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VARIATION OF VOLATILE ORGANIC COMPOUNDS IN A NEW OFFICE BUILDING AS A FUNCTION OF TIME

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ABSTRACT

Volatile organic compounds (VOCs) and aldehydes were studied as a function of time in a new office building with ventilation operated at a high efficiency and with ventilation switched off. The results show that in a new efficiently ventilated building the concentrations of the chemicals do not differ from normal values in offices. When the ventilation was switched off the concentrations were high in the beginning but levelled off during the seven month test period.

INTRODUCTION

Strong emissions caused by building materials are often characteristic of new buildings. The concentration levels of chemicals emitting from materials to indoor air are mainly determined by the strength of the emission sources and the ventilation efficiency. They are also affected by physical factors such as adsorbing materials present in the building which act as "sinks" and thus affecting the concentration levels of the indoor air and the decay of emissions. This study was carried out to establish in a new office building the levels of different types of airborne chemicals, as well as their variation in different parts of the building, their decay as a function of time, and the influence of ventilation on the indoor concentrations. The measurements were done in four open office spaces on two floors in the building. The follow-up of the chemicals in the indoor air was performed during a seven month period.

METHODS

Description of the building

The new office building chosen for this investigation is characterized by innovative construction and ventilation solutions. The building was completed in the end of June 1990 but some painting work continued till the moving in which was in August-September. The measurements started in the beginning of September and continued until April the following year. The building consists of two floors and is divided to two parts, eastern and western separated by a staircase and sanitary rooms. The east side of the ground floor consists of an open office space surrounded by closed office rooms and above this on the 1st floor there is an open office space with one closed room. The west side of the building consists of a conference room on the ground floor which was at the time of the measurements only in occasional use and on the 1st floor, west side, there was a single, unfurnished space not in use at the time of the measurements. The ventilation set in value in the building was 2 $l*m^{-2}*s^{-1}$ corresponding to ACH 2.5. The ventilation was in operation from Monday morning to Friday evening. The air samples were collected on Fridays (ventilation on) and on Saturdays (ventilation off). The floors in the building are of a special structure made of concrete with ventilation channels in the concrete. The exception is the east part of the ground floor which has an assembled cassette system with an foamed polystyrene sheet as under layer and a wood-based construction plate as the supporting layer. Linoleum was used as floor covering in all spaces of the building. The ceilings were covered with acoustic plates of pressed mineral wool with glass-fibre lining and the walls were painted with water-based paints. Acoustic screens fixed in wood frames and with textile linings separated the work stations in the open office space.

Sampling and analytical methods

The air samplings were performed on both floors in the center of the open spaces at a height of 1.5 m. The volatile organic compounds (VOC) were collected into glass tubes containing 150 mg of Tenax TA adsorbent. The chemical compounds were identified with a Jeol SX-102 masspectrometer and of the identified compounds the most abundant ones were chosen for quantitive follow up as a function of time performed with a HP 5890 Series II gas chromatograph equipped with FID. The TVOC values were calculated from the FID-detector response in toluene equivalents.

Aldehydes were collected into impinger flasks containing DNPH dissolved in 2-M HCl and analysed with HPLC.

RESULTS AND DISCUSSION

Volatile organic compounds

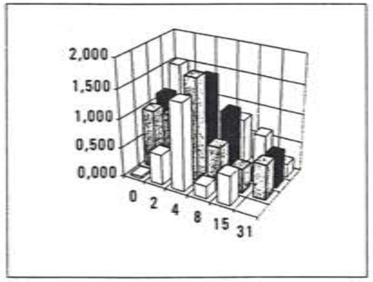
The TVOC results in the four measurement points of the building with ventilation on showed no specific trend of the TVOC values as a function of time during the seven month measuring period. Mean, minimum, and maximum TVOC values with ventilation on measured on Fridays are given in Table 1.

Table **1.** Mean, minimum, and maximum TVOC-values in the ventilated office building.

	Ground floor east	Ground floor, west	1st floor, east	1st floor, west
Mean, (mg/m³)	0,135	0,163	0,106	0,123
Minimum, (mg/m³)	0,042	0,048	0,077	0,059
Maximum, (mg/m³)	0,290	0,277	0,131	0,250

Table 1 shows that the chemical air quality is slightly better on the first floor compared to the ground floor and better in the east wing with office activities compared to the empty west wing.

In order to verify the effect of ventilation on the removal of the chemicals from indoor air the ventilation was switched off on Fridays after working hours and a second series of measurements were performed on Saturdays. The TVOC results with ventilation switched off are presented in Figure1.



Week	1st fl, East	1st fl, West	Ground floor West	Ground floor East
0	0,036	1,017	1,137	1,531
2	0,523	1,035	0,832	1,059
4	1,495	1,739	1,586	0,742
8	0,215	0,678	1,100	0,818
15	0,510	0,420	0,086	0,630
31		0,600	0,567	0,224

Figure **1.** Variation of TVOC-concentrations as mg/m³ as a function of time with the ventilation turned off. The z-axle represent the the sites of the building.

In Figure 1 the highest TVOC values in the unventilated building are up to fives times higher compared to respective maximum values with ventilation on in Table 1. At week four there is a rise in TVOC values probably due to some painting and fixing work in the building. The TVOC values in the unventilated building show a descending trend after four weeks.

The behaviour of individual volatile organic compounds VOCs was also studied and the individual volatile organic compounds present in the building are shown in Table 2.

Table **2.** Individual volatile organic compounds detected in the office building.

2-Methylpentane	Hexanal	Decane
Butanal	Tetrachloroethene	1,2,3-Trimethylbenzene
Hexane	Ethylbenzene	Terpene
2,3-Dihydro-4-methylfurane	m+p-Xylene	Undecene
1,1,1-Trichlorethene	Styrene	Undecane
Benzene	o-Xylene	Dodecane
2-Methylhexane	Nonane	Tridecane
Pentanal	Isopropylbenzene	Tetradecane
Heptane	a-Pinene	Pentadecane
Methylcyclohexane	1,3,5-Trimethylbenzene	Hexadecane
Toluene	1,2,4-Trimethylbenzene	Heptadecane
1-Pentanol	Phenol	Octadecane

Of the compounds in Table 2 the most abundant ones were selected for quantitative determinations and follow-up analyse vs time. In the ventilated building the measurements showed a random variation of individual VOCs, summarized in Table 3.

Table **3.** Variation of individual VOCs with ventilation on.

Chemical compound	Mean,(mg/m³)	Maximum, (mg/m³)
Toluene	0,040	0,121
Octane	0,002	0,011
Ethylbenzene	0,002	0,007
m+p-Xylene	0,004	0,013
Styrene	0,001	0,008
o-Xylene	0,002	0,011
a-Pinene	0,002	0,004
1,2,4-Trimethylbenzene	0,001	0,002
Decane	0,001	0,003
Undecane	0,001	0,004
Dodecane	0,001	0,002

The behaviour of selected individual VOCs as with ventilation switched off was studied as a function of time in the eastern part of the ground floor. A decay of individual chemicals can be noticed (Figure 2).

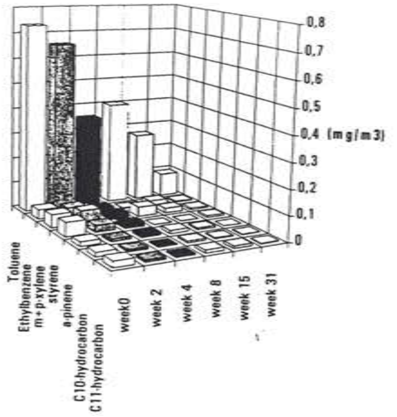


Figure 2. Variation of VOC concentrations as a function of time in the eastern part of the ground floor with the ventilation turned off.

According to Figure 2 toluene is the dominant emission and has a strong decay as function of time. The toluene concentration is halved in about eight weeks but the strong concentration drop continues and after 31 weeks the toluene concentration, 0.093 mg/m³, is still higher than the average in other measured buildings (1).

The decay of the other six chemicals in Figure 2 are presented in more detail in Figure 3. From Figure 1 it can be seen that the highest boiling hydrocarbons level off in about four weeks as the decay of the lower boiling chemicals continues up to 31 weeks. These final VOC-concentrations in the eastern part of the ground floor with ventilation turned off are near the mean values of the respective chemicals found in other offices (1).

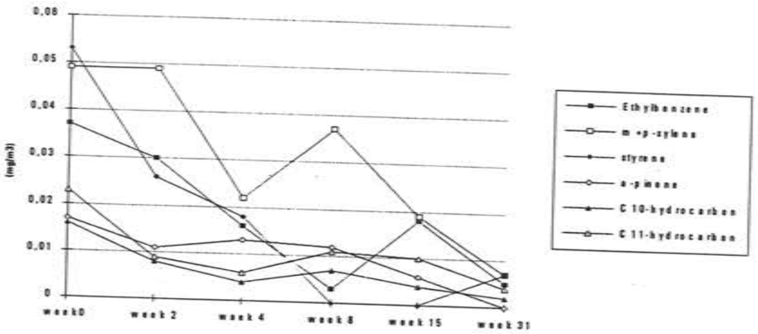


Figure 3. Variation of VOC-concentrations (except toluene) as a function of time in the eastern part of the ground floor with the ventilation turned off.

Aldehydes

Aldehydes were measured only from one site in the building, the 1st floor in the east wing, and followed as function of time both with the ventilation on and with ventilation switched off. The results from the unventilated room are presented in Figure 4 and from the ventilated in Figure 5. Both figures are in the same scale. In Figure 4, in the unventilated case, the concentration of pentanal at week 4 reached a value of 1.6 mg/m³ and exceeds the scale in Figure 4.

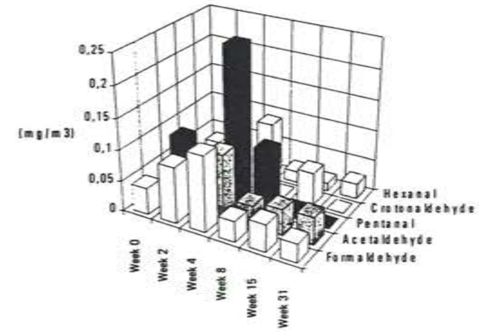


Figure 4. Variation of aldehydes as a function of time in the eastern part of the 1st floor with ventilation switched off.

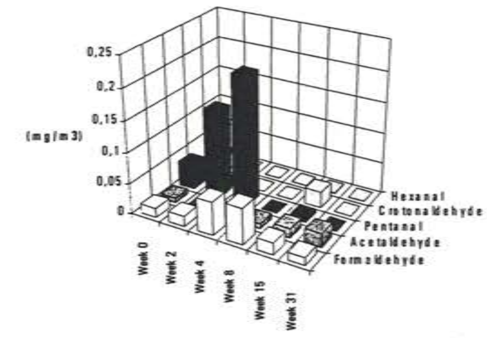


Figure 5. Variation of aldehydes as a function of time in the eastern part of the 1st floor in the ventilated building

In the unventilated building most aldehydes seem to have a rising trend in the beginning but after 4 to 8 weeks the concentrations begin to decline. The same phenomenon could be seen also with the VOCs. The maximum value of formaldehyde reaches to 0.122 mg/m³ which is just below the maximum value allowed in Finland (2). The strong peak of pentanal may result from the fixing works occasionally carried out in the building during the measurements. Wood and wood-based materials can for example be sources of pentanal (3). Even in the ventilated building the aldehydes show an upward trend on weeks four and eight. The formaldehyde concentration had a maximum value of 0.059 mg/m³ at week eight.

DISCUSSION

The concentrations of volatile chemicals in a new unventilated building were high as could be expected. The technician performing the samplings considered the air stuffy. The concentrations were practically equal in both the unused and used part of the building and the emissions can be considered to originate from building materials since the office activities did not have an effect on the chemical air quality. The originally high individual VOC-concentrations in the building when the ventilation was switched off, levelled off during the seven month control period except those of toluene which still at the end of the test period were higher than normal (1). The TVOC concentration level after seven months corresponded to the Scanvac Air Quality Class II or inferior (4,3).

When the ventilation was in operation the concentrations were similar to those found in other office buildings (1) and the air quality of the office corresponded to the Scanvac Air Quality Class I. It seems that with efficient ventilation the emissions can even in a new office building be kept at a normal good office level. It is however uncertain if even the high ventilation efficiency used in the building had remarkably speeded up the decline of the emissions.

This study confirms the existence of high emission levels caused by new materials and it suggests that with effective ventilation the emissions can be reduced to levels which do not cause uncomfort or reverse health effects. This is however not accomplished for example in dwellings where little effort has been made to design and secure effective ventilation systems.

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