust ventilation and open the door for 30 minutes before closing the hair salon, than before the installation.

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Author Contributions

PS and SW conceived the ideas, collected the data, analyzed the data, and led the writing.

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