

Influence of terpenes on indoor air quality

KLAUDIA PYTEL*, RENATA MARCINKOWSKA, BOŻENA ZABIEGAŁA

*Department of Analytical Chemistry, Faculty of Chemistry, Gdańsk University of Technology,
G. Narutowicza 11/12, 80-233 Gdańsk Poland ✉ klapytel@student.pg.edu.pl*

Keywords

hairdresser
indoor air
d-limonene
secondary organic
aerosol
terpenes

Abstract

The aim of this study was to investigate air quality in hairdresser salons, focusing on terpenes determination. Terpenes are known reactive volatile organic compounds that contribute to secondary organic aerosol formation. Those compounds are frequently found in cosmetic products as fragrance agents. Hairdresser salons are special kind of environment, where secondary organic aerosol concentration may be elevated. One hairdresser salon in Gdynia was chosen to carry out preliminary research. Indoor air samples from the salon were collected using diffusive samplers and sorbent tubes, which were later desorbed and analyzed by TD-GC-FID and TD-GC-MS. Determined limonene concentration varied between 6–74 $\mu\text{g m}^{-3}$.

1. Introduction

According to United States Environmental Protection Agency 90% of the time people spent in closed spaces, which makes indoor air an important factor that influences human health [1–3]. The problem of indoor air quality arose in late 1960s and 1970s, when the term “sick building syndrome” appeared [4]. This term refers to symptoms like: irritation of upper airway, eyes, mucous membranes and skin [5]. It is believed that sick building syndrome is caused by volatile organic compounds [6] with terpenes as one of the contributors. Terpenes are produced mostly by conifer plants [7–8], however they are also emitted into indoor air from cleaning agents, perfumes, air fresheners and cosmetic products [9–11]. Terpenes most commonly present in indoor air are: d-limonene, α -pinene and β -pinene [12]. Products formed due to the series of reactions initiated by terpenes oxidation may cause human health deterioration [6; 13–15]. The reason why the presence of terpenes in indoor air may be considered as a threat to human health is because products of their transformations undergo condensation and form secondary organic aerosol [17]. Secondary organic aerosol nanosized particles are able to penetrate deeply human respiratory track and even reach the bloodstream [18].

There were already a lot of studies on terpenes presence in indoor air, but to the best of our knowledge, there was no research concerning terpenes determination in hairdressers salons published yet. In this work we present the preliminary

Table 1

Thermal desorption, GC-MS and GC-FID parameters applied during analysis.

	GC-MS	GC-FID
Column	DB5MS 60 m × 0.25 mm × 1 μm (Agilent J&W)	DB1 30 m × 0.32 mm × 5 μm (Agilent Technologies)
Column flow	0.5 ml min ⁻¹	2.2 ml min ⁻¹
Temperature program	70 °C held for 1 min, ramped at 15 °C min ⁻¹ to 120°C and held for 1 min, ramped at 10 °C min ⁻¹ to 280 °C and held for 5 min	40 °C held for 1 min, ramped at 10 °C min ⁻¹ to 125 °C, ramped at 15 °C min ⁻¹ to 240 °C and held for 5 min
Detector temperature	Ion source: 250 °C Quadrupole: 150 °C	250°C
Thermal desorption prepurge	1 min (split ON)	1 min (split ON)
tube desorption	10 min at 300 °C (split OFF)	10 min at 300 °C (split OFF)
trap desorption	Trap low: 1°C Trap high: 300 °C (split OFF)	Trap low: 1°C Trap high: 300 °C (split OFF)

research concerning indoor air quality of this type of public service space. The aim is to determine chemical composition of indoor air, with a special attention paid to terpenes concentration, and its variability in hairdresser salon.

2. Experimental

2.1 Reagents and chemicals

Methanol (gradient grade for LC, Sigma-Aldrich), (R)-(+)-limonene (Sigma-Aldrich), calibration solutions were of following concentrations: 10; 100; 200 and 500 ng μl⁻¹.

2.2 Instrumentation

Radiello[®] diffusive passive samplers with Carbograph[®] sorbent and tubes filled with Tenax[®] were applied to sample the indoor air. Passive samplers and sorbent tubes were desorbed using thermal desorption (TD) unit Markes[®]. Gaseous samples were analyzed by gas chromatography coupled to mass spectrometry (GC Agilent Technologies 6890, MS Agilent Technologies 5973) and flame-ionization detector (GC-FID Agilent Technologies 7820A). Parameters of thermal desorption unit and two chromatographic units are presented in Table 1.

2.3 Methodology of analytical procedure

All of analytical proceeding stages are presented in Fig.1. Location of Radiello[®] and active sampling with sampling tubes is presented in Fig. 2.



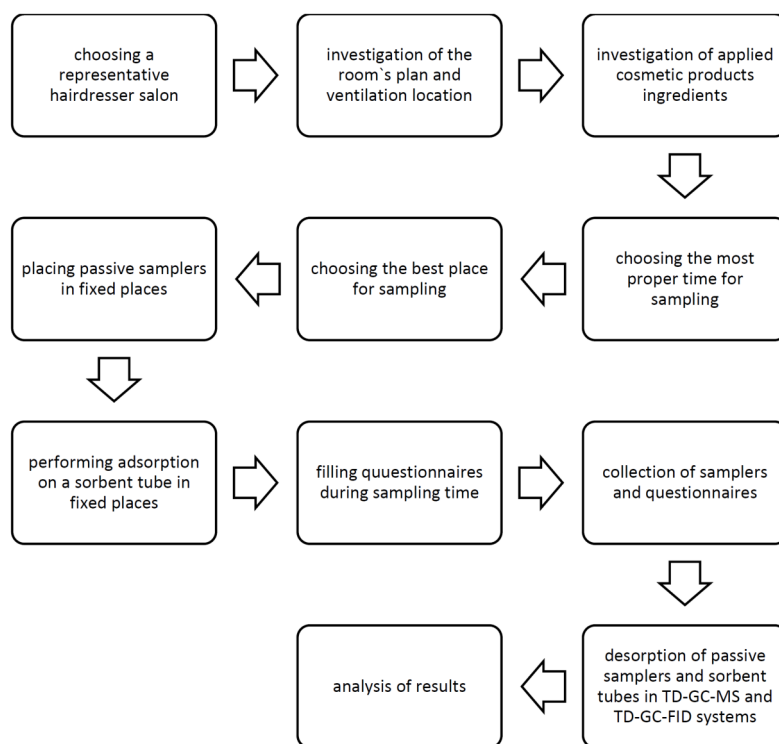


Fig. 1 Analytical proceeding steps applied in this research.

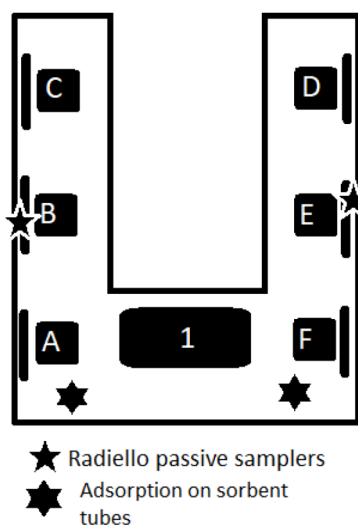


Fig. 2 Location of passive samplers and sorbent tubes sampling points at hairdresser salon.

Table 2

Limonene concentration determined in a chosen hairdresser salon.

Day of sampling	Limonene concentration/ $\mu\text{g m}^{-3}$	Total concentration of organic compounds/ $\mu\text{g m}^{-3}$
09.06.2018	6	322
16.06.2018	74	2246
20.06.2018	69	5122

3. Results and discussion

Sampling with Radiello® samplers last 5 hours (ca. since 10 a.m. to 3 p.m.) each day of sampling, whereas sampling with sampling tubes was performed around 2–3 p.m. each day. Sampling was carried out during the working days and at the weekend. Limonene concentrations calculated on the basis of the mass adsorbed on sampling tubes and determined by TD-GC-FID are presented in Table 2.

According to obtained results, limonene concentrations determined in hairdresser salon were sometimes higher in comparison to an exemplary studies carried out in Germany, which indicated limonene concentration at homes at a level of 15–20 $\mu\text{g m}^{-3}$ [19–22]. All differences in concentration could be caused by activities performed in the salon during the day. For example at 09.06.2018 limonene concentration was the lowest and sampling was carried out very close (1 meter) from the client with a hair dye. The type of hair dyes used in chosen salon does not have terpenes indicated in International Nomenclature of Cosmetic Ingredients and no noticeable scent. The highest concentration determined on the 16.06.2018 may be related to the fact that sampling occurred while hairdresser was using hair spray and other cosmetics in the form of aerosols, with relatively large amount of scented chemicals included. Chromatograms obtained by desorption of Radiello® samplers present more precise picture of the complicity of indoor air composition, which can be seen on an exemplary chromatograms obtained by TD-GC-FID and TD-GC-MS (Fig. 3) analysis.

MS detector was applied in order to carry out qualitative analysis and determine components of the indoor air. On the GC-MS chromatogram limonene peak intensity is relatively low in comparison to siloxanes (Fig. 3B). There are also alcohols peaks of high intensity visible at the beginning of chromatogram and their presence is justified due to the fact that they are common cosmetic ingredients. FID detector was applied mainly to get quantitative information about analytes present in the sample. Chromatogram obtained by GC-FID proves that indoor air from hairdresser salon is a complex sample containing a set of different chemicals (a lot of chromatographic peaks on Fig. 3A). Siloxanes are not visible on FID chromatogram, because FID is selective towards compounds that possess C–H bonding in a structure.

Such high concentration of siloxanes in indoor air of hairdresser salon may be explained by the fact that siloxanes are common ingredients of hair cosmetic



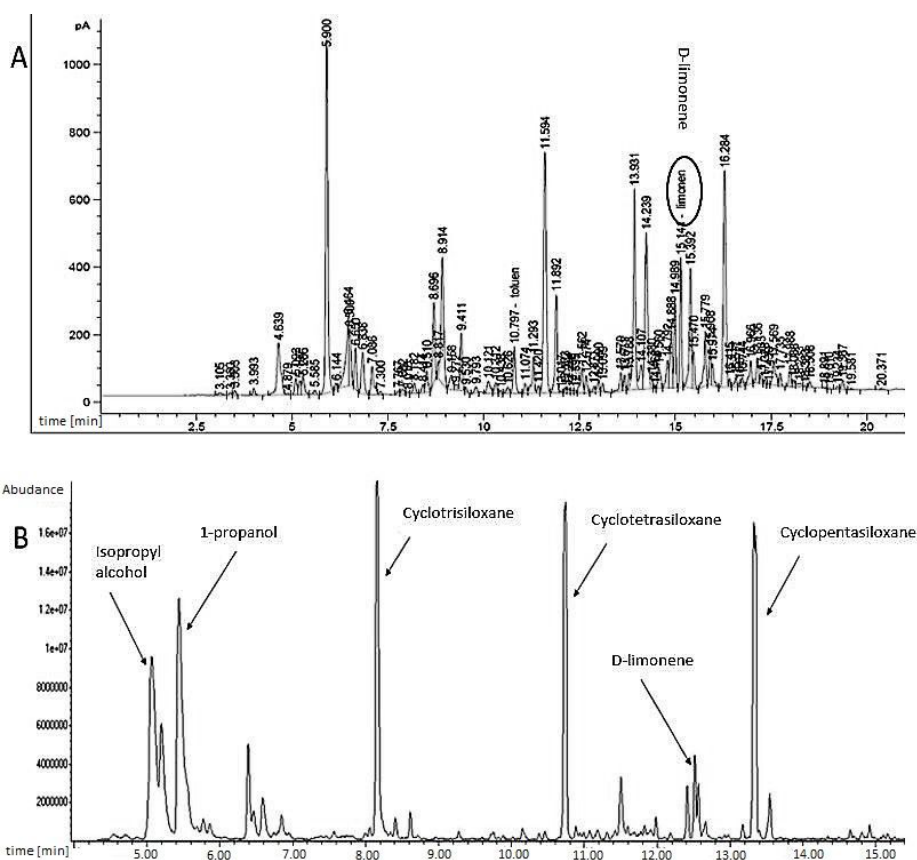


Fig. 3 Chromatogram obtained by (A) GC-FID, and (B) GC-MS analysis of the sample collected on the fourth day of sampling.

products. Such high concentration of siloxanes may also be considered as a threat for workers and clients health, because according to the literature, siloxanes were determined as components of atmospheric aerosol and may irritate human respiratory system [23].

4. Conclusions

In this paper we proved that indoor air of hairdresser salons contains precursors for secondary organic aerosol formation. It is necessary to continue this research in order to improve analytical approach and obtain more data. It would be very helpful to use in the future particle counters like SMPS (Scanning Mobility Particle Sizers) to determine the exact dependence between the amount of terpenes in indoor air and the amount and spatial distribution of created secondary organic aerosol particles.

References

- [1] US EPA: *Air Quality Criteria for Particulate Matter. National Center for Environmental Assessment Office of Research and Development. 1. 2001*
- [2] US EPA: *Air Quality Criteria for Particulate Matter. National Center for Environmental Assessment Office of Research and Development. 2. 2004.*
- [3] US EPA: *Air Quality Criteria for Particulate Matter. National Center for Environmental Assessment Office of Research and Development. 3. 1996.*
- [4] Sundell J.: On the history of indoor air quality and health. *Indoor Air* **14** (2004), 51–58.
- [5] Spengler J.D., Samet J.M., McCarthy J.F.: *Indoor Air Quality Handbook*. New York, McGraw-Hill 2001.
- [6] Missia D.A., Demetriou E., Michael N., Tolis E.I., Bartzis J.G.: Indoor exposure from building materials: A field study. *Atmospheric Environ.* **44** (2010), 4388–4395.
- [7] Curci G., Beekman M., Vautard R., Smiatek G., Steinbrecher R., Theloke J., Friedrich R.: Modeling study of the impact of isoprene and terpene biogenic emission on European ozone levels. *Atmospheric Environ.* **43** (2009), 1444–1455.
- [8] Schripp T., Langer S., Salthammer T.: Interaction of ozone with wooden building products, treated wood samples and exotic wood samples. *Atmospheric Environ.* **54** (2012), 365–372.
- [9] Nazaroff W.W., Weschler J.W.: Cleaning products and air fresheners: exposure to primary and secondary air pollutants. *Atmospheric Environ.* **38** (2004), 2841–2865.
- [10] Wolkoff P., Clausen P., Wilkins C., Nielsen G.: Formation of strong airway irritants in terpene/ozone mixtures. *Indoor Air* **10** (2000), 82–91.
- [11] Tsigonia A., Lagoudi A., Chandrinou S., Linos A., Elyogias N., Alexopoulos EC.: Indoor air in beauty salons and occupational health exposure of cosmetologists to chemical substances. *Int. J. Environ. Res. Public Health* **7** (2010), 314–324.
- [12] Hodgson A., Beal D.: Sources of formaldehyde, other aldehydes and terpenes in a new manufactured house. *Indoor Air* **12** (2001), 235–242.
- [13] Holcomb L.C., Seabrook B.S.: Indoor concentrations of volatile organic compounds: implications for comfort, health and regulation. *Indoor Environment*. **4** (1995), 7–26.
- [14] Kotzias D., Geiss O., Tirendi S., Josefa BM., Reina V., Gotti A., Graziella CR., Casati B., Marafante E., Sargiannis D.: Exposure to Multiple air contaminants in public buildings, schools, kindergartens–the european indoor air monitoring and exposure assessment (AIRMEX) study. *Fresenius Environ. Bull.* **18** (2009), 670–681.
- [15] Eriksson K.A., Levin J.O., Sandström T., Lindström–Espeling K., Lindén G., Stjernberg N.L.: Terpene exposure and respiratory effects among workers in Swedish joinery shops. *Scand. J. Work Environ. Health* **23** (1997), 114–120.
- [16] Wolkoff P., Larsen ST., Hammer M., Kofoed–Sørensen V., Clausen P.A., Nielsen G.D.: Human reference values for acute airway effects of five common ozone–initiated terpene reaction products in indoor air. *Toxicol. Lett.* **216** (2013), 54–64.
- [17] Ito K., Harashima H.: Coupled CFD analysis of size distribution on indoor secondary organic aerosol derived from ozone/limonene reaction. *Build. Environ.* **46** (2011), 711–718.
- [18] Borduas N., Lin V.S.: Research highlights: Laboratory studies of the formation and transformation of atmospheric organic aerosols. *Environ. Sci. Process. Impacts* **18** (2016), 425–428.
- [19] Schlink U., Rehwagn M., Damm M., Richter M., Borte M., Herbarth O.: Seasonal cycle of indoor–VOCs: comparison of apartments and cities. *Atmospheric Environ.* **38** (2004), 1181–1190.
- [20] Schlink U., Roder S., Kohajda T., Wissenbach D.K., Franck U., Lehmann I.: A framework to interpret passively sampled indoor–air VOC concentrations in health studies. *Build. Environ.* **105** (2016), 198–209.
- [21] Matysik S., Ramadan A.B., Schlink U.: Spatial and temporal variation of outdoor and indoor exposure of volatile organic compounds in Greater Cairo. *Atmos. Pollut. Res.* **1** (2010), 94–101.

- [22] Rosch C., Kohajda T., Roder S., Bergen M., Schlink U.: Relationship between sources and patterns of VOCs in indoor Air. *Atmos. Pollut. Res.* **5** (2014), 129–137.
- [23] Chandramouli B., Kamens M.R.: The photochemical formation and gas–particle partitioning of oxidation products of decamethyl cyclopentasiloxane and decamethyl tetrasiloxane in the atmosphere. *Atmospheric Environ.* **35** (2001), 87–95.