2-Ethyl-1-hexanol emission from floor structure and health symptoms

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ABSTRACT

A small scale study was conducted in order to find out whether or not there are any connections between 2-ethyl-1-hexanol emissions from the floor structure and symptoms of the residents. Two blocks of flats (target and reference) with PVC floor covering on concrete floor were studied. In all flats residents were asked to fill out a modified questionnaire based on Örebro and Tuohilampi questionnaires. Volatile organic compounds (VOC) were measured by the GC/MSD system. In some of the target flats there had been moisture-damage in the concrete floor. The damage caused quite high concentrations of 2-ethyl-1-hexanol in indoor air, which seem to have increased the risk of symptoms such as nose and eye irritation, throat symptoms, 'heavy head' and dry facial skin. However, no dose-response correlation between 2-ethyl-1-hexanol concentration level and symptoms was found. 2-ethyl-1-hexanol seems to be only one of the irritants of VOC compounds in indoor air. Dampness in concrete floor seems to be the trigger for adverse health effects. Results of this survey indicate that these findings are potentially of major public health importance.

INDEX TERMS

2-Ethyl-1-hexanol emission; Moisture; Plasticizer; Health effects; Floor structure

INTRODUCTION

The idea for this study came from complaints of some residents living in the same block of flats. They were reporting building related symptoms and there was dampness in concrete floor structures. The first four apartments were studied carefully and the only thing found was 2-ethyl-1-hexanol concentration level that was considered quite high. There were yellow, red and purple stains on PVC floor coverings.

The City of Helsinki Environment Centre decided to study all of the apartments in this flat (target block) and find a suitable reference block with similar conditions and without any complaints from the residents. We found a reference block that was built in the same year (2000) in the same area of Helsinki City. It had also exactly the same kind (same manufacturer and type) of low emitting, M1 label according to the Finnish classification system (Säteri, 2002), PVC floor covering.

In both blocks there were mechanical ventilation systems for the outlet. The inlet is through fresh air openings on the exterior wall of the living room and bedrooms. Fresh air openings are not preheated and have a filter for only coarse particles.

There is an increasing body of evidence that poor indoor air quality increases the frequency of skin, mucosal and upper respiratory tract symptoms. Low rates of ventilation and air exchange seem to enhance the effects of indoor air pollutants (Bornehag and Stridh, 2000). Previous studies have found an increased prevalence of asthma among subjects with domestic exposure to newly painted surfaces (Wieslander *et al.*, 1997). Plastics (PVC) and textile wall materials also appear to have a role in the development of asthma and bronchial obstruction in young children (Jaakkola *et al.*, 2000). Asthma symptoms may be related to increased

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humidity in concrete floor construction and emission of 2-ethyl-1-hexanol (Norbäck *et al*., 2000).

2-ethyl-1-hexanol is an alcohol, which is a common degradation product of phtalate-based plasticizers in PVC floor covers and the glue in alkaline media. It has a distinct, bitter-sweet odour and is a suspect cause of many indoor air problems (Saarela *et al*., 2000).

Nose, throat and also mucous membrane symptoms were connected with 2-ethyl-1-hexanol emissions (Villberg *et al*., 2002). Emissions related to the degradation of di-(2-ethylhexyl) phtalate (DEHP) due to dampness in the floor, indicated by increased 2-ethyl-1-hexanol in the air, may affect the mucous membranes in the eyes and nose, decrease tear film stability and increase the occurrence of ocular and nasal symptoms (Wieslander *et al*., 1999). Throat irritation and cough were suggested to be the result of the irritating nature of 2-ethyl-1-hexanol (Kamijima *et al*., 2002).

Destruction products from carpet glue on damp concrete, not 2-ethyl-1-hexanol, were the main cause for SBS symptoms (Follin, 1997).

The storage capacity of concrete for decomposition products of PVC-carpet and glue is a critical factor for future emissions from the floor, since up to one-half of the decomposition products can be transported downwards and stored in the concrete. The organic compounds stored in the concrete can, if conditions change, be emitted to the indoor air over a long period (Sjöberg, 2001). High quantities of 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate (TXIB) were still emitting from floor structures that were over 10 years old (Metiäinen *et al.,* 2002). It is possible to reduce 2-ethyl-1-hexanol emissions and other destruction products by airing out concrete floor structures (Follin, 1997).

METHODS

Health effects were investigated by a cross sectional study. Indoor Air Quality (IAQ) measurements were conducted during the home calls. The inspector of the City of Helsinki Environment Centre conducted an interview, an overall study by sense perception, ventilation rate measurements and checked moisture condition of the structures (on the surface). Later on, air samples for volatile organic compound (VOC) measurements were collected. In the target block, air samples for ammonia measurements and bioaerosol samples were collected by an Andersen sampler in four apartments. Background facts of the flats are given in Table 1.

Table 1 Investigated blocks

	Target block	Reference block
Year of completion	2000	2000
Number of apartments	19	20
Indoor air measurements	19 (100%)	4 (20%)
Frame structure	Concrete elements	Concrete elements
Ventilation system	Mech. outlet and fresh air openings on the wall	Mech. outlet and fresh air openings on the wall
Floor covering	PVC-plastic cover	PVC-plastic cover

The ventilation rate was estimated by measuring the air flow through outlets (TSI Veloci Calc 8388). The moisture condition of the structures was estimated from the surface (Gann Hydromette UNI 1). The owner of the target block measured the moisture content of the concrete slab from drilled holes (Vaisala HMI41/HMP42). The VOCs were collected on Tenax TA from indoor air (in the middle of the living room and the bedroom, 1.2 m above floor level). VOCs were thermally desorbed from sampling tubes into a GC/MSD system (Hewlett Packard 6898). 2-ethyl-1-hexanol concentration levels were verified by the SIM-method.

A questionnaire was mailed to all residents. The questionnaire inquired about the residents' symptoms, medical history and living conditions. The response rate was around 89% from the target block and 74% from the reference block. The questionnaire used in this study was the Örebro (MM-40-FIN) questionnaire where a few questions from the Finnish Tuohilampi questionnaire were added. There are several versions of the Örebro questionnaire (e.g. working places, schools and day-care centres). The version used in this study contains questions about personal data, previous illnesses, physical and psychological environmental factors in the home and symptoms experienced. Both questions about indoor climate factors and symptoms have three alternative answers: 'Yes, often (every week)', 'Yes, sometimes' and 'No, never'. The residents were asked to report symptoms during the last 3 months (autumn 2002) and diseases during the last 12 months. The validity of the questions and test–retest reliability have been tested and found to be acceptable (Andersson, 1992). Background information of the residents who responded to the questionnaire is found in Table 2.

Table 2 Information on the residents

	Age (years)		Smokers	Pets in families	Number of persons	Allergic rhinitis	Asthma
	Median	Range					
TARGET				5	$n = 41$		
Women	32	20–42	4 (29%)		14	3 (21%)	1 (7.1%)
Men	35	25–45	4 (44%)		9	–	–
Adults	35	20–45			23		
Children < 16 years	3.5	0–16	–		18	4 (25%)	2 (13%)
REFERENCE				5	$n = 25$		
Women	43	17–75	3 (21%)		14	4 (29%)	3 (21%)
Men	43	30–58	3 (50%)		6	–	–
Adults	43	17–75			20		
Children < 16 years	7	2–16	1 (20%)		5	1 (20%)	–

All statistical analyses were made using the statistical package SPSS. The chi-square test and logistic regression methods were used in the analysis of the differences in subjective environmental factors and symptoms between the groups. The Spearman test was used for the correlation analysis.

RESULTS

In the target block there were some indications, that PVC floor covers were glued on wet concrete floor structures. High RH levels were found (98%) in the concrete and water was found inside the tubes of precast hollow core floor slabs. There were colourful stains on the PVC floor coverings in about half of the apartments. A careful inspection of four apartments did not reveal a sign of mould growth or elevated levels of ammonia even though there was dampness in the floor structures. In the reference block there were no signs of dampness in floor structures. In both apartment buildings, the ventilation rate was considered as adequate (see Table 3). There was significant difference in the TVOC and 2-ethyl-1-hexanol concentrations. In the target block TVOC concentrations and 2-ethyl-1-hexanol concentrations were two times and three times, respectively, higher than the concentrations found in the reference block. Some residents in the target block were suffering from SBS-symptoms, even though 2-ethyl-1-hexanol concentrations were less than in the reference block.

Table 3 Indoor air quality measurements

Measurement	Target block		Reference block	
	Mean/Median	Range	Mean/Median	Range
Ventilation rate (1/h)	0.55/0.50	0.30–0.90	0.45/0.40	0.40–0.60
TVOC concentration (μg/m³)				
Living room	484/470	250–870	262/210	170–400
Bedroom	574/485	190–1750	228/240	160–280
2-ethyl-1-hexanol concentration (μg/m³)				
Living room	21/19	9–45	7/7	<3–13
Bedroom	22/18	8–53	6/6	<3–12

Samples taken from PVC floor covering indicated that the 2-ethyl-1-hexanol emissions came from the PVC floor coverings used in these apartments (purge and trap method). Also a new PVC floor covering was emitting 2-ethyl-1-hexanol. Those apartments having dampness and/or stains had significantly higher 2-ethyl-1-hexanol concentration (Mann-Whitney-test, $p < 0.05$).

The residents from the target block were suffering significantly more from nose, eye and throat symptoms compared to the residents of the reference block, Table 4.

Table 4 Symptoms which had occurred every week (%)

Symptom	Target block				Reference block			
	Women	Men	Adults	Children[1]	Women	Men	Adults	Children[1]
Fatigue	71	44	61	38	43	17	35	50
Headache	57	11	39	13	7	33	15	–
Heavy head	50	67	57	13	21	17	20	–
Mucous rising	29	11	22	25	14	–	10	–
Eye irritation	71	44	61**	38	14	–	10	–
Nose irritation	71	67	70**	44	36	17	30	–
Runny nose	43	33	39	31	14	17	15	–
Throat symptoms	64	11	44[2]	38	14	–	10	–
Hoarse throat	50	11	35	31	14	–	10	–
Shortness of breath	14	–	8.7	6	7	–	5	–
Cough	21	–	13	31	7	–	5	–
Flushed facial skin	36	11	26	25	7	–	5	25
Dry facial skin	64	33	52	50	36	–	25	–

χ^{2}-test, alternatives: symptom during last 3 months, every week, more seldom, almost never.
* $p < 0.05$, ** $p < 0,01$, [1]under 16 years of age, [2]$p = 0.08$.

The results did not reveal a dose–response relationship between 2-ethyl-1-hexanol concentration level and symptoms. There was no significant difference between the residents suffering from infectious diseases in the target and the reference blocks. The residents from the target block complained more (bothering every week) during the previous months prior to the questionnaire about draught, low indoor temperature, dry air and unpleasant odour than the residents from the reference block. In most cases there was no significant difference between the women's and the men's opinion about their perceived living environment.

Dampness in the concrete floor seems to be the major factor and 2-ethyl-1-hexanol is merely a marker for decomposing products.

Subsequently, 10 flats from the target block were repaired. The old PVC-carpets and glue were removed; concrete floor slabs were dried out; room air temperature and ventilation rate were increased for a couple of weeks in order to air out organic compounds from the floor structure. The moisture content of the concrete floor slabs were measured from drilled holes before a new low-emitting M1 labelled PVC-carpet was glued on the floor with low-emitting M1 labelled glue. Three months after repairs a new questionnaire and IAQ measurements will be mailed and repeated. Results after these repairs were not available when this article was submitted.

DISCUSSION

An Indoor Air Questionnaire was used to study symptoms of inhabitants in two buildings during 3 months. Irritation symptoms such as nose and eye symptoms have in many studies been connected to 2-ethyl-1-hexanol emissions. This study confirms those results.

Quite high concentrations of 2-ethyl-1-hexanol in the indoor air of the target block were found. At the construction phase it was quite certain that the PVC floor cover was glued on wet concrete and screed surface. Then, the alkaline water in concrete might have reacted with the screed, glue and PVC floor cover.

DEHP is widely used as a plasticizer in many PVC-products all over the world. DEHP is sensitive to alkaline hydrolysis and decomposes into 2-ethyl-1-hexanol and mono-(2-ethylhexyl) phtalate (MEHP). Both DEHP and MEHP are of very low volatility. They tend to condense on surfaces and they have a high affinity for particles, so they could be mediated by respirable dust (Wieslander, 1999).

CONCLUSION

Both PVC floor covering and glue are sensitive to alkaline hydrolysis. Decomposition products have potential to provoke adverse health effects in the residents of moisture-damaged buildings. 2-ethyl-1-hexanol is a good marker for decomposition activity and its concentration is easy to measure from indoor air.

We have several questions to solve, for example, what concentration of 2-ethyl-1-hexanol is to be considered normal from PVC floor covering and glue? How can we verify old moisture-damage, which has dried out during the years? Decomposition products and their health effects should be studied more thoroughly.

Pollution from floor structures can be prevented by using high quality, low emitting products and by controlling moisture of the concrete floor before installing surface layers.

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