

INDOOR AIR QUALITY AND HEALTH PROBLEMS ASSOCIATED WITH DAMP FLOOR COVERINGS IN AN OFFICE BUILDING

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ABSTRACT

In an office of about 130 employees eight new cases of asthma were found during four years. In addition, the workers complained respiratory, conjunctival and nasal symptoms. Emissions indicating the degradation of plastic floor coverings (e.g. 2-ethyl-1-hexanol, 1-butanol) were found in the indoor air samples. In two working rooms, the plastic floor coverings, adhesives and the levelling layers were carefully removed. It was observed that the volatiles had been diffused into the concrete slabs. To eliminate the volatiles, the surface of the concrete was warmed up to remove the diffused VOCs from these areas. Thereafter, new low emitting surface materials were installed in these workrooms.

INDEX TERMS

Indoor air, Chemical impurities, PVC floor coverings, Asthma.

INTRODUCTION

Several studies have reported increased number of respiratory symptoms among persons exposed to dampness and microbes in buildings (Brunekreef et al, 1989; Koskinen et al, 1997, 1999). Building dampness may also increase the emission of volatile organic compounds (VOCs) from the materials. E.g. dampness in the concrete floor is known to increase the chemical degradation of plasticizers in the polyvinyl chloride (PVC) floor coatings and glues, with the emissions of ammonia and VOCs in indoor air (Gustavsson and Lundgren, 1997; Wiglusz et al, 1998).

Our institution was called to study an indoor air problem in this office. We conducted a number of indoor air evaluations, building constructional studies and studies on the symptoms and diseases of the employees. In most of the working rooms there was PVC flooring material on damp concrete surface. The PVC carpet was set with adhesive and levelling layers on top of the concrete floor. Indoor air was sampled for VOCs. Material samples were taken from the PVC floor and studied in the laboratory conditions to examine the emitted VOC profile. In situ VOC emission measurements were performed with the FLEC (Field and Laboratory Emission Cell) method. The employees' symptoms were surveyed by a questionnaire and the incidence of asthma was also calculated.

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METHODS

The workers investigated were employed in a 15 years old office building located in a suburban area in the middle of Finland. The building was three storied and the studied workrooms were in the second and third floor of the building. The supporting constructions of the building were made of reinforced concrete and the roof was made of sheet metal. The outer walls of the building were made of bricks and the insulation material was mineral fiber. The building had a mechanical air supply and exhaust ventilation system. In most of the workrooms, there was a PVC floor covering.

VOCs were studied in air samples of different workrooms. Material samples of PVC floor coverings were collected and placed in the laboratory in small glass chambers. From the chamber air the volatiles emitted from the materials were collected and analyzed in similar way as the air samples. In addition, the FLEC placed on the top of the concrete surface was used to measure the emission of VOCs. VOCs were collected by pumping air through Tenax adsorbent tubes. The analysis of VOCs included thermal desorption, gas chromatographic separation and detection of different volatile compounds with a mass selective detector. VOCs in the samples were identified both according to the mass spectral library and the retention times of the authentic standards. The results of individual VOCs and the total volatile organic compounds (TVOC) are given in $\mu\text{g}/\text{m}^3$ in air samples and in $\mu\text{g}/\text{m}^2\cdot\text{h}$ in FLEC samples.

In two working rooms, the plastic floor coverings, adhesives and the levelling layers were removed. Thereafter, these rooms were warmed up and carefully ventilated for a week. The emissions of the concrete floor were measured before and after the warm up period with the FLEC.

Furthermore, a moisture detector (Tramex Moisture Encounter) was used in the measurements of moisture content in the floor structures of the building.

The employees' symptoms were surveyed by a questionnaire and the incidence of asthma was calculated for four years. The incidence was compared with the incidence of asthma in this part of Finland in the working aged population.

RESULTS

The concentration of VOCs in the air samples collected from the workrooms is presented in Table 1.

Table 1. The concentration of total volatile organic compounds (TVOC, $\mu\text{g}/\text{m}^3$) and the main volatile compounds ($\mu\text{g}/\text{m}^3$) in three workroom air samples studied.

<i>VOC</i>	<i>concentration, $\mu\text{g}/\text{m}^3$</i>	<i>TVOC, $\mu\text{g}/\text{m}^3$</i>
Workroom 1:		30
decamethylcyclopentasiloxane	6	
1-butanol	5	
nonanal	4	
hexanal	3	
2-ethyl-1-hexanol	3	
decanal	2	
propylene glycol	1	
toluene	1	
α -pinene	1	
Workroom 2:		22

hexanal	3	
nonanal	3	
decamethylcyclopentasiloxane	3	
1-butanol	2	
propylene glycol	2	
2-ethyl-1-hexanol	2	
decanal	2	
toluene	1	
menthol	1	
Workroom 3:		30
1-butanol	5	
hexanal	4	
nonanal	4	
propylene glycol	3	
2-ethyl-1-hexanol	3	
decanal	3	
methyl-isobutylketone	2	
toluene	1	
α -pinene	1	
3-carene	1	
decamethylcyclopentasiloxane	1	

Several material samples (pieces of PVC floor coverings) were collected from the building and their emissions were studied in small chambers in the laboratory. The results of a typical VOC emission profile of the PVC floor covering are presented in Table 2.

Table 2. Typical VOC emission profile of a PVC floor covering collected from the workroom.

VOCs emitted from the floor covering	% of the amount of total VOCs emitted from the floor covering
2-ethyl-1-hexanol	58
1-butanol	11
3-heptanone	11
toluene	4
α -pinene	2
sesquiterpenes	2
hexane	<1
2-pentanone	<1
1,4-dioxane	<1
heptane	<1
hexanal	<1
4-methyl-2-hexanone	<1
4-heptanone	<1
styrene	<1
xylene	<1
nonane	<1
ethylmethylbenzene	<1

Figure 1 shows the VOC emissions of the concrete floor before and after the workroom heating period.

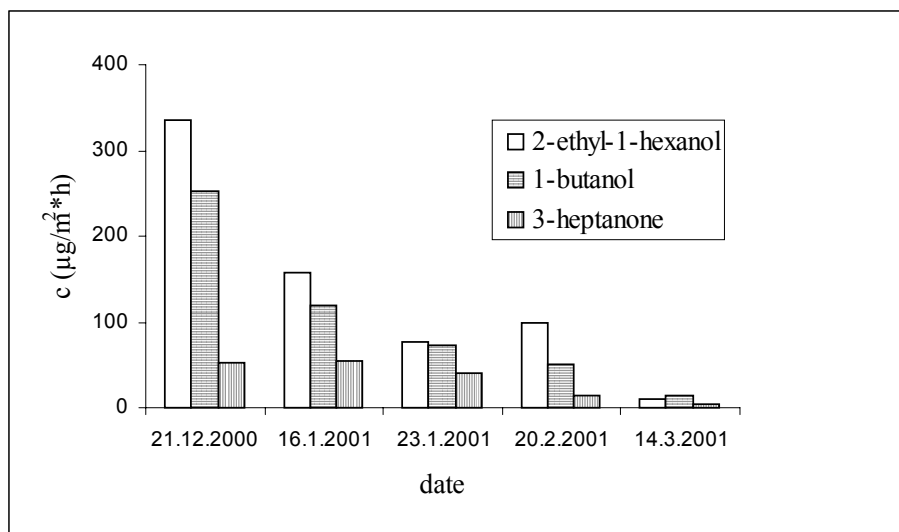


Figure 1. Emissions of the three main volatiles ($\mu\text{g}/\text{m}^2\cdot\text{h}$) from the workroom floor. 21.12.2000: concrete slab before warming, 16.1.2002: concrete slab after one week warming period, 23.1. and 20.2.2002: concrete slab, 14.3.2001: new ceramic tile.

The workers complained unpleasant odour in the workrooms and several skin, eye and respiratory symptoms, e.g. headache, tiredness, eczema, hoarseness, cough and mucous secretion. During four years eight new cases of asthma were found in the personnel of about 130 employees. Since the yearly incidence of asthma among the working aged population in this part of Finland is about one case in 1100 persons, the risk of getting asthma was about 16 times higher among these office employees.

DISCUSSION

The concentration of TVOC in the indoor air of the studied building was very small; below $100 \mu\text{g}/\text{m}^3$. However, small amounts of 2-ethyl-1-hexanol (mean concentration $3 \mu\text{g}/\text{m}^3$) and 1-butanol (mean concentration $4 \mu\text{g}/\text{m}^3$) were detected in the indoor air samples. When the pieces of PVC floor coverings collected from the workrooms were studied, they showed that the source of these two above mentioned alcohols in indoor air was the degradation of the flooring material laid on damp concrete surface. 2-ethyl-1-hexanol was always the main volatile compound emitted from the material samples. The amount of 2-ethyl-1-hexanol and 1-butanol ranged from 46 to 76 % and from 6 to 31 % of the amount of total volatile organic compounds emitted from the material samples, respectively.

In two working rooms, the plastic floor coverings, glues and the levelling layers were carefully removed. It was observed that the volatiles (e.g. 2-ethyl-1-hexanol, 1-butanol, 3-heptanone) had been diffused into the concrete slabs. Therefore, the surface of the concrete was warmed up to remove diffused VOCs from these areas.

VOCs can also cause odours in the indoor air. For example, 2-ethyl-1-hexanol has an unpleasant smell and it has previously been reported to cause irritation of eyes, upper respiratory tract and skin (Wieslander et al, 1999). Plastic interior materials might be potential sources of chemicals that may cause airway inflammation and also increase the risk of

bronchial obstruction and asthma. In a study of Norbäck et al. (2000) asthma symptoms were more common in two buildings with signs of dampness-related degradation of di(ethylhexyl)phthalate (DEHP) in PVC floor material, detected as presence of 2-ethyl-1-hexanol in indoor air samples.

CONCLUSION AND IMPLICATIONS

There was an indoor air problem caused by emissions of damaged flooring material in this office building. The degradation of plastic floor coverings caused emissions of certain indicative VOCs in the indoor air. The possible source is the residual moisture in the concrete slabs. Nowadays, the emissions of VOCs from building materials is an important parameter for the chemical impact on the indoor air quality. Especially materials used on large surfaces (like PVC carpets) are of great importance for VOC emissions. The concentration of VOCs is usually quite low in indoor air, but they are emitted over long time periods.

The VOCs can also easily diffuse into the concrete slabs as clearly showed in this study. However, the warming up of the concrete slab and careful ventilation of the workroom air successfully removed these volatiles from the concrete. Therefore, when doing renovations in the buildings, it is important to do the work very carefully. New, low emitting materials should be always installed on clean, dry surfaces.

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