



Advanced Calcium Aluminate Cement Technology

A study of
Calcium Aluminate
Self-leveling Underlayments

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SAN LUIS OBISPO

VOC EMISSIONS FROM FLOORING SYSTEMS AND THE IMPACT OF FLOOR LEVELING SCREEDS

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EXECUTIVE SUMMARY

This report summarizes the findings of a literature review into the placement of flooring materials on concrete slabs and the possible risk to indoor air quality. The investigation focuses on secondary emissions caused by the transport of alkalis from the concrete slab via moisture migration to the flooring materials. Reactions between alkalis and certain adhesives and PVC based flooring materials, subsequently react to produce volatile organic compounds (VOCs), including 2-ethyl-1-hexanol (2E1H) and *n*-butanol. Secondary emissions of 2E1H and *n*-butanol have been related to health impacts and are a possible source of sick building syndrome.

The relative humidity of the concrete prior to placement of flooring materials is shown to significantly influence the migration of alkalis, as measured by pH, and is demonstrated to greatly increase secondary VOC emissions from systems containing PVC flooring. Reducing the pH at the flooring material is correlated to a reduction in the long-term secondary emission of VOCs including 2E1H and *n*-butanol. Use of floor leveling screeds between the concrete slabs and the flooring materials is shown in some instances to decrease the rate of moisture migration and the buildup of alkalis just below the flooring materials and subsequently reduce VOC emissions when placed on slabs with initial relative humidity (RH) of 91% and lower. When placed on slabs with 96% RH; however, self-leveling screeds have been shown to delay the migration of alkalis resulting in reduced VOC emissions within the first two years and have greater VOC emissions after three years. Lastly, low alkali self-leveling screeds are shown to result in lower pH levels than higher alkali screeds at the interface between the screed and flooring materials.

DISCLAIMER

The conclusions drawn are those of the authors based on their interpretations of the best available reports at the time of the writing of this report. The conclusions are not those of the Department of Civil Engineering nor those of the California Polytechnic State University, San Luis Obispo. While the authors gratefully acknowledge the financial support of Advanced Resurfacing Concrete Products, Inc., the conclusions were drawn independently of and without the influence of ARC, Inc.

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INTRODUCTION

This report contains a review of published literature regarding emissions of VOCs from the combination of PVC flooring materials placed on concrete slabs. Within the scope of PVC flooring over concrete slabs, the report addresses: the mechanism by which VOCs are emitted, what factors influence VOC emissions, the health implications of the emitted VOCs, and whether self leveling screeds, specifically calcium aluminate based screeds, can reduce VOC emissions.

Flooring systems addressed within this report, illustrated in Figure 1, consist of a concrete slab, an optional layer of self leveling screed, an adhesive, and the flooring material.

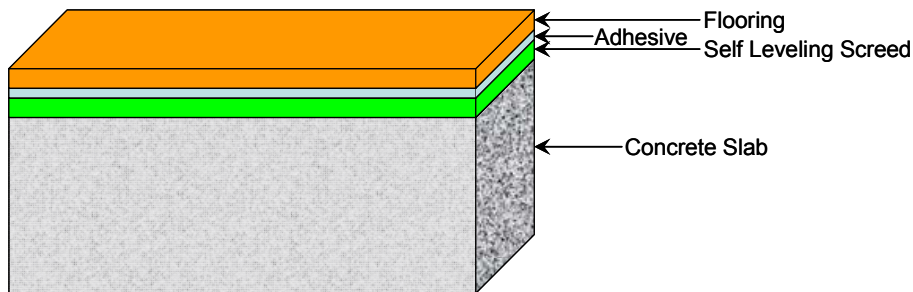


Figure 1: Illustration of flooring system

While the flooring material can consist of carpet, linoleum, vinyl (PVC), wood, or other materials, the focus of this report will be on PVC flooring. As it will be shown later, the VOC emissions leading to health issues of occupants have been identified with PVC flooring applied over concrete slabs, although there are indications that other flooring materials could also be susceptible. PVC flooring is favored in many applications due to its durability in high traffic areas and relatively low cost.

Flooring adhesives are typically a form of acrylate co-polymers (butyl acrylates or ethylhexyl acrylates, for example), but others are used. The available research regarding VOC emissions from PVC flooring on concrete have predominantly used acrylate co-polymers.

Concrete is a mixture of water, ordinary portland cement (OPC), and aggregates (sand and gravel). It also typically contains supplementary cementitious materials such as fly ash

and chemical admixtures such as water reducers. The mechanism by which concrete hardens is the chemical reaction, call hydration, between water and the portland cement. When hydration takes place, all the water is not consumed, but some remains within pores in the hardened cement paste. One of the reaction products between OPC and water is calcium hydroxide, Ca(OH)_2 . When calcium hydroxide is in an aqueous solution, the OH^- ions go into solution increasing the pH of the water; water saturated with calcium hydroxide has a pH of 12.4. The pH in pore water within concrete is typically around 13 whereas for high alkaline cements the pH can be in excess of 13.5 (Mindess et al., 2003). Note that a pH of 13 has 10 times greater concentration of OH^- ions than a pH of 12 and 100 times greater than a pH of 11; subsequently, a pH of 13.5 has 3.2 times higher concentration of OH^- ions than a pH of 13. The actual pH within the pore water in hardened concrete depends on factors such as the OPC and supplementary cementitious materials used. The amount of residual moisture in concrete depends largely on the mixture proportions of the concrete, in particular the ratio of the water-to-cementitious materials ratio (cementitious materials being the sum of the OPC and supplementary cementitious materials), how long hydration has been allowed to take place, the duration and type of moist curing of the concrete, and the duration and environmental conditions of post-cure drying.

Self leveling screeds are an optional component in floor construction. They are used to provide flat level surfaces onto which the flooring can be attached. While they are a cement based material, many are based on calcium aluminate cement (CAC) rather than OPC. CAC reacts faster than OPC and have lower shrinkage. The actual composition of self-leveling screeds vary considerably by manufacturer, but may contain CAC, OPC, fly ash, fine fillers (sand). CAC based self leveling screeds have lower pH levels than OPC when mixed with water (pH of ~11 versus a pH of 12.4 for OPC or only ~4% of the OH^- concentration).

INDOOR AIR QUALITY

Basic Science of Indoor Air Quality

The health impact of a pollutant depends on the duration, frequency, and concentration of the exposure. Consequently, pollutant exposures in the indoor environment (residences, schools, offices, etc) are of particular concern since people spend a significant fraction of their time in these environments, and concentrations for some pollutants are substantially higher indoors than they are outdoors. In the National Human Activity Pattern Survey, Klepeis et al. (2001) found that average U.S. residents spend approximately 87% of their time inside buildings and that this percentage appears to be relatively stable across different regions of the United States and Canada. These values are similar to those found for Californians in the late 1980s (Jenkins et al., 1992). In addition to the total duration of indoor exposures, most people have lifestyles which lead to the primary exposures occurring in a small number of indoor locations, typically their home, workplace, or school. This leads to an increase in the frequency of exposure to the specific pollutants present in these locations. Finally, researchers often find that the concentration of pollutants can be significantly higher in the indoor environment than in the outdoor environment. For instance, Bluyssen et al. (1996) found total volatile organic compound concentrations (TVOC) in office buildings average up to 5 times the outdoor concentrations and Daisey et al. (2003) report from several studies which found (TVOC) inside classrooms to be over two times the concentration outside.

In the simplest sense, the quality of indoor air is determined by the amount and type of pollutants entering and leaving the airspace. This means that the best air quality within a building will be achieved by minimizing the introduction of pollutants and maximizing their removal. Pollutants both enter indoor air from the outdoors and are generated within the space. They are removed by mechanical ventilation, open windows and doors, and exfiltration (leakage). Historically, acceptable air quality was readily achieved through infiltration/exfiltration since buildings were leaky enough to provide adequate ventilation under almost all meteorological conditions. However, in an effort to conserve energy, changes in building standards and practices have led to a significant decrease in the amount of air infiltrating into buildings and have lowered mechanical ventilation rates. An example

of this can be seen in residential construction, where the average leakiness of homes decreased by about two thirds between 1950 and 1995 (Chan et al. 2003). The Association of Heating, Ventilation, and Air Conditioning Engineers (ASHRAE) recommends a minimum air exchange rate of 0.35/hr for acceptable ventilation in residential housing and 15 cfm (cubic feet per minute) per person for mechanically ventilated non-smoking buildings. These air exchange rates represent the current consensus for a reasonable balance between energy efficiency and air quality, as opposed to being based strictly on air quality concerns. Figure 2 shows the major processes affecting indoor air quality and pollutant concentration.

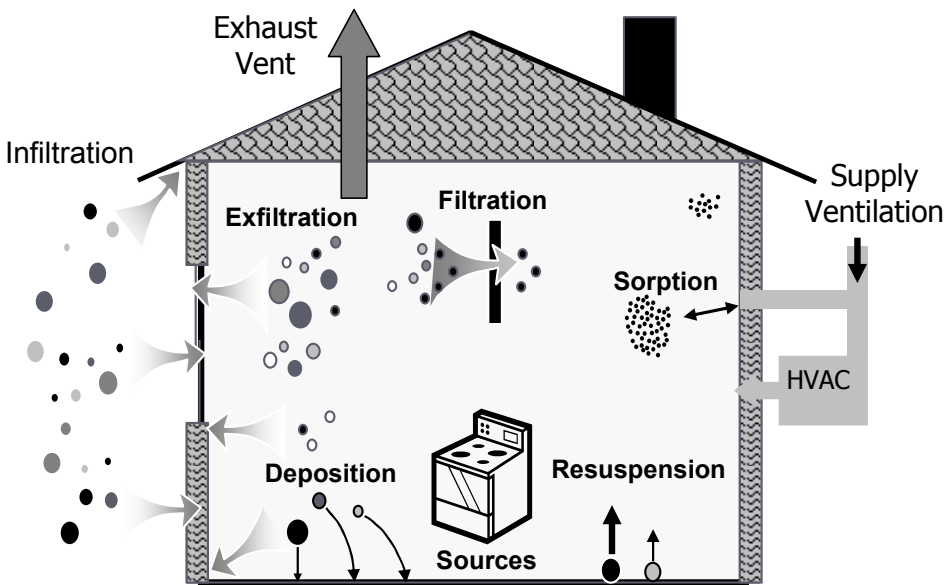


Figure 2: Schematic of important processes influencing the indoor concentration of pollutants

The concentration of a pollutant in the indoor environment can be described using a mass balance model which accounts for all of the physical and chemical processes which are significant. In the most general form, it can be expressed as:

$$\frac{dC_I}{dt} = (C_O P - C_I) \lambda_v - C_I \beta + G + F_{Rxn} + S_{desorption} \quad (1)$$

Where:	C_I	=	indoor concentration
	t	=	time of interest
	C_O	=	outdoor concentration
	P	=	the fraction of the pollutant that penetrates the building shell
	λ_v	=	ventilations rate (includes mechanical, natural, and infiltration)
	β	=	loss rate to surfaces
	G	=	generation rate of pollutant indoors
	F_{Rxn}	=	formation of pollutant through indoor reactions (negative if a loss)
	$S_{desorption}$	=	desorption of pollutant from indoor surfaces

This model illustrates the interaction between indoor concentrations and ventilation rate, outdoor concentrations, indoor sources, and interactions within the indoor environment. As ventilation rates are reduced, the same indoor generation rate will cause higher concentrations in the indoor space. One of the keys to lowering pollutant concentrations and improving indoor air quality for buildings is to minimize the generation of pollutants within the space (terms G , F_{Rxn} , and $S_{desorption}$ in the equation above). The two primary sources of indoor pollutant generation are emissions from building materials and emissions from indoor activities, such as cooking and cleaning. Emissions from building materials typically occur at a higher rate when initially installed and then emit at a lower rate over a long period of time. The nature of the pollutants emitted can also change over time. When evaluating material emissions, the toxicity, duration, and emission rate must all be considered. Although typically the highest concentrations will occur initially, the largest and/or most toxic exposure may occur during the longer term/low emission rate period. In addition, semi-volatile pollutants may absorb into other materials and then desorb slowly over time. The strength of pollutant sources from building materials can be reduced through material substitution, using materials and compounds with lower emission rates and advantageous properties. Minimizing indoor generation will improve air quality without increasing ventilation rates and therefore energy usage.

Primary vs. Secondary Emissions

Sources for indoor pollutants can be classified as either primary or secondary emissions. Primary emissions are from a single material or single source. While primary emissions may be influenced by environmental conditions such as temperature and humidity, they can typically be identified by testing of the material before the product containing the offending source is installed indoors (Haghighat and De Bellis, 1998). Secondary emissions can be further divided into two categories (Hall, 2003):

- a) emissions of absorbed substances
- b) emissions from the reaction of combinations of materials

Secondary emission of absorbed substances is identifiable and preventable as the original source of the emissions, which are subsequently absorbed, can be tested. The difficulty with secondary emissions of absorbed substances lies in determining the long-term rates of the emissions as they depend on the absorptive characteristics of the structure and contents. Subsequently testing of the original source for emissions alone cannot predict the secondary emissions; however, one can surmise that initial high rates of emissions may lead to secondary emissions as the rate of absorption will depend on the concentration buildup within the structure.

Secondary emissions from the reaction of combinations of materials consist of chemicals that are not present in the original materials and can persist over long periods of time. These emissions are far more difficult to predict, and the sources are difficult to find even when the offending emission is found.

Health Implications Related to Flooring Systems

For the same ventilation conditions, the health impact of emissions from materials will depend on both the emission rate and the toxicity of the materials emitted. However, in the case of organic emissions from materials, there is an almost unlimited variety of pollutants emitted, and limited data on the composition, toxicity, and reaction processes of these pollutants in the indoor environment. With the exception of several common organics, such as formaldehyde and nicotine, much of the emissions data has been determined for general categories of organics, such as 'volatile organics' and 'semi-volatile organics'. For flooring system emissions, two of the secondary emissions that have been quantified are 2-

ethyl-1-hexanol (2E1H) and ammonia. However, many of the secondary emissions are in the form of unidentified organics (Wilke et al., 2004).

Lundholm et al. (1990) compared concentrations of amines and ammonia in buildings with and without health complaints (headaches, eye irritations, etc). They found that the “sick” buildings had higher levels of both amines and ammonia than the control buildings. In addition, they measured the concentrations of these compounds in the headspace beneath the floor covering material and found that the headspace concentrations of amines were over two orders of magnitude higher than in the room air, and ammonia was over one order of magnitude higher. They also found that the homes with elevated headspace concentrations also had elevated airborne concentrations. This indicates a high likelihood that the compounds are emanating from beneath the floor covering.

Kamijima et al. (2002) report a case study in Japan in which they measured airborne concentrations of 42 organics within a building with air quality complaints. They found that within the room which produced the most severe complaints, the compound with the highest concentration was 2-ethyl-1-hexanol (2E1H), which also had a concentration 5.5 times higher than in a nearby office where there were fewer reported symptoms. For the other 41 compounds measured, concentrations in the 2 locations were generally similar, with factors between 0.8 and 2.

Norbäck et al. (2000) measured concrete subfloor dampness as well as 2E1H and ammonia concentrations in four geriatric hospitals. They found a correlation between floor dampness and concentrations of 2E1H and ammonia. They also found a correlation between 2E1H concentrations in the indoor air and the prevalence of asthma symptoms among workers. Tuomainen et al. (2004) performed an intervention in a building with health problems suspected of emanating from degradation of flooring in contact with damp, alkaline concrete. Symptoms and airborne concentrations were measured before and after renovation. Degradation products were also found in the concrete under the flooring. These compounds were removed by heating the slab for 1 week to increase volatilization. This intervention was found to reduce airborne concentrations of 2E1H and TVOCs. They also found a reduction in the incidence of headache, odor complaint, and dermal dryness.

Reiser et al. (2002) investigated complaints of deteriorated air in a building in Switzerland shortly after renovations took place. They identified the source of the offending

odorous compounds as vinyl (PVC) flooring, and more than nine months after the renovations, they found the flooring to emit a number of VOCs including phenol and 2E1H. More than a year after the renovations, they found the emission rates of some VOCs, including 2E1H, to still be increasing. In rooms which were renovated with linoleum flooring, they found significantly lower VOC emissions in comparison to rooms renovated with vinyl flooring. For many of the compounds which were emitted at high rates with the vinyl flooring, including 2E1H and 1-butanol, insignificant or undetectable emission rates were found with the linoleum flooring.

In looking at health effects, it is important not only to determine the type of emissions which occur, but also to quantify the magnitude of these emissions. Emissions from flooring and other surface materials are generally reported in terms of mass per area per time. Other emissions may be reported in terms of emissions per time (such as cooking or burning a candle), emissions per mass used (such as cleaning products) or mass per event (such as a cigarette smoking). Emissions from the reaction of alkaline materials beneath flooring, in the presence of moisture, can be significant. Sjöberg and Ramnäs (2007) determined emissions rates for *n*-butanol of 300 to 600 $\mu\text{g}/\text{m}^2 \text{ hr}$ and for 2-ethyl-1-hexanol (2E1H) of 200 - 1000 $\mu\text{g}/\text{m}^2 \cdot \text{hr}$. Chino et al. (2009) reported 2E1H emission rates from PVC flooring that ranged between 50 and 400 $\mu\text{g}/\text{m}^2 \cdot \text{hr}$ 50 to 100 days after construction and between 50 and 200 $\mu\text{g}/\text{m}^2 \cdot \text{hr}$ 200 days after construction. For comparison, Destailats et al. (2008) reported emission rates for 2E1H of 19.6 $\mu\text{g}/\text{hr}$ for a desktop computer and 0.14 $\mu\text{g}/\text{hr}$ for a laptop computer.

INDOOR EMISSIONS FROM FLOORING MATERIALS

Introduction

The earliest scientific inquiries into emissions from flooring substrates were conducted in the Scandinavian countries. Due to the harsh winters, well-sealed and energy efficient housing has been a priority in this region and have resulted in low air exchange rates. As a consequence, indoor emissions create higher indoor concentrations than would occur in leakier structures with the same source strengths. The production of secondary

emission products formed by reactions within flooring materials has been of particular concern.

Studies have been performed by several research groups investigating emissions from flooring systems under a variety of different conditions (Saarela and Järnström, 2003; Sjöberg and Ramnäs, 2007; Chino et al., 2009). These studies, and most of the studies cited in this report, measured surface emissions using the Field and Laboratory Emission Cell (FLEC) developed by Wolkoff et al. (1991). The FLEC is well accepted within the emission monitoring community and has been shown to produce repeatable results (Roache et al., 1994; Wolkoff et al., 1995). Emissions from small chamber test equipment such as the FLEC are difficult to extrapolate to full scale room concentrations due to the variety and number of different surfaces and emission sources. For instance, Järnström et al. (2008b) found that airborne VOC concentrations in 6 apartments were about twice the levels predicted using air exchange rates and surface emission measurements. However, the FLEC has been shown to provide reliable data for comparing emissions from different materials.

Mechanism of Secondary VOC Emissions from Flooring on Concrete Slabs

The general mechanism by which VOCs, 2-ethyl-1-hexanol (2E1H) and *n*-butanol in particular, are emitted is through secondary emissions as illustrated in Figure 3 below. Moisture within the concrete slab migrates to the adhesive and flooring due to moisture gradients, carrying soluble alkalis with it. At the adhesive and flooring interface with the concrete, compounds within the flooring and adhesive react through alkaline hydrolysis to form organic compounds (OCs). These OCs then either migrate through the flooring and are emitted into the air as VOCs, or they build in concentration within the concrete slab to be emitted into the environment later (Sjöberg and Nilsson, 2002).

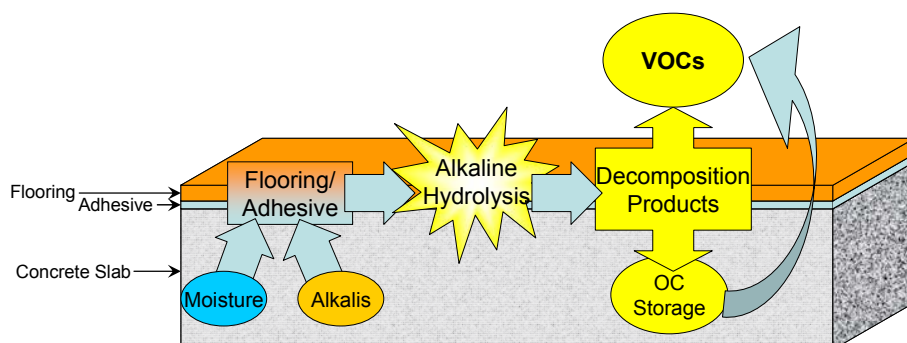


Figure 3: Process for VOC emissions from flooring systems (based on Sjöberg and Nilsson, 2002)

While some research identified plasticizers in flooring materials containing PVC as the compound that the moisture and alkalis from the concrete react with to form the VOCs (Björk and Eriksson, 2002; Kamijima et al. 2002), others pointed to acrylate polymer adhesives as the reactant (Sjöberg and Nilsson, 2002). The more modern consensus is that the moisture and alkalis may react with either or both the plasticizers in PVC flooring and a variety of types of adhesives (Alexanderson, 2004; Chino et al., 2004; Järnström et al., 2008a; Sjöberg and Ramnäs, 2007; Uhde and Salthammer, 2007). Regardless of whether the alkaline hydrolysis occurs with compounds in the flooring material or the adhesive, sufficient moisture and alkalis from the concrete is required. PVC flooring may not a necessary component to supply a reactive compound; however, it is important in the sense that it has low permeability so it helps retain high humidity under its surface which is a key component of alkaline hydrolysis with compounds in adhesives. Sjöberg and Nilsson (2002) did measure high VOC emissions stemming from alkaline hydrolysis of acrylate polymers in adhesives with linoleum, which acted as a vapor barrier similar to PVC flooring.

Sjöberg and Ramnäs (2007) also showed that for alkaline hydrolysis of adhesive materials to occur, the minimum pH had to be within the range of 11 to 13. By investigating the impact of humidity and surface alkalinity on emission of the secondary emission products (represented by *n*-butanol and 2-ethyl-1-hexanol) from flooring systems, they found that the secondary emissions due to adhesive degradation were up to 30 times higher for samples exposed to alkaline solutions of pH 13 (similar to alkaline cement materials) than for those

exposed to a buffered solution with a pH of 11. In addition, emission rates of these secondary pollutants persisted at approximately the level for the 52 week duration of the tests.

Comment [MSOffice1]: Humidity and alkalinity

Luo and Niu (2004, 2006) studied the diffusion of VOCs through a mortar (OPC, water, and sand) slab. They found that the porous structure of mortar, hence the hardened cement paste, reduced diffusion of VOCs. The low diffusion rates in mortar results in slow movement of VOCs from the bulk material and continuing emissions over a long period of time.

Comment [MSOffice2]: diffusion in concrete

Effect of Concrete Moisture Content on VOC Emissions

It is clear that moisture plays a large role in VOC emissions from flooring systems as it is a necessary component for alkali hydrolysis of compounds in the adhesive or PVC flooring to occur. As a reference, Alexanderson (2004) adhered PVC flooring directly on concrete with different relative humidities (RH) and demonstrated the high emission rate of total volatile organic compounds (TVOC) over the first 1.5 years when the RH is on the order of 96% as shown in Figure 4. The RH values in Figure 4 were measure 0.5 years after application of the PVC flooring. The rapid decrease in the emission rate of the sample with PVC applied over a concrete of 96% RH was attributed to a decrease in the RH of the concrete due to drying of the concrete as moisture diffused through the PVC flooring; when the testing was complete, the RH in the 96% sample had decreased to 86%. While Figure 4 presents the TVOC, Alexanderson (2004) also measured 2E1H and *n*-Butanol emissions and reported the same general trend although the *n*-butanol emissions were at undetectable levels for the sample where the PVC was placed on concrete with an initial RH of 86%.

Björk and Eriksson (2002) measured the change in the pH in the concrete slab and in the self leveling screed by periodically taking samples at different depths of the flooring systems and squeezing the pore water out of the samples. They found that in the concrete just below the self leveling screed the pH increased when the RH of the concrete was 95% at the time the flooring was adhered, but they saw no rise in pH when applied to concretes with initial RH of 85% or 90%.

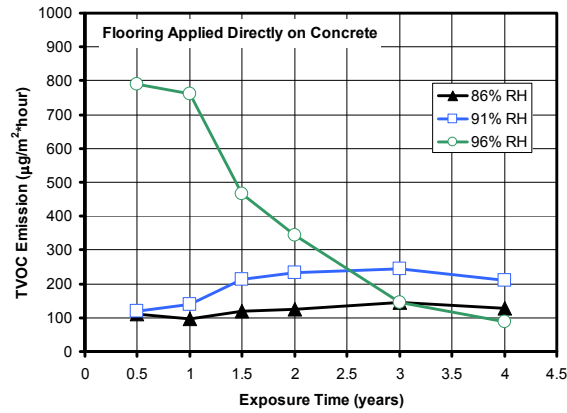


Figure 4: Effects of initial humidity on TVOC emissions from flooring systems (based on Alexanderson, 2004)

Sjöberg and Nilsson (2002) measured the concentration, c , of butanol in concrete after 2 years as shown in Figure 5. Their measured values support the premise that OCs are being stored in the concrete as the butanol concentration is highest at the concrete adhesive interface (0 depth in concrete). They further modeled the reaction and transport of OCs into the concrete and showed how a decrease in relative humidity of the concrete before application of flooring decreases the buildup of OCs as demonstrated in Figure 5.

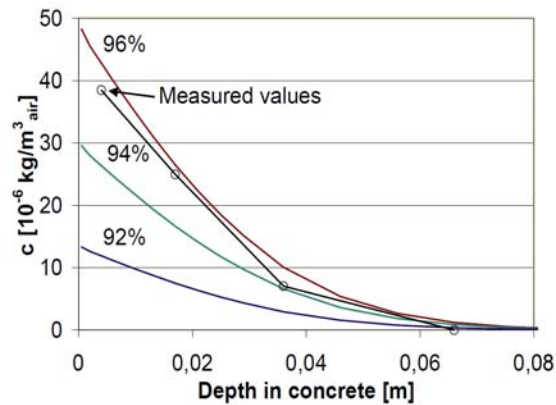


Figure 5: Distribution profile of butanol within concrete 2 years after application of flooring (Sjöberg and Nilsson, 2002)

In contrast to the work already described, Chino et al. (2009) altered the moisture content of the self leveling screed before applying the adhesive and placed no flooring material on the adhesive. In addition, they reported the moisture content of the screed rather than the relative humidity of the material. In measuring 2E1H emissions of an acrylic resin adhesive on self leveling screeds with 4% and 11% moisture contents, the initial emission rate for the adhesive on the lower moisture content screed was approximately 75% of the rate for the adhesive on the high moisture content screed. After just one day, however, the emission rate for the adhesive on the low moisture content screed was less than 15% of the rate for the adhesive on the high moisture content screed and the ratio continued to decline for the 14 day duration of the test.

Effect of Self Leveling Screeds on VOC Emissions

Alexanderson (2004) also measured the VOC emissions of different self leveling screeds at different RH (86%, 91%, and 96%) and compared it to application of the PVC flooring material directly onto the concrete slab (see Figure 6). Samples with RH of 91% and 86% (not shown) resulted in considerable reduction in TVOCs; similar trends were found for the emission of 2E1H. In this investigation, screed 'A' had a binder consisting of calcium aluminate cement blended with calcium sulfate and OPC, and screed 'B' contained only calcium aluminate cement and calcium sulfate. While screed 'B', without the OPC, performed better than screed 'A' with OPC, they both dramatically reduced VOC emissions at relative humidities of 86% and 91%.

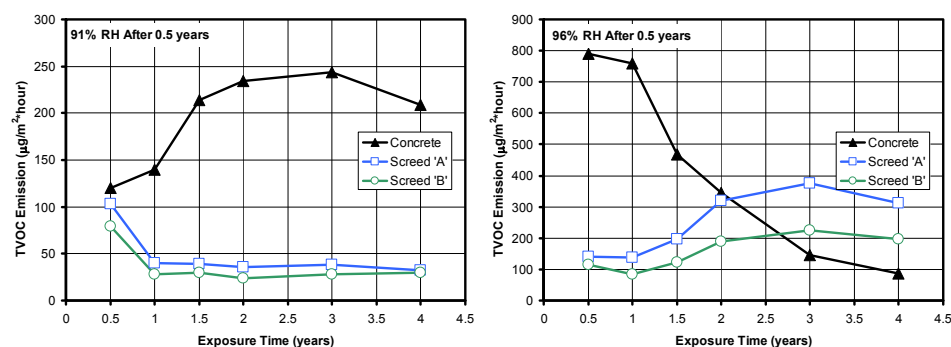


Figure 6: Effects of screeds on TVOC emissions from flooring systems (based on Alexanderson, 2004)

Saarela and Järnström (2003) measured emissions from concrete floor structures in seven buildings in Finland. They found that emission rates of Total Volatile Organic Carbon (TVOC) and ammonia were influenced by the screed thickness, humidity of the screed, and the type of flooring that had been laid over the concrete, even though the flooring had been removed prior to the emissions measurements. They also found that for some sites, significant TVOC emissions still occurred during the last measurement set which was taken 48 weeks after construction.

Comment [MSOffice3]: Flooring material...elaborate

Chino et al. (2009) found primary emission rates of 2E1H were 4 to 5 times higher when adhesives were attached to a gypsum and powder based self-leveling sub-floor than they were when attached to a glass surface. They also measured secondary emissions for 3 different adhesives attaching PVC flooring to the self-leveling subfloor. Although each type of adhesive showed a different trend, all 3 adhesives showed significant secondary emissions at the end of the 200 days of sampling, with emissions from one of the adhesives still increasing with time.

Comment [MSOffice4]: Self leveling screed and adhesives

Wilke et al. (2004) observed the formation of secondary emissions from two flooring adhesives. They identified a variety of secondary compounds that were not present in samples taken during the first 28 days of sampling, from aliphatic acids to aldehydes. Although the onset of emissions for some secondary compounds began at 28 days, other compounds continued to appear over the first 50+ days. Many of these secondary emissions persisted over the 130 day testing period.

Comment [MSOffice5]: adhesives

SUMMARY AND CONCLUSIONS

The importance of reducing indoor emissions of secondary compounds which cause odor, irritation, or health problems is widely agreed upon (Bluyssen, 2009; Bernstein et al., 2008; Udhe and Salthammer, 2007). PVC flooring and adhesives used with PVC flooring have been identified as sources of VOC emissions, *n*-butanol and 2E1H in particular, which have contributed to poor indoor air quality to the point where occupants have become ill or have complained of offending odors. Laboratory investigations have supported the findings from the field and have identified alkaline hydrolysis of compounds within adhesives and PVC flooring as the sources of secondary emission of VOCs. Subsequent storage of VOCs

Comment [MSOffice6]: source of secondary emissions. Needs elaboration

in the concrete can contribute to long term secondary emission of VOCs. Allowing the concrete to dry to the point where the relative humidity in the concrete is below 91% before application of flooring materials can significantly decrease the secondary VOC emissions. Use of self leveling screeds can further decrease secondary VOC emissions from alkaline hydrolysis of PVC flooring and associated adhesives at relative humidities below 91%. While there is not a strong consensus, there is evidence that low alkali self leveling screeds based on calcium aluminate cements, can help reduce the pH at the interface with adhesive and flooring which should decrease secondary emissions of VOCs associated with hydrolysis of PVC flooring and adhesive.

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