

Occupational exposure of hairdressers to air pollutants in Hong Kong

Eugena Li, Shun Cheng Lee*

Department of Civil and Structural Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong Special Administrative Region, People's Republic of China

ABSTRACT

Levels of PM_{2.5}, PM₁₀ and VOCs were measured in the breathing zone (about 1.5 m above ground) at eight hair salons in Hong Kong to assess the occupational exposure of hairdressers to these pollutants. Although all target pollutants were well below the international and local occupational exposure limits, average concentrations of several CO₂ and RSP (PM_{2.5} and PM₁₀) samples were found to have exceeded Levels 1 and 2 of the Hong Kong IAQ Objectives. All measured pollutants were found to be higher on weekends than on weekdays, except methylene chloride. Based on analysis of samples obtained from individual dyeing and perming procedures, the activities in decreasing order of contribution to PM_{2.5}, PM₁₀ and VOC concentrations are: mixing and application of chemicals, smoking (if smokers are present), heating of the hair and wrapping of the hair. It also shows that dyeing procedures produced more pollutants on average than perming, though the effects of interference and other variations were not taken into account in this study.

INDEX TERMS

Hairdresser; Chemical treatments; Occupational exposure; Particulate matter; VOC

INTRODUCTION

In addition to traditional cutting and cleaning, hairdressers nowadays also perform conditioning, bleaching, colouring, straightening and waving of the hair. As a result, hairdressers are constantly being exposed to a large variety of chemicals, including hair dyes, shampoos, hair conditioners, permanent wave solutions, detergents, hair sprays, and perfumes. The compounds with potential health effects that are commonly found in these hairdressing products include benzene, chloroform, ethylbenzene, methylene chloride, toluene and xylene, just to name a few. The Occupational Safety & Health Administration (OSHA) of the United States revealed that approximately 20% of hairdressers in the U.S. leave the profession for health reasons (Estrada, 1998). Studies have been conducted in various countries to associate adverse health effects, including many cancers, reproductive disorders, asthma, respiratory tract and lung diseases, with prolonged chemical exposures of hairdressers. For instance, a case-control study in Los Angeles found an association between occupational exposure to hair dyes and an increased risk of bladder cancer (Gago-Dominguez *et al.*, 2001). Several epidemiological cohort studies of female hairdressers found increased risks of various cancers, such as non-Hodgkin's lymphoma and ovarian cancer (Giles *et al.*, 1984; Teta *et al.*, 1984; Lynge and Thygesen, 1988; Pukkala *et al.*, 1992). Exposures to hairdressing chemical agents were also found to affect the reproductive outcomes among female hairdressers, such as an increased risk reduced fertility, spontaneous abortions, having intrauterine growth retarded infants, low birth-weight infants, and infants with major malformation (Kersemakers *et al.*, 1997; Rylander, 2002). In order to address these issues based on a local setting, this preliminary study focused on the characterization of the indoor air quality of hair salons in Hong Kong. Our objectives were to identify and quantify concentrations of selected air pollutants, such as PM_{2.5}, PM₁₀, and VOCs, emitted from the use of various hair products; to

* Corresponding author. E-mail: ceslee@polyu.edu.hk

compare the compliance of hair salons with local and overseas indoor air quality objectives; and to characterize the concentration profiles of air contaminants with respect to the activity patterns of hairdressers so as to investigate individual's exposure during working hours.

METHODS

Eight hair salons of different scales in various districts were selected for this study, all of which were located in non-industrial buildings with air-conditioned (HVAC) systems. Sites located on the ground floor were selected to assess outdoor contributions to the indoor pollutants. Each salon contains three or more hairdressers, and is currently operating with extensive use of hairdressing products, including hair dyes, bleaching products, perming solutions and hair sprays. Within the sampling period of Oct 2002 to February 2003, indoor and outdoor samples of CO, NO, NO₂, SO₂ and THC were collected at each site.

Concentrations of CO, CO₂, PM₁₀, PM_{2.5} and VOCs were measured near the breathing zones of the hairdressers for 8 h. The measured species and their corresponding measurement methods are presented in Table 1. Among the 8 selected sites, the 2 salons with the poorest indoor air quality were used

as worst-case scenarios, in which activity patterns were recorded. They were visited twice to assess weekday and weekend variations.

Moreover, since the highest concentration peaks were found during chemical treatments, 6 participants were invited to dye or perm their hair at hair salons of their own choices to assess their exposures to the target pollutants at the time.

Table 1. Sampling parameters, measurement methods and analyses

Parameter	Method / Equipment
Indoor & Outdoor air samples	Air samples were collected in Teflon bags (25 L) by SKC pumps (Airchek sampler, Model 224-43xR) at a flow rate of 1 L/min for 20 minutes. The samples were analyzed for CO by a Gas Filter Correlation CO Ambient Analyzer (Thermo Electron Model 48), NOx by a Chemiluminescence NO-NO ₂ -NOx Analyzer (Thermo Electron Model 42), SO ₂ by a Pulsed Fluorescence SO ₂ Analyzer (Thermo Electron Model 43B), and an THC by an APHA-300E Ambient HC Monitor (HORIBA Ltd.).
PM ₁₀ & PM _{2.5}	Continuous monitoring by 2 Dust-Trak Aerosol Monitors (Model 8520, TSI Ltd.)
CO, CO ₂ , Temperature & Relative Humidity	Continuous monitoring by a Q-Trak IAQ Monitor (Model 8550, TSI Ltd.) at 1-min intervals.
VOCs	VOCs were collected by a pre-cleaned and pre-evacuated 6-Liter SUMMA stainless steel canisters assembled with mass controllers at the air inlets. Gas sample was then analyzed by GC (Model HP 5890A) and an MSD (HP 5973) according to TO-14 method (U.S. EPA, 1997).
TVOC	Continuous monitoring of TVOC was performed using a ppbRAE photoionization detector (PGM 76K, RAE Systems) at a flow rate of 0.5 L/min for 8 hours. Before each sampling period, the photoionization detector was calibrated with zero air and the span standard gas, isobutylene. All measured concentrations were therefore expressed as isobutylene equivalents.

RESULTS

Table 2. 8-hr averages of selected air quality parameters from 8-hour sampling at 8 selected hair salons^a

Air Quality Parameter	Indoor					Outdoor					I/O Ratio	R ²
	n	Median	Mean ^b	S.D. ^b	Range	n	Median	Mean ^b	S.D. ^b	Range		
SO ₂ (ppb)	10	4	8	10	1 - 17	10	3	8	8	1 - 20	1.0	0.9451
NO (ppb)	10	54.6	107.4	123.5	1.4 - 333	10	48.950	91.23	86.396	0.8 - 214	1.2	0.7992
NO ₂ (ppb)	10	41.0	52.6	28.2	13.5 - 105.1	10	50.050	54.22	26.4	25.3 - 116	1.0	0.0775
CO (ppm)	10	1.15	1.65	1.41	0.71 - 5.4	10	1.125	1.40	0.69	0.76 - 2.76	1.2	0.0117
THC (ppm)	10	2.50	2.74	0.61	2.21 - 4.2	10	2.600	2.55	0.25	2.04 - 2.98	1.1	0.2525
Methylene Chloride (ppb)	10	4.09	83.88	158.70	<0.20 - 486.26	10	0.360	0.84	1.32	<0.20 - 4.01	99.5	0.0747
Chloroform (ppb)	10	0.63	10.26	29.14	<0.20 - 93.10	10	<0.20	0.18	0.40	<0.20 - 1.18	56.4	0.1756
Benzene (ppb)	10	0.42	0.99	1.10	<0.20 - 2.90	10	0.360	0.74	0.99	<0.20 - 2.99	1.3	0.2574
Toluene (ppb)	10	8.97	12.43	13.40	<0.20 - 40	10	2.340	3.73	3.84	<0.20 - 11.82	3.3	0.4827
Ethylbenzene (ppb)	10	0.44	1.11	1.57	<0.20 - 4.38	10	<0.20	0.17	0.36	<0.20 - 1.10	6.4	0.4131
Xylene (ppb)	10	0.55	1.33	2.02	<0.20 - 6.69	10	<0.20	0.19	0.28	<0.20 - 0.68	7.0	0.0007
Temperature (°C)	10	22.9	23.5	1.6	21.5 - 26.4							
RH (%)	10	60.6	60.8	8.6	45.1 - 73.6							
CO ₂ (ppm)	10	1050	1067	457	488 - 1763							
PM ₁₀ (µg/m ³)	10	290	320	230	58 - 770							
PM _{2.5} (µg/m ³)	10	260	290	190	55 - 660							

^aTwo of the salons were sampled twice, both on a weekday and a weekend.

^bValues less than 0.2 ppb were treated as 0 for calculations of the mean and standard deviation.

n = number of measurements

S.D. = standard deviation

I/O ratio = ratio of Indoor mean to Outdoor mean

The sampled hair salons varied from 28 to 115 m² in floor area, with 3 to 8 hairdressers at work, and had 5 to 78 customers visiting on a sampling day. All selected salons were located on the street level on main roads, except one that was situated next to a public garden, which

also had the lowest NO, CO₂, CO and VOC concentrations detected. Summary statistics for the concentrations of all measured pollutants in indoor and outdoor air are listed in Table 2.

The I/O ratio indicates the difference between indoor and outdoor levels, and their correlation implies a source relationship between the indoor and outdoor environments. From Table 2, SO₂, NO₂ and THC had an average I/O ratio of approximately 1; while the average I/O ratios of NO and CO were slightly larger than 1. Among these pollutants, SO₂ and NO had an R^2 larger than 0.7 (0.95 and 0.80, respectively), meaning that the indoor concentrations of these pollutants were well correlated with the outdoor levels, where NO was from the infiltration of outdoor motor vehicle exhaust. The R^2 of NO₂, CO and THC ranged from 0.08 to 0.25, indicating a less correlation between their indoor and outdoor concentrations. The low average I/O ratio and correlation for NO₂ also support the fact that NO₂ was being formed from the reaction of NO with ozone and other minor constituents, especially in the presence of sunlight. CO had an I/O ratio of 1.2 and a low correlation of 0.01, suggesting an indoor source of CO, such as tobacco smoking. The average I/O ratio of THC was 1.1 and its correlation was poor ($R^2 = 0.25$). This shows that the THC level was not only affected by the outdoor environment, but was also contributed by indoor sources such as building construction materials, tobacco smoke, cleaning products and other solvents. All of the 6 target VOCs had an I/O ratio greater than 1 (ranging from 1.3 to 99.5), and an R^2 less than 0.7 (ranging from 0.0007 to 0.48), meaning that there were major indoor sources of these 6 compounds with little correlation between their indoor and outdoor concentrations.

Table 3. Description of salons and activities recorded during the 8-hr sampling at Salons A & B

Hair Salon	Day	Floor Area (m ²)	No. of hairdressers	No. of customers	No. of dyes	No. of waving	No. of straightening	Total no. of chemical treatments	No. of hairspray applications	No. of tobacco smoked
A	Wed	57	8	33	7	2	0	9	11	10
A	Sat	57	8	78	4	6	0	10	26	11
B	Wed	80	6	14	2	2	1	5	5	2
B	Sat	80	6	17	2	2	4	8	2	1

Table 4. Comparison of weekday & weekend results* for Salons A & B

Air Quality Parameter	Salon A		Salon B	
	Weekday	Weekend	Weekday	Weekend
Temperature (°C)	26.4	22.7	23	22.2
RH (%)	54.9	64.7	58.7	58.04
CO ₂ (ppm)	1343	1763	1408	1627
PM ₁₀ (mg/m ³)	0.355	0.365	0.632	0.773
PM _{2.5} (mg/m ³)	0.323	0.381	0.538	0.657
Methylene Chloride (ppb)	8.18	1.59	486.26	119.3
Chloroform (ppb)	N.D.	1.25	0.8	3.88
Benzene (ppb)	N.D.	1.52	2.04	2.30
Toluene (ppb)	10.90	17.21	7.54	10.40
Ethylbenzene (ppb)	N.D.	0.72	N.D.	0.56
Xylene (ppb)	0.56	1.42	0.50	0.54

N.D. = not detectable (detection limit = 0.2 ppb)

* All results are 8-hr averages from field sampling

Comparison between the weekday and weekend results of Salons A and B indicates a general increase in pollutant concentrations (except methylene chloride) during the weekend. This suggests that the frequency of salon activities relate positively with the pollutant concentrations measured. Methylene chloride is often used in cleaning agents, and one possible explanation for it being higher on weekday was that more cleaning activities took place while there were

fewer customers. A summary of the activities within the salons and the measured concentrations are presented in Tables 3 and 4. Even though the number of customers on weekend more than doubled that on weekday for Salon A, the total number of chemical treatments performed was similar, so that the measured pollutant concentrations did not differ significantly. And despite the fact that there were more occurrences of activities (except the number of hair straightening) recorded in Salon A, the PM_{2.5} and PM₁₀ concentrations were higher for Salon B compared to Salon A. This could be due to the different ventilation rates and sampling locations in the two salons. In Salon B, the sampling equipment was placed nearly in the centre of the salon; while in Salon A, the equipment was set up on a shelf due to the physical limitations. As a result, the Dust-Traks in Salon B might be able to detect more PM concentrations, especially when there were people walking past the set-up.

Over the 8 h of sampling, concentration peaks were typically observed when chemical treatments took place. Therefore, extra samples were obtained during individual visits of hair coloring and permanent waving for more detailed assessments. A summary of the results is listed in Table 5. Note that the average concentrations shown are actual measurements while background concentrations were not subtracted.

Table 5. Average concentrations during individual dyeing and perming sessions

	D1	D2	D3	Mean	P1	P2	P3	Mean
CO ₂ (ppm)	2911	976	1035	1641	1734	685	714	1044
PM ₁₀ (mg/m ³)	304	219	262	262	476	126	147	250
PM _{2.5} (mg/m ³)	232	199	242	224	383	100	90	191
TVOC (ppb isobutylene equiv.)	4983	1333	1216	2511	3317	224	263	1268
Methylene Chloride (ppb)	2.72	0.44	0.51	1.22	0.94	N.D.	N.D.	0.31
Chloroform (ppb)	N.D.	0.62	0.67	0.43	3.04	N.D.	0.19	1.08
Benzene (ppb)	6.06	2.35	2.79	3.73	1.22	0.18	0.19	0.19
Toluene (ppb)	122.26	6.33	7.12	45.24	76.92	0.61	0.61	0.61
Ethylbenzene (ppb)	2.02	0.41	0.41	0.95	0.92	N.D.	N.D.	0.31
Xylene (ppb)	N.D.	0.20	0.21	0.14	0.86	N.D.	N.D.	0.29

D1, D2, D3 are air samples obtained during dyeing procedures

P1, P2, P3 are air samples obtained during perming procedures

For instance, the PM₁₀ concentration for D1 increased by 369 $\mu\text{g}/\text{m}^3$ during the first application of the colouring solvent. At the same time, PM_{2.5} concentration increased by 225 $\mu\text{g}/\text{m}^3$, and TVOC concentration by 3553 ppb. Similarly, PM₁₀ level for P1 increased by 478 $\mu\text{g}/\text{m}^3$, PM_{2.5} concentration by 502 $\mu\text{g}/\text{m}^3$ and TVOC concentration by 751 ppb during the application of wave solution. A similar trend was observed during wrapping and heating of the hair, but of a slightly lower magnitude. Higher concentrations during wrapping and heating could be due to the volatilization of particulates and VOCs by heat. The contributions by individual activities to total exposure of PM₁₀, PM_{2.5} and TVOC are summarized in Figures 1–3, respectively.

DISCUSSION

All eight hair salons complied with the international occupational exposure limits. However, the measured CO₂ and RSP levels of several samples exceeded the Levels 1 and 2 of the Hong Kong IAQ Objectives. According to these objectives, Level 1 represents very good air quality that a high-class and comfortable building should have; and Level 2 represents indoor air quality that provides protection to the public at large including the very young and the aged. The rationale in devising these objectives is that ‘If all the parameters for “Level 2” or “Level 1” are met, the likelihood of indoor air pollution leading to health problems or discomfort in the building is remote. Building owners and employers therefore should endeavour to achieve at least Level 2 of the IAQ Objectives as far as practicable” (HKSAR, 1999). The compliance of the samples obtained in this study is compared with these IAQ objectives in Table 6.

Concentration profiles of PM_{2.5}, PM₁₀ and TVOC also reveal that the highest risk of exposure occurs mainly during the mixing and application of the chemicals, smoking, heating of the hair with a hair steamer or hair processor, and wrapping of the hair, in decreasing order of emission.

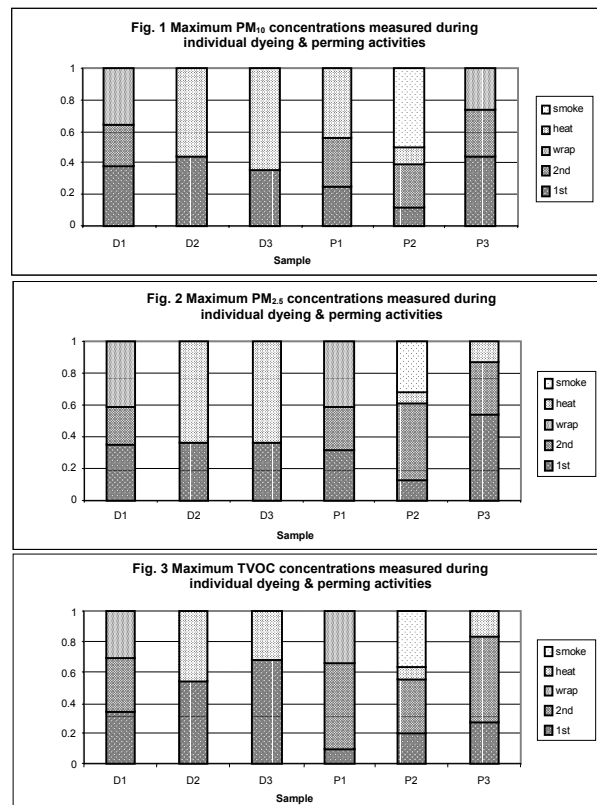


Table 6. Compliance of samples to Hong Kong IAQ Objectives (HKSAR, 1999)

Parameter	# Compliant to Level 1		# Compliant to Level 2		# of Incompliance
	Level 1	Level 2	Level 1	Level 2	
CO ₂ (ppm)	<800	4	<1,000	0	6
CO ($\mu\text{g}/\text{m}^3$)	<2,000	7	<10,000	3	0
RSP ($\mu\text{g}/\text{m}^3$)	<20	0	<180	3	7
NO ₂ ($\mu\text{g}/\text{m}^3$)	<40	2	<150	8	0
Room Temperature ($^{\circ}\text{C}$)	20 - 25.5	9	<25.5	0	1
Relative Humidity (%)	40 - 70	8	<70	0	2

The CO₂ concentration in salons in the Netherlands were found to be between 400 and 800 ppm in summer and reached its maximum at 2600 ppm in winter. The higher CO₂ concentration in winter was due to closed entrance door and windows and lack of mechanical ventilation (van der Wal *et al.*, 1997). Among the eight selected hair salons in this study, which had CO₂ levels ranging from 488 to 1763 ppm, four had CO₂ levels above 1000 ppm. Significant seasonal variations are not expected because all sampled salons are equipped with air-conditioners and their entrance doors and windows are kept closed throughout the year. In an extreme case, the maximum CO₂ concentration raised to as high as 3141 ppm during a hair dye sampling in one of the participant-selected salon (D1). This was because that particular hair salon was the largest, with over 20 hairdressers at work, and over 30 customers present at the time of sampling. The higher average CO₂ concentration detected in Hong Kong salons comparing to that in the Netherlands is most likely due to crowding and relatively poor ventilation.

While there was no significant difference found between weekday and weekend PM_{2.5} and PM₁₀ concentrations at the same hair salon, differences in their average concentrations up to a factor of 10 were present between salons (PM₁₀ ranging from 55 to 770 $\mu\text{g}/\text{m}^3$ and PM_{2.5} ranging from 58 to 660 $\mu\text{g}/\text{m}^3$). High PM concentrations were due to a combination of factors, including smoking, poor ventilation, crowding, and chemical applications (i.e. sprays, dyes, and perms). The respirable particles (<5 μm) measured in a Netherlands study (van der Wal *et al.*, 1997) ranged from 30 to 200 $\mu\text{g}/\text{m}^3$ with a mean of 100 $\mu\text{g}/\text{m}^3$ in summer. The winter measurements were a little higher, ranging from 80 to 390 $\mu\text{g}/\text{m}^3$ with a mean of 210 $\mu\text{g}/\text{m}^3$. These averages are lower than the average PM_{2.5} and PM₁₀ levels listed in Table 2, possibly because the salons selected in this study had lower ventilation rates, and higher intensity of tobacco smoking and applications of hairsprays, which are the major PM sources.

The VOC species and concentrations vary between salons due to the different brands of hair products used and different chemical treatments performed on the sampling day. Therefore, chloroform, for instance, was not detected at one salon but found to be as high as 93.1 ppb in another. VOC concentrations were found to be slightly higher on weekends than on weekdays in general due to the larger number of chemical treatments performed. Except for toluene and xylene, lower pollutant concentrations were detected in Salon A than Salon B, even though the former had a lot more chemical treatments taken place. Possibilities of such unexpected results are different exposure time (i.e. the time it took to mix the chemicals and to apply them to the customer), different procedures practiced by the hairdressers (e.g. some required heating of the hair while others did not), different brands of hair products used, as well as different ventilation rates in the salon. In spite of this, toluene and xylene levels were still found to be higher in Salon A than Salon B because these compounds are typically used in dyes, and there was a significantly larger number of hair dyeing performed in Salon A. Hollund and Moen (1998) measured toluene levels in six hair salons in Norway, and the concentrations ranged from 0.038 to 0.11 mg/m^3 (i.e. 10.08–29.19 ppb) with a mean of 0.06 mg/m^3 (15.92 ppb). In this study, the toluene levels measured in the salons (excluding that in which toluene was not detected) ranged from 0.63 to 40 ppb, with a mean of 13.81 ppb. The toluene level varies greatly among hair salons in Hong Kong, even though the average

concentration is comparable to that of the Norway study. This was due to the significantly different number of chemical treatments taken place in each salon on the day of sampling.

CONCLUSIONS

The toluene, CO₂ and PM_{2.5} and PM₁₀ levels were found to be in similar levels and slightly higher in comparison with the findings from previous salon studies in the Netherlands and Norway. Concentrations of the target pollutants were found to be higher on weekend than weekday, and higher during dyeing procedures than perming. However, interference from other chemicals within the salon and the intensity of solvents being applied were not taken into account. Therefore, detailed assessment of salon agents used in each process should be conducted, preferably in an environmental chamber, to investigate their individual constitution to the target pollutants. Although all target compounds measured were well below the current occupational exposure limit, hairdressers are exposed to a mixture of chemical agents at occasional high peaks. While there is very limited human data for effects of exposure to chemical mixtures, it would be of interest to focus future studies on exposure assessment to a large variation of specific hair products. More data sets and detailed activity patterns should be obtained to better differentiate between sources of specific pollutants.

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