DAMAGED FLOORING MATERIAL AND ABSENTEEISM IN AN OFFICE

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ABSTRACT
Flooring materials may break down if mounted on a damp concrete surface. There are some reports relating to upper respiratory and asthma symptoms caused by degradation by-products of polyvinyl chloride building materials. Here, we report increased number of upper respiratory, conjunctival and dermal symptoms among employees exposed to the degradation by-products of linoleum floor coverings. The number of sick leaves caused by respiratory symptoms and diseases rose simultaneously. The damaged flooring materials were removed and replaced by epoxy coating, which is not affected by moisture. After the repairs, the number of sick leaves due to respiratory symptoms and diseases decreased by 14%. It was calculated that the repair costs were paid back in two years in terms of decreased expenditures on the care of respiratory diseases and symptoms.

INDEX TERMS
Flooring material, linoleum, volatile organic compound, cost-effectiveness, absenteeism

INTRODUCTION
The break down of flooring materials can cause indoor air problems. Polyvinyl chloride (PVC) building materials are known to degrade in damp alkaline conditions and the degradation products have been related to upper respiratory symptoms and signs of inflammation (Wieslander G, et. al., 1999) as well as asthma symptoms (Norbäck et al., 2000). Linoleum flooring material has been reported to cause facial dermatitis (Karlberg et al., 1996) and acrylate-styrene copolymer has been linked to ocular and respiratory symptoms (Malmberg et al., 2000).

We describe a work environment where a few months after moving into a renovated building, workers complained several building-related symptoms, especially respiratory symptoms. At the same time the sickness absenteeism also rose. The concrete slabs were found to be damp and the chemicals related to the degradation of linoleum flooring materials were found in indoor air. Within a few months these floors were repaired to eliminate the problem. This case study describes an indoor air problem, the renovations made to eliminate the problem and the adverse health effects and its associated absenteeism.

METHODS
The office moved to new facilities, into a large downtown office building with a two-storey-high ceiling in southern Finland. The total area of the office is 1540 m² located in two storeys. The new upper floor was built using a composition slab structure. The used flooring material was linoleum. The company operated a telemarketing business and the number of employees

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varied daily, many of whom worked part-time. The number of employees varied each month between 100 and 160 during the study period.

The relative humidity and the temperature of the concrete slabs were measured inside the concrete composition slab at the depth of 65 and 80 mm in 4 areas (Lumme and Merikoski, 1997). The time required for the drying of the concrete slabs was estimated by using the tables described in the manuals of the Finnish Concrete Association (BLY 4/by 31, 1989).

Two material samples were taken from the linoleum floor covering for microbial analysis. Microbial samples of the settled dust were collected from seven surfaces. Mesophilic fungi were cultivated on Rose Bengal malt extract agar (Hagem), dichloran-glycerol-agar (DG18), malt extract agar (MEA) and bacteria on tryptone yeast exact glucose agar (TYG).

Volatile organic compounds (VOCs) in the indoor air and their emission from the flooring materials were measured in a chamber and with the field and laboratory emission cell (FLEC). VOCs were collected into Tenax adsorbent tubes. The analysis of VOCs included thermal desorption, gas chromatographic separation and detection and quantification of different VOCs with a mass selective detector.

The symptoms of the personnel (N=78) were surveyed with a MM-40 questionnaire (Andersson et al., 1993). The sick leaves of the personnel were followed from assigned certificates. The employer followed the expenditure of the sick leaves. Absenteeism caused by respiratory diseases and symptoms were calculated before and after the renovations and the costs of absenteeism and renovations were compared.

RESULTS
The moisture of the new composition slab exceeded 91% (Table 1). However, RH 90% is the maximum moisture limit value in the Finnish building code for mounting linoleum floor covering. That limit value should not be violated in order to avoid material damage, although before the year 2000 the limit value was RH 85%.

Table 1. Measurements of relative humidity (RH), temperature (T) and the calculated (Nevander and Elmarsson, 1994) saturation vapour contents (v_s) in the inspected floor structures. The older floor was used as reference.

<table>
<thead>
<tr>
<th>measurements</th>
<th>RH (%)</th>
<th>T (°C)</th>
<th>v_s (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1 - 7, composition slab</td>
<td>91.0 ... 93.7</td>
<td>21.3 ... 23.3</td>
<td>17.4 ... 19.6</td>
</tr>
<tr>
<td># 8 - 11, older floor</td>
<td>29.4 ... 38.3</td>
<td>22.6 ... 23.3</td>
<td>6.0 ... 8.0</td>
</tr>
<tr>
<td>indoor air (2001-03-12)</td>
<td>27.0</td>
<td>22.3</td>
<td>5.3</td>
</tr>
</tbody>
</table>

The time needed for the concrete slab to dry can be estimated by using the adaptation factors given in the manual of the Finnish Concrete Association (BLY 4/by 31, 1989). A composition slab is erected on a steel profile and therefore it can dry only into one direction. In this case, the time needed to achieve the RH 90% limit value is approximately 165 days. The time reserved for the renovation project was 90 days. Thus the concrete slabs had no possibility to adequately dry within the contract time.

The VOCs indicating the breakdown of the linoleum flooring material were detected in the emission studies. The same compounds were also found in the indoor air. Microbial growth and microbial volatile organic compounds (MVOCs) were detected in the damaged material.
samples. In the material samples, the only microbe species found was *Eurotium* which indicates a moisture damage. The summary of the material VOC-analyses is shown in Table 2.

Six samples of indoor air were taken for the VOC analysis. The mean of the total volatile organic compounds (TVOCs) was 24 µg/m$^3$ (range 8...36µg/m$^3$). The compounds indicating the breakdown of the linoleum flooring materials were found in small concentrations: e.g. nonanal, hexanal and 2-butoxyethoxyethanol. The measurements were taken during the normal ventilation was functioning.

The personnel reported increasing cases of conjunctival (37%) and nasal irritation (49%), hoarseness (55%) and dermal symptoms (39%) in the questionnaire.

The damp composition slabs were repaired in July 2001 by replacing the linoleum flooring material with moisture inert epoxy coating. The linoleum floor coverings were removed from the damp slabs and the concrete surface was removed in order to remove the contaminated levelling. Because the space between main and upper floors was open, it was difficult to accomplish the shielding against dust and other particles perfectly. The concentration of particles may have risen in the inhaled air due to the repair.

**Table 2.** Summary of the flooring material VOC-analyses.

<table>
<thead>
<tr>
<th>Method</th>
<th>Material</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>TVOC</strong> µg/m$^3$</td>
</tr>
<tr>
<td>Glass-chamber</td>
<td>linoleum on the moist slab</td>
<td>7694...28059</td>
</tr>
<tr>
<td></td>
<td>linoleum on the old floor</td>
<td>71</td>
</tr>
<tr>
<td>FLEC</td>
<td>linoleum on the moist slab</td>
<td>997...2294</td>
</tr>
<tr>
<td></td>
<td>linoleum on the old floor</td>
<td>204</td>
</tr>
</tbody>
</table>
The changing number of sick leaves and the associated costs were studied both before (and after the repairs (Figure 1). The reduction in the number of sick leaves due to the respiratory diseases was about 14% during the comparison periods (mean January-March 2001 0,030 days, October-December 2001 0,026 days).

![Figure 1. Sick leaves due to the respiratory symptoms and diseases before, during and after the repairs.](image)

Absenteeism-related expenditures caused by respiratory diseases and symptoms were calculated per total hours within the surveyed period. In the beginning of the year the cost of the respiratory diseases rose to 0.35€/h decreasing 10% after the repairs to 0.31€/h. The total savings per year would be estimated to be approximately 13400€.

The total cost of the repairs was 28500€. If the reduction of the absenteeism would stay at this level, the repairs would pay off almost in two years.

**DISCUSSION**

Moisture in the composition concrete slab and floor coverings may cause respiratory complaints. When using the composition concrete slab structure, the critical factors for causing the damage were: i) too short building time, ii) mistakes in the measurement of the moisture before installing the linoleum flooring and iii) the use of organic flooring material on damp surfaces.

The contractor ensured that the moisture of the slabs was measured and was found to fulfil the requirements for mounting of the linoleum floor covering. However, the structure was found damp which meant that i) there were problems in the measuring of the moisture in the correct depth of the slab (measured too close from the surface), ii) the measuring device was not calibrated properly, or iii) the measuring was carried out improperly.

Moisture in the composition concrete slabs and the breakdown of the flooring material have probably caused at least some of the respiratory complaints, since the number of sick leave days decreased after the repairs. In our follow-up, the number of sick leaves caused by respiratory symptoms and diseases increased in September. During the repairs dust and gases were released to indoor air. These impurities may have increased the symptoms of the employees right after the repairs. An alternative explanation would be the common flue.
However, according to the occupational health care unit, there were no signs of any outbreak of infections in other companies in this area.

The expenditure of the repairs is paid back in two years merely by the savings of the sick leaves caused by respiratory diseases and symptoms. Nevertheless, absenteeism is only a partial measure of all the costs of indoor air problems and does not include for instance expenditures associated with reduced productivity. Thus, the true pay back time is shorter.

To reliably evaluate the effects of the repairs, longer observation time is needed and we will follow the rate of absenteeism in the future.

**CONCLUSION AND IMPLICATIONS**
Alkaline dampness of concrete slabs may damage linoleum flooring materials leading to indoor air problems. Repairing the damaged flooring materials is cost-effective.

**REFERENCES**


