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Air quality and particulate matter speciation in a beauty salon and surrounding outdoor environment: exploratory study

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Abstract

Beauty salons are considered occupational environments where the staff personnel and clients are exposed to high levels of airborne pollutants. In this study, air quality monitoring was carried out in León, Spain. Temperature, relative humidity, CO₂, CO and particulate matter were continuously monitored inside and outside areas of the salon. PM₁₀ was simultaneously collected onto filters. Volatile organic compounds and carbonyls were sampled inside the salon. Indoor PM₁₀ concentrations exceeded the recommended 24-h guideline of 50 µg m⁻³. A detailed PM₁₀ chemical characterisation included organic and elemental carbon, trace elements, water-soluble ions and organic speciation. Indoor vs outdoor ratios of PM₁₀, as well as the majority of PM₁₀-bound organic compounds, were > 1. During work periods, organic carbon accounted for 29.5 ± 1.8 and 16.2 ± 4.5 %wt. of PM₁₀ indoors and outdoors, respectively. More than 200 individual organic compounds were detected in the PM₁₀, including aliphatic alcohols, fatty acids, phthalates, glycerol derivatives, fatty acid alkyl esters, phenolic compounds, alkanes and polycyclic aromatic hydrocarbons, among others. Many of them are part of formulations widely

used in hair cosmetics, personal care and cleaning products. Inadequate ventilation, working activities and the use of specific products can greatly contribute to high indoor levels of organic air pollutants. Formaldehyde revealed a cancer risk of 4.6×10^{-6} , higher than the guideline level, suggesting a “possible risk” for workers. The total excess lifetime cancer risk from exposure to multiple compounds was 9.3×10^{-6} , which is lower than the acceptable risk, but not negligible.

Keywords: Air quality, VOCs, Carbonyls, PM₁₀, Elemental composition, Organic compounds.

1. Introduction

The US Environment Protection Agency (EPA) ranked indoor air pollution as one of the top five environmental risks to public health. Population spends the bulk of their time in residential or non-residential indoor environments, which can have 2–5 times higher pollutant levels than outdoors (EPA, 2015; Jafari et al., 2015; Hadei et al., 2018; Morawska et al., 2013; Pegas et al., 2011; Weisel et al., 2008). Furthermore, human exposure to indoor air pollutants may occasionally be more than 100-fold higher when compared to outdoor areas (EPA, 2015). Exposure to indoor air pollutants in private and professional environments can lead to a broad range of health problems. Poor indoor air quality can be a common problem in homes (Bentayeb et al., 2015; Du et al., 2020), schools (Kalimeri, et al., 2016; Lucialli et al., 2020; Pegas et al., 2011), offices (Guo et al., 2004; Saraga et al., 2014), restaurants (Guo et al., 2004; Lee et al., 2001) and other public facilities such as hospitals, elderly care centres, libraries, pharmacies, gymnasiums and museums (Bruno et al., 2008; Śmiełowska et al., 2017).

Several hazards have been associated with the hairdressing profession due to the use of a vast array of cosmetic products, many of which have constituents classified as dangerous (Aglan and Mansour, 2020; Czene et al., 2003; EU-OSHA, 2014; Labrèche et al., 2003; Pak et al., 2013; Quiros-Alcala et al., 2019). It was recognised that hairdressers are exposed to serious occupational health risks related not only to their work, but also to workspace environment as well (Ana et al., 2019; Czene et al., 2003; EU-OSHA, 2014). Particularly, the products and treatment techniques used in beauty salons can put both the salon personnel and customers at risk of exposure to hazardous chemicals. Work-related symptoms and diseases such as respiratory symptoms (Al-Marshad et al., 2016; Foss-Skiftesvik et al., 2017; Nemer et al., 2017), asthma (Dahlgren and Talbott 2018), reproductive disorders (Baste et al., 2008; Henrotin et al., 2015; Pak et al., 2013; Ronda et al., 2009; Rylander et al., 2002) and skin diseases

(Hajaghazadeh et al., 2018; Mancini et al., 2018) have been reported for the hairdressers and nail technicians.

Indoor air quality (IAQ) in beauty salons can be affected by various contaminants such as ammonia (NH₃), volatile organic compounds (VOCs) and particulate matter (PM). Pollutant concentrations in beauty salons depend on the type of products used, the area of the facility, the efficiency of air exchange and the number of occupants and treatments (Chang et al., 2018; de Gennaro et al., 2014; Goldin et al., 2014).

Benzene, toluene, ethylbenzene and xylene (BTEX), commonly found in indoor environments, are well known to be toxic, mutagenic and/or carcinogenic. Health risk assessment studies showed that benzene, ethylbenzene, formaldehyde and acetaldehyde, measured in beauty salons, represent a possible cancer risk, while toluene, ethylbenzene and xylene had negligible non-carcinogenic risks (Hadei et al., 2018; Baghani et al., 2018). Formaldehyde has been widely reported to cause dermatologic allergic reactions (Kim et al., 2011) and was classified as a probable human carcinogen by the Integrated Risk Information System (IRIS) and as a carcinogenic by the International Agency for Research on Cancer (IARC) and by the U.S. National Toxicology Program (NTP) agencies. Polycyclic aromatic hydrocarbons (PAHs), commonly found in particulate matter, were considered as potent carcinogens and associated with lung cancer (WHO, 2010).

Hairdressers are chronically exposed to formaldehyde concentrations that meet or exceed current occupational exposure limits in the work environment. These exposures are predominantly associated with the use of products for hair straightening (Aglan and Mansour, 2020; Dahlgren and Talbott, 2018; Peteffi et al., 2016; Pexe et al., 2019; Pierce et al., 2011; Stewart et al., 2013). Furthermore, cancer risk values for prolonged exposure to benzene and ethylbenzene can be drastically higher than recommended levels (Baghani et al. 2018).

Several IAQ and/or exposure assessment studies have been carried out in hairdressing and beauty salons, but most of them assessed a limited number of air pollutants. Ronda et al. (2009) examined comfort parameters (air temperature, relative humidity), CO and CO₂ and found low exposure levels for thirty-three VOCs in the working environment of hairdressers. Gennaro et al. (2014) have reported much higher indoor levels in hair salons for several VOCs, including oxygenated compounds and terpenes, when compared to outdoor concentrations. Total volatile organic compounds (TVOC) concentration, CO₂ and PM_{2.5} were measured in nail salons by Goldin et al. (2014). The results of their study demonstrate that TVOCs and PM with aerodynamic diameter less than 2.5 µm (PM_{2.5}) exceed typical levels found in residential environments. The concentrations of oxygenated VOCs, CO₂, formaldehyde and phthalate

esters were measured at hairdressing salons by Chang et al. (2018). They detected higher levels of VOCs and phthalates than what has been monitored in residential areas. Relatively few studies measured airborne particles in beauty salons. Exposure levels of persulphate ($S_2O_8^{2-}$) containing particles were measured by Mounier-Geyssant et al. (2006) and Nilsson et al. (2015). Shao et al. (2021) characterised indoor $PM_{2.5}$ and PM_{10} concentrations in hair salons primarily serving a Black/Latino clientele. Their findings suggest that hairdressers could be potentially overexposed to respirable particles during an 8-hour shift based on current occupational exposure limits. Saraga et al. (2014) studied the respirable particle levels in different workplaces and recorded the maximum particle concentration at a hairdresser store. In other studies, performed in beauty salons, total suspended particulate matter (TSP), its respirable sub-fraction (PM_4) and carbonaceous content (organic and elemental carbon, OC and EC) were simultaneously measured indoors and outdoors (Rogula-Kopiec et al., 2017; 2019). The chemical composition of airborne particles in beauty salons is poorly known. Therefore, there is a need for further research, given that beauty salon staff are exposed to a vast number of airborne chemicals during the whole workday and that the characterisation of the chemical composition of PM is an important factor to establish the relationship between occupational health hazards and IAQ. The main objective of this study was focused on air quality monitoring in a beauty salon in León (Spain) with special emphasis on PM_{10} -bound compounds. A detailed characterisation of organic and inorganic components of PM_{10} was carried out for the first time. Additionally, comfort parameters and VOC concentrations were evaluated.

2. Methodology

2.1. Sampling site and strategy

The study was carried out between 20th and 24th of November 2017 in a hairdresser salon located in the vicinity of a relatively dense traffic avenue in León, Spain. The salon is located in a building nearby the university and is open from Monday to Friday for 10 hours straight. Customers were either regular or occasional, generally of both sexes, with a higher proportion of men. The space layout included a reception/ waiting room at the front, two hairstyling areas, a waxing room and a dispensary room in the back. Most hair care products are mixed in the dispensary where most of hairstyling products are stored. The salon offers a wide range of services including manicures, pedicures, waxing services and hair styling/colouring. The number of clients and the respective type of treatments were monitored for each sampling day (Table S1). There were no heating, ventilation or air conditioning (HVAC) systems inside the working space. Taking into account that the measurement campaign took place in winter, the windows were closed. The door was opened periodically during the entrance and exit of clients.

The sampling design is presented in Table S2. Comfort parameters, CO, CO₂ and PM monitoring were carried out for five working days and one weekend day. The measurements were performed simultaneously inside and outside of the salon during occupancy periods and only in the indoor environment during the non-occupancy period. Airborne PM₁, PM_{2.5} and PM₁₀ were continuously monitored by a photometric method. Two samplers were used to collect PM₁₀ onto quartz and Teflon filters for gravimetric analysis and determination of trace elements, water-soluble ions, carbonaceous content, and speciation of organic compounds. The monitoring equipment and PM samplers were placed in the centre of the salon. Outdoors, the equipment was placed about 3 m away from the salon. Considering that the main objective of this study was focused on chemical composition of PM, VOCs and carbonyl compounds were sampled only indoors for three working days. Three VOC/carbonyl samples per day, covering the working hours, were collected.

Health risk were assessed according to the methodology established by the United States Environmental Protection Agency (Supporting Information).

2.2. Air quality monitoring

2.2.1. Comfort parameters, CO, CO₂ and ventilation rate

Temperature, relative humidity, CO₂ and CO were continuously monitored with air quality probes inside (TSI, model 7545) and outside (Gray Wolf®, WolfSense IQ-610) the salon. The air exchange rate (AER) was estimated by the CO₂ concentration decay method (Alves et al., 2020).

2.2.2. Volatile organic compounds

VOCs for quantitative analysis were collected on tenax/sulphicarb tubes (Gradko) connected to sampling pumps, which were calibrated to provide a volumetric airflow rate of 50 mL min⁻¹. VOC samples were analysed via thermal desorption and gas chromatography-mass spectrometry (GC-MS) in an accredited laboratory (Gradko International Ltd) following the methodology established in ISO 16000-6, Part 6.

Carbonyls were sampled with Waters Sep-Pak® DNPH-silica cartridges at a flow rate of 2 L min⁻¹. The elution of aldehyde derivatives was performed with 3 mL of acetonitrile (Fischer Scientific). The carbonyl-DNPH derivatives were analysed by high performance liquid chromatography (HPLC). HPLC measurements were carried out with a Jasco PU-980 pump, a Rheodyne 7125 six-port valve with a 20 µL loop and a Jasco MD-1510 diode array detector. An isocratic mixture of acetonitrile and water (60:40), with a flow rate of 1.5 mL min⁻¹, was used to separate the 2,4-DNPH on a Supelcosil™ LC-18 column (5 µm particle size; L × I.D. 250 × 4.6 mm). Calibration of the analytical system was performed using DNPH-derivatives of

carbonyl compounds from Supelco. The Statistical Package for Social Sciences (IBM SPSS Statistics 27) was used for calculation of Pearson correlation coefficient.

2.2.3. Particulate matter

Airborne PM mass concentrations were continuously measured by a laser photometric instrument (TSI, DustTrak DRX 8533) in the indoor and outdoor environments, simultaneously. These continuous monitoring instruments were operated with 1-min resolution. PM₁₀ samples were collected onto 150 mm quartz fibre filters (Pall Corporation) with two high volume air MCV (model CAV-A/mb) instruments, working at a constant flow of 30 m³ h⁻¹. PM₁₀ samples were also collected on Teflon membrane filters (47 mm diameter, Pall Corporation) with a TCR TECORA (model 2.004.01) operated at a flow of 2.3 m³ h⁻¹. The gravimetric quantification was performed with an analytical balance (Mettler Toledo, XPE105 DeltaRange®).

The carbonaceous content (OC and EC) in PM₁₀ samples (quartz filters) was analysed by a thermal optical transmission technique. The method consists of particulate carbon volatilisation by means of controlled heating, with subsequent conversion by oxidation to CO₂ for detection. The monitoring of the blackening of the filters through light transmittance allows the separation of EC formed by OC pyrolysis from the one that was originally in the sample (Pio et al., 2011). Two 47 mm diameter punches of each quartz filter were extracted with dichloromethane (125 mL, 24 h) and methanol (25 mL for 10 min, two extractions). The total organic extracts were concentrated using a Turbo Vap® II concentrator (Biotage) and dried under a nitrogen stream. Night sampling filters were extracted all at once, while the indoor and outdoor samples collected during the occupancy periods were extracted individually. Each total organic extract was separated into five different organic fractions by flash chromatography described in detail by Alves et al. (2011). All extracts were analysed by gas chromatography-mass spectrometry (GC-MS) with quadrupole. Data were acquired in the electron impact (EI) mode at 70 eV using helium as carrier gas at 1.1 mL min⁻¹. Aliphatic and polycyclic aromatic hydrocarbons extracts were analysed in a Shimadzu QP5050A equipped with a TRB-5MS 30 m × 0.25 mm × 0.25 µm column. The oven temperature program was as follows: 60 °C (1 min), 60–150 °C (10 °C min⁻¹), 150–290 °C (5 °C min⁻¹), 290 °C (30 min). The aliphatic compounds were analysed in full scan mode while PAHs were monitored in selected ion mode (SIM). Before chromatographic injection, polar organic compounds were derivatised to trimethylsilyl ethers by addition of N,O-bis(trimethylsilyl)trifluoroacetamide (BSTFA):trimethylchlorosilane (TMCS) 99:1 (Supelco) and pyridine containing 2 internal standards: 1-chlorohexadecane (Merck) and tetracosane-d₅₀ (Aldrich). The reaction mixture was heated in an oven at 70 °C for

3 h. The GC-MS used for the determination of oxygenated compounds was from Thermo Scientific (Trace Ultra, quadrupole DSQ II), equipped with a TRB-5MS 60 m × 0.25 mm × 0.25 µm column. The oven temperature program was as follows: 60 °C (1 min); 60–150 °C (10 °C min⁻¹), 150–290 °C (5 °C min⁻¹), 290 °C (37 min). The silylated compounds were analysed in both full scan and selected ion monitoring (SIM) modes.

After weighing the Teflon filters for PM₁₀ quantification, one half of each filter was used for the determination of the elemental composition by proton-induced X-ray emission (PIXE), which enables a non-destructive and simultaneous analysis of elements with atomic number above 10 (Lucarelli et al., 2014). The other half of the filter was extracted with Milli-Q water by ultrasonic agitation (15+15 min) for ion chromatography analysis. A detailed description of the sample preparation method and analytical equipment can be found elsewhere (Vicente et al., 2020).

2.2.4. QC & QA measures

All monitoring equipment was calibrated prior to use by employing routine calibration procedures. The pump flowrate was calibrated before sampling of VOCs using a soap bubble glass flow meter. To avoid contamination, the quartz filters were pre-baked at 500 °C for 6 h. The GC-MS calibration was performed in six levels (3-50 ppm) by injection of more than a hundred authentic standards. Standards and samples were both co-injected with internal standards. All chemicals were of analytical reagent grade (Sigma-Aldrich). The limit of detection (LOD) and limit of quantification (LOQ) varied from 0.02 to 6.3 and from 0.07 to 20.8 ng m⁻³, respectively, depending on the compound. Generally, the extraction recovery was accomplished based on previous works and varied from 60 to 99% for oxygenated compounds and from 38 to 133% for PAHs and phthalates (Vicente et al., 2019). Quality assurance procedures also included field blanks for each technique, which were subjected to the same analytical procedures, and their concentrations were subtracted from those of real samples.

3. Results and Discussion

3.1. Comfort parameters, CO, CO₂ and ventilation rates

Temperature and relative humidity affect the perception of comfort in an indoor environment and are related to one's metabolic heat production, transfer of heat to the environment, physiological adjustments and body temperature. For winter, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) indoor environmental guidelines recommend maintaining the temperature in the range between 20.3 and 23.9 °C, assuming 50% relative humidity. The mean indoor temperature during working hours in the beauty salon was 18.7 ± 0.7 °C (Table S3). These values do not provide reasonable comfort without special

clothing and could present discomfort to both workers and clients. The relative humidity recorded inside the salon was between 28.6 and 53.2%, which is within the comfort zone: below 65% and in the 30-60% range recommended by ASHRAE and EPA, respectively. Carbon dioxide, a by-product of the human metabolism, is widely used as an indicator of IAQ and ventilation rate. The mean daily indoor concentration of CO₂ (818 ± 82 ppm) remained within the ASHRAE permissible limit of 700 ppm above outdoor CO₂ concentrations. The distribution pattern showed higher CO₂ levels during the day and lower at night (Fig. 1). The indoor CO₂ concentrations correlated linearly with the daily number of clients attending the salon ($R^2 = 0.72$). The highest CO₂ concentrations near the ASHRAE permissible level were observed on the 1st day and were related to the maximum number of customers per day. Indoor CO concentration levels did not exceed the maximum allowable short-term limit of 9 ppm established by ASHRAE for CO in indoor air.

The air exchange rate (AER) values ranged between 0.28 and 0.41 h⁻¹, which indicate lack of adequate ventilation. The minimum recommended ventilation rates for acceptable IAQ in beauty and barber shops range from 6 to 10 h⁻¹ (Engineering ToolBox, 2005). Given that during wintertime airing of the salon can be limited, the installation of heating and ventilation systems could provide the necessary conditions to assure the acceptable thermal comfort and IAQ.

3.2. Volatile organic compounds

3.2.1. BTEX

BTEX are commonly the most abundant compounds amongst VOCs found in the indoor environment. Primary indoor sources of BTEX include building materials, fuel combustion, tobacco smoke and consumer products. Combustion of fossil fuels has been pointed out as the largest contributor to outdoor air concentrations of these compounds (Bolden et al., 2015). BTEX are referred by the World Health Organisation (WHO) as hazardous air pollutants due to their toxicity. WHO classified benzene as a human carcinogen, however, no safe level of exposure has yet been established. Toluene, ethylbenzene and xylenes are also classified as potential carcinogens to humans.

BTEX levels of the present work were lower than those observed in previous studies (Table 1). Among them, toluene and *m,p*-xylene showed the highest mean concentrations (Fig. 2). The presence of high indoor concentrations of toluene and xylene isomers can be related to the use of cleaning products and hair sprays containing these compounds as solvents (Rahman and Kim, 2014; Rothe et al., 2011). Benzene and ethylbenzene showed relatively low mean concentrations and were well below the professional exposure limits for Spain (INSHT, 2014). Higher average concentrations of toluene (up to 816 µg m⁻³), comparable to those measured in

studies involving oil refinery and auto garage workers, were detected in nail salons (Lamplugh et al., 2019). Moradi et al. (2019) found higher average indoor concentrations of BTEX than those in ambient air. They concluded that urinary BTEX concentrations in beauty practitioners were significantly higher than in the control group. The urinary concentrations were associated with BTEX concentrations in the air. Hadei et al. (2018) detected the highest indoor concentration for *o*-xylene ($10\text{--}23\ \mu\text{g m}^{-3}$) in large beauty salons. It was concluded that concentrations of benzene and toluene were affected by the number of hair dyeing treatments, while the concentration of xylene was affected by the number of hair styling. Baghani et al. (2018) recorded the highest indoor levels for ethylbenzene and benzene. In their study, the concentration of benzene was significantly influenced by operational conditions (e.g. type of ventilation system, area of salons, the number of people in the salon and number of services). Tsigonia et al. (2010) examined the exposure of workers to VOCs in beauty salons and observed that pollutant levels were influenced by the number of treatments performed, the ventilation, and the number and type of products that were open during the measurements. Ronda et al. (2009) did not observe differences between exposure levels in salons in central and suburban areas of Spain. It was suggested that the exposure was mostly related to hair dye products, highly rich in chemicals, which are extensively used during treatments.

Although the BTEX levels in the outdoor air have not been measured, the concentrations monitored outside a cafeteria, located a few meters from the hairdressing salon, in a monitoring campaign carried out at practically the same time (November-December 2017) than that of the present study, can be taken as a comparative reference. In that campaign, outdoor concentrations ($\mu\text{g m}^{-3}$) of 0.6-0.8 (benzene), 1.3-1.6 (toluene), 0.3-0.5 (ethylbenzene), 0.6-1.0 (*m*-xylene), 0.3-0.4 (*p*-xylene) and 0.3-0.5 (*o*-xylene) were obtained (Alves et al., 2020). These values are 2 to 20 times lower than those measured in the hairdressing salon, proving the importance of BTEX emissions from indoor sources.

3.2.2. Formaldehyde and acetaldehyde

Among carbonyl compounds, formaldehyde and acetaldehyde are most frequently identified in indoor environments. Typical indoor sources of these compounds in non-smoking environments include housing and furniture materials, cleaning products such as detergents, disinfectants, softeners, carpet cleaners and shoe products, cosmetics such as liquid soaps, shampoos, nail varnishes and nail hardeners and other consumer items such as insecticides (WHO, 2010). Formaldehyde has been classified as a probable human carcinogen (group B1)

by IRIS and as a human carcinogen (Group 1) by IARC. Acetaldehyde is also considered as a probable human carcinogen (Group B2) by IRIS.

In this study, formaldehyde and acetaldehyde presented higher indoor levels than BTEX, with mean concentrations of 11.5 ± 3.5 and $8.96 \pm 4.6 \mu\text{g m}^{-3}$, respectively (Fig. 2). Formaldehyde was below the short-term (30-minute) guideline of $100 \mu\text{g m}^{-3}$ recommended by the WHO and below the Short-Term Exposure Limit (STEL) of 46 mg m^{-3} recommended by the Spanish National Institute of Safety and Hygiene (INSHT, 2014). Acetaldehyde was also significantly below the STEL of 0.37 mg m^{-3} in Spain. The formaldehyde and acetaldehyde outdoor levels measured in the vicinity in another monitoring campaign were, on average, $1.3 \mu\text{g m}^{-3}$ and below the detection limit, respectively (Alves et al., 2020).

Highly variable indoor concentrations of carbonyl compounds have been reported in previous studies. Chang et al. (2018) conducted an IAQ study in different areas of 10 hairdressing salons in Taipei (Taiwan), and found accumulation of air pollutants, especially in the working areas. The highest concentration ($1.04 \times 10^3 \mu\text{g m}^{-3}$) of formaldehyde was observed at the working area, while the lowest concentration ($12.4 \mu\text{g m}^{-3}$) was obtained at the reception area. The authors associated the number of workers, perming treatments and frequency of using formaldehyde releasing products with levels of formaldehyde. Labrèche et al. (2003) reported a mean concentration of formaldehyde of $27 \mu\text{g m}^{-3}$ measured in 26 hairdressing salons in Montreal (Canada). In 6 nail salons in Colorado (USA), formaldehyde average concentrations ranged between 5.32 and 20.6 mg m^{-3} (Lamplugh et al., 2019).

A higher mean concentration of acetaldehyde ($32.6 \pm 12.6 \mu\text{g m}^{-3}$) was measured in beauty salons by Hadei et al. (2018), while the formaldehyde concentration was found to be lower ($11.9 \pm 5.9 \mu\text{g m}^{-3}$), being affected by the number of hair styling and nail treatments. The release of formaldehyde into the work environment was predominantly associated with the use of professional hair straightening products (Aglan and Mansour, 2020; Dahlgren and Talbott, 2018; Peteffi et al., 2016; Pexe et al., 2019; Pierce et al., 2011; Stewart et al., 2013). Hair straighteners, containing methylene glycol or glyoxylic acid, are capable of releasing formaldehyde when heated during the blow-dry and hot iron application (Dias, 2015).

Strong correlations, with high statistical significance, were found between toluene, ethylbenzene and xylenes ($R^2 > 0.76$), suggesting that these compounds could have the same origins (Table S4). Formaldehyde was also strongly correlated with ethylbenzene and xylenes ($p < 0.01$). In addition, a significant correlation was obtained between formaldehyde and

acetaldehyde ($R^2 = 0.52$), indicating that 52% of formaldehyde and acetaldehyde variations are associated.

3.3. Particulate matter

3.3.1. PM_{10} concentrations

The strong linear relationship between the photometric and gravimetric PM measurements ($R^2 = 0.93$) showed high agreement between both methods (Fig. S1). The real-time data of PM_{10} concentrations collected by the photometric monitors showed strong variations over the sampling period (Fig. 3A). The diurnal maximum and minimum values of PM_{10} concentrations measured in the indoor air ranged between 212-1840 $\mu\text{g m}^{-3}$ and from 7 to 13 $\mu\text{g m}^{-3}$, respectively. The concentration peaks are usually related to strong short-term emissions from specific sources like use of sprays and hairdryers (Saraga et al., 2014; Van Der Wal et al., 1997). In this study the major indoor peaks of PM_{10} that were registered over the sampling days coincided with the drying operation of long hair and the use of hair lacquer sprays. PM emissions during drying may be related to the flaking of dead hair cells, as well as the release of products applied to the hair by brushing and drying heat. The turbulence generated by the dryer can also lead to the resuspension of particles deposited on surfaces and clothing. Generally, PM_{10} peaks occurred after a few minutes (<15 min) the emissions started, while the decrease took more than 1 h 30 min after the end of drying/lacquer operation. Other activities such as washing/cutting hair, short time hair drying (<5 min), manicure and sweeping of hair had a substantially lower contribution to the increase of PM_{10} . During the night, inside the beauty salon, the PM_{10} concentrations dropped drastically ranging from 2 to 19 $\mu\text{g m}^{-3}$. In the first four days, the outdoor concentrations corresponding to occupancy periods were lower (8-226 $\mu\text{g m}^{-3}$). The outdoor PM_{10} concentration peak (621 $\mu\text{g m}^{-3}$) was observed on the 5th day between 11:00 and 12:00, when construction works across the street took place. The $PM_{2.5}/PM_{10}$ indoor ratios represented values between 0.91 and 0.96 (avg = 0.94 ± 0.03) during the sampling period, with the exception of the 4th day ($PM_{2.5}/PM_{10} = 0.63$). On average, the ratio of outdoor $PM_{2.5}/PM_{10}$ was 0.81 ± 0.04 for all sampling days, evidencing the dominance of fine-mode particles.

From gravimetric measurements, mean indoor PM_{10} concentrations of 89 ± 39 and 22.8 ± 2.1 $\mu\text{g m}^{-3}$ were recorded during the occupancy and non-occupancy hours, respectively, while a value of 50 ± 12 $\mu\text{g m}^{-3}$ was observed outdoors (Fig. 3B). The indoor vs outdoor (I/O) ratio, which is a critical indicator of internal sources, ranged between 0.9 and 4.3 with a mean value of 1.97. The indoor PM_{10} concentrations exceeded the 24-h guideline of 50 $\mu\text{g m}^{-3}$

recommended by the WHO. Son et al. (2006) have reported indoor and outdoor concentrations of PM₁₀ of 30.5 ± 25.8 and $31.0 \pm 53.6 \mu\text{g m}^{-3}$, respectively, in beauty shops in South Korea. Saraga et al. (2014) measured respirable particles in sixteen different working environments and recorded the maximum particle concentration (on average $285 \mu\text{g m}^{-3}$) at a hairdresser store. Other study took place in 20 workplaces, including three hair salons, located in Alexandroupolis (Greece) and recorded PM_{2.5} concentrations between 127 and $171 \mu\text{g m}^{-3}$ (Kogianni et al., 2020). Similar mean concentrations of PM₄, between 92.8-170 and $9.4\text{-}105 \mu\text{g m}^{-3}$, were measured by Rogula-Kopiec et al. (2019) inside and outside 4 beauty salons in Silesia (Poland), respectively. The corresponding indoor and outdoor mean concentrations of TSP varied from 136 to $277 \mu\text{g m}^{-3}$. The mean I/O ratios of PM₄ and TSP were in the ranges 2.2-9.6 and 2.0-9.0, respectively.

3.3.2. PM₁₀ chemical composition

3.3.2.1. Carbonaceous content

On average, the indoor concentration of the total carbonaceous content (TC = OC + EC) was 4.7 times higher during the occupancy than non-occupancy periods (Fig. 4A). OC was the most abundant carbonaceous component, reaching 26.6 ± 11.8 , 5.63 ± 0.89 and $8.21 \pm 3.09 \mu\text{g m}^{-3}$ for occupancy, non-occupancy periods and outdoor samples, respectively. Unlike outdoors, a strong correlation was found between indoor PM₁₀ and OC concentrations ($R^2 = 0.99$) (Fig. 4C and 4D). The I/O ratio of OC, during working hours, ranged between 1.8 and 9.7 with a mean value of 4.0. I/O >1 and a good relationship between indoor PM₁₀ and OC concentrations pointed out to the existence of indoor sources of organic compounds. The products used for hair treatments and biological matter, such as filings of nails and hard nail gels, tiny hair snippet and epidermis, can also contribute to OC-bound coarse PM (Rogula-Kopiec et al., 2017). Indoor and outdoor EC concentrations, during the occupancy period, were substantially lower (3.80 ± 1.39 and $4.30 \pm 1.63 \mu\text{g m}^{-3}$, respectively) and presented a mean I/O ratio of 0.9. Elemental carbon is mostly emitted from combustion processes or pyrolysis of biological material (Jones and Harrison, 2005).

Total carbon accounted for 34.1 ± 2.2 , 28.7 ± 1.0 and 25.0 ± 5.2 %wt. of PM₁₀ during occupancy and non-occupancy periods and outdoor samples, respectively, with an OC/EC ratio between 1.5-7.8 (Fig. 4B). OC constituted the major mass fraction, accounting for 29.5 ± 1.8 and 16.2 ± 4.5 %wt. of PM₁₀ in indoor and outdoor samples during working hours, respectively, while the corresponding EC fractions were substantially lower (4.53 ± 1.42 and 8.86 ± 3.51 %wt. of PM₁₀, respectively). Mass contributions to total carbon of indoor OC and EC during occupancy and night-time periods were practically the same, around 87% and 13%, respectively. Outdoor OC

and EC accounted for 65% and 35% of TC, respectively. The increase of mass shares of EC in outdoor samples suggested road traffic contribution to ambient PM. Similar to the present study, Rogula-Kopiec et al. (2017) provided strong evidence of the contribution of indoor sources of OC to PM-bound carbon in beauty salons. The authors recorded a mass contribution of OC to total carbon in PM₄ between 94 and 97% for indoor samples; their mean I/O ratios of PM₄-bounded OC and EC were in the ranges 2.6 – 12.0 and 1.4 – 3.7, respectively.

3.3.2.2. Trace elements and water-soluble ions

In order to achieve a chemical mass closure, measured element concentrations were converted to their common oxides, which constituted around 10.7, 44.3 and 40.6 %wt. of the total PM₁₀ mass in samples collected indoors during the occupancy and non-occupancy periods and outdoors, respectively (Fig. 5A). Among them, Na, Mg, Al, Si, S, K, Ca and Fe were the most abundant elements (Table S5). An appreciable decrease of indoor concentrations was registered for all elements during non-occupancy periods, which can be related to dust settling due to the absence of human activity at night. I/O ratios higher than one were observed for Cu (2.8), Ni (2.4), Br (2.2) and Mo (1.8), suggesting the presence of indoor sources. Inside beauty salons, emissions of these elements can be associated with the use of hair cosmetics. Some metals (Cd, Pb, Cr, Cu, Co, Ni, Mn and Fe) have been detected in several hair treatment products, including hair relaxers, pomades, dyes, conditioners and shampoos (Borowska and Brzóska, 2015; Iwegbue et al., 2016). In this study indoor concentrations, observed for Cu ($99.2 \pm 39.4 \text{ ng m}^{-3}$), were still significantly higher. Lower indoor concentrations of Cu ($48.2 \pm 46.8 \text{ ng m}^{-3}$) were measured in beauty shops of Kwang-Ju (South Korea) (Son et al., 2006). Copper was found in shampoos and hair care products with concentrations ranging from 0.07 to 12.80 $\mu\text{g g}^{-1}$, respectively (Amartey et al., 2011; Iwegbue et al., 2016; Lavilla 2009; Ullah et al., 2017). The international use of some elements (Ni, Sb, As, Cd, Cr and Co) as ingredients of cosmetic products is prohibited by Annex II of Directive 76/768/EEC of the European Union due to their high toxicity (Bocca et al., 2014). Nevertheless, these compounds persist in existing cosmetic products, owing to their ubiquitous nature and contamination from production processes. A wide concentration range of Ni, up to $11.3 \pm 10.5 \mu\text{g g}^{-1}$, was found in anti-dandruff hair shampoos and other hair care products (Amartey et al., 2011; Arshad et al., 2020; Iwegbue et al., 2016; Lavilla et al., 2009; Ullah et al., 2017). In the present study, Ni, Pb, As and Cr presented relatively low levels in all samples (Table S5). Significantly higher mean concentrations of Ni ($83.9 \pm 212.2 \text{ ng m}^{-3}$), Pb ($70.2 \pm 31.8 \text{ ng m}^{-3}$), Cr ($299 \pm 110 \text{ ng m}^{-3}$), Zn ($370 \pm 751 \text{ ng m}^{-3}$) and Mg ($259 \pm 209 \text{ ng m}^{-3}$) inside of beauty shops located near roadways compared to outdoor air were measured by Son et al. (2006). In their study, the I/O ratios of

metals were generally lower than one, indicating contribution of vehicle emissions to poor indoor air quality. Bromine is one of the most used chemicals in the production of flame retardants (BFRs), which are added to plastics and applied in a series of commercial products and construction materials to meet fire safety standards. Additive BFRs do not form a chemical bond with the material and can be easily released (through abrasion, volatilisation, and leaching during usage) into the indoor air, where they are partitioned between the dust/particulate and gas phases (Genisoglu et al., 2019). In the present study, indoor sources of Br may be related to the use of hairdressing tools and electrical equipment (e.g. hairdryer, hot air stylers, curling tongs, hair straighteners, clipper accessories, etc).

In this study, enrichment factors (EF) were calculated for each element to show the degree of enrichment of a given element compared to the relative abundance of that element in crustal material. EF is defined as $EF = (E/R)_{air}/(E/R)_{crust}$, where E and R refer to concentrations of element E under analysis and a reference element R. Fe was used as reference element and the average element concentrations in the upper continental crust were taken from Wedepohl (1995). According to Table S5, Se exhibited the highest EFs (564) in outdoor samples. Br, Cu, As, Mo, Zn, S, Cl and Pb showed moderate enrichment ($9 < EF < 66$). A high enrichment suggests predominance of anthropogenic sources for these elements and points out that a variety of emissions may contribute to their loading in the ambient air. On the contrary, low enrichment factors (< 5) were observed for Na, Mg, Al, Si, P, K, Ca, Ti, V, Cr, Mn, Rb, Sr and Y, indicating negligible contribution of anthropogenic sources and a main origin in the airborne dust.

Water-soluble ions accounted for 2.52 ± 0.21 (indoor, occupancy), 12.40 ± 1.10 (indoor, non-occupancy), 10.30 ± 0.96 (indoor, weekend) and 7.93 ± 0.91 (outdoor, occupancy) %wt. of PM_{10} . Mean I/O ratios of SO_4^{2-} and Na^+ were > 1 , whereas the ratios were < 1 for all other constituents (Fig. 6). The indoor concentrations of Ca^{2+} , NH_4^+ and NO_3^- measured during the occupancy periods were 3.9, 3.5 and 2.7 times lower than the corresponding outdoor levels, respectively. Among cations, Ca^{2+} and NH_4^+ were dominant in outdoor samples collected during working hours, while Ca^{2+} and K^+ were the major ions in the corresponding indoor samples. The most abundant anions were NO_3^- and SO_4^{2-} in all samples. Ionic balances have been commonly used to shed light on the aerosol acidity and to determine any possible missing ionic species (Tripathy et al., 2016; Wang et al., 2006). In the present study, a cation excess was observed. The anion deficit may be due to carbonate, which has not been measured in this study.

3.3.2.3. Organic matter

To account for the mass of unmeasured hydrogen, oxygen and other atoms in organic matter (OM) of PM₁₀, the OM concentration was obtained by multiplying the OC concentration by a factor of 1.8 (Polidori et al., 2008). In the present study, OM accounted for 53.2, 45.2 and 29.1 %wt. of PM₁₀ in indoor samples collected during occupancy, non-occupancy periods and outdoors, respectively (Fig. 5A). Multiple compounds were found in the PM₁₀ organic extracts. Concentrations of major identified compounds are presented in Table 2, while their complete list is given in the Supporting Information (Table S6). Aliphatic alcohols and fatty acids were the major compound classes, followed by phthalates, glycerol derivatives, alkyl esters of fatty acids and phenolic compounds (Fig. 5B and 5C). Other compound classes represented a minor contribution to PM₁₀.

Highly variable levels of *aliphatic alcohols* (C₈ to C₂₆) were detected in PM₁₀ samples (Table 2 and Table S6). Long-chain alcohols, as well as fatty acids, are commonly present in atmospheric aerosol and can derive from both natural (e.g. vascular plant waxes, microbiota) and anthropogenic sources (e.g. fossil fuel combustion, biomass burning, cooking activities, etc). In this study, on average, total concentrations of alcohols were as follows: 7614 ± 7298 ng m⁻³ (indoor, working hours), 489 ng m⁻³ (indoor, night), 332 ng m⁻³ (indoor, weekend, daytime) and 88.8 ± 30.4 ng m⁻³ (outdoor, working hours). The highest indoor concentrations during working hours were recorded for 1-octadecanol, 1-hexadecanol and 1-tetradecanol. I/O ratios of these alcohols ranged from 30 to 338. Their indoor concentrations were from 3 to 45 times higher during occupancy than non-occupancy periods, suggesting the presence of strong indoor sources. Cetyl and stearyl alcohols are added as non-ionic surfactants to shampoo and hair conditioners to reduce the static electricity generating effects caused by the anionic surfactants (Dias, 2015). Furthermore, aliphatic alcohols are extensively used in consumer, cleaning and personal care products such as laundry powder, general/hard surface cleaners, fabric conditioners, styling gels and mousses, cleaners, body washes, skin lotions and creams (Veenstra et al., 2009).

Highly variable levels of *alkanoic acids* from C₈ to C₂₆ and some *alkenoic acids* were also detected in organic extracts (Table 2 and Table S6). On average, total concentrations of carboxylic acids, measured inside the beauty salon, were 5262 ± 2744 ng m⁻³ and 375 ng m⁻³ during working hours and at night-time, respectively, and far exceeded those observed outside. The professional activities inside the beauty salon and the use of various hair products can explain the very high I/O ratios (up to 194) of some acids. Myristic acid was the most abundant indoors, followed by palmitic, palmitoleic, pentadecanoic and linoleic acids. Fatty acids are commonly present in vegetable oils such as coconut, palm, almond, grape seed, olive, corn,

sesame, wheat germ, among others, which are widely used in hair cosmetics (Agarwal et al., 2018; Briefs and Digne, 2016; Mank and Polonska, 2016). The most common fatty acids in vegetable oils are saturated palmitic and stearic acids, monounsaturated oleic acid and polyunsaturated linoleic acid (Veenstra et al., 2009). Relatively high levels of C₁₄-C₁₆, C₁₈ and C₁₉ acids, observed in outdoor samples, can derive from anthropogenic sources such as coal and biomass burning, vehicular exhaust emissions and cooking activities (Harvey et al 2012; Rogge et al 1993; Zhao et al 2007).

Significant amounts of *alkyl fatty acid esters* were found in PM₁₀ (Fig. 5B). Most of them presented higher indoor concentrations ($\Sigma_{21} = 546 \pm 252 \text{ ng m}^{-3}$) than outside ($\Sigma_{21} = 20.6 \pm 14.2 \text{ ng m}^{-3}$) the beauty salon (working hours), pointing out the impact of indoor sources. Among them, alkyl esters of decanedioic, hexadecenoic and octanoic acids were the most abundant (Table 2). Alkyl esters, such as ethyl myristate, ethyl palmitate, ethyl stearate and ethyl oleate, are found in many hair products (Hartwig et al., 2003). Ethyl-hexyl palmitate, isopropyl myristate and isopropyl palmitate can be found at high concentrations in cosmetics. Moreover, alkyl esters, also used in cosmetic sprays at high concentrations (77% isopropyl myristate in hair sprays, 45% ethylhexyl palmitate in indoor tanning preparations, and 23% isopropyl myristate in deodorant formulations), could possibly be inhaled when aerosolised. The synthetic wax, widely used in cosmetic and personal care applications, is composed of a mixture of esters of saturated fatty acids and fatty alcohols with carbon chain lengths between 14:0 and 18:1 (Fiume et al., 2015).

Phthalate esters are ubiquitous environmental contaminants and predominantly used as plasticisers to improve the flexibility of polymers in a variety of consumer products, commodities and building materials. They are not chemically bound to plastic polymers and can leach, migrate or evaporate into the air (Heudorf et al., 2007). With regard to cosmetics, phthalates were detected in many formulations, including perfumes, nail polish, hair products and deodorants (Hyun and Byung, 2004). In this study, on average, the total indoor concentration of plasticisers were significantly higher ($595 \pm 507 \text{ ng m}^{-3}$) than those measured in background air at night-time (198 ng m^{-3}) and on the weekend (346 ng m^{-3}). Among the identified phthalates, bis(2-ethylhexyl)phthalate also known as DEHP was the most abundant (Table 2). DEHP is the most common plasticiser of polymer products, mainly in flexible polyvinyl chloride (PVC) used in numerous consumer products. Relatively high concentration of DEHP observed inside the salon are probably related to the emissions from building materials, such as flooring, cables, profiles, etc. DEHP is considered as being carcinogenic by exposure via inhalation and brings concerns in indoor and occupational environments (Miao et

al., 2017). Regarding hairdressing salons, only a few studies have reported concentrations of phthalate esters. Chang et al. (2018) studied air quality in working, washing, technical and reception areas in hair salons and recorded concentrations of dibutyl phthalate (DBP), diethyl phthalate (DEP), dimethyl phthalate (DMP), butyl benzyl phthalate (BBP) and DEHP between 3.09×10^{-2} and $4.96 \mu\text{g m}^{-3}$. Ronda et al. (2009) evaluated the exposure of chemical compounds in the air of Spanish hairdresser salons and reported DEP concentrations (mean, minimum and maximum) of 0.48 (0.01-0.97) and 0.12 (0.00-0.75) mg m^{-3} for personal and stationary samples, respectively. Labrèche et al. (2003) reported mean concentrations of 0.003 mg m^{-3} for DBP measured inside hair salons in Quebec.

Similarly, the mean total indoor concentrations of *phenolic compounds* ($307 \pm 307 \text{ ng m}^{-3}$) measured during the occupancy period largely exceeded their night-time (50.1 ng m^{-3}) and outdoor ($27.4 \pm 26.5 \text{ ng m}^{-3}$) counterparts (Fig. 5C). Some of the identified phenolics (Table 2-3) are extensively used as natural or synthetic antioxidants in rubber, plastic, cosmetic and pharmaceutical industries to retard the oxidation process (Liu and Mabury, 2019; Soto et al., 2015).

n-Alkanes in the range from C_{11} to C_{35} were quantified in this study (Table S6). The mean total concentrations of *n*-alkanes were 145 ± 104 , 1.36 and $7.57 \pm 5.44 \text{ ng m}^{-3}$ in samples collected in the salon during working hours, non-working hours and outdoors, respectively. The highest average indoor concentrations, during working hours, were registered for C_{24} , C_{23} and C_{25} . Extremely high I/O ratios of 144, 111, 47.6 and 46.7 were found for C_{25} , C_{24} , C_{27} and C_{23} , respectively (Table 2). Straight-chain saturated hydrocarbons are a part of mineral oils and waxes, which are incorporated as moisturisers and non-allergenic ingredients in many cosmetic products (skin creams, lotions, sunscreens, lip care products and hair gels). Concentrations of mineral oils in cosmetics can range from 1% to 99% depending on the product (Chuberre et al., 2019). Significantly lower I/O (0.09-1.04) ratios and very low concentrations of alkenes (C_{12} , C_{14} , C_{16} , C_{18} and C_{21}) were observed.

Contrary to homologous series of fatty alkanes, alcohols and acids, saccharides and polyols presented low I/O ratios, which suggest the predominance of outdoor sources (Table 2). Among saccharides, levoglucosan was the most abundant compound. Levoglucosan is well recognised as a tracer of biomass burning, which is formed from the pyrolysis of cellulose and hemicellulose (Bhattarai et al., 2019; Leithead et al., 2006). Similarly, I/O ratios for most of PAHs were less than one, ranging from 0.04 to 0.60, except for acenaphthene and fluorene (Table S6). PAHs are by-products of incomplete combustion of fossil fuels and biomass.

Many other *organic oxygenated compounds*, which are constituents of various consumer products, were detected in the indoor air of the beauty salon (Table 2 and Table 3). Many of them presented very high mean I/O ratios or weren't even detected in outdoor PM₁₀ samples, indicating strong indoor emissions. The use of specific cosmetic applications and cleaning products, and professional activities can contribute to pollutant build-up in beauty salons.

3.4 Health risk assessment

The carcinogenic (excess cancer risk (CR)) and non-carcinogenic risks (hazard quotients (HR)), associated with inhalation exposure by hairdressers to VOCs and PM₁₀-bound metals, PAHs and trace elements are presented in Tables S7 and S8 (supporting information). Formaldehyde presented a cancer risk between 1×10^{-4} and 1×10^{-6} suggesting a "possible risk". CR and HQ of other studied compounds were lower than the USEPA guidelines and thus can be interpreted as being risk-free. It should be noted that these results are only indicative and non-conclusive due to the short time series. However, endocrine disrupting chemicals, such as phthalates (Li et al., 2021; Piazza and Urbanetz, 2019), were found at high concentrations in this study, which may require special attention in future studies.

3.5. Study strengths and limitations

Although exploratory, this is a pioneer study in detailed PM₁₀ chemical characterisation in beauty salons. More than 200 organic compounds, as well as the carbonaceous content, trace elements and water-soluble ions were quantified in indoor and outdoor samples, during occupancy (working hours) and non-occupancy (night-time) periods. Additionally, VOCs and comfort parameters were monitored.

However, some limitations might be pointed out. Measurements were carried out within one week only in wintertime and may not reflect seasonal differences of natural ventilation.

Regarding PM₁₀ measured by gravimetry, two samples were collected inside (occupancy and non-occupancy periods) and one outside (occupancy period only) of the salon for each sampling day. Accordingly, each indoor sample was compared with the respective outdoor sample. VOCs and carbonyls were only measured inside the beauty salon, which does not allow to trace their origin (e.g. traffic or internal emissions). To get around this difficulty, VOC and carbonyl levels measured in the vicinity in another monitoring campaign in the same season were taken for comparative purposes. Only a long-term sampling campaign with detailed analysis of the chemical composition would allow the application of source apportionment methodologies, such as positive matrix factorisation. The quantities of products used were not monitored, which makes it difficult to interpret the concentrations obtained.

It should also be borne in mind that the levels of both BTEX and PM measured inside the salon do not reflect emissions only from the use of cosmetic products. Many compounds can come from skin and clothing of customers, as well as be emitted from building materials and furnishings. In addition, traffic emissions can infiltrate and accumulate, contributing to indoor concentrations of both BTEX and PM. In conclusion, further studies to address the aforesaid limitations are highly recommended. Given that hairdressers are exposed to high concentrations of pollutants with a potentially dangerous composition, it would be desirable to assess toxicity, through bioassays, especially of particulate matter.

4. Conclusions

The results of this study, based on a weeklong sampling campaign inside and outside a beauty salon (León, Spain), allowed, for the first time, to characterise the chemical composition of PM₁₀ in this type of professional environment. PM₁₀ indoor concentrations exceeded the 24-h guideline of 50 µg m⁻³ recommended by the WHO. From gravimetric measurements, average PM₁₀ concentrations of 89 ± 39 and 50 ± 12 µg m⁻³ were recorded in the salon during the occupancy period and in the outdoor air, respectively. I/O ratios of PM₁₀, as well as of the majority of PM₁₀-bound organic compounds, were higher than one and in some cases as high as 100, thus indicating strong emissions from indoor sources. OC constituted the major mass fraction of PM₁₀ during occupancy periods, accounting for 29.5 ± 1.8 and 16.2 ± 4.5 wt% in indoor and outdoor samples, respectively. More than 200 individual organic oxygenated compounds were detected in PM₁₀, aliphatic alcohols and fatty acids being the most abundant, followed by phthalates, glycerol derivatives, alkyl esters of fatty acids and phenolic compounds. Many of the identified compounds are extensively used in hair cosmetics, cleaning and personal care products, which can be the source of indoor emissions. It is worth noting that, in this study, metals and PAHs presented I/O < 1 and significantly lower levels, when compared to other PM₁₀-bound species.

Simultaneously, comfort parameters, concentrations of BTEX, formaldehyde and acetaldehyde were assessed. CO₂ concentrations were correlated with the number of clients attending the salon. The air exchange rate values indicated lack of adequate ventilation. BTEX, formaldehyde and acetaldehyde were found in concentrations below the recommended guidelines. Formaldehyde presented a higher cancer risk (4.6×10^{-6}) than the USEPA guideline level (1×10^{-6}), suggesting a “possible risk”. The total estimated excess cancer risk of exposure to multiple compounds was 9.3×10^{-6} , which is lower than the USEPA acceptable risk, but not negligible.

Although exploratory, this study can be considered as an evaluation of the “worst case scenario”. As concentrations are generally higher in winter due to lower ventilation rates, the adoption of measures to improve air quality must comply with the precautionary principle aimed at preventing the worst possible consequences.

In conclusion, professional activities inside a beauty salon and the use of various hair and cosmetic products can greatly contribute to high indoor levels of organic air pollutants. The installation of heating and ventilation systems should be contemplated to maintain thermal comfort parameters and reduce indoor pollutant concentrations. In addition, to improve air quality in beauty salons, air quality guidelines or a mandatory occupational regulatory framework is needed. Finally, identifying and prohibiting cosmetic products with potentially toxic emissions could reduce pollutant exposures of both workers and clients.

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Conflicts of interest

The authors declare no conflict of interest.

Appendix A. Supporting Information

Supporting information to this article can be found online at <https://doi.org/XXX>

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Table 1. Comparison of BTEX indoor concentrations (mean \pm SD, (min-max), $\mu\text{g m}^{-3}$) of the present study with those reported in the literature.

Study/ Limit values	Location N of salons	Benzene	Toluene	Ethylbenzene	<i>m/p</i> -Xylene	<i>o</i> -Xylene
STEL/TWA ^a (mg m^{-3})	-	3.25/-	192/384	441/484	221/442	221/442
This study	León, Spain, 1 beauty salon	1.6 ± 0.3 (1.3-2.1)	4.6 ± 1.3 (3.2-6.6)	1.55 ± 0.3 (1.3-2.2)	3.5 ± 1.1 (2.6-6.3)	1.65 ± 0.4 (1.3-2.6)
Lamplugh et al. (2019)	Colorado, USA, 6 nail salons	(3.13-51.8)	(26.7-816)	(1.65 - 9.52)		5.16 - 34.6 ^b
Moradi et. al. (2019)	Tehran, Iran, 36 beauty salons	4.9	118.7	7.5	16.7	7.5
Baghani et al. (2018)	Ardabil, Iran, 50 beauty salons	32.4 ± 26.4	16.1 ± 14.3	62.4 ± 32.4	13.8 ± 11.6^b	
Hadei et al. (2018)	Tehran, Iran, 20 beauty salons	(~5-10)	(~5-12)	(~8-22)		(~10-23) ^b
Tsigonia et al. (2010)	Athens, Greece, 4 beauty salons	-	3-67 ^c	-		(0-10) ^b
Ronda et al. (2009)	Alicante, Spain, 10 hairdressing salons	0.01×10^3 (0.00-0.02) $\times 10^3$	0.12×10^3 (0.02-0.31) $\times 10^3$	0.01×10^3 (0.00-0.04) $\times 10^3$	0.03×10^3 (0.00-0.03) $\times 10^3$	0.01×10^3 (0.00-0.03) $\times 10^3$
Bruno et al. (2008)	Italy, Bari, 2 hairdressing salons	2.6-2.8	20.7-55.2	5.5-10.6	51.6-102.4	18.1-30.4
Son et al. (2006)	Kwang-Ju, S. Korea 20 beauty shops	0.2 ± 0.7 -	9.8 ± 5.8 -	0.6 ± 1.8 -	30.3 ± 20.3^b -	 -
Labrèche et al. (2003)	Montreal, Canada, 26 hairdressing salons	-	0.54×10^3 (0.02-8.37) $\times 10^3$	-	-	-

^aSTEL = Threshold Limit Value (Spain); TWA = Time Weighted Average is a TLV based on a 8-hour workday and a 40-hour workweek from INSHT (2014);

^b*m,p*-xylene + *o*-xylene.

^c8-h-TWA levels.

Table 2. Concentrations (ng m⁻³) of major oxygenated organic compounds in PM₁₀.

	Indoor occupancy	Indoor non- occupancy	Indoor weekend	Outdoor occupancy	I/O occupancy
<i>Alkanes</i>					
Tricosane	24.6 ± 14.9	bdl	1.50	0.526 ± 1.11	47
Tetracosane	30.9 ± 21.3	bdl	bdl	0.279 ± 0.623	111
Pentacosane	23.9 ± 19.9	bdl	bdl	0.166 ± 0.371	144
Hexacosane	14.1 ± 13.7	bdl	bdl	bdl	-
Heptacosane	9.81 ± 9.25	bdl	bdl	0.206 ± 0.461	48
<i>Aliphatic alcohols</i>					
1-Dodecanol	11.4 ± 6.7	10.3	6.94	0.906 ± 0.547	13
1-Tetradecanol	192 ± 275	70.9	87.2	6.37 ± 2.28	30
1-Pentadecanol	34.3 ± 18.7	28.6	16.6	10.4 ± 4.27	3.3
Hexadecanol	2502 ± 2413	247	147	18.1 ± 5.25	138
1-Octadecanol (Stearyl alcohol)	4689 ± 4844	103	54.6	13.9 ± 5.05	338
1-Nonadecanol	10.8 ± 11.0	0.303	0.242	1.30 ± 2.00	8.4
1-Eicosanol	91.8 ± 92.8	0.978	bdl ^b	0.965 ± 0.890	95
1-Heneicosanol	2.37 ± 2.57	nd	nd	0.095 ± 0.116	25
1-Docosanol (Behenyl alcohol)	17.5 ± 20.4	0.462	0.460	0.912 ± 1.04	19
<i>Aliphatic carboxylic acids</i>					
1-Decanoic (caproic) acid	17.2 ± 15.3	1.07	3.99	0.849 ± 0.518	20
1-Dodecanoic (lauric) acid	25.4 ± 9.1	18.2	65.7	4.66 ± 1.94	5.5
1-Tridecanoic acid	3.24 ± 3.68	5.59	5.85	0.548 ± 0.591	5.9
C ₁₃ acid isomers	11.4 ± 12.1	nd	nd	1.21 ± 1.52	9.4
1-Tetradecanoic (myristic) acid	1274 ± 543	274	141	26.9 ± 9.7	47
Tetradecenoic acid	52.9 ± 40.8	1.49	2.96	nd	-
1-Pentadecanoic acid	526 ± 295	22.3	25.7	4.27 ± 2.05	123
Pentadecenoic acid	46.5 ± 50.7	nd	nd	nd	-
C ₁₅ acid isomers	153 ± 143	12.5	9.78	nd	-
1-Hexadecanoic (palmitic) acid	950 ± 594	0.067	206	47.7 ± 35.1	20
C ₁₆ acid isomers	294 ± 218	8.20	4.34	nd	-
9-cis-Hexadecenoic (palmitoleic) acid	600 ± 414	0.033	0.544	3.09 ± 5.59	194
1-Heptadecanoic acid	145 ± 94	0.046	7.19	1.89 ± 1.29	77
C ₁₇ acid isomers	217 ± 139	4.57	11.1	6.48 ± 5.89	34
Heptadecenoic acid	105 ± 97	nd	nd	nd	-
1-Octadecanoic (stearic) acid	210 ± 116	0.192	42.6	62.2 ± 55.7	3.4
cis,cis-9,12-Octadecadienoic (linoleic) acid	56.0 ± 58.8	0.138	0.896	1.73 ± 2.18	32
cis-9-Octadecenoic (oleic) acid	380 ± 260	bdl	5.21	5.85 ± 5.01	65
cis-11-Octadecenoic acid	20.1 ± 25.4	nd	nd	nd	-
1-Nonadecanoic acid	9.72 ± 7.03	0.021	Nd	0.243 ± 0.198	40
1-Eicosanoic (arachidic) acid	19.3 ± 10.2	0.264	1.31	3.08 ± 2.70	6.3
Eicosenoic acid	9.26 ± 8.10	nd	nd	nd	-
1-Docosanoic (behenic) acid	10.8 ± 5.0	1.63	1.68	4.75 ± 3.66	2.3
1-Tetracosanoic acid	19.7 ± 6.79	3.54	nd	6.35 ± 2.80	3.1
1-Pentacosanoic acid	5.28 ± 2.84	nd	nd	0.318 ± 0.636	17
<i>Alkyl esters of fatty acids</i>					
Isopropyl myristate	24.4 ± 26.3	57.9	nd	3.75 ± 5.57	6.5
Methyl palmitate	6.98 ± 8.04	3.02	81.6	6.46 ± 4.10	1.1
Isopropyl palmitate	8.42 ± 12.00	nd	25.1	0.845 ± 0.979	10
2-Hydroxyethyl palmitate	11.4 ± 11.5	nd	nd	nd	-
1-Monomyristin	39.1 ± 30.9	nd	1.55	nd	-
Palmitic acid methyl ester	48.2 ± 38.6	160	121	3.31 ± 2.11	15
Isopropyl palmitate	56.6 ± 55.5	57.3	22.2	0.519 ± 0.453	109
1-Propylpentyl laurate	9.61 ± 10.39	12.7	9.68	0.505 ± 0.419	19
Methyl stearate	26.7 ± 32.2	56	12.3	0.702 ± 0.534	38
Dodecyl octanoate	4.80 ± 5.46	3.02	nd	0.126 ± 0.183	38
Tetradecyl octanoate	7.73 ± 11.03	nd	nd	nd	-
Hexadecyl octanoate	24.5 ± 32.1	nd	nd	nd	-

Hexadecyl 2-ethylexanoate	50.5 ± 42.8	11.8	21.3	1.86 ± 1.29	27
Octadecyl 2-ethylexanoate	31.5 ± 30.0	2.76	nd	0.147 ± 0.294	214
Dioctyl sebacate	164 ± 285	nd	nd	nd	-
Hexadecyl palmitate	18.5 ± 21.1	nd	nd	0.270 ± 0.390	69
Dibutyl adipate	5.75 ± 8.87	nd	2.72	1.94 ± 2.66	3.0
<i>Glycerol derivatives</i>					
Glycerol	107 ± 14	53.2	62.2	39.1 ± 13.3	2.7
Diethylene glycol	34.8 ± 12.8	25.9	29.4	6.61 ± 1.60	5.3
Triethylene glycol	27.3 ± 16.3	20.3	6.48	nd	-
Pentadecanoic acid, Glycerine-(1)-monoester	11.2 ± 15.4	nd	nd	nd	-
1-Monopalmitin	259 ± 139	1.32	5.31	9.82 ± 2.18	26
1-Monostearin	135 ± 91	nd	7.77	29.5 ± 3.9	4.6
α-Glyceryl pentadecanoate	17.1 ± 15.2	nd	1.49	nd	-
<i>Phenolic derivatives</i>					
2,4-Di-tert-butylphenol	37.0 ± 21.0	4.68	bdl	6.94 ± 4.84	5.3
Benzyl alcohol	97.0 ± 77.0	14.6	2.08	6.10 ± 6.89	16
Benzoic acid alkyl esters	158 ± 233	26.8	11.0	8.68 ± 14.06	18
<i>Phthalates</i>					
Diethyl Phthalate	4.83 ± 10.76	bdl	2.02	nd	-
Di-n-butyl Phthalate	4.23 ± 8.35	bdl	2.70	0.279 ± 0.228	15
Bis(2-ethylhexyl)phthalate	39.8 ± 86.4	bdl	9.45	0.280 ± 0.362	142
Other phthalates	545 ± 403	198	331	104 ± 166	5.3
<i>Saccharides and polyols</i>					
Galactosan	1.02 ± 1.29	0.984	1.27	4.10 ± 2.71	0.2
Mannosan	3.37 ± 1.93	2.02	2.29	8.71 ± 3.29	0.4
Levogluconan	43.2 ± 27.2	23.2	49.8	73.3 ± 25.4	0.6
<i>Other compounds</i>					
Cholesterol	59.5 ± 68.1	0.220	0.126	0.348 ± 0.383	171
Methyl dihydrojasmonate	41.8 ± 33.8	73.4	1.75	0.441 ± 0.278	95
Ethylene brassylate	26.7 ± 26.8	13.6	8.92	0.637 ± 0.485	42
Geranylacetone	1.76 ± 2.63	nd	nd	nd	-
Parsol MCX	202 ± 209	11.9	3.69	8.88 ± 11.86	23
Tributyl acetylcitrate	8.74 ± 8.84	2.98	1.81	0.355 ± 0.250	25
Tetramethrin	15.2 ± 34.0	nd	nd	nd	-
Oxidised irgafos 168	12.6 ± 20.2	9.82	nd	5.52 ± 10.93	2.3
Irganox 1086 (Antioxidant 1076)	3.18 ± 7.11	bdl	nd	8.64 ± 11.70	0.4
Vitamin E acetate	32.5 ± 43.8	nd	nd	1.01 ± 0.73	32
Butylphenyl methylpropional (lilial)	2.31 ± 2.95	0.287	nd	0.025 ± 0.050	93
Farnesyl acetaldehyde	14.3 ± 24.5	nd	nd	nd	-
Galaxolide	40.1 ± 79.4	21.9	nd	0.821 ± 1.642	49

nd – not detected

bdl – below detection limit

Table 3. Organic compounds described in the literature as components of consumer and personal care products detected in the PM₁₀ samples of the present study.

Compounds	Use	Reference
Dehydroabietic acid, isopimaric acid	Primary component of rosin, used as adhesive or emulsifier in depilatory wax and cosmetics.	Liu et al. (2014), Nilsson et al. (2008)
Glycerol	Fragrance ingredient, solvent and humectant in a wide range of hair cosmetics.	Becker et al. (2019)
1-Monopalmitine, 1-monostearine	Added to cosmetic formulations mostly as emollients.	Arachidonate et al. (2004)
Cholesterol	Emulsifier in cosmetic skin/hair care products and eye/face makeup formulations.	Elder (1986)
Benzyl alcohol	Fragrance component in makeup goods, fine fragrances, shampoos, toilet soaps and other toiletries, and in cleaners and detergents.	Andersen et al. (2001)
2,4-Di-tertbutylphenol	Synthetic phenolic antioxidant in various personal care products (hair conditioners, hair sprays, shaving gels, face/hand/sun creams, etc.).	Liu and Mabury (2019)
Benzoic acid alkyl esters	Included in cosmetics as fragrance ingredients, skin-conditioning agents (emollient), skin-conditioning agents (miscellaneous), preservatives, solvents, and plasticisers.	Becker et al. (2012)
Parsol MCX	Ingredient in sunscreen hair care formulations (gels or sprays) and skin care products.	Maillan (2002)
Ethylene brassylate, methyl dihydrojasmonate	Fragrance ingredient in cosmetics products (fine fragrances, shampoos, toilet soaps, other toiletries), household cleaners and detergents.	McGinty et al. (2011) Scognamiglio et al. (2012)
Galaxolide	Fixative for retarding the release of other fragrances with higher volatility in synthetic polycyclic musk; ingredient in personal care (body creams, body lotion, shampoo, soap, toothpaste and hair conditioner) and household products.	Correia et al. (2013)
Acetyl tributyl citrate	Used in cosmetic products (hair sprays) and as a plasticiser in vinyl products, adhesives and coatings.	Johnson (2002)
Lilial,	Fragrance components in cosmetic products (shampoos, hair conditioners, liquid soaps, and wet tissues) and in detergents (multi-purpose cleaners and washing-up liquids).	Yazar et al. (2011)
Oxidised Irgafos 168	Antioxidants in the production of plastics.	Hermabessiere et al. (2020)
Vitamine E acetate	Antioxidant and humectant in a wide range of hair and skin cosmetic products.	Fiume (2002)

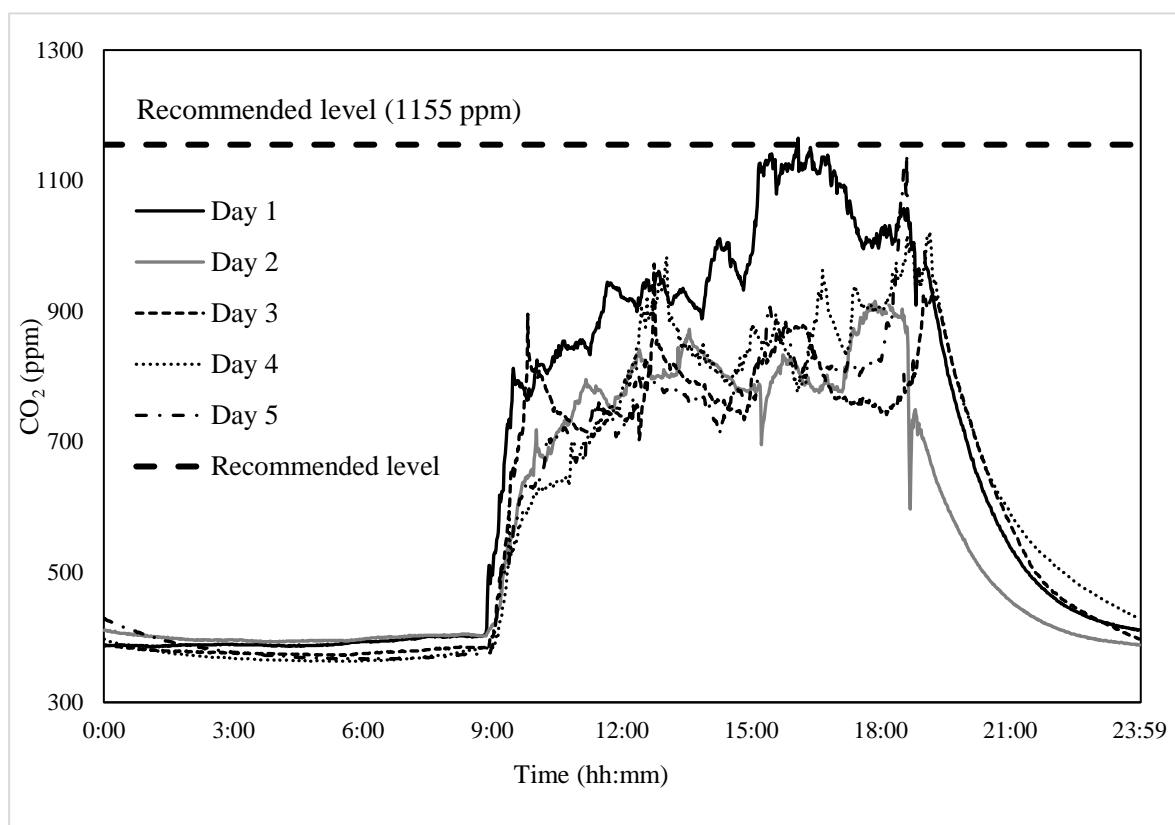


Figure 1. Variation of indoor CO₂ concentrations on weekdays (According to ASHRAE, the recommended level was estimated as 700 ppm above outdoor mean CO₂ concentration).

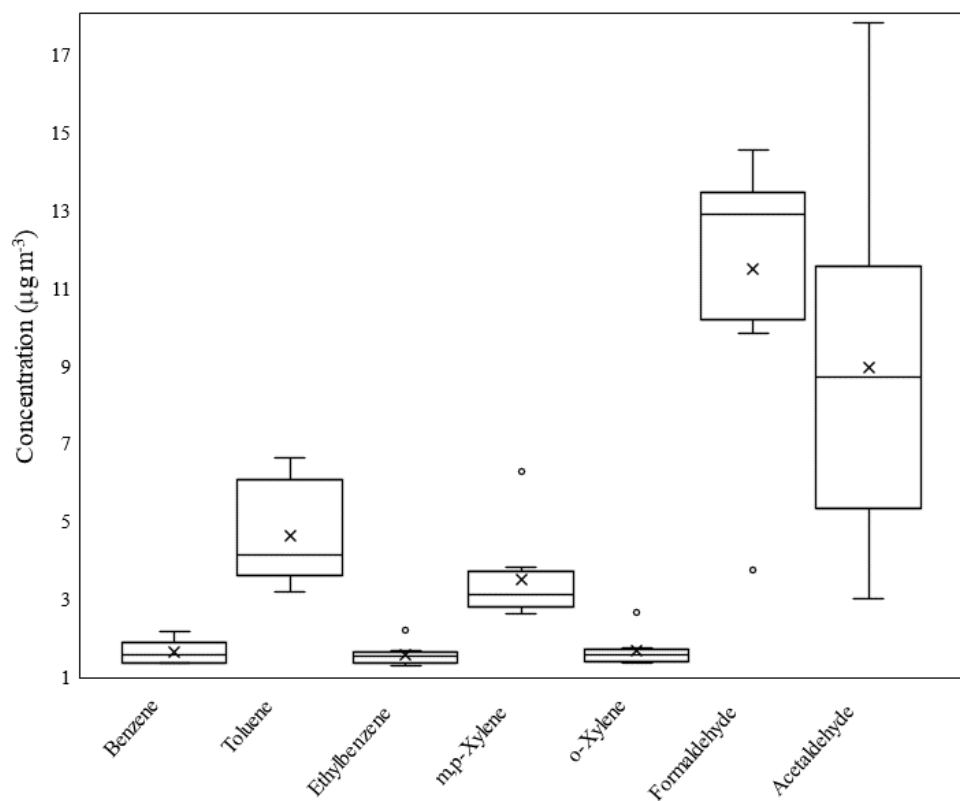


Figure 2. Boxplots for BTEX, formaldehyde and acetaldehyde concentrations ($\mu\text{g m}^{-3}$) in the indoor air of the beauty salon.

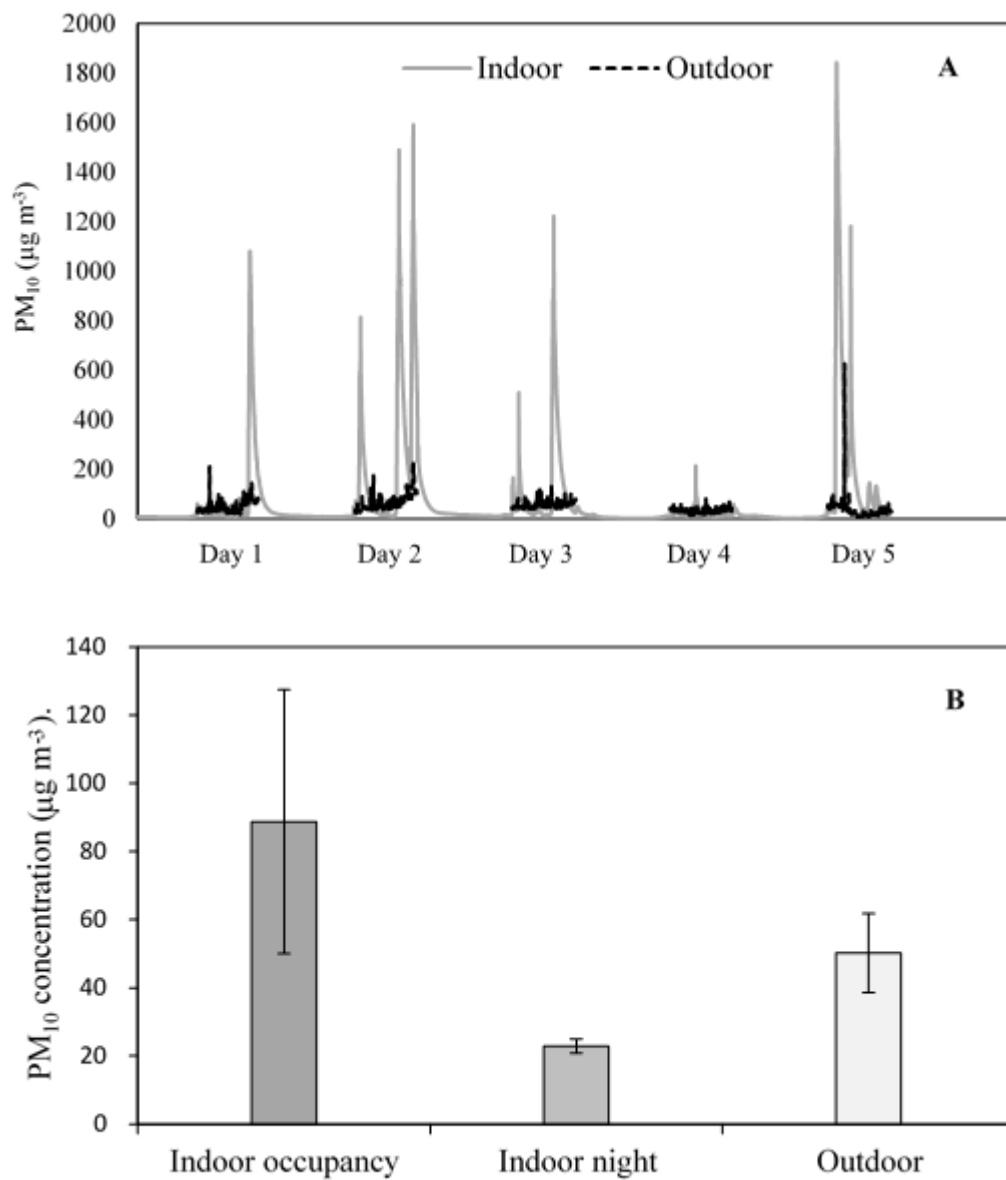


Figure 3. Daily evolution of PM₁₀ concentrations indoors and outdoors during the working time period (9:00-19:00) (A) and mean concentrations of PM₁₀ (B).

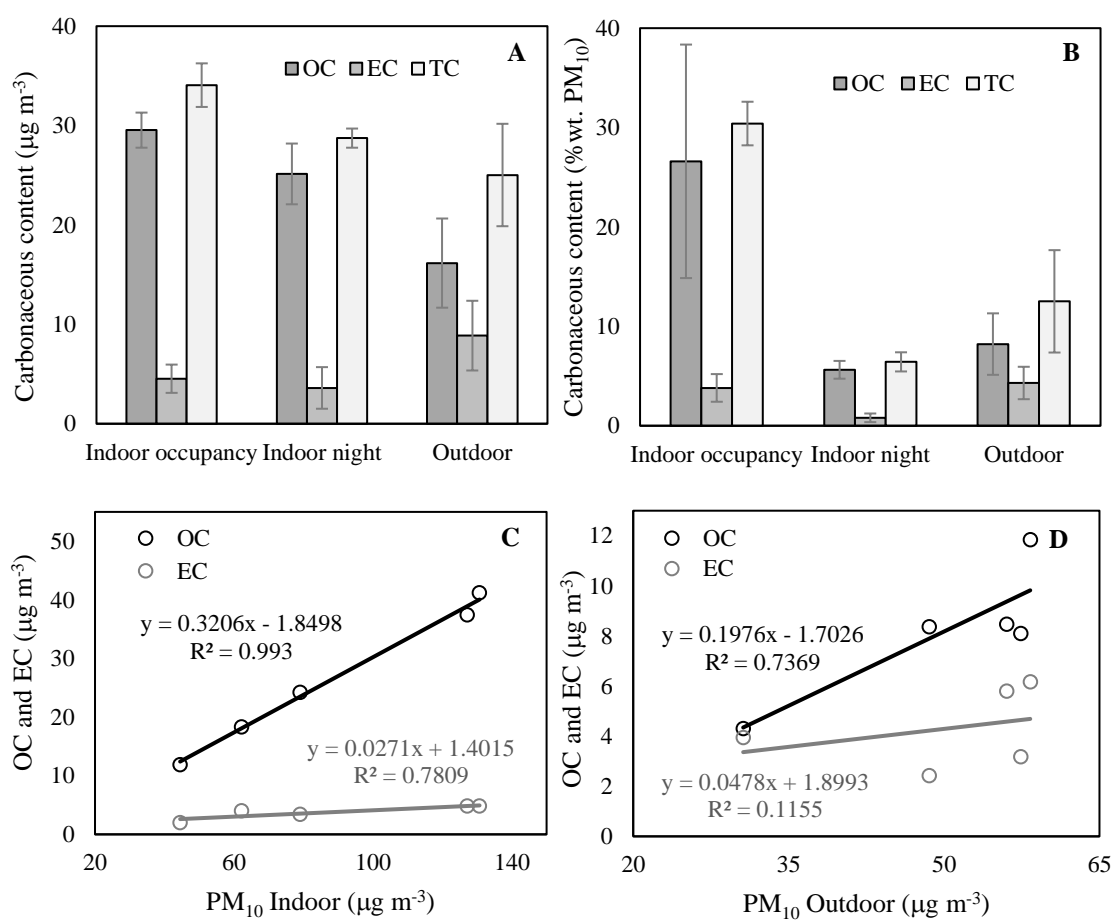


Figure 4. PM_{10} concentration ($\mu\text{g m}^{-3}$) (A) and mass fraction (%wt. PM_{10}) (B) of OC, EC and TC. Correlations between PM_{10} concentrations ($\mu\text{g m}^{-3}$) and its carbonaceous fractions (C, D).

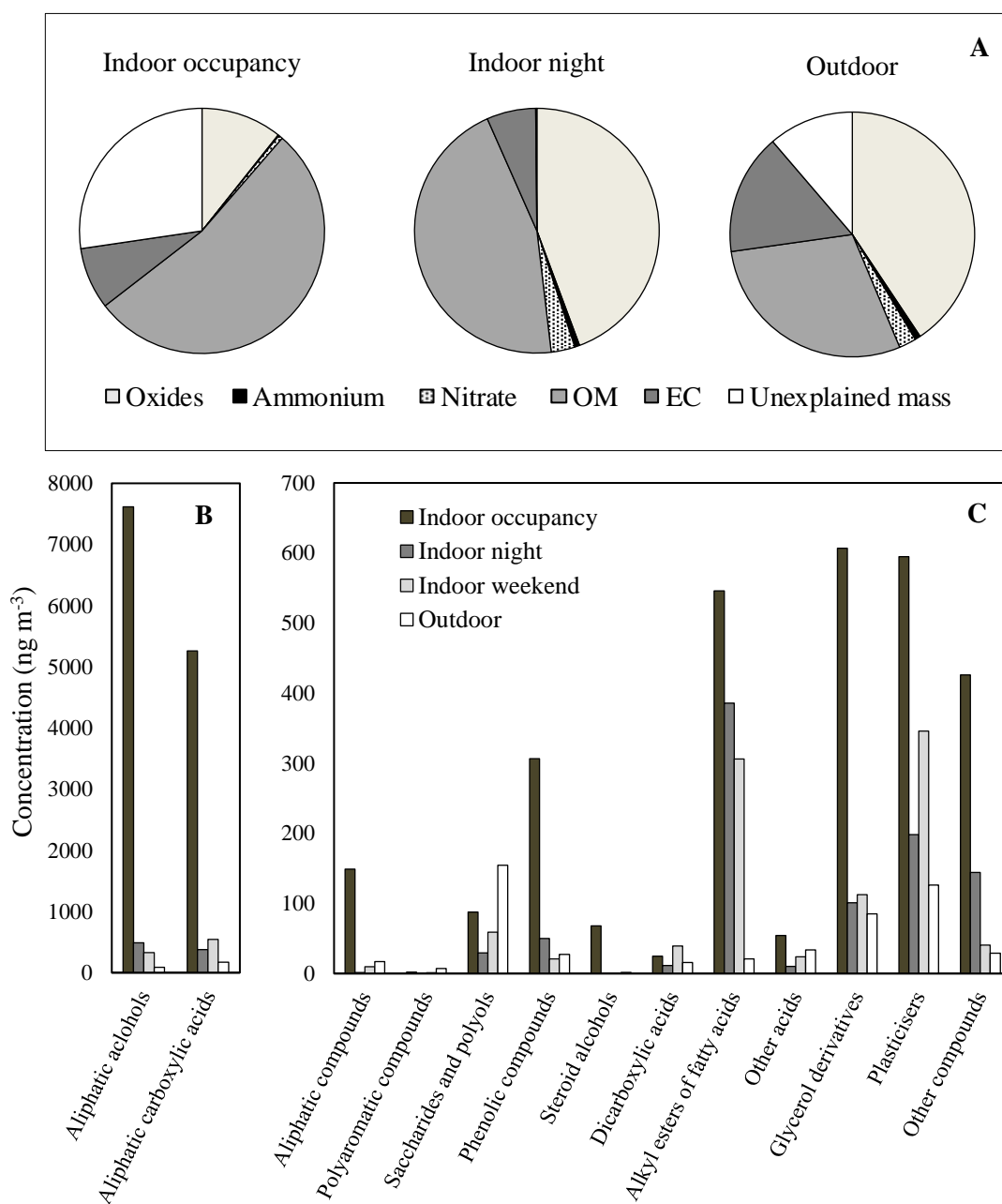


Figure 5. Chemical mass closure of PM_{10} (A) and total mean concentrations (ng m^{-3}) of different classes of PM_{10} -bound organic compounds.

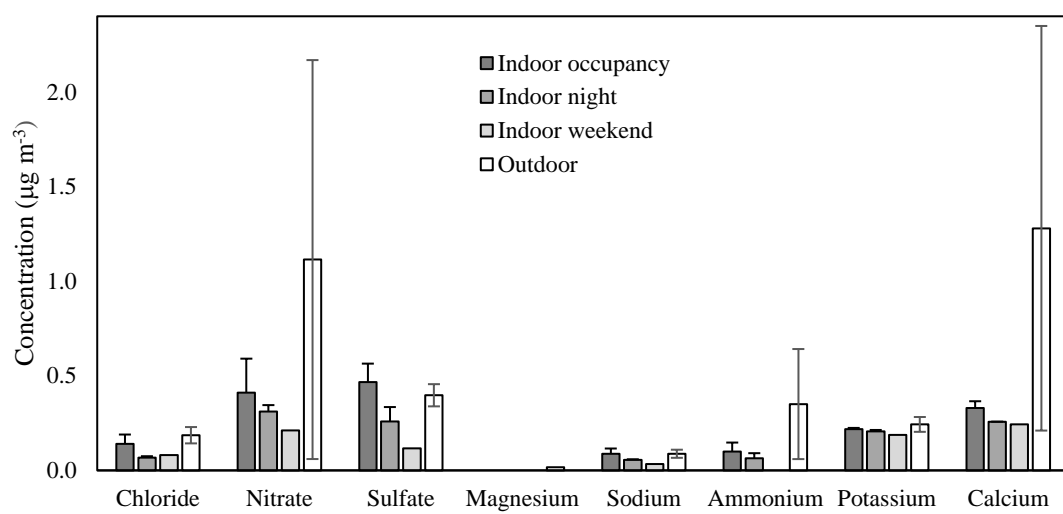


Figure 6. Concentrations (mean \pm SD) of water-soluble ions (ng m^{-3}) in PM_{10} .

SUPPORTING INFORMATION

Air quality and particulate matter speciation in a beauty salon and surrounding outdoor environment: exploratory study

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Health risk assessment

The cancer and non-cancer risks to human health from exposure to toxic substances via inhalation were calculated according to the methodology established by the United States Environmental Protection Agency (USEPA, 2009).

The excess cancer risk (CR) attributable to inhalation exposures to carcinogenic species *i* (e.g. benzene, formaldehyde, acetaldehyde, Cr, Ni, As and Pb), was estimated as follows:

$$CR_i = EC_i \times IUR_i \quad (1)$$

where EC_i is the exposure concentration of compound i ($\mu\text{g m}^{-3}$) and IUR_i is the inhalation unit risk ($(\mu\text{g m}^{-3})^{-1}$). IUR values were obtained from databases provided by USEPA. In the case of Cr, which was determined as Cr(VI), one seventh of the measured concentration was used to estimate the risk, based on a Cr(VI):Cr(III) proportion of 1/6 and the IUR available for Cr(VI). This metal occurs in the ambient air in the trivalent (Cr(III)) and the hexavalent (Cr(VI)) stable forms. There is not enough data to know if chromium (III) causes cancer. However, according to the USEPA classification, Cr(VI) is considered as a human carcinogen (Group A) by exposure via inhalation route. In the case of PAHs, benzo[a]pyrene equivalent concentrations (BaP_{eq} , ng m^{-3}) were used to estimate CR. The BaP_{eq} concentrations were calculated by multiplying each measured concentration of individual PAHs by the respective toxic equivalent factors (TEF) taken from Bari et al. (2010).

The exposure concentration (EC) of a selected compound i was calculated as follows:

$$EC_i = (C_i \times ET \times EF \times ED) / AT \quad (2)$$

where C_i is the measured concentration of compound i ($\mu\text{g m}^{-3}$), ET is the exposure time (8 hours day⁻¹), EF is the exposure frequency (48 weeks \times 5 days \times 8 hours / 24 hours = 80 days year⁻¹, by accounting for 5 workdays per week and 4 weeks of vacation per year), ED is the exposure duration (25 years) and AT is the averaging time for 70 years (70 years \times 365 days year⁻¹ \times 24 hours day⁻¹).

For non-carcinogenic species, the risk was assessed by calculating the Hazard Quotient (HQ) as follows:

$$HQ = EC / RfC \quad (3)$$

where HQ_i is the hazard quotient of compound i , and RfC_i is the chronic reference concentration of compound i in $\mu\text{g m}^{-3}$. Additionally, the hazard index (HI) was calculated as the sum of the HQ of each individual compound. RfC_i values were obtained from the databases provided by the Office of Environmental Health Hazard Assessment (OEHHA) and the Integrated Risk

Information System (IRIS) of USEPA (2019). For elements, for which inhalation reference doses are unavailable, RfC values were estimated from the reference doses for oral exposure (RfD) according to the USEPA methodology (USEPA, 2013).

Supplementary tables and figures

Table S1. Working activities, equipment and products used in the beauty salon during measurements.

	Number of occupants (women/men)	Indoor activities (number of offered services)	Equipment/accessories used	Products used	Observations
Day 1	Worker (1) Customers (1/12)	Hair cut (13) Wash & blow dry (8) Sweeping hair	Hair cutting machine Scissors Hair dryer	Shampoo Conditioner	
Day 2	Worker (1) Customers (4/3)	Hair cut (3) Wash & blow dry (7) Cleaning the bathroom Sweeping hair	Scissors Hair dryer	Shampoo Conditioner Hair foam Lacquer spray Air freshener spray	
Day 3	Worker (1) Customers (6/2)	Hair cut (1) Wash & blow dry (4) Manicures (3) Waxing in the next room with the door closed (1) Sweeping hair	Scissors Hair dryer	Shampoo Conditioner Hair foam Lacquer spray Wax Manicure products	
Day 4	Worker (1) Customers (3/8)	Hair cut (5) Wash & blow dry (6) Hair bleaching (1) Hair hydration treatment (1) Manicure (1) Waxing in the next room with the door open (1) Waxing in the next room with the door closed (1) Sweeping hair	Hair cutting machine Scissors Hair dryer Hair steamer UV nail dryer machine	Shampoo Conditioner Curly hair product Wax Hair hydration product Manicure products	
Day 5	Worker (1) Customers (6/2)	Wash & blow dry (3) Hair straightening (1) Manicure (1) Waxing in the next room with the door closed (1) Sweeping hair	Hair cutting machine Scissors Hair dryer Hair straightening iron	Shampoo Conditioner Hair gel Lacquer spray Manicure products	It rained during the night Construction works across the street

Table S2. Experimental design.

	Sampling location		Sampling period	Sampling time (h)	Sampling volume (m ³)	Samples per day	Chemical analysis
	Inside	Outside					
Comfort parameters, CO and CO ₂	Centre of the salon	~ 3 m away from the salon	5 working days and 1 weekend day	Continuous	-	-	-
VOCs	Near the wall on a stand	-	3 working days	10	0.009	3	BTEX
Carbonyls	Near the wall on a stand	-	3 working days	10	0.216 – 0.303	3	FA, ACT ^a
PM ₁₀ (gravimetric method)	Centre of the salon	~ 3 m away from the salon	5 working days and 1 weekend day	10 (occupancy) 14 (non-occupancy)	14.7 – 18.3 ^b 182 – 243 ^c	3 ^d	Teflon filters - trace elements, water-soluble ions Quartz filters - carbonaceous content, speciation of organic compounds
PM (photometric method)	Centre of the salon	~ 3 m away from the salon	Continuous	Continuous	-	-	-

^a FA – formaldehyde, ACT – acetaldehyde.

^b sampling volume for PM₁₀ samples collected on Teflon filters with high volume air MCV (model CAV-A/mb) instruments.

^c sampling volume for PM₁₀ samples on quartz fibre filters with a TCR TECORA.

^d two indoor samples (occupancy and non-occupancy period) and one outdoor sample (occupancy period).

Table S3. Comfort parameters and CO and CO₂ concentrations.

	CO ₂ (ppm)		CO (ppm)		T (°C)		HR (%)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Indoor	818 ± 82	425-1165	0.25 ± 0.26	bdl-0.90	18.7 ± 0.7	14.8-21.5	39.7 ± 8.8	28.6-53.2
Night	388 ± 12	362-674	0.25 ± 0.32	bdl-1.00	16.4 ± 1.5	14.6-18.8	33.3 ± 7.8	27.8-50.4
Weekend	380 ± 17	386-414	0.12 ± 0.05	0.10-0.50	16.1 ± 0.8	15.5-17.5	31.8 ± 2.8	28.1-35.3
Outdoor	455 ± 12	420-535	0.16 ± 0.19	bdl-0.90	9.5 ± 1.1	2.0-20.4	55.9 ± 21.0	15.5-86.9

bdl – below the limit of detection

Table S4. Pearson's correlation coefficients between mean concentrations of BTEX, formaldehyde and acetaldehyde.

	Benzene	Toluene	Ethylbenzene	<i>m/p</i> -Xylene	<i>o</i> -Xylene	Formaldehyde	Acetaldehyde	BTEX
Benzene	1	0.39	0.23	0.24	0.15	0.23	-0.59	0.40
Toluene		1	0.79*	0.75*	0.76	-0.36	-0.30	0.92**
Ethylbenzene			1	0.98**	0.98**	-0.80*	-0.63	0.95**
<i>m/p</i> -Xylene				1	0.99**	-0.84**	-0.67	0.94**
<i>o</i> -Xylene					1	-0.84**	-0.56	0.93**
Formaldehyde						1	0.52	-0.63
Acetaldehyde							1	-0.57
BTEX								1.00

* $p < 0.05$; ** $p < 0.01$ Table S5. Minimum, maximum and mean concentrations of elements (ng m⁻³), enrichment factors and indoor/outdoor ratios.

	Indoor (working hours)			Indoor (night)	Indoor (weekend)	Outdoor (working hours)				I/O
	Min	Max	AVR			Min	Max	AVR	EF	
Na	76.4	251	143	119	44.5	206	501	312	0.34	0.46
Mg	64.5	114	88.1	67.1	20.2	105	207	159	0.25	0.55
Al	226	627	441	331	110	214	1685	1191	0.27	0.37
Si	917	1515	1132	837	233	687	4500	3210	0.19	0.35
P	11.1	15.8	13.9	5.10	4.92	24.6	38.1	32.5	1.06	0.43
S	287	520	414	321	156	442	652	543	14.0	0.76
Cl	77.5	223	168	24.4	20.4	193	569	338	14.9	0.50
K	138	215	183	174	52.4	194	651	433	0.30	0.42
Ca	272	1096	603	154	80.0	440	3258	2209	1.30	0.27
Ti	22.7	38.3	30.8	20.3	7.24	13.7	90.5	61.8	0.35	0.50
V	-	1.60	0.40	0.089	-	-	2.35	0.80	0.28	0.50
Cr	0.44	3.28	1.46	0.69	-	2.83	7.11	5.47	3.08	0.27
Mn	3.81	9.08	6.23	3.64	2.50	10.1	31.7	22.1	0.80	0.28
Fe	214	572	377	157	144	812	2265	1589	1.00	0.24
Ni	0.46	2.42	1.05	0.59	0.52	-	1.33	0.44	0.44	2.37
Cu	45.5	140	99.2	3.52	6.01	23.1	49.1	35.1	50.2	2.83
Zn	23.1	31.6	26.2	13.1	8.94	26.1	55.2	44.2	17.2	0.59
As	-	3.64	1.64	0.73	-	-	3.15	2.07	26.9	0.79
Se	0.19	3.11	1.64	0.65	2.46	0.76	6.24	2.70	564	0.61
Br	1.78	18.1	10.0	2.24	1.25	3.60	5.10	4.49	66.1	2.22
Rb	-	1.91	0.76	0.48	1.52	0.92	11.5	6.11	0.91	0.12
Sr	3.89	12.6	7.16	1.34	1.74	3.68	27.2	19.3	1.06	0.37
Y	-	1.66	0.45	0.92	0.60	0.71	2.80	1.63	1.82	0.28
Zr	-	2.48	1.51	-	0.13	2.20	8.92	5.65	0.44	0.27
Mo	-	5.58	2.47	1.14	2.81	0.45	1.83	1.32	24.0	1.87

Pb	-	7.16	2.22	2.64	5.41	2.22	8.21	5.73	9.14	0.39
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Table S6. Concentrations (ng m⁻³) of organic compounds in PM₁₀.

	Indoor occupancy	Indoor non occupancy	Indoor weekend	Outdoor occupancy	I/O occupancy
<i>Alkanes and alkenes</i>					
Undecane	0.168 ± 0.312	0.659	Nd	0.221 ± 0.497	0.8
Dodecene	0.018 ± 0.040	0.168	Nd	0.075 ± 0.168	0.2
Dodecane	0.031 ± 0.068	0.129	0.164	0.147 ± 0.139	0.2
Tridecane	0.146 ± 0.020	0.070	0.172	0.063 ± 0.064	2.3
Tetradecene	0.015 ± 0.033	bdl	bdl	0.169 ± 0.378	0.1
Pentadecane	Nd	Nd	bdl	0.105 ± 0.235	-
Hexadecene	0.081 ± 0.115	Nd	bdl	0.077 ± 0.173	1.0
Octadecene	0.083 ± 0.051	bdl	bdl	0.133 ± 0.169	0.6
Octadecane	0.619 ± 0.798	bdl	bdl	bdl	-
Nonadecane	1.83 ± 1.49	bdl	bdl	0.213 ± 0.292	8.6
Eicosene	Nd	bdl	Nd	0.028 ± 0.062	-
Eicosane	4.12 ± 2.46	Nd	0.63	1.18 ± 0.79	3.5
Heneicosane	5.63 ± 3.92	bdl	1.38	1.48 ± 1.04	3.8
Docosane	11.5 ± 7.52	bdl	3.64	1.24 ± 0.58	9.2
Tricosane	24.6 ± 14.9	bdl	1.50	0.526 ± 1.11	47
Tetracosane	30.9 ± 21.3	bdl	bdl	0.279 ± 0.623	111
Pentacosane	23.9 ± 19.9	bdl	bdl	0.166 ± 0.371	144
Hexacosane	14.1 ± 13.7	bdl	bdl	bdl	-
Heptacosane	9.81 ± 9.25	bdl	bdl	0.206 ± 0.461	48
Octacosane	5.20 ± 5.02	bdl	bdl	bdl	-
Squalene	3.10 ± 0.798	4.53	0.431	9.01 ± 11.8	0.3
Nonacosane	3.51 ± 5.42	bdl	bdl	0.321 ± 0.718	11
triacontane	4.26 ± 3.28	Nd	Nd	0.758 ± 1.38	5.6
Hentriacontane	2.71 ± 4.06	Nd	0.711	0.318 ± 0.711	8.5
Dotriacontane	1.27 ± 2.92	Nd	0.536	0.110 ± 0.247	12
Tritriacontane	0.792 ± 1.37	Nd	Nd	0.096 ± 0.215	8.2
Tetratriacontane	0.377 ± 0.517	Nd	0.965	Nd	-
Pentatriacontane	0.176 ± 0.265	Nd	Nd	Nd	-
<i>PAHs</i>					
Naphthalene	0.005 ± 0.004	0.016	bdl	0.046 ± 0.102	0.1
Acenaphthylene	0.314 ± 0.283	Nd	Nd	Nd	-
Acenaphthene	0.016 ± 0.008	0.012	Nd	0.004 ± 0.008	3.7
Fluorene	0.012 ± 0.023	bdl	bdl	0.003 ± 0.008	3.3
Phenanthrene	0.072 ± 0.025	0.028	0.024	0.259 ± 0.208	0.3
Anthracene	0.002 ± 0.003	bdl	bdl	0.015 ± 0.016	0.1
Fluoranthene	0.141 ± 0.044	0.065	0.161	0.986 ± 0.863	0.1
Pyrene	0.121 ± 0.041	0.037	0.131	1.01 ± 0.76	0.1
Chrysene	0.183 ± 0.117	bdl	bdl	1.03 ± 0.508	0.2
Perylene	0.031 ± 0.016	0.008	0.004	0.051 ± 0.027	0.6
p-Terphenyl	0.001 ± 0.003	Nd	Nd	0.033 ± 0.036	0.04
Benzo[a]anthracene	0.057 ± 0.071	bdl	bdl	0.499 ± 0.311	0.1
Benzo[b]fluoranthene	0.163 ± 0.096	bdl	bdl	0.669 ± 0.373	0.2
Benzo[k]fluoranthene	0.202 ± 0.189	bdl	Nd	0.374 ± 0.295	0.5
Benzo[e]pyrene	0.304 ± 0.101	0.124	0.286	0.781 ± 0.336	0.4
Benzo[a]pyrene	0.209 ± 0.135	bdl	0.200	0.521 ± 0.393	0.4
Indeno[1,2,3-cd]pyrene	0.118 ± 0.067	0.007	0.027	0.227 ± 0.167	0.5
Dibenzo[a,h]anthracene	0.009 ± 0.008	bdl	Nd	0.023 ± 0.022	0.4
Benzo[g,h,i]perylene	0.130 ± 0.076	0.012	bdl	0.286 ± 0.194	0.5
Carbazol	0.003 ± 0.007	Nd	Nd	0.023 ± 0.024	0.1
<i>Aliphatic alcohols</i>					
1-Octanol	2.24 ± 2.22	0.587	Nd ^a	0.023 ± 0.046	98
1-Decanol	0.449 ± 0.351	0.267	0.018	0.016 ± 0.020	28

1-Dodecanol	11.4 ± 6.7	10.3	6.94	0.906 ± 0.547	13
C ₁₃ alcohol isomers	4.35 ± 3.40	6.06	5.59	4.88 ± 3.83	0.9
1-Tetradecanol	192 ± 275	70.9	87.2	6.37 ± 2.28	30
C ₁₄ alcohol isomers	0.627 ± 0.749	1.35	1.39	6.36 ± 3.03	0.1
1-Pentadecanol	34.3 ± 18.7	28.6	16.6	10.4 ± 4.27	3.3
C ₁₅ alcohol isomers	7.05 ± 5.32	7.46	4.17	10.3 ± 4.42	0.7
Hexadecanol	2502 ± 2413	247	147	18.1 ± 5.25	138
C ₁₇ alcohol isomers	16.0 ± 18.5	3.70	5.07	0.519 ± 0.304	31
1-Octadecanol (Stearyl alcohol)	4689 ± 4844	103	54.6	13.9 ± 5.05	338
1-Nonadecanol	10.8 ± 11.0	0.303	0.242	1.30 ± 2.00	8.4
C ₂₀ alcohol isomers	25.1 ± 33.3	4.10	Nd	4.04 ± 3.90	6.2
1-Eicosanol	91.8 ± 92.8	0.978	dlb	0.965 ± 0.890	95
1-Heneicosanol	2.37 ± 2.57	Nd	Nd	0.095 ± 0.116	25
1-Docosanol (Behenyl alcohol)	17.5 ± 20.4	0.462	0.460	0.912 ± 1.04	19
C ₂₂ alcohol isomers	0.292 ± 0.654	Nd	Nd	Nd	-
1-Tricosanol	0.700 ± 0.653	0.043	0.039	0.110 ± 0.099	6.4
1-Tetracosanol	3.78 ± 2.94	0.512	Nd	1.73 ± 0.965	2.2
1-Heptacosanol	0.037 ± 0.024	0.035	0.014	0.088 ± 0.084	0.4
1-Octacosanol	0.663 ± 0.474	0.416	0.190	1.83 ± 1.96	0.4
1-Tricontanol	0.166 ± 0.100	0.120	0.031	0.532 ± 0.656	0.3
1-Pentacosanol	0.208 ± 0.155	0.078	0.042	0.139 ± 0.123	1.5
1-Hexacosanol	1.64 ± 1.17	1.49	1.07	5.30 ± 4.05	0.3
<i>Steroid alcohols</i>					
Stigmasterol	0.454 ± 0.348	0.123	0.117	0.388 ± 0.438	1.2
β-Sitosterol	0.638 ± 0.436	0.130	0.086	0.897 ± 1.29	0.7
<i>Steroid alcohols</i>					
Cholesterol	59.5 ± 68.1	0.220	0.126	0.348 ± 0.383	171
5-Cholesten-3-ol (dihydrocholesterol)	2.99 ± 5.11	Nd	Nd	0.031 ± 0.038	98
Lathosterol	4.26 ± 4.66	Nd	Nd	Nd	
<i>Aliphatic carboxylic acids</i>					
1-Octanoic (caprylic) acid	0.720 ± 0.657	0.080	0.292	0.111 ± 0.044	6.5
1-Nonanoic (pelargonic) acid	1.085 ± 0.714	0.007	0.782	0.271 ± 0.279	4.0
1-Decanoic (caproic) acid	17.2 ± 15.3	1.07	3.99	0.849 ± 0.518	20
1-Undecanoic acid	0.525 ± 0.422	0.034	1.423	0.312 ± 0.165	1.7
1-Dodecanoic (lauric) acid	25.4 ± 9.1	18.2	65.7	4.66 ± 1.94	5.5
1-Tridecanoic acid	3.24 ± 3.68	5.59	5.85	0.548 ± 0.591	5.9
C ₁₃ acid isomers	11.4 ± 12.1	Nd	Nd	1.21 ± 1.52	9.4
1-Tetradecanoic (myristic) acid	1274 ± 543	274	141	26.9 ± 9.7	47
C ₁₄ acid isomers	69.4 ± 55.9	19.8	4.73	Nd	-
Tetradecenoic acid	52.9 ± 40.8	1.49	2.96	Nd	-
1-Pentadecanoic acid	526 ± 295	22.3	25.7	4.27 ± 2.05	123
Pentadecenoic acid	46.5 ± 50.7	Nd	Nd	Nd	-
C ₁₅ acid isomers	153 ± 143	12.5	9.78	Nd	-
1-Hexadecanoic (palmitic) acid	950 ± 594	0.067	206	47.7 ± 35.1	20
C ₁₆ acid isomers	294 ± 218	8.20	4.34	Nd	-
Hexadecenoic acid isomer	6.42 ± 10.27	Nd	Nd	Nd	-
9-cis-Hexadecenoic (palmitoleic)acid	600 ± 414	0.033	0.544	3.09 ± 5.59	194
1-Heptadecanoic acid	145 ± 94	0.046	7.19	1.89 ± 1.29	77
C ₁₇ acid isomers	217 ± 139	4.57	11.1	6.48 ± 5.89	34
Heptadecenoic acid	105 ± 97	Nd	Nd	Nd	-
1-Octadecanoic (stearic) acid	210 ± 116	0.192	42.6	62.2 ± 55.7	3.4
C ₁₈ acid isomers	1.69 ± 3.77	Nd	Nd	Nd	-
cis,cis-9,12-Octadecadienoic (linoleic) acid	56.0 ± 58.8	0.138	0.896	1.73 ± 2.18	32
cis-9-Octadecenoic oleic acid	380 ± 260	bdl	5.21	5.85 ± 5.01	65
cis-11-Octadecenoic acid	20.1 ± 25.4	Nd	Nd	Nd	-
1-Nonadecanoic acid	9.72 ± 7.03	0.021	Nd	0.243 ± 0.198	40
Nonadecenoic acid	3.42 ± 4.69	Nd	Nd	Nd	-

1-Eicosanoic (arachidic) acid	19.3 ± 10.2	0.264	1.31	3.08 ± 2.70	6.3
Eicosenoic acid	9.26 ± 8.10	Nd	Nd	Nd	-
C ₂₁ acid isomers	4.47 ± 3.73	0.561	Nd	0.399 ± 0.797	11
1-Docosanoic (behenic) acid	10.8 ± 5.0	1.63	1.68	4.75 ± 3.66	2.3
C ₂₂ acid isomers	0.926 ± 1.31	Nd	Nd	Nd	-
1-Tetracosanoic acid	19.7 ± 6.79	3.54	Nd	6.35 ± 2.80	3.1
1-Pentacosanoic acid	5.28 ± 2.84	Nd	Nd	0.318 ± 0.636	17
1-Hexacosanoic acid	4.98 ± 4.21	0.670	0.142	2.64 ± 2.83	1.9
C ₂₆ acid isomers	0.654 ± 1.23	Nd	Nd	Nd	-
1-Tricosanoic acid	2.50 ± 2.67	Nd	Nd	Nd	-
C ₂₃ acid isomers	3.47 ± 3.12	Nd	Nd	Nd	-
Dicarboxylic acids					
Laevulic acid	9.80 ± 4.77	7.36	10.94	2.07 ± 1.31	4.7
Hydroxybutanedioic (malic) acid	1.15 ± 1.20	1.36	11.92	3.98 ± 4.32	0.3
Butanedioic (succinic) acid	1.17 ± 0.97	0.531	7.98	4.99 ± 2.22	0.2
1,5-Pentanedioic acid	5.31 ± 2.55	bdl	3.69	1.23 ± 0.54	4.3
Hexanedioic acid	5.34 ± 4.02	1.657	2.84	0.900 ± 0.238	5.9
Octanedioic acid	1.51 ± 1.52	0.319	0.969	0.472 ± 0.097	3.2
Heptanedioic (pimelic) acid	0.389 ± 0.211	0.100	0.767	0.456 ± 0.156	0.9
Decanedioic (sebacic) acid	0.123 ± 0.168	Nd	Nd	0.289 ± 0.554	0.4
Hexadecanedioic (thapsic) acid	0.011 ± 0.015	0.017	0.030	0.029 ± 0.032	0.4
Other acids					
Glyceric acid	6.50 ± 5.77	5.26	8.10	6.81 ± 2.08	1.0
Hydracrylic acid	8.25 ± 9.24	1.20	7.73	4.32 ± 2.78	1.9
3-hydroxybutanoic acid	0.427 ± 0.428	0.023	0.755	0.377 ± 0.338	1.1
3,4-Dihydroxybutanoic acid	0.568 ± 0.372	0.547	0.334	0.665 ± 0.504	0.9
Cis-Pinonic acid	0.426 ± 0.166	0.317	0.471	4.99 ± 4.14	0.1
Citric acid	0.042 ± 0.052	0.121	1.20	7.85 ± 10.20	0.1
Pinic acid	1.11 ± 0.53	0.908	2.85	5.52 ± 2.51	0.2
12-Hydroxystearic acid	Nd	0.988	1.21	14.2 ± 10.5	-
Pimaric acid	3.71 ± 5.67	Nd	Nd	Nd	-
Abietic acid	0.999 ± 0.606	0.006	Nd	0.045 ± 0.045	22
Isopimaric	15.6 ± 15.6	0.063	0.066	0.095 ± 0.042	163
Dehydroabietic acid	16.3 ± 18.7	0.576	1.10	3.05 ± 0.83	5.3
15-Hydroxydehydroabietic acid	0.431 ± 0.599	Nd	Nd	0.046 ± 0.093	9.3
Alkyl esters of fatty acids					
Butyl hexanoate	4.72 ± 3.62	6.61	Nd	0.270 ± 0.401	18
Dodecyl octanoate	4.80 ± 5.46	3.02	Nd	0.126 ± 0.183	38
Octan-4-yl dodecanoate	9.61 ± 10.39	12.7	9.68	0.505 ± 0.419	19
Methyl tetradecanoate	1.64 ± 2.87	5.14	8.25	Nd	-
Butyl tetradecanoate	0.248 ± 0.342	4.31	Nd	Nd	-
Methyl hexadecanoate	6.98 ± 8.04	3.02	81.6	6.46 ± 4.10	1.1
Ethyl hexadecanoate	0.897 ± 1.036	5.36	Nd	Nd	-
2-Hydroxyethyl hexadecanoate	11.4 ± 11.5	Nd	Nd	Nd	-
Isopropyl hexadecanoate	8.42 ± 12.00	Nd	25.1	0.845 ± 0.979	10
Hexadecyl hexadecanoate	18.5 ± 21.1	Nd	Nd	0.270 ± 0.390	69
Dibutyl hexanedioate	5.75 ± 8.87	Nd	2.72	1.94 ± 2.66	3.0
Tetradecyl octanoate	7.73 ± 11.03	Nd	Nd	Nd	-
Glycerol derivatives					
Glycerol	107 ± 14	53.2	62.2	39.1 ± 13.3	2.7
Diethylene glycol	34.8 ± 12.8	25.9	29.4	6.61 ± 1.60	5.3
Triethylene glycol	27.3 ± 16.3	20.3	6.48	Nd	-
Pentadecanoic acid, Glycerine-	11.2 ± 15.4	Nd	Nd	Nd	-
(1)-monoester					
Heptadecanoic acid, glycerine-					
(1)-monoester	1.11 ± 1.54	Nd	Nd	Nd	-
1-Monopalmitin	259 ± 139	1.32	5.31	9.82 ± 2.18	26
2-Monopalmitin	7.19 ± 16.08	Nd	Nd	Nd	-
1-Monostearin	135 ± 91	Nd	7.77	29.5 ± 3.9	4.6
Glycerol tricaprolate	7.44 ± 14.55	Nd	Nd	Nd	-

α -Glyceryl pentadecanoate	17.1 \pm 15.2	Nd	1.49	Nd	-
Phenolic derivatives					
Cresol	1.76 \pm 0.12	0.302	Nd	0.030 \pm 0.059	60
Pyrocatechol	0.011 \pm 0.003	0.001	0.001	0.003 \pm 0.003	3.4
5-Isopropyl-3-Methylphenol	0.060 \pm 0.044	0.031	0.058	0.060 \pm 0.072	1.0
Thymol	1.00 \pm 0.63	0.214	0.150	0.226 \pm 0.245	4.4
Resorcinol	0.115 \pm 0.176	0.005	0.004	0.022 \pm 0.021	5.2
4-Methyl catechol	0.004 \pm 0.002	0.001	0.001	0.002 \pm 0.001	2.0
2,6-Dimethoxyphenol	0.001 \pm 0.001	0.001	0.001	0.001 \pm 0.001	1.0
Eugenol	0.006 \pm 0.007	0.001	bdl	Nd	-
Methoxy eugenol	0.003 \pm 0.003	0.004	0.002	0.007 \pm 0.004	0.5
2,4-Di-tert-butylphenol	37.0 \pm 21.0	4.68	bdl	6.94 \pm 4.84	5.3
Pyrogallol	0.003 \pm 0.002	0.001	0.001	0.003 \pm 0.003	1.1
Isoeugenol	0.178 \pm 0.100	bdl	0.092	0.031 \pm 0.061	5.8
2-Methoxy-4-propylphenol	0.001 \pm 0.001	0.001	0.002	0.003 \pm 0.003	0.4
4-Phenylphenol	0.009 \pm 0.021	Nd	0.018	0.009 \pm 0.011	1.0
4-Octylphenol	0.062 \pm 0.128	Nd	Nd	Nd	-
Benzyl alcohol	97.0 \pm 77.0	14.6	2.08	6.10 \pm 6.89	16
Sinapyl alcohol	0.030 \pm 0.029	0.013	0.202	0.014 \pm 0.026	2.2
Benzoic acid	0.165 \pm 0.137	bdl	0.071	0.204 \pm 0.189	0.8
4-hydroxybenzoic acid	0.329 \pm 0.115	0.068	0.386	1.36 \pm 0.54	0.2
Benzoic acid alkyl esters	158 \pm 233	26.8	11.0	8.68 \pm 14.06	18
4-tert-Butylphenol	6.60 \pm 4.23	1.68	1.62	1.80 \pm 1.67	3.7
4-Hydroxybenzoic acid methyl ester (methylparaben)	0.870 \pm 1.140	0.408	1.01	0.079 \pm 0.158	11
Vanillin	0.168 \pm 0.165	0.040	0.082	0.033 \pm 0.059	5.0
Vanillic acid	0.037 \pm 0.055	0.020	0.215	0.133 \pm 0.092	0.3
Trans-cinnamic acid	0.133 \pm 0.093	0.013	0.112	0.248 \pm 0.129	0.5
4-Hydroxy-3-methoxycinnamic (ferulic) acid	0.040 \pm 0.058	0.043	0.254	0.035 \pm 0.049	1.2
Syringic acid	0.056 \pm 0.046	0.034	0.401	0.060 \pm 0.043	0.9
Phthalic acid	0.743 \pm 0.784	Nd	2.89	1.37 \pm 0.55	0.5
α -Hexylcinnamaldehyde	2.06 \pm 3.52	1.12	Nd	Nd	-
Phthalates					
Diethyl Phthalate	4.83 \pm 10.76	bdl	2.02	Nd	-
Di-n-butyl Phthalate	4.23 \pm 8.35	bdl	2.70	0.279 \pm 0.228	15
Bis(2-ethylhexyl)phthalate	39.8 \pm 86.4	bdl	9.45	0.280 \pm 0.362	142
Other phthalates	545 \pm 403	198	331	104 \pm 166	5.3
(S)-(-)- β -Citronellol	0.922 \pm 0.871	1.18	Nd	0.037 \pm 0.046	25
2,6-Di-tert-butyl-p-benzoquinone	1.78 \pm 1.84	bdl	2.49	0.267 \pm 0.387	6.7
Benzyl butyl phthalate	0.483 \pm 1.080	bdl	0.209	Nd	-
Bis(2-ethylhexyl) adipate	0.022 \pm 0.049	bdl	0.451	0.009 \pm 0.018	2.4
Saccharides and polyols					
Galactosan	1.02 \pm 1.29	0.984	1.27	4.10 \pm 2.71	0.2
Mannosan	3.37 \pm 1.93	2.02	2.29	8.71 \pm 3.29	0.4
Levoglucozan	43.2 \pm 27.2	23.2	49.8	73.3 \pm 25.4	0.6
Other compounds					
Cis-2-Methylcyclohexanol	0.058 \pm 0.022	0.029	Nd	0.008 \pm 0.013	7.4
(S)-(-)- β -Citronellol	0.922 \pm 0.871	1.18	Nd	0.037 \pm 0.046	25
(1S, 2S, 3R, 5S)-2,3-Pinenediol	0.091 \pm 0.040	0.158	0.027	0.032 \pm 0.064	2.9
Meso-Erythritol	Nd	Nd	Nd	0.047 \pm 0.094	-
1,2,3-Hexanetriol	0.007 \pm 0.015	Nd	bdl	Nd	-
2,6-Di-tert-butyl-p-benzoquinone	1.78 \pm 1.84	Nd	2.49	0.267 \pm 0.387	6.7
Methyl dihydrojasmonate	41.8 \pm 33.8	73.4	1.75	0.411 \pm 0.249	95
2-Propanol, 1-chloro,phosphate	3.98 \pm 3.72	5.15	2.38	0.319 \pm 0.468	13
7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione	5.68 \pm 5.28	1.57	7.76	1.29 \pm 1.35	4.4

Anthraquinone	Nd	Nd	Nd	0.682 ± 0.588	-
Ethylene brassylate	26.7 ± 26.8	13.6	8.92	0.637 ± 0.485	42
Geranylacetone	1.76 ± 2.63	Nd	Nd	Nd	-
Parsol MCX	202 ± 209	11.9	3.69	8.88 ± 11.85	23
Tributyl acetyl citrate	8.74 ± 8.84	2.98	1.81	0.355 ± 0.250	25
Tetramethrin	15.2 ± 34.0	Nd	Nd	Nd	-
Isodecyl diphenyl phosphate	2.91 ± 1.92	1.51	Nd	Nd	-
Oxidised irgafos 168	12.6 ± 20.2	9.82	Nd	5.52 ± 10.93	2.3
Irganox 1086 (Antioxidant 1076)	3.18 ± 7.11	nd	Nd	8.64 ± 11.70	0.5
Vitamin E acetate	32.5 ± 43.8	Nd	Nd	1.01 ± 0.73	32
(±)-α-Tocoferol (Vit, E)	0.014 ± 0.026	Nd	0.005	0.009 ± 0.011	1.6
5-oxo-L-proline	5.13 ± 3.21	Nd	2.77	Nd	-
Lilial	2.31 ± 2.95	0.287	Nd	0.025 ± 0.050	93
Farnesyl acetaldehyde	14.3 ± 24.5	Nd	Nd	Nd	-
Galaxolide	40.1 ± 79.4	21.9	Nd	0.821 ± 1.642	49
Lupeol	0.233 ± 0.148	0.254	0.170	0.647 ± 0.632	0.4
Tetradecanal	3.77 ± 4.44	0.535	8.75	0.075 ± 0.150	50
Isophorone	0.004 ± 0.008	bdl	bdl	0.056 ± 0.125	0.1

nd - not detected.

bdl - below detection limit.

Table S7. Mean risks from inhalation exposure to carcinogenic and noncarcinogenic VOCs.

Compounds	CR ^{a)} (mean)	CR (min)	CR (max)	HQ ^{b)} (min)	HQ (mean)	HQ (max)
Benzene	8.32×10^{-7}	6.89×10^{-7}	1.10×10^{-6}	4.20×10^{-2}	3.48×10^{-2}	5.57×10^{-2}
Toluene	-	-	-	7.57×10^{-5}	6.26×10^{-5}	1.00×10^{-4}
Ethylbenzene	1.01×10^{-7}	8.34×10^{-8}	1.42×10^{-7}	8.10×10^{-6}	6.67×10^{-6}	1.14×10^{-5}
o-Xylene	-	-	-	4.30×10^{-4}	3.48×10^{-4}	6.90×10^{-4}
m,p-Xylene	-	-	-	9.12×10^{-4}	6.81×10^{-4}	1.64×10^{-3}
Formaldehyde	4.50×10^{-6}	1.47×10^{-6}	5.69×10^{-6}	3.33×10^{-2}	1.09×10^{-2}	4.22×10^{-2}
Acetaldehyde	6.31×10^{-7}	2.10×10^{-7}	1.26×10^{-6}	2.60×10^{-2}	8.65×10^{-3}	5.17×10^{-2}
Σ	6.06×10^{-6}	-	-	1.03×10^{-1}	-	-

^{a)} CR – excess cancer risk. USEPA guideline 1×10^{-6} for negligible cancer risk; values between 1×10^{-4} and 1×10^{-6} suggest a “possible risk”.

^{b)} HQ – noncancer hazard quotient. It expresses whether the exposure is higher (> 1) or lower (< 1) than the maximum exposure in which there is no effect on human health.

Table S8. Mean risks from inhalation exposure to PM₁₀-bound metals, trace elements and PAHs.

Compounds	Risk	Range (min-max) / Values
Metals (Cr, Ni, As, Pb)	CR	$6.94 \times 10^{-10} - 4.58 \times 10^{-7}$
PAHs	CR	$7.60 \times 10^{-10} - 1.33 \times 10^{-8}$
Trace elements (Al, V, Mn, Fe, Cu, Zn, Se, Sr, Zr)	HQ	-
PM ₁₀ -bound metals	Σ(CR)	6.50×10^{-7}
PM ₁₀ -bound PAHs	Σ(CR)	8.13×10^{-9}
PM ₁₀ -constituents (metals, trace elements, PAHs)	Σ(CR)	9.34×10^{-6}

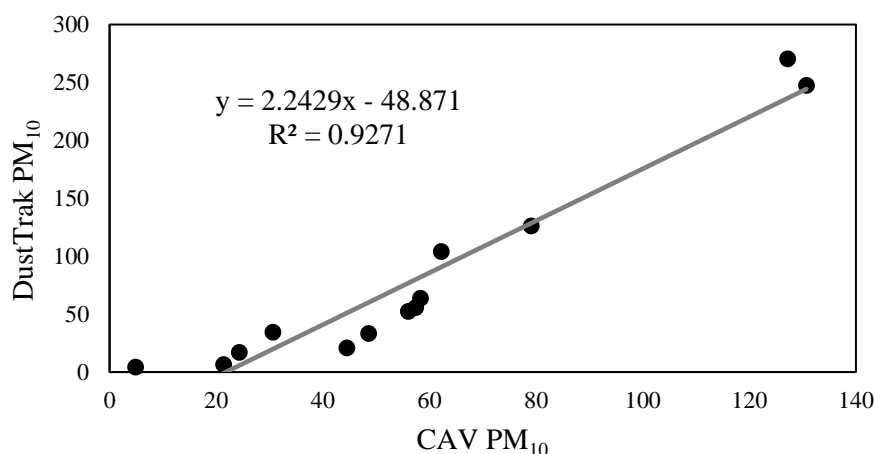


Figure S1. Relationship between the photometric and gravimetric PM measurements.

References:

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