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Assessing Indoor Air Quality in New York City Nail Salons

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Abstract

Nail salons are an important business and employment sector for recent immigrants offering popular services to a diverse range of customers across the United States. However, due to the nature of nail products and services, salon air can be burdened with a mix of low levels of hazardous airborne contaminants. Surveys of nail technicians have commonly found increased work-related symptoms, such as headaches and respiratory irritation that are consistent with indoor air quality problems. In an effort to improve indoor air quality in nail salons, the state of New York recently promulgated regulations to require increased outdoor air and “source capture” of contaminants. Existing indoor air quality in New York State salons is unknown. In advance of the full implementation of the rules by 2021, we sought to establish reliable and usable baseline indoor air quality metrics to determine the feasibility and effectiveness of the requirement. In this pilot study, we measured total volatile organic compounds (TVOC) and carbon dioxide (CO_2) concentrations in ten nail salons located in New York City to assess temporal and spatial trends. Within salon contaminant variation was generally minimal, indicating a well-mixed room and similar general exposure despite the task being performed. TVOC and CO_2 concentrations were strongly positively correlated (ρ=0.81; p<0.01) suggesting that CO_2 measurements could potentially be used to provide an initial determination of acceptable indoor air quality for the purposes of compliance with the standard. An almost tenfold increase in TVOC concentration was observed when the American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ANSI/ASHRAE) target CO_2 concentration of 850 ppm was exceeded compared to when this target was met.

Keywords

nail salons; total volatile organic compounds; indoor air quality; occupational exposure

INTRODUCTION

The nail salon industry in the United States has undergone a rapid expansion in the last two decades. The successful marketing of the affordable manicure has brought New York City (NYC) approximately 2,000 nail salons,(1) with 800 salons located in Manhattan alone.(2) In NYC, the nail salon industry is a significant source of business revenue and

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employment for Korean, Chinese, Vietnamese, and Nepalese immigrants, including many with limited English language skills and employment options.[3] In 2015, a series of investigative reports in *The New York Times* described the city's nail salon workers as facing multiple challenges at work, including a lack of formal health and safety training, exploitive employment practices, and limited protection from recognized hazards.[1, 4] The response to the national public attention these articles garnered included new funding for training efforts and promulgation of "emergency" regulations in New York State (NYS) to reduce hazardous exposures and to improve wage and employment conditions. These regulations have been controversial, with industry groups claiming that the new rules are burdensome and unnecessary.[5] However, the regulations, which include compliance with American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ANSI/ASHRAE) ventilation standards, have survived legal challenges and were made effective October 2016.

As has been well documented, nail salon workers are routinely exposed to a variety of chemicals across multiple pathways.[6–10] Chemicals commonly found in nail salon products[11] include carcinogens (formaldehyde)[12], endocrine disruptors (phthalates)[13], teratogens (toluene)[14], sensitizers (methacrylates)[15], and respiratory irritants (acetone, acetonitrile, and isopropyl acetate)[16]. In addition to the many volatile organic compounds (VOCs) emitted from products used for nail coatings, artificial nails, cleaners, adhesives, and coating removers, particles containing semi-volatile compounds can be emitted directly into the breathing zone by activities such as filing and shaping of artificial and coated nails and application of acrylic powders.[7, 17] The formation of secondary ultrafine particles in nail salons is possible due to the presence of VOCs and reactive gasses commonly found in urban environments.[18, 19] Indoor air (IAQ) studies have also shown that formaldehyde may be generated through reactions between ozone and VOCs.[18, 20]

Indoor concentrations of toluene, total VOCs (TVOCs), and methyl methacrylate (MMA) have been measured in a small number of nail salon studies. In general, mean concentrations of individual contaminants were below occupational exposure limits (OELs) [7–9, 21, 22]; however, one study conducted in Salt Lake City, UT did observe formaldehyde levels above the National Institute of Occupational Safety and Health (NIOSH) Recommend Exposure Limit (REL) in 58% of the salons surveyed (n=12).[9] Although airborne exposures in nail salon are generally well below OELs, a number of cross-sectional studies have reported health effects consistent with exposure to chemicals found in nail products and there are challenges in applying OELs in the nail salon environment.[23–26] A 2008 study conducted in Boston, MA found that nail salon workers commonly experience skin problems, respiratory irritation, and headaches.[24] In addition, nasal symptoms and airway inflammation have been associated with working in a nail salons. [23, 26] Neurological problems have also been reported; significant decreases in attention and processing speeds in a small sample of nail salon technicians (n=33) compared to demographically similar control group (n=35) were observed. [27]

In 2015 NYS promulgated regulations to improve IAQ in salons and to respond to some of these public health issues for workers, owners, and salon patrons. They require nail salons to install mechanical general ventilation (HVAC) and local exhaust ventilation systems (LEVs) to provide outside air and to exhaust contaminated air from the general salon environment and from manicure and pedicure stations directly to the outside. The recirculation of air within the salon or between the salon and other spaces was also prohibited. Salons must install or redesign their air moving systems to provide 20 cubic feet per minute (cfm)/per person (pp) of outdoor air plus 0.12 cfm of fresh air per 1000 ft^2 of space. The standard occupancy of 25 people per 1000 ft^2 was adopted; salons larger than 1000 ft^2 would need to increase the amount of fresh air provided to the salon. They must also install capture hoods at all manicure and pedicure stations no more than 12 in from the “source” with an airflow of at least 50 cfm.[28] These regulations are based upon ANSI/ASHRAE Standard 62 “Ventilation for Acceptable Indoor Air Quality” which is embedded in the 2015 International Mechanical Code and state building code.[29] All new salons were required to comply with this regulation effective October 2016, while nail salons licensed before regulation came into effect in October 2016 will have five years to comply with the requirements.

No exposure assessment or ventilation studies or surveys of acceptability of IAQ have been published to establish a baseline assessment of current conditions in NYS salons. Exposure and control strategies in previous studies may or may not be comparable across geographical regions due to differences in occupant density, building codes, climate, and other factors. The objectives of the current study were to determine feasible strategies for measurement of baseline IAQ in a pilot sample of NYC nail salons and assess temporal and spatial trends in contaminant variability. Results from this pilot study will be used to guide sampling methodology for a larger study.

METHODS

Recruitment

Ten nail salons were recruited for this pilot study from August to November 2017. All salons that were recruited had an owner or manager that spoke English. The participating salons were located in Manhattan (8) Queens (1), and the Bronx (1). The Manhattan salons were recruited by canvassing areas with a high concentration of nail salons. We would approach the manager or owner of the salon at the front desk and explain the purpose of the study and the instrumentation used to measure IAQ. We would then provide flyers to the owner/manager summarizing the study and our contact information. Of the 270 salons in total that were visited, 158 did not have an owner/manager present, 9 refused to participate, and 95 needed more time to decide or to consult with the salon owner and the salon did not follow up within the project timeframe. The participating salons located in Queens and the Bronx were recruited through partnerships with local community groups.

All recruitment materials, consent processes, and the study protocol and instruments were approved by the City University of New York Institutional Review Board. Each participating salon received a report interpreting the findings from their salon and providing recommendations for improvement if necessary.

Walkthrough Survey

We began the sampling protocol by administering a short questionnaire to the manager regarding the characteristics of the nail salon. The goal of the survey was to determine factors in the nail salon that may influence airborne concentrations and the types of ventilation and other air moving devices presently in use. We then performed a brief walk-through of the nail salon and sketched the layout of the nail salon including the location of diffusers, intakes, and any LEV ducts. The salon layout also included the approximate location of manicure and pedicure stations, waiting area, and other rooms in the salon (massage, waxing, etc.). Salon dimensions were determined using a laser distance measurer (GLM 30, Bosch, Gerlingen, Germany) with a maximum distance of 100 ft.

Air Monitoring

In each salon we deployed two CO_2 (IAQ-Calc model #7545, TSI Shoreview, MN) and two photo ionization detectors (PID), calibrated with isobutylene, with a 10.6 eV lamp (ppbRAE model# 3000, Honeywell, Morris Plains, NJ) to measure total volatile organic compounds (TVOC) concentrations. The PID has a range of 0.05 to 10,000 ppm. Table I shows chemicals that have been previously identified in nail salons, whether a PID is capable of detecting them, and the correction factor for the PID. The majority of common VOCs found in nail salons such as acetone, ethyl acetate, isopropyl alcohol, methyl methacrylate, and toluene are detectable with a PID. For some chemicals found in nail salons the ionizing potential is unknown; therefore, we could not assess whether it was detectable with a PID.[16]

Two locations in the salon were chosen to co-locate the monitors. Our goal was to capture the greatest amount of contaminant variability in the salon while sampling as close as possible to workers' and clients' breathing zone. When feasible, the instruments sets were positioned on opposite sides of the room, with one set of monitors near nail tables and the other set of monitors near pedicure chairs. All instruments were calibrated according to the manufacturer's instructions. All direct reading instruments were programmed to datalog concentrations every minute.

All measurements were collected on weekdays and monitors were set up in the morning when the salon was not busy and allowed to continue to datalog until the salon closed. Closing time for salons in the study ranged from 8:00 to 10:00 pm. Samplers were retrieved by technicians the following day and data were downloaded from the instruments. Sampling time differed by salon and ranged from 345 to 706 minutes.

Acceptable IAQ for Nail Salons

There are no accepted IAQ standards for measured concentrations of mixed contaminants, nor for most of the individual contaminants found in nail salons. The ANSI/ASHRAE standard for ventilation for acceptable indoor air quality proposes that "acceptable" IAQ is likely to be achieved when specified guidelines for provision of fresh air and exhaust of contaminated air are followed, measured contaminants do not exceed consensus standards, and 80% of occupants agree that the air quality is acceptable.[30] As discussed above, the NYS standard adopts the values presented in this standard's Table 6.2.2.1 Minimum

Ventilation Rates in Breathing Zone for beauty and nail salons. This table specifies a "default value" of outside air provided at 25 cfm/pp which can be used in place of a calculated value that considers specific salon size, season, and occupancies. Given human respiration rates, and this default value of 25 cfm/pp of outside air, the target indoor CO_2 concentrations in salons should not exceed 850 ppm (approximately), given an outdoor CO_2 concentration of 430ppm (measured by the authors in NYC). CO_2 levels alone are not recommended as a measure of acceptable IAQ, but can be used as an indicator in conjunction with other performance and outcome metrics, such as assessment of acceptability of indoor air to occupants and use of local exhaust ventilation near contaminant sources.

Statistical Analyses

Data analyses were conducted using SAS statistical software (version 9.4, Cary, NC). Normality of TVOC and CO_2 concentrations were assessed using the Kolmogorov-Smirnov test and determined to be not normally distributed even when data were log-transformed. Descriptive statistics including arithmetic means, medians, 25^{th} and 75^{th} percentiles, and range of airborne concentrations were calculated. Scatter plots of CO_2 and TVOC concentrations by time were created using the LOESS option to determine how exposure inside the salon varies over the course of the day. Spearman's correlations (ρ) were calculated for both continuous and categorical variables. For correlations between TVOC and CO_2 concentrations and salon characteristics (salon volume, number of pedicure and manicure stations, etc.), concentrations within the salon were averaged and the mean concentration was used to assess the correlation between contaminant concentration and the selected salon characteristic. TVOC measurements below the limit of detection (LOD) were substituted with the LOD/$\sqrt{2}$.

RESULTS

General characteristics of the participating nail salons are presented in Table II. The average nail salon volume was 14200 ft^3 with almost a tenfold difference between the smallest and largest salon surveyed (range: 6075–42500 ft^3). This variability was also observed in the number of manicures (range: 30–500), pedicures (range: 30–400), and artificial nails (range: 1–50) performed per week, with an order of magnitude difference between salons. While all participating salons had a HVAC system, only 7 (70%) salons were using mechanical ventilation during the time of sampling. In general, salons that were not using their HVAC system relied on natural ventilation by opening their doors. Other air moving devices observed in the salons included ceiling fans (1), table fans (5), and air purifiers (3). No participating salons had LEV systems installed.

Descriptive statistics of averaged air monitoring data are shown in Table III. Overall, TVOC data was highly right skewed with a median of 4.0 ppm, a mean of 12 ppm, and a range spanning four orders of magnitude (0.035–67 ppm). Mean CO_2 concentrations across all nail salons was 800 ppm with concentrations spanning one order of magnitude (range 400–1800 ppm). Relative humidity and temperature were fairly uniform in all salons and met recommended guidelines for thermal comfort.[31]

With the exception of CO_2 measurements in Salon 1, CO_2 and TVOC concentrations were measured in two different locations in the nail salon and generally showed limited spatial variability (Table IV). Salon 10 was an outlier to this trend and TVOC and CO_2 were markedly increased in the manicure area compared to the pedicure area. The Spearman's correlation between the two CO_2 monitors for all salons was 0.95 ($p<0.01$), while the correlation was slightly lower (0.83), but still highly significant ($p<0.01$) for TVOC monitors. Greater variation in TVOC and CO_2 concentrations were observed between salons with TVOC concentrations differing by as much as two orders of magnitude. Due to relative homogeneity of contaminant concentrations, CO_2 and TVOC monitoring data from the two sets of monitors were averaged within salons by sampling time.

TVOC concentrations averaged within salons were stratified by the ANSI/ASHRAE target CO_2 concentration of 850 ppm (Table V). Three salons were below the CO_2 target over the entire sampling period, while two salons were above the target for the majority of the sampling period. Overall, TVOC concentration averaged 32 ppm during times when the target was exceeded and 4.1 ppm when the target was achieved. The percent increase in TVOC concentrations when the target CO_2 was exceeded ranged from 18–250% depending on the salon.

We found a highly significant ($p<0.01$) positive correlation (0.81) between CO_2 and TVOC concentrations inside salons. No other variables (reported number of pedicures and manicures performed during the week, number of customers per busiest day, salon volume, and total number of nail tables and pedicure chairs) were correlated with either TVOC or CO_2 concentrations.

DISCUSSION

The objectives of this study were to establish feasible and effective IAQ metrics for nail salons located in NYC and to assess temporal and spatial trends in contaminant concentrations to help inform future exposure assessment studies. Overall, CO_2 and TVOC concentrations were not uniform and varied throughout the day. TVOC and CO_2 concentrations were strongly positively correlated suggesting that CO_2 measurements could potentially be used as a screening indicator as part of an assessment of acceptable IAQ in salons, per the NYS standard. In general, within salon contaminant variation was minimal indicating a well-mixed room.

Airborne concentrations of CO_2 and TVOC were fairly spatially uniform throughout the salons we sampled. The one exception was in Salon 10 which was an outlier from the other salons we recruited. The salon was smaller (volume= 6600 ft^3) and specialized in artificial nails and did not perform many pedicures per week (n=50). In addition, the pedicure chairs were located near the only entryway which could also account for the decreased TVOCs and CO_2 concentrations near this area.

Overall CO_2 concentrations observed in this study were lower than what has been previously reported, which may be due to the higher prevalence of HVAC systems in the sample, seasonal effects, and the relatively large room volume of many of the nail salons in this study.[7, 9, 32] Measurements in this study were collected in the summer and autumn and some salons had their doors open or were inclined to use their HVAC system for comfort. The range of CO_2 concentrations varied by salon with Salons 5 and 8 approaching background CO_2 levels, while Salon 1 and Salon 2 exceeded the target CO_2 concentration of 850 ppm by 40–65%, respectively. In Salon 1, the HVAC system was turned off for the day and windows and doors were closed; however, in Salon 2 the HVAC system was turned on, yet CO_2 concentrations exceeded the target by 65% indicating that salon air was recirculated and/or inadequate outdoor air was injected into the salon. Figure 2 shows the fluctuations in TVOC and CO_2 concentrations throughout the day in Salon 2. Greater variation was observed in TVOC concentrations compared to CO_2 which appeared to achieve a steady state concentration as the day progressed.

Three of the salons did not exceed the 850 ppm CO_2 target concentration at any time during the sampling period, which would suggest that they were meeting the goals of the NYS nail salon regulation regarding provision of outside air. In addition to the requirements for provision of outside air, the NYS and ANSI/ASHRAE standard specifies that nail salons exhaust general air at 620 cfm/1000ft^2 and provide source capture at each manicure and pedicure station at 50 cfm within 12 inches of the point of generation. None of the salons in our sample met these additional specifications for source capture. We did not assess occupant perception of IAQ.

Since real-time instrumentation was used to measure TVOC concentrations, results from this study were not comparable to the majority of published studies which used a mass-based sampling strategy.[6–10] However, a recent study conducted in Boston, Massachusetts used similar instrumentation and achieved similar results. Investigators sampled seven locations inside salons for short periods of time (one minute). The overall TVOC concentrations observed in that study ranged from 0.66–38 ppm with a median concentration of 4.8 ppm. The authors also concluded that the distribution of TVOC concentrations were fairly uniform throughout the salon.[33] It is important to note that while the ANSI/ASHRAE guidelines can lower TVOC concentrations in nail salons, mean TVOC concentrations observed in this study were still many times greater than what would be considered acceptable in residences or office work environments.[34, 35]

Results from our study can help inform future exposure assessment, ventilation, and IAQ studies conducted in nail salons. The temporal trends in TVOC concentrations suggest that time-weighted average sampling underestimates peak concentrations. Many of the contaminants in nail salons are irritants which have a stronger association with peak exposures compared to traditional mass-based sampling. Epidemiological studies investigating health effects in nail salons may benefit from a combination of the two methods, real-time and mass-based, when evaluating the exposure-disease relationship. Futures studies should try to evaluate the effect of general and local exhaust ventilation in reducing contaminant concentrations and the patterns of use of these methods. We were unable to directly measure ventilation rates due to the configuration of the ceiling inside salons. Given these physical constraints, indirect measures of ventilation, such as CO_2 levels, may need to be relied upon to estimate outdoor air intake and provide evidence of acceptable IAQ and compliance with ventilation requirements in salons.

Our study had several limitations which may limit the generalizability of the results. We utilized a small convenience sample of salons located mainly in Manhattan. These salons, on the whole, tended to be more "upscale" and spacious compared to other salons in NYC. Although our refusal rate was low, overall our study had a low participation rate for approached salons. We do not have exposure data on salons that were approached but did not to participate in order to evaluate the representativeness of our sample. TVOC concentrations were measured using a PID calibrated to isobutylene which may overestimate or underestimate TVOCs depending on the contaminants in the salon air. We were interested in overall IAQ for all salon occupants and did not focus on salon workers' breathing zone personal measurements.

Strengths of the study include its relevance to public health policy concerns and its timely contribution to the understanding of baseline salon IAQ in advance of the full implementation of the rules by 2021. In comparison to previous exposure assessment studies, our study was unique and collected real-time measurements to evaluate temporal trends in IAQ. In addition, the study adhered to standard procedures to minimize between salon variations.

CONCLUSIONS

Despite observable "point sources" for contaminants resulting from nail enhancement tasks, within salon contaminant variation was minimal, demonstrating the importance and effectiveness of general exhaust ventilation as a strategy to improve IAQ in salons. Temporal trends indicate exposure inside salons are not uniform throughout the day suggesting that HVAC systems should be designed to adjust airflow to increase during peak operation times or in response to CO_2 sensors. While CO_2 concentration measurements alone have not been considered a suitable strategy for monitoring or achieving acceptable IAQ, our study suggests a decrease in CO_2 concentrations is associated with a reduction in TVOC concentrations. Since TVOC concentrations in nail salons vary throughout the day, full-shift sampling is necessary to adequately characterize airborne levels. Given this variability and that many of the chemicals found in nail salons are irritants, peak exposures should be considered when evaluating exposure-disease relationships. Further study is necessary to validate these metrics in a greater number of salons and to determine the additional impact of LEV source capture systems on overall IAQ.

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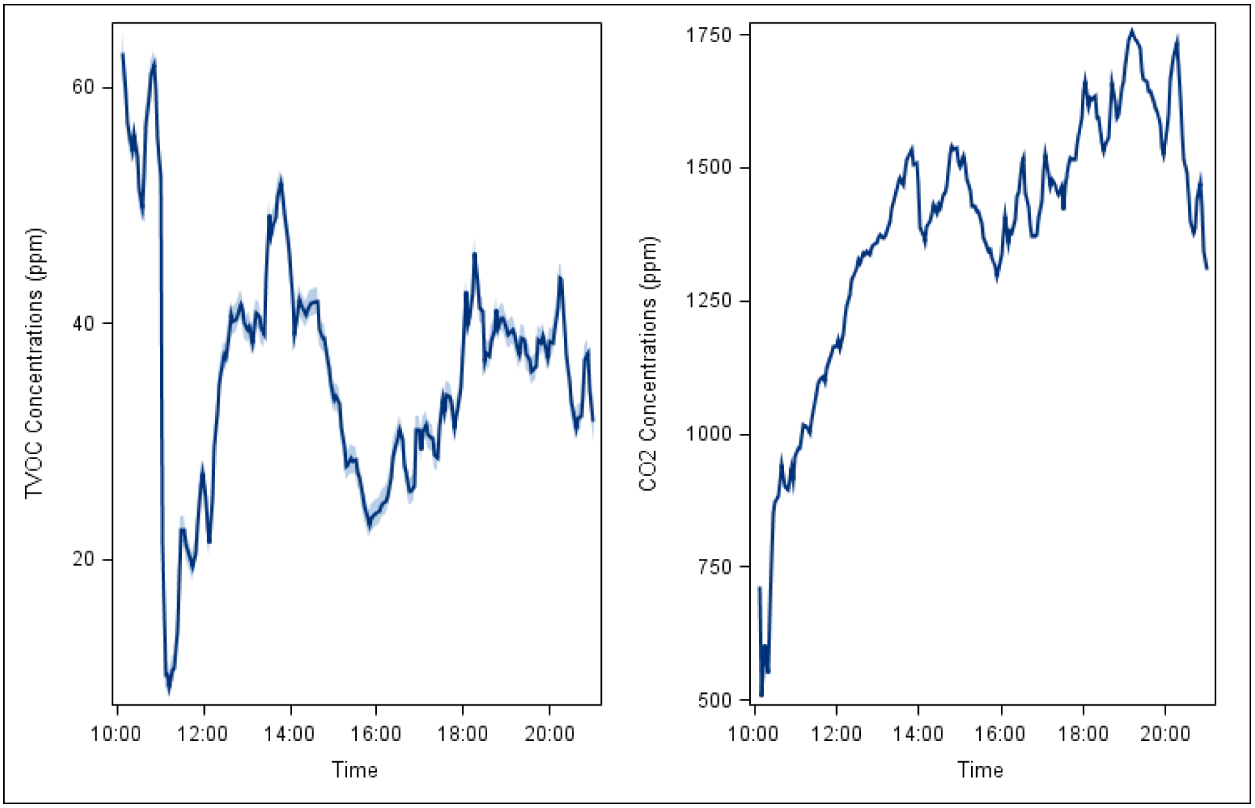

Figure I:
TVOC and CO_2 Concentrations (ppm) by Time for Salon 2

Table I:

List of Chemicals Commonly Found in Nail Salons

Chemical	Source(s)	Detectable with a PID	Correction Factor
Acetone	(6, 9, 11, 24)	Yes	1.1
Acetonitrile	(11, 24)	No	---
Benzene	(9)	Yes	0.53
Butyl acetate	(6, 11, 24)	Yes	2.6
Butyl methacrylate	(24)	Unknown	---
Dibutyl phthalate	(11, 24)	Unknown	---
Ethyl acetate	(6, 9, 11, 24)	Yes	3.49
Ethyl alcohol	(24)	Yes	10
Ethyl cyanoacrylate	(24)	Unknown	---
Ethyl methacrylate	(11)	Unknown	---
Formaldehyde	(9, 11, 24)	No	---
Isopropyl acetate	(6, 11)	Yes	2.1
Isopropyl alcohol	(6, 9, 11, 24)	Yes	6.0
Methacrylic acid	(11)	Unknown	---
Methyl ethyl ketone	(24)	Yes	0.9
Methyl methacrylate	(6, 9, 11, 24)	Yes	1.5
N-Methyl-2-pyrrolidone	(24)	Yes	0.80
Toluene	(6, 9, 11, 24)	Yes	0.50
Xylenes	(24)	Yes	0.39–0.46

TABLE II:

Descriptive Characteristics of Nail Salons Sampled

Variable	Mean (range) or n (%)
Volume (ft^3)	14200 (6075–42500)
Number of nail tables	9.4 (7–14)
Number of pedicure stations	8 (3–10)
Number of customers per busiest day	62 (20–110)
Number of manicures per week	182 (30–500)
Number of pedicures per week	157 (30–400)
Number of artificial nails per week	15 (1–50)
HVAC system in salon	10 (100)
HVAC in operation	7 (70)

TABLE III:

Indoor Air Quality Metrics for Nail Salons Surveyed

Sample	Mean	25th Percentile	50th Percentile	75th Percentile	Range
TVOC (ppm)	12	1.9	4.0	13	0.035–67
CO_2 (ppm)	800	590	720	900	400–1800
Temp (°C)	24	24	25	26	18–31
Relative humidity (%)	48	45	50	52	30–74

Table IV:

TVOC and CO_2 Concentrations (ppm) by Salon

Salon	Section	TVOC		CO_2	
		Mean	Range	Mean	Range
1	Pedicure	44	3.2–71	1200	630–1500
	Manicure	41	2.9–71	---	---
2	Pedicure	32	0.035–57	1500	960–1900
	Manicure	30	0.035–52	1400	480–1800
3	Pedicure	2.9	0.68–6.7	750	640–900
	Manicure	3.5	0.85–7.9	750	640–900
4	Pedicure	3.9	0.67–9.7	620	500–800
	Manicure	3.7	0.035–7.5	630	430–750
5	Pedicure	2.3	0.035–10	550	400–700
	Manicure	0.37	0.035–3.8	500	420–900
6	Pedicure	3.7	0.035–16	680	510–850
	Manicure	3.4	0.035–8.1	700	520–930
7	Pedicure	1.6	0.75–2.9	820	730–1000
	Manicure	2.1	0.035–4.3	830	600–1000
8	Pedicure	1.3	0.035–9.6	480	400–690
	Manicure	2.7	0.035–26	480	400–750
9	Pedicure	5.2	0.035–30	630	410–1100
	Manicure	5.3	0.035–38	620	430–1100
10	Pedicure	3.2	0.10–14	740	500–1100
	Manicure	19	9.0–53	860	520–1100

TABLE V:

TVOC Concentrations (ppm) Stratified by CO_2 Concentrations Above and Below the Target of 850 ppm

Salon	CO_2 target	% of time	Mean TVOC	Range TVOC
1	Above	88	46	19–67
	Below	12	13	3.1–20
2	Above	100	32	3.5–53
	Below	0	---	---
3	Above	9	6.7	5.8–7.3
	Below	91	2.9	0.80–5.7
4	Above	0	---	---
	Below	100	3.8	0.44–8.0
5	Above	0	---	---
	Below	100	1.4	0.035–5.1
6	Above	2	5.0	3.4–6.7
	Below	98	3.5	0.035–11
7	Above	25	2.1	1.0–3.0
	Below	75	1.7	0.44–3.1
8	Above	0	---	---
	Below	100	2.5	0.035–51.4
9	Above	20	11	7.1–18
	Below	80	4.5	0.035–50
10	Above	31	13	6.8–21
	Below	69	11	4.7–28