Measurements of stored decomposition products from flooring adhesives in a concrete floor, as a basis for choosing a new floor surface construction.

Claes Engström, MSc*
Anders Sjöberg, PhD*

1. INTRODUCTION

Today around 4000 VOC (volatile organic compounds) and SVOC (semivolatile organic compounds) have been identified in the indoor air (Salthammer et al 2000). The chemistry of these indoor air pollutants is largely unknown. Indoor air pollutants including VOCs are suspected of causing health effects and discomfort in indoor environments. However the knowledge of health effects of individual air pollutants is largely unknown (Andersson et al 1997). To summarize, there is still a lot we do not know about the health aspects of the indoor air pollutants. Tools available today for reducing the amount of indoor air pollutants are measurements of primary emissions of mainly surface materials, like indoor paint and flooring materials and steps taken to ensure that construction materials are not exposed to moisture, causing secondary emissions. In situations where flooring adhesive has been exposed to concrete moisture and alkali, secondary emissions of some VOCs are likely to occur (Wengholt-Johnsson 1995, Wessén and Hall 1999). Some of these emissions will be deposited in the concrete. These deposited emissions can later on emit to the indoor air (Sjöberg 2001, Sjöberg 2000). Swedish professional investigators of buildings where people experience sick building syndrome (SBS) have in several cases suggested that such emissions should be prevented. Typically, the outcome of flooring renovations in these cases is not scientifically evaluated and the results of the renovations stay with the investigators and their customers. Still a generally accepted opinion among investigators is that flooring renovations to stop emissions from decomposed (water solvent) adhesives sometimes have a positive effect in SBS-buildings (Hall 2001). This has created a market for products developed to stop emissions from floors from reaching the indoor air. Among these products are different surface layers put on the market as "blocking" layers, intended to prevent either alkali to reach the flooring adhesive and/or deposited emissions from reaching the indoor air.

This paper describes a case where secondary emissions were measured in a concrete floor. The results were used to calculate the flow of butanol and 2-ethylhexanol from the flooring. Limit values for the concentrations of butanol and 2-ethylhexanol immediately under the flooring were set by the facility manager. The purpose of the measurements and calculations was to create a basis to be used when choosing a new floor surface construction, capable of fulfilling the limit values.

2. OBJECT

A health care building in the Göteborg area has been the subject of a number of investigations, because the staff has complained about health problems anticipated to be connected to the building. The object is a 2-storeyed building. Both floor structures are concrete slabs with

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*Chalmers University of Technology, Dept. of Building Materials, S-412 96 Göteborg, Sweden.

screed, adhesive and different kinds of floorings in different rooms. Both concrete slabs were 10 cm thick with haunches in 120 by 120 cm cassettes. The thickness of the screed was approximately 2-3 mm. Exact thickness of the haunches was not measured, but they were estimated to be at least three times as thick as the slabs. Below the ground floor slab there is a crawl space.

3. METHOD

3.1 Sampling

Sampling sites were distributed across the building. Seven sites at the ground floor and five sites at the first floor. The sites were chosen with the intention of taking out cores from haunches. Cores were drilled out from the concrete floor using water as coolant. The cores were left to dry at the drilling site for approximately 1 hour before they were wrapped in aluminium foil. The cores were 10-15 cm deep and since the floor was not penetrated at any of the sites, sampling at the haunches was assumed successful. Two different core diameters were used, 7 cm and 10 cm. Cores 1-10 were stored for 1-4 days at room temperature in the lab before they were cracked open with a sledge and chisel. Concrete pieces at the depths of approximately 0-1, 2-3 and 4-5 cm (actual depths for each piece are given in table 1) were put in cap sealed glass bottles (see figure 1). For samples J205 and J225 this procedure was carried out at the day of sampling. Before pieces were taken from the cores, visible adhesive was removed with a file. The top level pieces contained screed.

3.2 Analysis

The concrete pieces were left in the bottles for a bit more than a week. During this period decomposition products butanol and 2-ethylhexanol are emitted from the concrete pieces. Equilibrium of butanol and ethylhexanol between the concrete and the air of the bottle was assumed to have been reached. A 20 ml sample of the air inside the bottle was absorbed in a TENAX tube. The TENAX tube was then placed in an injector oven and desorbed into a gas chromatograph. Amounts of butanol and 2-ethylhexanol are recalculated to $\mu g/m^3$ of the air in the sample bottle. The method is developed at Chalmers Technical University, Göteborg (Sjöberg 2001).
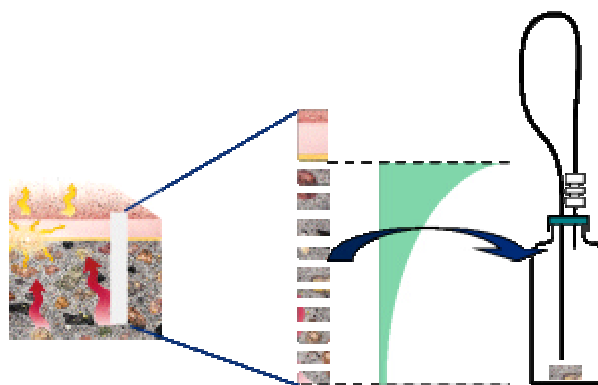

Figure 1   The drilled concrete core is split up in pieces that are put in bottles. The air of the bottle is analyzed for butanol and 2-ethylhexanol. Higher amounts could be expected closer to the adhesive if it has been decomposed.

4. RESULTS

In table 1 the figures give the concentration of butanol and 2-ethylhexanol in the air of the sample bottle shown in figure 1. The Flooring-column describes the kind of flooring in the rooms. In room C132 the flooring had been removed. In room J229 there was a second vinyl flooring bonded on top of the original vinyl flooring. From samples J205 and J225 only the top levels were analyzed. The result values should be regarded as approximate values since the exact accuracy of the analysis has not been fully evaluated in this particular case. In figure 2 the most contaminated level of every core is presented to give a view of the large range of the results between the different samples.

Table 1. Concentration of butanol and 2-ethylhexanol in the air of the sample bottles.

| Room	Floor	Flooring	Depth (cm)	Butanol ($\mu g/m^3$)	Ethylhexanol ($\mu g/m^3$)
J205	1	vinyl	0-2	90000	217000
B250	1	vinyl	0-1	126546	23612
			1-3	4500	1419
			2-4	63	1108
J229	1	vinyl	0-2	88767	21134
			2-4	5931	1595
			4,5-5	159	881
C112	0	linoleum	0-2	8875	1237
			2-4	1753	8322
			4-5	511	742
C229	1	vinyl	0-2	13259	2665
			2-4	2151	117
			4-5	350	44
C132	0	removed	0-1	1637	3150
			1-3	54	871
			4-5	476	1012
B131	0	vinyl	0-2	1815	673
			2-4	72	1227
			4,5-5	1171	1981
H107b	0	linoleum	0-2	1500	1010
			2-4	144	940
			4-5	2680	318
C149	0	linoleum	0-1	274	1240
			1-3	63	868
			3-5	3082	257
J225	1	linoleum	0-1	3351	1340
110	0	vinyl	0-2	193	1081
			2-4	139	43
			4-6	1219	113
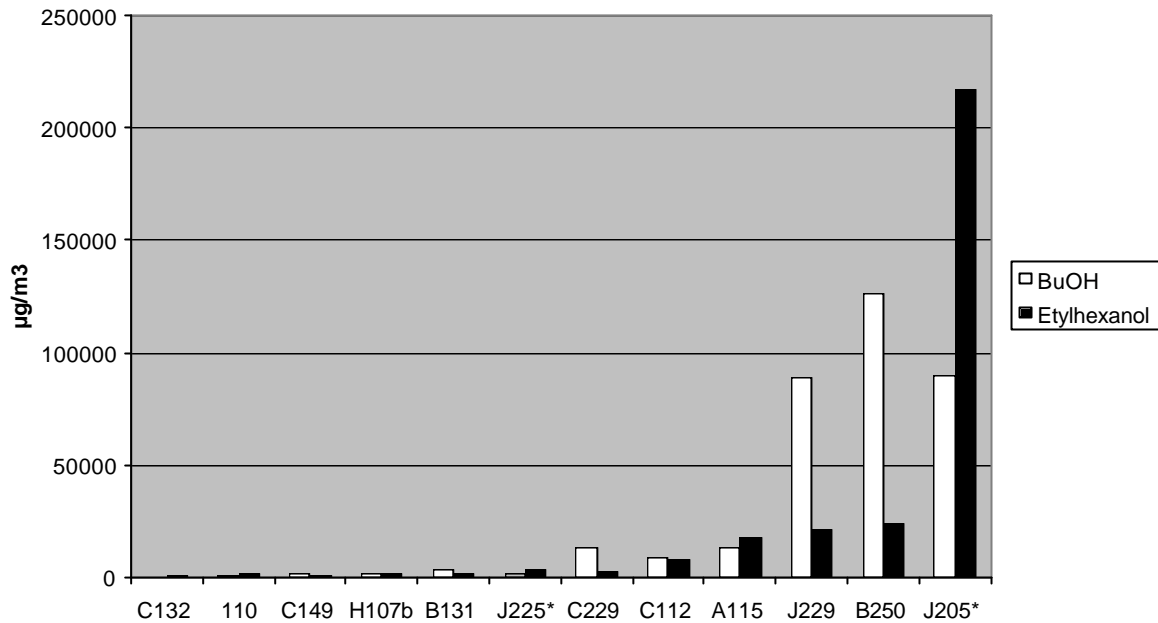
Figure 2   Butanol and ethylhexanol in the most contaminated level of every core.
* Only one level (the top level) of the concrete cores J225 and J205 has been
analyzed.

6. FLOORING RENOVATION ASPECTS

This study was made to give the facility manager a basis for choosing a new flooring construction in the object. The risk of stored VOCs emitting from the floor into the indoor air was to be reduced in a cost efficient way. The facility manager considered three different solutions:

1. Removing the flooring and screed and then let the deposited VOCs emit from the slab. This means that the object will not be in use during the emission process and it is most uncertain how long the emission process must be.

2. A ventilated air gap between the flooring and the slab could be built using fans and a flooring underlay with studs pointing downwards. This was regarded as an efficient method, but complicated and expensive.

3. A surface layer capable of blocking VOCs from the slab could be applied on the slab.

In the case of using the third solution (blocking layer), the facility manager had stated limit values for the concentrations of butanol and ethylhexanol immediately under the flooring. In order to evaluate if the limit values could be reached with some of the emission blocking surface layers on the market today, a model for calculating emissions from the slab was used. The model is described in figures 3-4 and equations 1-3 below and it is further described in Sjöberg (2001).
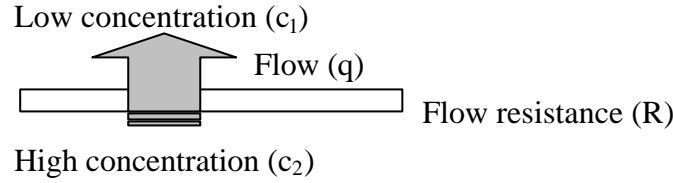
Figure 3   The flow q aims to equalize the differences in concentrations between the two sides of the flooring.

A simplified calculation of the flow of VOC through a flooring can be performed if it is assumed that there is only one resistance, without storage capacity, between the indoor air concentration (c_1) and the concentration immediately below the flooring (c_2), see figure 3. The equation takes the form of Fick's first law (Eq. 1).

$$q = \frac{(c_2 - c_1)}{R} \tag{1}$$

If there are two layers, like in the case of putting a blocking layer below the flooring, there are two resistances. Then at stationary conditions, the flow q_1 in figure 4 is equal to flow q_2 (Eq 2), e.g. all flows are equal at stationary conditions.
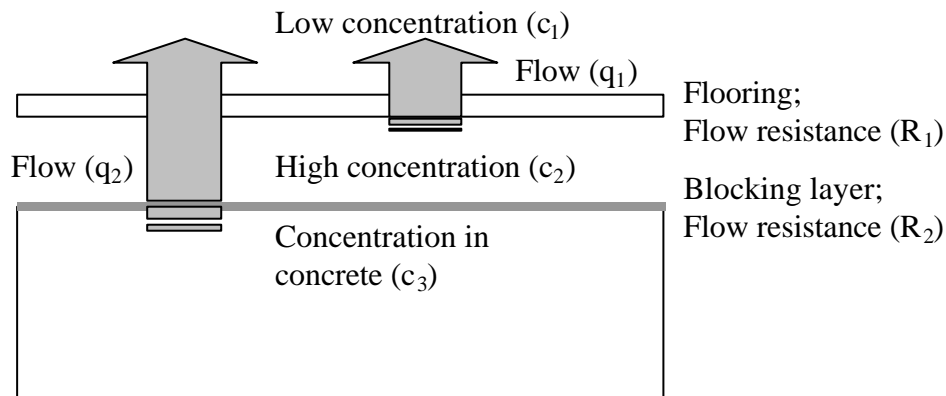

Figure 4   A model of the flows at stationary conditions.

$$q_1 = \frac{(c_2 - c_1)}{R_1} = q_2 = \frac{(c_3 - c_1)}{R_1 + R_2} \tag{2}$$

Equation 2 rewritten and shortened takes the following form:

$$c_2 = c_1 + \frac{R_1}{R_1 + R_2}(c_3 - c_1) \tag{3}$$

c_2 is the concentration immediately under the flooring that should not exceed the limit value stated by the facility manager. To solve the equation we need to know the flow resistance of the flooring

materials (R_1) and the blocking layer (R_2). In Sjöberg 2001 some experimental data on the flow resistance of PVC and linoleum are presented. Flow resistance values of several blocking layers have been experimentally determined in an investigation at Chalmers University of Technology, Institution of Building Materials and are presented in Sjöberg (2001B). Furthermore we have to know the concentration of the calculated VOC in the indoor air (c_1) and in the concrete (c_3). In this case the concentration in the indoor air was set to 0 and the measured top level concentrations in table 1 was used as c_3.

7. DISCUSSION AND CONCLUSIONS
Looking at the results in table 1 there are two trends that can be seen, but they are not without exceptions.

- Samples from the first floor contain more 2-ethylhexanol and butanol than samples from the ground floor.
- Samples taken from floors with vinyl floorings contain more 2-ethylhexanol and butanol than samples from floors with linoleum floorings.

Three samples from the first floor, from floors with vinyl floorings, contain considerably more 2-ethylhexanol and butanol than the rest of the samples. These are rooms J205, B250 and J229. Data at hand gives no reasonable explanation to why concrete from the second floor should be more contaminated than concrete from the ground floor. A possible explanation to why concrete under vinyl floorings should be more contaminated than concrete under linoleum floorings, is that the flow of 2-ethylhexanol and butanol is larger through the linoleum floorings than through the vinyl ones. This has been shown in the case of PVC and linoleum (Sjöberg 2001). Large variations among the results and the fact that room 110 with a vinyl flooring, has the least contaminated sample and sample C112 with a linoleum flooring, is among the more contaminated samples, indicates that the conditions at the different sampling sites has varied.

A parameter influencing the amount of chemical breakdown of flooring adhesive is the relative humidity of the concrete slab (Wengholt-Johnsson 1995). The RH in the concrete slabs at the time when the flooring was constructed is not known. Other data that might be of importance was not in the scoop of this limited study, such as detailed information on what adhesive(-s) and floorings that have been used and if different materials have been used at different places. Of course it would be interesting to compare the results with a geographic mapping of health problems in the object.

The concentration profiles of the cores with the highest amounts of butanol and ethylhexanol are consistent with profiles from contaminated concrete floors described in Sjöberg (2001). Concentrations are higher closer to the slab surface, and concentrations then decline with increasing depth, indicating a source of butanol and ethylhexanol at the slab surface. The concentration profiles of the less contaminated cores are more irregular and don't give same clear indication on how the butanol and ethylhexanol distribution have taken place.

The investigation has shown that there are secondary emissions deposited in the floors of the object and that there are large differences in the amounts of deposited emissions at different locations. This information gives the facility manager of the object a reason to choose a flooring construction that prevents the decomposition products from reaching the indoor air. The manager is then left with the

difficult task of assessing what flooring material could bring the emissions of decomposition products to an acceptable level. This requires information on the flow of decomposition products from the floor and the ability of different flooring products to stop it. Much of this information does not exist today and needs to be created through experiments. It also creates a need for limit values on secondary emissions from floorings. Sjöberg (2000) proposes a method for calculating the flow of ethylhexanol and butanol from the concrete through the flooring materials. That method was used in this case. However the method also requires material data that does not exist today, and further experiments, to be fully evaluated.

8. REFERENCES

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