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SOURCE OF ORGANICS IN THE AIR OF AN OFFICE BUILDING

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The inventory of organics in the air of a ten year old office building shows a wide variety of natural and synthetical volatile organic compounds (VOCs). Although 240 employees consume 1200 - 1500 cigarettes per day, the effective ventilation system reduces the ETS rapidly, however, aromatic hydrocarbons and some natural compounds still remain in the air in the higher $\mu g/m^3$-range. Systematic analyses of volatile compounds of all cleansers used shows that they are sources of higher limonene amounts. Aromatics entered by way of "fresh air" intake near the parking entrance at street level. The time depending concentration of the indoor air clearly showed maximums during the main arrival and departure times of cars (without catalytic converters).
The substitution of the cleansers and modifying the fresh air intake reduced the indoor concentration of VOCs significantly.

Introduction

The occurrence of volatile organics inside a ten year old office building in the city of Munich were investigated by an inventory of the airborne chemicals from indoor and outdoor, natural and man made sources with the goal to reduce contamination and ameliorate the indoor air quality. The possible transport of environmental tobacco smoke (ETS) between smoker and non-smoker offices via the air-conditioning plant, were also measured because of hints by employees. Air contamination resulted from tobacco smoking, a various mixture of sidestream and exhaled mainstream smoke and from combustion of tobacco containing products such as cigarettes, cigars, etc. ETS may be measured by its markers like nicotine, carbon monoxide, respirable suspended particulate matter or airborne particulates, nitrogen oxides, nitrosamines etc. ETS were controlled by measuring nicotine, because of its specificity to tobacco smoke, even if it is maybe, not the best ETS-tracer.

To evaluate the air quality by contamination with organics, all cleansing products in use in the building were analysed for volatile organic compounds by a simple laboratory headspace analysis. Also the outdoor air were measured for VOCs concentrations near the fresh air intake.

Materials and Methods

The ten year old office building is equipped with computer terminals, copy machines and laser-printers, but also classic typewriters and desks are present in subdivided openplan office style and several smaller conference-rooms. Above 240 employees work in the offices having a total tobacco consumption of 1200 - 1500 cigarettes per day. The building is equipped with a very suitable air condition system with an air exchange rate of 7.5.

An inventory of the present volatile organic chemicals was carried out by collecting indoor air samples using an air sampling pump at the working desk in each office compartment.

Air was pumped at 1 litre per minute for 4 hours through sorbent tubes containing XAD4 resin for nicotine and active charcoal for volatile organics. Collected samples were analyzed for nicotine by a gas chromatograph equipped with a nitrogen-phosphorous detector using the standard NIOSH analytical method (3). Volatile organics were desorbed by 1 millilitre CS_2 and analyzed by capillary gas chromatography with a flame ionization detector. The identification of the chemicals was carried out by capillary gas chromatography mass spectrometry and the quantification by authentic reference substances.

The investigation of the chemical products used in this building (cleaning agents) was made with a simple laboratory experiment. 100 microlitre of each product were filled undiluted in a 3 litre glass bulb. The headspace was sampled at 22°C with 5 litre air on active charcoal adsorption tubes, similar to (2) and analyzed like air samples for VOCs.

Results and Discussion

ETS - analysis

The results of 52 air samples for nicotine analysis show different values for smoking and non-smoking areas.

In the smoking areas mean concentrations of nicotine of 2.1 $\mu g/m^3$ were measured, with a median value of 1.4 $\mu g/m^3$. In non-smoking compartments the nicotine concentration was below the detection limit of 0.2 $\mu g/m^3$. Both results are below published values, indicating the good efficiency of the air conditioning and ventilating system(4). The tobacco consumption was quantified by collecting ashtray contents (cigarettes and cigars ends) and gravimetric counting of the total daily consumption. The mean tobacco consumption was 1300 cigarettes per day.

VOC analysis

The inventory of the identified volatile compounds is summarized in table I, with the range values of 132 indoor and mean values of 28 outdoor samples . These results suggest, that outdoor sources are the reason for several chemicals present. Others seem to be influenced by indoor sources. Simultaneous sampling of outdoor air, near the fresh air inflow place of the ventilating system, show the direct influence of the outdoor air quality. In this case, the fresh air inflow was at the street level, near the parking garage entrance, passed in the morning by about 230 middle class cars. The part of diesel powered cars was about 10 %. Modification of the fresh air intake resulted by a reduction- measured by random samples - of 30%, e.g. for toluene. The chemicals limonene, α-pinene, decane, 1-nonene and p-cymene may come from indoor sources. Although no health problems are ascribed in connection with the indoor air quality, the company decided to reduce this chemical contamination.

Product analysis

All chemical products used in the office area were collected and analyzed for volatile compounds.

Table II gives an overview on the materials and emitted volatile organics. We can conclude, that a number of chemicals detected in the indoor air could have been influenced by these products. They are the terpenes limonene, p-cymene, α-pinene, typical hydrocarbons and some aromatics. The recommendation to change the cleansers A, C, D and F lead to a significant reduction on terpene concentrations in the indoor air of the Building. (for limonene: 80%).. The concentrations of 1,4- diethylbenzene/butylbenzene, undecane, decane were significantly reduced, too.

Conclusions

The concentrations of constituents related to tobacco smoke (such as nicotine) were extremely low. The air-conditioning plant did not cause measurable air contamination in non-smoker areas in the investigated office building.

The concentrations of the observed volatile organic compounds are influenced by contaminated fresh air and by the use of chemical products containing volatile organic compounds. Changing the cleansers and modifying the fresh air intake resulted in a significantly lower indoor concentration of VOCs, 80 % for limonene by changing of cleansers and 30 % for toluene by modifying the fresh air intake. Although the chemical products (cleansers) are responsible for high indoor concentration values, we suspect that VOCs adsorbed on surfaces e.g. textiles or carpets may cause temporary higher concentrations indoors than outdoors, analog to earlier results regarding semivolatiles (5). Another publication about higher indoor concentrations of VOCs suggests the importance of indoor or attached sources with unexplained factors. (6).

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Table I.: Range of VOC concentration means inside the office building and simultaneous outdoor measurements (concentrations in μg/m³)

	indoors	outdoors	
		8.00 a.m.	11.00 a.m.
Hexadecane	0.4 - 2.7	n.d.	1.60
Dodecane	n.d. - 9.5	6.60	7.5
Camphene	n.d. - 1.4	0.4	0.4
1,2,3,5-Tetramethylbenzene	n.d. - 1.7	0.01	n.d.
1,2,4,5-Tetramethylbenzene	n.d. - 3.1	n.d.	n.d.
Undecane	n.d. - 2.4	0.6	0.6
1-Undecen	n.d. - 0.8	n.d.	n.d.
1,2-Diethylbenzene	0.2 - 3.5	n.d.	0.3
γ-Terpinene	n.d. - 0.5	n.d.	n.d.
1,4-Diethylbenzene/ Butylbenzene	0.5 - 1.7	n.d.	0.5
1,3-Diethylbenzene	n.d. - 0.5	n.d.	0.7
Limonene	0.4 - 84.0	n.d.	0.4
p-Cymene	0.01 - 4.5	n.d.	0.01
1,2,3-Trimethylbenzene	1.1 - 70.0	0.9	1.2
α-Terpinene	n.d. - 1.0	n.d.	n.d.
Decane	2.5 - 52.0	3.4	3.5
Myrcene/1-Decene	1.0 - 75.8	n.d.	74.8
1,2,4-Trimethylbenzene	n.d. - 65.4	44.9	n.d.
2-Ethyltoluene	0.8 - 1.3	1.7	1.0
β-Pinene	0.1 - 1.2	n.d.	0.2
1,3,5-Trimethylbenzene	n.d. - 14.0	35.0	n.d.
4-Ethyltoluene	7.3 - 17.5	n.d.	17.3
3-Ethyltoluene	12.0 - 25.5	50.0	24.7
Propylbenzene	1.2 - 1.7	2.8	1.7
δ-3-Carene	n.d. - 0.4	n.d.	n.d.
α-Pinene	n.d. - 10.9	n.d.	0.7
Nonane	3.5 - 24.5	4.9	4.1
1-Nonene	n.d. - 0.2	n.d.	n.d.
o-Xylene	9.8 - 34.5	48.9	25.9
m-p-Xylene	2.5 - 22.9	15.1	8.0
Ethylbenzene	13.4 - 28.6	44.6	24.6
Octane	1.0 - 4.0	4.6	3.0
1-Octene	n.d. - 2.1	n.d.	n.d.
Toluene	14.5 - 60.0	96.2	55.0
Heptane	0.9 - 5.0	4.7	3.7
1-Heptene	3.2 - 15.5	17.6	14.9

n.d. = not detectable; detection limit (av.): 0.01 μg/m³

Table II: List of chemical products used in the office part; main analyzed volatile components

Product	Main components
A: floor-wax	1,4-Diethylbenzene, Butylbenzene, Decane, 1,2,5-Trimethyl- benzene, 1-Nonene, Ethylbenzene, Xylene, Limonene;
B: carpet cleanser	aqueous solution with ammonia, no volatile organics;
C: ceiling cleanser	main constituents: Limonene, p-Cymene, Undecane, α-Pinene (fragrance ?);
D: ceramic-floor cleanser	Limonene, p-Cymene;
E: stone-floor cleanser	Heptene, Undecane, Nonane and Decane;
F: desk cleanser	strong smell with Limonene, Undecane and p-Cymene emissions;
G: glass cleanser	Heptane, ammonia, but no fragrance;