

Comparison of VOC and ammonia emissions from individual PVC materials, adhesives and from complete structures

H. Järnström^{a,b,*}, K. Saarela^a, P. Kalliokoski^b, A.-L. Pasanen^c

^a VTT, P.O. Box 1000, FIN-02044 VTT, Finland

^b University of Kuopio, Department of Environmental Sciences, P.O. Box 1627, FIN-70211 Kuopio, Finland

^c Finnish Institute of Occupational Health, P.O. Box 93, FIN-70701 Kuopio, Finland

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Abstract

Emission rates of volatile organic compounds (VOCs) and ammonia measured from six PVC materials and four adhesives in the laboratory were compared to the emission rates measured on site from complete structures. Significantly higher specific emission rates (SERs) were generally measured from the complete structures than from individual materials. There were large differences between different PVC materials in their permeability for VOCs originating from the underlying structure. Glycol ethers and esters from adhesives used in the installation contributed to the emissions from the PVC covered structure. Emissions of 2-ethylhexanol and TXIB (2,2,4-trimethyl-1,3-pentanediol diisobutyrate) were common. High ammonia SERs were measured from single adhesives but their contribution to the emissions from the complete structure did not appear as obvious as for VOCs. The results indicate that three factors affected the VOC emissions from the PVC flooring on a structure: 1) the permeability of the PVC product for VOCs, 2) the VOC emission from the adhesive used, and 3) the VOC emission from the backside of the PVC product. © 2007 Elsevier Ltd. All rights reserved.

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1. Introduction

Emissions of pollutants from interior structures are important contributors to the indoor air quality (IAQ) as elevated concentration levels of chemical pollutants can cause adverse health effects and discomfort. To improve IAQ, labeling schemes for tested, low-emitting building materials have been introduced (ECA, 2005). Standardized methods for environmental emission test chambers have been established (ISO, 2006a,b). Emission profiles of volatile and semi volatile organic compounds (VOCs and SVOCs) have been reported for several building materials including floor coverings and adhesives (Wolkoff, 1995; Yu and Crump, 1998; Lundgren et al., 1999; Wilke et al., 2004). Recently, Clausen et al. (2007) published a physically based emission model for SVOCs that was consistent

with the experimental data and independent of relative humidity. However, emissions from real building structures are affected by the surroundings due to sorption, hydrolysis, and oxidative processes, which can lead to the production of secondary emissions (Gustafsson, 1990, 1996; Wolkoff, 1998; Wilke et al., 2004). These emissions, which are developing after a delay and are often long lasting, are not usually considered in the labeling schemes, which focus on primary emissions.

A wide range of VOCs and SVOCs are emitted from PVCs. These include plasticizers, solvent residues, unreacted monomers, and secondary degradation products. Plasticizers are often SVOCs (Saarela, 1999). Color changes in PVC floor structures and/or discomfort to IAQ have often been detected in humid conditions, especially in the presence of alkaline concrete. As an example, elevated structure humidity in alkaline conditions has been shown to cause degradation of the 2-diethylhexylphthalate (DEHP) in the PVC polymer (Gustafsson, 1990, 1996). Special attention has been paid to 2-ethylhexanol, which is generally considered to be a degradation product of DEHP and has been

* Corresponding author. VTT, P.O. Box 1000, FIN-02044 VTT, Finland.
E-mail address: helena.jarnstrom@vtt.fi (H. Järnström).

measured in buildings with indoor air complaints, e.g. bad odor and/or irritation symptoms (Brown et al., 1993; Norrbäck et al., 2000; Metiäinen et al., 2003; Tuomainen et al., 2004).

The plasticizer TXIB™ (2,2,4-trimethyl-1,3-pentanediol diisobutyrate) has also been detected in the indoor air in case studies where irritancy in the throat and eyes have occurred (Brown et al., 1993; Metiäinen et al., 2002). Odor and chemosthesis investigations, however, indicated that TXIB could contribute to odor but hardly to sensory irritation at these concentration levels (Cain et al., 2005).

The TVOC specific emission rates (SER) from vinyl/PVC floorings have been shown to range from 10^2 to 10^4 $\mu\text{g}/\text{m}^2$ h (Yu and Crump, 1998). A set of PVC flooring materials ($n=50$) produced in the 90's were investigated by Lundgren et al. (1999). The main VOCs were 2-butoxyethanol, 2-(2-butoxyethoxy) ethanol, phenol, hepta and octa decanes, and trimethylbenzene. Reduction factors (=the difference between the 4 week and 26 week emissions) of less than 0.5 were found ten compounds including TXIB indicating that these compounds may affect the IAQ over a long period of time (Lundgren et al., 1999). In another study, the TVOC SER from the single 28-day-old PVCs (five products) varied widely including SERs up to 1000 $\mu\text{g}/\text{m}^2$ h. The main compounds were TXIB and alkylbenzenes (SVOCs). Besides the single materials (floor covering materials and adhesives) the emissions from complete structures were also measured. The total SERs were lower for the tested compositions than the sum of total SERs from the single components (Wilke et al., 2004).

Only a few studies have published where the emissions have been tested both from separate materials in laboratory and from the complete structures on site. Zellweger et al. (1995) compared emissions measured in test chambers with concentration levels measured on site. The expected room concentrations were calculated with the air exchange rate measured. The predicted levels of cyclohexane and hexanal were more than one order of magnitude higher than those measured in the

indoor air. Application (i.e., substrate) and sink effects were possible explanations for the difference. A good agreement between the predicted and measured concentrations was found for N-methyl-2-pyrrolidone from parquet lacquer applied on wood and room concentration. On the contrary, the predicted concentration from parquet lacquer applied on glass were much higher than the measured ones.

In this paper, emissions of VOCs and ammonia measured from single PVC materials and adhesives were compared to the results from on-site measured complete structures. The study is a part of a larger investigation of material emissions and indoor air concentrations in newly established residential buildings with low-emitting materials, the results of which have been published partially recently (Järnström et al., 2006, 2007).

2. Methods

The study buildings and materials as well as the sampling and analysis techniques have been presented in the other previous publications (Järnström, 2006, 2007). The analysis of ammonia is non-specific and is a total measure of ammonia including "aliphatic" amines. For consistency, the same numbering is used for the buildings as in the previous publications. The buildings where PVC was used as the floor covering material included buildings 1 (two apartments), 2, 4, and 7 (two apartments). No adhesive was used in the installation of the floor covering in one of the apartments in building 7. The PVCs (products 5 and 6) used in this building were otherwise similar products with a polyurethane reinforced surface. The PVC 2 had also a similar surface finish. The PVC products (1–6) and adhesives 2 and 4 were M1-classified, i.e. the SERs from the 28-day-old, single product measured at 23 °C, 50% RH and 0.5 h^{-1} do not exceed the following target values: 200 $\mu\text{g}/\text{m}^2$ h (TVOC), 30 $\mu\text{g}/\text{m}^2$ h (ammonia) and 50 $\mu\text{g}/\text{m}^2$ h (formaldehyde, FiSIAQ, 2001).

Emissions were first measured on site from the floor structure with the Field and laboratory emission cell (FLEC, ISO, 2006b) four weeks after the floor covering was installed and construction work was still going on. Then, the floor covering and adhesive were removed and the emission was measured from the underlying floor structure after one and three days (the residues of PVC and adhesive were removed with a spatula prior to the FLEC measurement).

In the laboratory, the adhesives were spread on a glass plate (spreading with a specific trowel in a 45° angle) and emissions were measured at 23 °C, 50%

Table 1

Specific emission rates (SER, $\mu\text{g}/\text{m}^2$ h) of TVOC and ammonia from parallel sampling on site from the structure with FLEC (sd=standard deviation, rsd=relative standard deviation)

Building, age, measured structure	TVOC SER ($\mu\text{g}/\text{m}^2$ h)			Ammonia SER ($\mu\text{g}/\text{m}^2$ h)		
	FLEC1	FLEC2	sd (rsd %)	FLEC1	FLEC2	sd (rsd%)
<i>Building 2 (PVC 3)</i>						
6 month-old, uncovered floor structure, day 1	315	265	25 (9)	42	29	7 (18)
6 month-old, uncovered floor structure, day 3	212	264	26 (11)	24	8	8 (50)
<i>Building 7, apartment 1 (PVC 5)</i>						
6 month-old, uncovered floor structure, day 1	2600	2212	194 (8)	231	221	5 (2)
6 month-old, uncovered floor structure, day 3	1228	1983	378 (24)	90	107	9 (9)
12 month-old, uncovered floor structure, day 1	1745	1862	59 (3)	93	97	2 (2)
12 month-old, uncovered floor structure, day 3	1097	806	146 (15)	37	42	3 (6)
<i>Building 7, apartment 6 (PVC 6)</i>						
6 month-old, uncovered floor structure, day 1	1863	1816	24 (1)	207	219	6 (3)
6 month-old, uncovered floor structure, day 3	1208	1236	14 (1)	112	116	2 (2)
12 month-old, uncovered floor structure, day 1	1572	1586	7 (0.4)	101	108	4 (3)
12 month-old, uncovered floor structure, day 3	1056	807	125 (13)	56	55	1 (1)

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