

# Managing harmful floor emissions including 2-ethylhexanol by using an emissions barrier

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**Abstract.** The present communication describes the use of an emissions barrier to prevent spread of hydrolysis products from plastizisers in plastic mats and from the glue used to attach such mats onto a concrete slab. In particular, 2-ethylhexanol was focussed at. Elevated air concentrations of 2-ethylhexanol has been associated with a range of health symptoms such as e.g. cough, airways irritation, fatigue, skin and mucous membrane irritation. Here we describe how such health problems can be avoided by using an emissions barrier.

## 1 Introduction

Building moisture typically results in spread of chemical and biological emissions into the indoor air leading to illnesses and symptoms such as asthma, skin and eye irritation, fatigue etc, so-called BRI (building related illnesses) [1, 2]. The emissions may be e.g. volatile organic compounds (VOC) or semi-VOC (sVOC) from paints, glue, insulation materials, chipboards, microorganisms, impregnation and plasticizer chemicals, or toxins from microorganisms such as mould.

2-Ethylhexanol is frequently used as a fragrance ingredient in cosmetics, schampoos and soaps as well as in household cleaners and detergents [3]. Consequently, the chemical is commonly found in indoor air. Elevated air concentrations, however, typically result from hydrolysis of plasticizers including phthalates such as 2-diethylhexylphthalate (DEHP) and di(2-ethylhexyl) adipate (DEHA), used in the processing of plastics and rubber and, notably, as ingredients in PVC floorings. 2-Ethylhexanol is also used as a raw material for the production of 2-ethylhexyl acrylate, an adhesive component frequently used to attach a plastic flooring onto a concrete slab.

The ester linkages in phthalates and in 2-ethylhexyl acrylate may be cleaved resulting in the release of 2-ethylhexanol. For this cleavage – hydrolysis – to occur is required moisture at alkaline conditions. In the case of floor emissions the alkaline is typically attributed to the concrete while the moisture may stem either from the glue itself, from water diffusing through a concrete slab in the absence of a capillary barrier, and/or from attaching the flooring too early, viz before the newly laid concrete has been dried enough. Elevated air

concentrations of 2-ethylhexanol is associated with a bad perceived indoor air quality (IAQ) and a variety of symptoms [3].

In the present communication we show how emissions of 2-ethylhexanol and other VOC or sVOC can be prevented from reaching the indoor air by using an emissions barrier. We report three sets of experiments where an emissions barrier was used successfully to stop 2-ethylhexanol from reaching the indoor air. We used the surface emissions trap (cTrap), a device developed from research at Lund University Sweden. This specific device is a chemical free flexible laminate with two protective sheets of nonwoven polyester fabric surrounding an adsorbent layer and a hydrophilic polymer sheet. The device (the cloth) is air tight but open for moisture [4, 5].

## 2 Laboratory studies

A series of experiments was performed. Results were evaluated by using active air sampling during 30 min through a cartridge (250 ml/min) containing activated charcoal followed by extraction by dichloromethane and analysis by gas chromatography-mass spectrometry (GC-MS) [4, 5].

**2.1 Reduction of air concentrations of 2-ethylhexanol.** An aqueous solution with 12 different VOC including 2-ethylhexanol (27 µM) was prepared. A 20-ml aliquot of the solution was transferred to plastic boxes (300 × 200 × H6.5 mm, 2.6-L) which were then closed with a lid which had a 14.5-cm long and 1-cm wide rectangular slit. In subsequent experiments, the slit was either covered using 71 cm<sup>2</sup> of the barrier, firmly attached to the lid by an adhesive tape (VOC free), or

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left open. The boxes were stored at separate locations for up to 72 h. At regular time intervals a box was placed in a wooden closet following active air sampling. The closet (75 × 40 × 35.5 cm) had a 1-cm diameter hole to allow for sampling of VOC through a tube. The empty closet did not contain any detectable amounts of any of the test VOC upon air sampling.

The impact of RH and temperature was studied. 20-ml aliquots of the solution mentioned above were transferred into separate glass Petri dishes. Each Petri dish was placed in a plastic box with a lid as described above, with the slit being covered by a piece of the device attached on the inner side lid by using an adhesive tape. The plastic boxes were placed consecutively in a climate chamber adapted for air sampling by having two sampling ports. Air samplings were performed 1 h after the study conditions (30 and 40 C; 35, 60, and 85% RH) were attained. After each sampling (n=2) plastic boxes with uncovered lids were placed in the chamber and after 1 h sampled at 23 C and 55% RH, as positive controls. Results were calculated as a percentages of 2-ethylhexanol reductions (due to the device) comparing to the emissions from uncovered boxes.

*Results.* The air concentrations (in the closet) of 2-ethylhexanol was 556 µg/m<sup>3</sup> (toluene equivalents), immediately after the solutions had been transferred to the plastic boxes (before applying the barrier, thus with open slits). Closing the slits by the cloth resulted in a decrease of the 2-ethylhexanol concentrations by 99.9% (after 0.5h), 100.0% (24h), 99.9% (48h), and 100.0% (72 h) thus demonstrating the high efficiency of the device in reducing exposure to 2-ethylhexanol.

The reduction of 2-ethylhexanol was 87.6% at the highest temperature (60 C) and RH (85%) used. Thus, even at these conditions the device offers an efficient protection against 2-ethylhexanol exposure.

**2.2. Adsorption capacity.** Solutions with 20-ml aliquots of 2-ethylhexanol (1.08 mM) were added to several 250-ml glass beakers which were covered by 23.5 cm<sup>2</sup> discs of the barrier, fixed by using an adhesive tape, and stored. Every second day the solutions were replaced with new 20-ml solutions, and 1 cm<sup>2</sup> of the cloth from one of the beakers was extracted and analyzed by GC-MS. The tests continued until the cloth was saturated as judged by the GC-MS results. Standard curves were constructed by injecting 0.66–13.2 ng of 2-ethylhexanol and 2.4 ng of N-octanol (internal standard).

*Results.* The adsorption capacity for 2-ethylhexanol was 27.1 ± 6.02% (n = 5) mg/g cTrap (13.5 ± 6.02% g/m<sup>2</sup>).

**2.3. Accelerated aging.** We studied the possible impact of aging of the device by exposing it to elevated temperatures, considering the 10-degree rule [6] where

increasing the temperature by 10 C will cause approximately a doubling of the rate of chemical reactions. Pieces (20 x 12 cm) of the device were placed in a climate chamber at 75 C and 60% RH (ambient temperature was 23 C). The experiment was carried out for up to a hundred days corresponding to 10 years of aging. Samples treated 10, 50 and 100 days as described, simulating 1, 5 and 10 years of aging, were taken out from the chamber, wrapped in air tight bags, and kept in the dark at room temperature until analyzed for their capability to reduce 2-ethylhexanol.

*Results.* The average emissions reduction of the aged device was 99.9% for the studied VOCs and 99.5% for unaged material.

### 3 Field studies

A series of experiments were performed in buildings that had been subject to water damage leading to elevated concentrations of 2-ethylhexanol in the indoor air.

**3.1 Building 1.** A school built in the 1970s, with a long history of complaints on air quality among the pupils and the school staff, was studied. Increased ventilation and use of air purifiers in the rooms had not resulted in any major improvements in the perceived air quality. The barrier was loose laid on the existing PVC flooring, by using a double sided adhesive tape, in a small office room (room A, 9 m<sup>2</sup>). Thereafter the device was installed in a class room (room B, 30 m<sup>2</sup>); over the barrier was laid a laminate flooring. Because of the unsatisfactory perceived air quality, room B was not in use since several months. The ventilation in both rooms was 2-2.5 air exchanges per hour as measured by the HVAC system. Air samples as well as samples of the cloth were taken from the floor (immediately replaced with new pieces of the device) at different time periods for measuring the amounts of 2-ethylhexanol in the air and adsorbed on the cloth, respectively. 2-Ethylhexanol was the dominating VOC found in air samplings taken before the device was installed. Tenax TA tubes were used for passive air samplings for 1 week and sent to IVL (Stockholm, Sweden) for thermal desorption and GC-MS analysis. The cloth pieces (approximately 3 cm<sup>2</sup>, n = 4) were extracted by using dichloromethane following GC-MS [4, 5]. Material was also collected from the surface of the device (n = 3), laminated flooring (n = 2), and PVC flooring (n = 2) by using an adhesive tape 13 months after the surface emissions trap had been applied in room B, and sent to IVL (Stockholm, Sweden) for mold microscopy.

*Results.* After the installation several of the staff reported that the unpleasant smell had disappeared, and another 470 m<sup>2</sup> of the material was installed in the school building directly on the PVC flooring and subsequently covered by a laminate flooring. Decreased air concentrations of 2-ethylhexanol, from 6-7 mg/m<sup>3</sup> to

2 mg/m<sup>3</sup>, were found two months after the device had been applied; the concentrations of 2-ethylhexanol in the installed piece of the device rose from 0 (unused device) to 280.3 mg/g after 13 months of use. This amount of 2-ethylhexanol corresponds to 1.01% of the adsorption capacity of the barrier. Neither the surface of the material, laminated floor, nor the PVC flooring taken 13 months after application of the barrier contained any hyphae as judged by phase contrast light microscopy of the tape lifts at 400 times magnification.

**3.2 Building 2.** The efficiency of the device in reducing floor emissions was studied in a storage room with a PVC flooring. FLEC (Field and Laboratory Emissions Cell) measurements had previously revealed distinct amounts of n-butanol, 2-ethylhexanol, and 2,2,4-trimethyl-1,3-pentanediol diisobutyrate (TXIB) being emitted from the flooring.

Two identical 1-L glass desiccator lids with two sampling holes were applied on the flooring either covered or uncovered by the device. By using an adhesive tape an aluminum foil was attached on the edges of the desiccator lids in such a way that it covered the flooring surrounding the experiment devices. Air samples were taken three months after the application of the devices. In brief, air was pumped through Tenax TA tubes for 30 min at 100 ml/min, which were then sent to IVL (Stockholm, Sweden) for analysis.

*Results.* Covering the flooring with the device resulted in reduced air concentrations of n-butanol, 2-ethylhexanol, and TXIB. The TVOCs reduction was 97% whereas 2-ethylhexanol was reduced by 99% thus confirming the high efficiency of the device as a shield from 2-ethylhexanol exposure.

**3.3 Building 3.** A townhouse was studied where the tenants suffered from itching all over the body when staying at home, symptoms which disappeared when outside the building. A PVC flooring had been glued onto a concrete slab which had become moist through diffusion of water from the ground. The air concentration of 2-ethylhexanol was 63 µg/m<sup>3</sup> (directional measurement using FLEC). The cTrap was attached onto the existing flooring, and the itchiness disappeared.

*Results.* Three months after device had been installed the air concentration was 1.5 µg /m<sup>3</sup>, a value which persisted in a follow-up study 6 years after the installation - and the residents still reported no symptoms. These results demonstrate that the device is efficient also over time.

## 4 Discussion

Airborne particles in a building may be removed by using portable air cleaners with mechanical air filtration (HEPA etc) or by electronic cleaning where the particles

are charged and thereafter accumulated on a collector or precipitated following reaction with ions generated with an ion generator [7]. VOC (including odours) may be removed by pumping the air through a filter containing an adsorbent. Some air cleaners are designed to destroy the contaminants; for example, microbes may be killed by UV light. PCO (photocatalytic oxidation) cleaners and ozone generators use UV together with a catalyst aiming to convert harmful pollutants to less harmful products. Such measures, just as increasing the ventilation, may decrease the concentrations of the airborne contaminants, but will not prevent them from being spread into the indoor air. Furthermore, PCO cleaners as well as ozone generators may de facto increase the concentrations of some other VOC including potential lung irritants such as formaldehyde [8-10]. Replacing damaged materials with new ones may in some instances be useful but also very time-consuming, costly, and - when the damaged materials are vital for the stability and function of the building - often impossible to do.

Attaching a sealant at surfaces indoors (floor, ceiling, or walls) from where the emissions are spread constitutes an alternative approach. Examples of sealants are various polymers, aluminum/plastic laminates etc. Such sealants can be extremely efficient in stopping the emissions and thus improving the IAQ; however, it is necessary to first know the source of the emissions. In the present study we applied the surface emissions trap (cTrap), a type of emissions barrier [4, 5] developed at Lund University Sweden to stop emissions in buildings with complaints regarding the IAQ. This specific product is a laminate comprising a hydrophilic polymer sheet and an adsorbent layer; it is air tight but has at the same time a very low water vapour resistance. The device has been found to provide a reliable solution over time and an improved perceived air quality [5, 12].

The use of the cTrap emissions barrier for stopping floor emissions was described in a multi-storey house of approximately 60 apartments, built three years before the start of the investigation [11]. The investigations were initiated by complaints of bad perceived IAQ from many residents. Based on subsequent indoor air and moisture measurements, as well as technical assessment of the building structures and condition, deterioration of the flooring material was identified as the most likely cause for the bad IAQ; measurements taken from indoor air and from floor surfaces indicated elevated emissions of 2-ethylhexanol and C9 – C10 alcohols. The latter alcohols stem from newer plasticizers such as DIDN, DIDP, or DINCH. The existing plastic flooring was removed whereafter the carpet glue and the old screed were removed by milling. The barrier cloth was simply rolled over the flooring and attached by using an adhesive tape. Over the cloth was then installed a new laminate flooring. The result of these measures was that the floor surface emissions rates dropped to below the determination limit [11].

Inhalation exposure to 2-ethylhexanol has in experimental animals been shown to cause mucous membrane irritation in the eyes, nose, and throat. Studies in human volunteers has revealed an increase in olfactory irritation and eye discomfort [3]. Such symptoms have been found even at air concentrations as low as a few  $\mu\text{g}/\text{m}^3$  - notably, air concentrations exceeding  $1000 \mu\text{g}/\text{m}^3$  in indoor air have also been reported [3]. Since symptoms thus seem to appear even at only slightly elevated air concentrations of 2-ethylhexanol it is currently being discussed whether this specific compound should be viewed in a wider perspective, viz. as a general marker of a floor emissions problem rather than as a main causative agent in itself. Anyhow, research has shown that decreasing the air concentrations of pollutants e.g. due to floor emissions results in an improved perceived air quality [13, 14], and that an emissions barrier which contains an adsorbent provides efficient protection over time [14, 15].

In summary, the present communication illustrates how an emissions barrier effectively can reduce air concentrations of floor emissions including 2-ethylhexanol, which is a serious IAQ health concern worldwide.

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