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Achieving a healthy indoor environment by using an emissions barrier for stopping spread of chemicals from building into the indoor air

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Abstract

An emissions barrier was used in premises with indoor air complaints due to emissions from the buildings in question. The emissions comprised chlorophenols/chloroanisoles and polycyclic aromatic hydrocarbons (PAH) from treated wood, and volatile organic compounds (VOC), mainly 2-ethylhexanol, from PVC flooring and the glue used to paste the flooring onto a concrete slab. Attaching the barrier at the surfaces from where the emissions were spread (floor, walls, ceiling) resulted in a fresh and odour-free indoor air. We conclude that using an emissions barrier in buildings made unhealthy by moisture is an efficient way of restoring a pleasant and healthy indoor air.

Keywords

Emissions barrier, adsorbent, healthy buildings, restoration

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 (Mendell et al. 2011, Bornehag et al. 2004). Drying is a necessary first step in remediation because it will stop further moisture-driven reactions with the building materials as well as (continued) mould growth. However, drying is not enough to secure a clean indoor air, since the numerous chemicals that have been formed from water - or moisture – acting on the materials will still remain in the building construction and over time inevitably be emitted into the indoor air. The emissions may be e.g. VOC from paints, glue, insulation materials, chipboards, microorganisms, impregnation and plasticizer chemicals, or toxins from microorganisms such as mould.

Airborne particles released from the building construction 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 (Zhang et al., 2011). 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 air-borne contaminants, but will not prevent them from being spread into the indoor air. Furthermore, PCO cleaners (Kolarik and Wargocki, 2010) as well as ozone generators (Weschler, 2006; Wolkoff et al., 2000) may de facto increase the concentrations of some other VOCs including potential lung irritants such as formaldehyde. 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 indoor air quality (IAQ); however, it is necessary to first know the source of the emissions. In the present study we applied a new type of emissions barrier (Markowicz and Larsson 2012, 2015) developed at Lund University Sweden to stop emissions in some buildings with different complaints regarding the IAQ.

Methods

Three buildings with IAQ complaints due to emissions from the building construction were studied. In short, the surfaces from where the emissions were spread (floor, ceiling, walls) were covered with an emissions barrier to prevent them from reaching the indoor air. In the specific barrier used, the cTrap, an adsorption layer functions together with a hydrophilic polymer sheet making the adsorption virtually irreversible (Markowicz and Larsson 2012, 2015). The flexible cTrap cloth was attached at the surfaces using an adhesive tape and/or a staple gun. The indoor air concentrations of the emissions were measured both before and after the cTrap installations by pumping air through an adsorbent followed by thermal or chemical desorption and analysis using gas chromatography-mass spectrometry.

Results

1. We studied the living-room and a bedroom of a wooden summer house built in 1964 with a disturbing "summer cottage smell" indoors which was attributed to chloroanisoles. The building had previously been treated with chlorophenol-containing preservatives which were widely used in the 1960-70s; at moist conditions chlorophenols may be biomethylated to form chloroanisoles having an intense, characteristic mould-like odour. The ceiling, walls and floor in the bedroom (as well as the doorway between the bedroom and the living room), but not in the living-room. were covered with the cTrap cloth. Subsequently, air sampling for chlorophenols/chloroanisoles was carried out simultaneously in both rooms. Tetrachlorophenol, trichloroanisole, and pentachloroanisole were detected in the air of the living-room, but only tetrachlorophenol was found in the bedroom, and in an air concentration 93% lower than in the living room (Table 1). Also, the mouldy odour disappeared in the bedroom following the cTrap installation.

2. A building where a creosote-based tar layer had been attached onto the concrete slab as a moisture barrier was studied. The air concentrations of PAH were 1726 ng/m3 air. There was a disturbing smell inside the building which persisted even after the tar had been removed. Then, the cTrap cloth was installed on about 75 percent of the wall surface. The smell disappeared and the PAH air concentrations decreased to 139 ng/m3, thus corresponding to a reduction of 92% (Table 1).

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, a compound which is ubiquitous in small concentrations in indoor air but found in increased concentrations e.g. following hydrolysis of glue and/or phthalates of PVC floorings, was 63 µg/m3 (directional measurement). The cTrap was attached onto the existing flooring, and the itchiness disappeared. 3 months after cTrap had been installed the air concentration was 1.5 µg /m3 (Table 1), a value which persisted in a follow-up study 6 years after the installation - and the residents still reported no symptoms.

Results are summarized in Table 1.

Table 1. Results of cTrap installations

Emissions (µg/m^3 air)	Without cTrap	With cTrap
Tetrachlorophenol Chloroanisoles	0.14 0.013	0.01 n.d.
PAH	1.726	0.139
2-ethylhexanol	63	1.5

Discussion

Staying in a moist building can cause health problems (Mendell et al. 2011, Bornehag et al. 2004) e.g. skin and mucous irritation and respiratory disorders. Such conditions are frequently referred to as BRI (building related illnesses) and are caused by spread of chemical emissions from the building itself into the indoor air. Research has shown that mixtures of VOC emitted from building materials may act in synergy in worsening the perceived air quality (Knudsen et al., 1999; Patterson et. al, 1993) even when present in concentrations below the odour thresholds. The studies presented here demonstrate that such emissions can be effectively stopped by using an emissions barrier. Through scientifically validated questionnaires it has also been found that health symptoms and/or unpleasant odours can be decreased or totally eliminated (data not shown). Still, the awareness that use of emissions barriers is an efficient weapon against BRI is not wide-spread – not even among indoor air professionals.

The specific device used in the studies presented here, the cTrap (surface emissions trap) cloth, contains two active layers; one adsorption layer and one hydrophilic polymer layer. The device is air tight while at the same time allowing moisture to pass through with almost no resistance at all, and will thus not affect the moisture balance of the building. It has been shown to be efficient against a wide range of chemicals including e.g. alcohols, aldehydes, sulfur compounds, PAH, chloroanisoles, chlorophenols, mould products, and odours (Markowicz and Larsson 2012, 2015). After the device has been applied on a floor a surface layer, e.g. a laminate, parquet, or plastic flooring etc, is installed on top of the cTrap cloth. When attached on walls or ceiling the cloth is usually covered with a gypsum board which is then painted or decorated with a wall-paper. When the building one time will be demolished then the cTrap cloth, with the adsorbent layer containing the emitted chemicals, will be sent for combustion thus avoiding leakage of the chemicals into the environment from deposited building materials.

In summary, we conclude that use of an emissions barrier represents an effective, economic, and eco-friendly way of restoring a healthy indoor air in buildings affected by moisture.

Conclusions

An emissions barrier can be used to restore a fresh and healthy indoor air in buildings made unhealthy due to moisture damage.

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Authorship contribution

Johan Mattsson was instrumental in initiating and realizing the described projects while Lennart Larsson compiled the data and did most of the writing.

Conflicts of interest

Johan Mattsson is employed by cTrap Ltd Sweden.

References

Bornehag, C.G., Sundell, J. and Sigsgaard, T. (2004). Dampness in buildings and health (DBH): Report from an ongoing epidemiological investigation on the association between indoor environmental factors and health effects among children in Sweden. *Indoor Air* Suppl 7, 59-66.

Knudsen, H.N., Kjaer, U.D., Nielsen, P.A. and Wolkoff, P. (1999). Sensory and chemical characterization of VOC emissions from building products: impact of concentration and air velocity. *Atmos. Environ.* 33, 1217-1230.

Kolarik, J., and Wargocki P. (2010). Can a photocatalytic air purifier be used to improve the perceived air quality indoors? *Indoor Air* 20, 255-262.

Markowicz, P. and Larsson, L. (2012). The surface emissions trap: A new approach in indoor air purification. *J. Microbiol. Methods* 91, 290-294.

Markowicz, P. and Larsson, L. (2015). Improving the indoor air quality by using a surface emissions trap. *Atmos. Environ.* 106, 376-381.

Mendell, M., Mirer, A., Cheung, K., Tong, M. and Douwes, J. (2011). Respiratory and allergic health effects of dampness, mold, and dampness-related agents: a review of the epidemiologic evidence. *Environ. Health Perspect.* 119:6, 748-756.

Patterson, M.Q., Stevens, J.C., Cain, W.S. and Cometto-Muñiz, J.E. (1993). Detection thresholds for an olfactory mixture and its three constituent compounds. *Chem. Senses* 18, 723-734.

Weschler, C.J. (2006). Ozone's impact on public health: contributions from indoor exposures to ozone and products of ozone-initiated chemistry. *Environ. Health Perspect*. 114, 1489-1496.

Wolkoff, P., Clausen, P.A., Wilkins, C.K. and Nielsen, G.D. (2000). Formation of strong airway irritants in terpene/ozone mixtures. *Indoor Air* 10, 82-91.

Zhang, Y.P., Mo, J.H., Li, Y.G., Sundell, J., Wargocki, P., Zhang, J.S., Little, J.C., Corsi, R., Deng, Q.H., Leung, M.H.K., Fang, L., Chen, W.H., Li, J.G. and Sun, Y.X. (2011). Can commonly-used fan-driven air cleaning technologies improve indoor air quality? A literature review. *Atmos. Environ*. 45, 4329-4343.