

VOC and fine particles in a newly renovated building—a case study

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ABSTRACT

In a small case study involving an office room and a laboratory in a building equipped with a HVAC system VOC and particle samples were collected. Both rooms used for the experiments were newly renovated and low, but measurable amounts of typical indoor VOC and SVOC were present in the air several weeks after finishing of the renovation work. The VOC concentrations decreased slowly during the test period of 3 weeks.

Particulate matter in the room air was characterized regarding the size distribution by SMPS. Several samples of particles were collected on glass fibre filters to be tested for adsorbed VOC using a dynamic Headspace-GC/MS method. Since the particle concentration in the rooms was quite low, even with a sample volume of ~18 m³ the total particle mass on the collected filters was below 1 mg. Only trace amounts of VOCs and SVOCs identified in the room air could be detected on the collected particle samples after thermal desorption.

INDEX TERMS

VOC; Particulate matter; Office building

INTRODUCTION

The particle concentration in the indoor environment is influenced by several parameters: The release of particles indoors (e.g. from office equipment), the penetration of particles from the outdoor environment (involving the outdoor concentration and the air exchange rate) and the particle deposition rate (Thatcher and Layton, 1995; Morawska *et al.*, 2001). The VOC concentration level in an indoor environment, however, is mostly controlled by indoor sources, outdoor concentrations are usually lower and the penetration of outdoor VOC into a room is negligible in most cases (an exception is, e.g. benzene from vehicle exhaust). In many cases either external sources (particles) or internal sources (VOC/SVOC) are monitored, but for a general assessment of indoor air quality both parameters are important.

This is especially true in the case of multifunctional buildings with ventilation or HVAC systems where sources of both particulates and gaseous organic compounds may be present inside the building and pollutants of outdoor sources (parking lots, loading zones, etc.) might be forced into the building by the ventilation system.

The measurement of particles and gas phase organic compounds gives the opportunity to check for the presence of adsorbed organic compounds on the particulate matter. This topic has received certain attention, e.g. the adsorption of PAH on fine particles in the outdoor environment is well described in the literature. Especially automobile exhaust, a source of both particles and PAH has been the target of research for many years (Ristovski *et al.*, 2000). Few details have been published up to now for organic compounds adsorbed to particles in the indoor environment (Weschler and Fong, 1984; Abadie *et al.*, 2001), where generation of particles (combustion processes, electronic devices, cooking) and release of volatile organic compounds (building products, cleaning agents) may happen at the same time. The effect that volatile and semivolatile organic compounds (SVOC) tend to adsorb to particles is nowadays

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often used for screening procedures regarding contaminations with plasticizers, pesticides and flame retardants in buildings by use of dust samples. This paper presents the results of a building examination starting shortly after major renovation work. VOC and particle concentrations were monitored and the particles collected were tested for adsorbed organic compounds.

METHODS

The measurements were carried out in two rooms of a newly renovated building in the Queensland University of Technology Gardens Point campus. Room 1 was an office room, room 2 a laboratory room. Both rooms were connected to the building's HVAC system. The renovation of the building occurred 2 months before the start of the experiments. The most obvious sources of VOC in the rooms were new furniture, wall paints and carpets. No particular complaints regarding indoor air quality were expressed, but all rooms and hallways featured a weak, but specific odour.

VOC sampling on Tenax was done by use of stainless steel thermal desorption tubes (Perkin-Elmer) filled with 0.3 g Tenax TA (Chrompack). The sampling volume was 0.5 l. All sampling tubes were thermally desorbed at WKI with a desorption autosampler (Perkin Elmer ATD 400, desorption temperature 320°C), the collected substances were separated and quantified by GC/MS (Hewlett-Packard 6890/5972). Quantification was done using external standards of the target compounds as reference.

Particles were collected on glass fibre filters (PALL TCLP 47 mm, 0.7 µm nominal) which were pre-treated to reduce the blank value of the organic compounds by two times ultrasonic extraction with dichloromethane for 25 min followed by a 2-h thermal cleaning at 250°C. Afterwards the filters were conditioned at 23°C/50% RH for 2 days and sealed in aluminium foil. For the sampling a TEOM[®] head (2.5 µm) with filter holder and a pump was used. The sampling rate was set to 16.6 l/min, samples were taken overnight to achieve sample volumes of 15–18 m³.

The particles collected on filter disks were thermally desorbed at WKI in a thermal desorption unit (TDS 2, Gerstel GmbH, Germany): The filters were cut into stripes, put into a glass thermal desorption tube, secured with glass wool plugs and desorbed for 8 min at 200°C. The cold trap was filled with Tenax TA and cooled to –50°C during the desorption process. Analysis of the trapped substances occurred after heating of the trap to 320°C with a 5890/5970 GC/MS system in scan mode.

Particle size distributions were measured by the TSI Model 3934 Scanning Mobility Particle Sizer (SMPS). The operating principles of this instrument are described elsewhere (Knutson and Whitby, 1975).

RESULTS

During the experiment the VOC measurements in the office room showed low, mostly decreasing concentrations of several organic volatiles: aromatics (toluene, xylenes, C3-benzenes), siloxanes (hexamethylcyclotrisiloxane, octamethylcyclohexasiloxane) and 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate. The summed concentrations were below 150 µg/m³ all of the time, over the period of observation they decreased by 10–25% (see Figure 1). Although a specific odour was still detectable in all rooms, the air pollution with volatile organic compounds in this building can be regarded as very low. An additional measurement carried out 18 month later showed a further decrease of the VOC concentrations, the two main compounds, toluene and trimethylpentanediol-monoisobutyrate, showed concentrations of 7 and 12 µg/m³, respectively.

In addition to the compounds presented in Figure 1, nonanal and decanal were detected in very low concentrations (5 and $3 \mu\text{g}/\text{m}^3$, respectively). The specific odour was no longer detectable at that time.

The VOC measurement in the laboratory room was significantly influenced by experimental work in the laboratory. Butanol used for Condensation Particle Counters (CPC) was maintained in the laboratory and different cleaning agents led to unsteady VOC concentrations in that room.

After sampling of $14\text{--}16 \text{ m}^3$ of air on the filter disks a visible but not weighable amount of particles could be detected. The particle concentrations (PM_{10}) in the two rooms were found to be around $10 \mu\text{g}/\text{m}^3$.

Two example chromatograms of the thermally desorbed filter disks are shown in Figure 2. The cleaning of the filter disks successfully removed organic contaminants, a thermally desorbed blank filter showed no traces of organic substances. The filter disks with collected particles from both rooms showed small amounts of siloxanes and alkanes and traces of hexanal. The concentrations were below the determination limit. In all cases the filter disks from the office room showed lower concentrations of desorbable VOC than the ones from the laboratory.

The determination of the particle size distribution showed a maximum at $40\text{--}60 \text{ nm}$, the overall particle numbers were below $4.5 \times 10^3 \text{ cm}^{-3}$.

No significant differences in the particle size distribution could be detected when the door was opened or closed. Human activity did also not have a major impact on the particle size distribution.

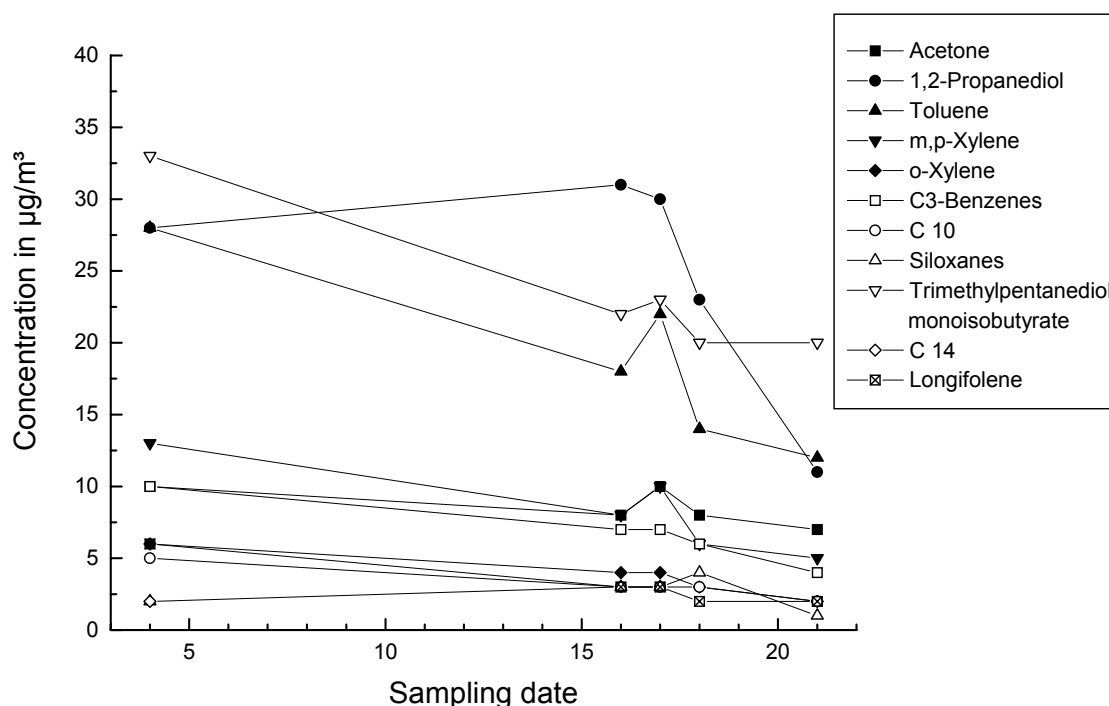


Figure 1 VOC concentrations measured in the office room.

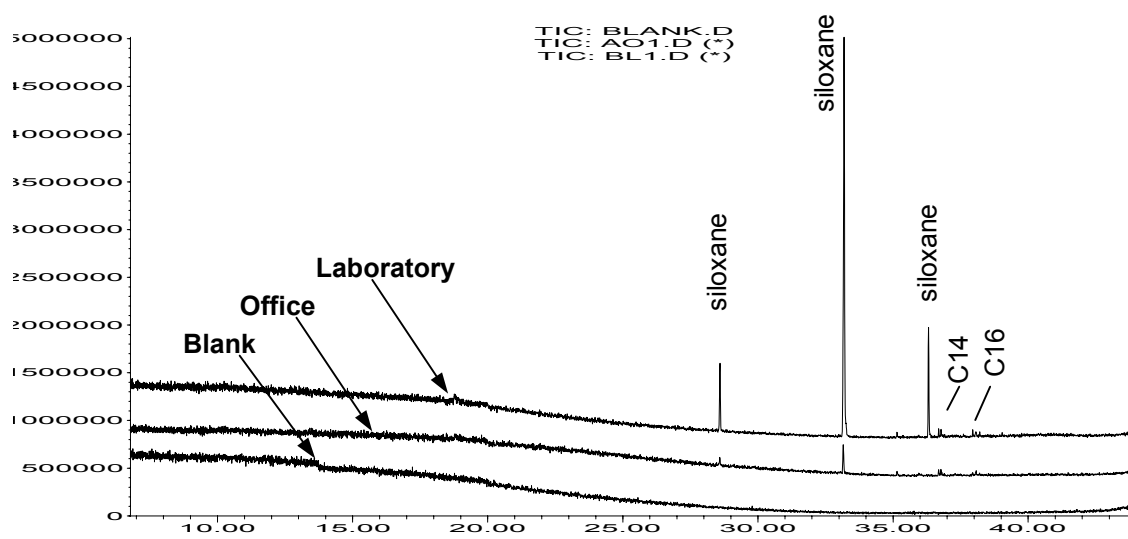


Figure 2 GC/MS chromatograms of the thermally desorbed filter disks.

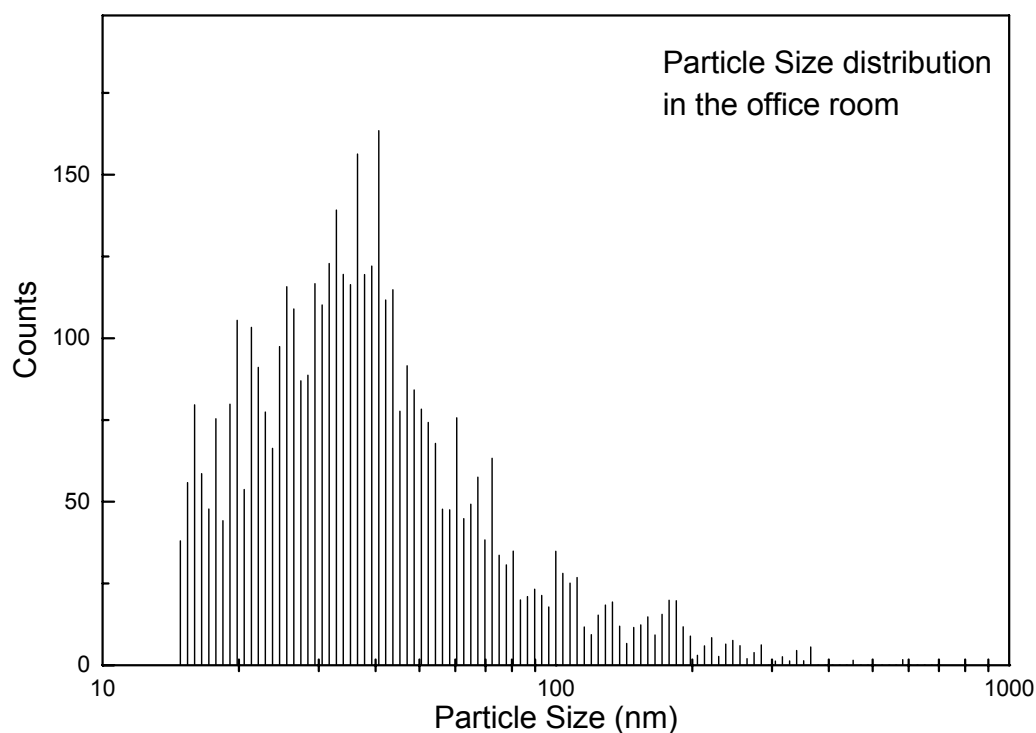


Figure 3 Particle size distribution in the office room.

DISCUSSION

The measurements showed low concentrations of particles and volatile organics in the tested room. Additional VOC emissions from new carpets and furniture were successfully removed by the HVAC system. Therefore, the recent renovation did lead to increased concentrations of volatile organics in the two rooms. It is possible that the specific odour detectable in all rooms

was caused by low concentrations of 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate, aromatic hydrocarbons and trace amounts of hexanal. With a sum value of less than 150 $\mu\text{g}/\text{m}^3$ for VOC and PM_{10} concentrations of $\sim 10 \mu\text{g}/\text{m}^3$ the ventilation system is successfully operated to maintain a good air quality in the building.

The low concentrations of volatiles and particles also had an impact on the desorption experiments: only trace amounts of organic substances could be desorbed from the collected particle samples. Although several siloxanes, aldehydes and alkanes are also present in the room air could be detected under the desorbed substances, polar substances with high boiling points like 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate could not be identified. This might be due to the surface activity of the particles or the desorption conditions, but it is also possible that the adsorption did not happen in the tested room and that the presence of alkanes and siloxanes is due to other sources, e.g. in the HVAC system.

ACKNOWLEDGEMENTS

This project was partly funded by the International Bureau of the Bundesministerium für Bildung und Forschung (BMBF). Thanks are due to Dr Milan Jamriska and Dr Stephen Thomas for helpful discussions.

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