Emissions from construction materials. Results from the National 'Healthy Building' Programme

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ABSTRACT
The Healthy Building Technology Programme was established in Finland to abolish the factors causing building related problems as it was clearly seen that deficiencies in indoor air had an economical importance even at the national level (Rantama, 2003). The key research areas in the programme were:

- services and business concepts;
- ventilation and building services;
- moisture;
- emissions from construction materials

The objective of the 'Emissions from construction materials' was to develop processes for evaluating of indoor air quality, diagnosing and rectifying indoor air and the health problems in buildings.

INDEX TERMS
Emissions; Air quality; IAQ assessment; Modelling; Moisture; Reference values

INTRODUCTION
Moisture and emissions from new materials are the most common causes that give rise to building related complaints. Solvents, monomer residues, additives and impurities contained in materials cause the emissions from new materials. Today, several labelling systems all over the world exist with the objective to restrict emission from new materials. The objective of emission labelling is to attain an indoor air quality that is comfortable and healthy. In Finland, the Indoor Classification 2000 gives target values for three indoor air quality classes. Are these values reached in buildings constructed using labelled good quality materials?

On the other hand, materials oxidize and even degrade in buildings sooner or later during their service life giving rise to irritative emissions. Especially degradation of materials caused by the humidity of structures gives rise to a major part of the complaints in buildings.

Complaints of defect indoor air quality and demands for remedial actions are a big and expensive issue. Up to now there has been a lack of reference values to validate the indoor air quality suspected to be responsible for the complaints. In the case of known indoor quality defect, the source should be reliably detected and successfully remediated. The field measurement techniques of emissions from structures have not been well developed and reference values have been leading to lack of reliability and credibility of the required remedial actions.

These shortcomings have been an issue of dispute in the building industry and for the residents. A need for an objective verification of a suspected indoor air problem and remedial actions has become an important issue and gave rise to this research of the 'Healthy Building' technology programme.

The research area 'Emissions from construction materials' consisted of projects dealing with the following topics:

- development of modelling techniques for studying the effect of emissions from structures on indoor air quality;
- effect of labelling systems on attained indoor air quality;

- development of measurement techniques for emissions from structures on site;
- comparison of emissions from chamber tests to emissions from structures on site;
- establishing reference emission values for structures to be used in commissioning buildings during the construction phase and as reference values in possible complaint cases;
- establishing reference values for indoor air quality in new buildings;
- taking out remedial actions in problem buildings and studying the effect of remedial actions on indoor air quality.

RESULTS

New Buildings

The Finnish Classification 'Indoor Climate 2000' includes a classification for building materials aiming at attaining an indoor air quality that can be chosen from three classes depending on the demand of the builder or user. This is achieved using defined amounts of classified materials of different classes. Also in European projects models have been drafted for calculation of indoor air quality on the basis of material emissions (Brite Euram, Mathis) taking into account factors like ventilation efficiency and sorption of the building surfaces.

Indoor air measurements in new residential buildings showed that the planned indoor air quality classes S1 to S2 were not attained using M1-classified materials at the moment when the building was completed and the inhabitants moving in. The bake-out time with heating operating and full ventilation before inhabitants moving in did not affect the indoor concentrations during the first months nor did the finishing materials. The only factor that had an effect on the TVOC value was the ventilation type. In residential and office buildings equipped with supply air ventilation system S2-class indoor air quality was reached already at the moving in stage and S1-class within a few months to 1 year. In residential buildings with only exhaust ventilation system the indoor air quality reached the S2-class within from half a year to 1 year and the planned S1-class was not reached during the first year.

The research showed, however, in two identical buildings, that when using low emitting materials compared to non-label products, the indoor TVOC-value was halved. See Figure 1 for the illustration of the development of material emissions after the 'Indoor Climate 2000', 'Classification of Material Emissions' came out.

As the TVOC value had a sinking tendency during the first year of inhabitancy, the formaldehyde and ammonia varied or even rose during the year. The concentrations correlated with relative humidity of indoor air.

Emissions from materials on structures were higher during the building phase and the first year of the building compared to those of single materials measured in laboratory. The relative humidity of the structures did not have an effect on the emissions.

A model for calculation of the transport of diffusion-controlled emissions from structures to indoor air was developed. In addition to the diffusion controlled emission, the effect of leakage on the indoor air can be calculated.

Problem Buildings

The indoor air problems encountered in Finland are caused, in addition to the emission from new materials, by humidity-damaged structures. Abnormal humidity in structures causes in addition to mould growth also oxidation and degradation reactions in materials and as a result often irritating chemical emissions are emitted to indoor air.

Moist structures. In surveys of complaint buildings built in the 1970s and 1980s it was shown that the major part of the problems were caused by humidity in structures. The factors that caused the defects in structures were charted and were found to be due to wrong design or bad maintenance of the building. The study showed that if the buildings had been constructed

according to today's Building code and other guidelines, the defects would have been avoided. Also the Indoor Climate Classification 2000 gives guidance of how to avoid humidity defects by design and proper handling of materials on the building site. In this technology programme practical solutions for safe structures were presented.

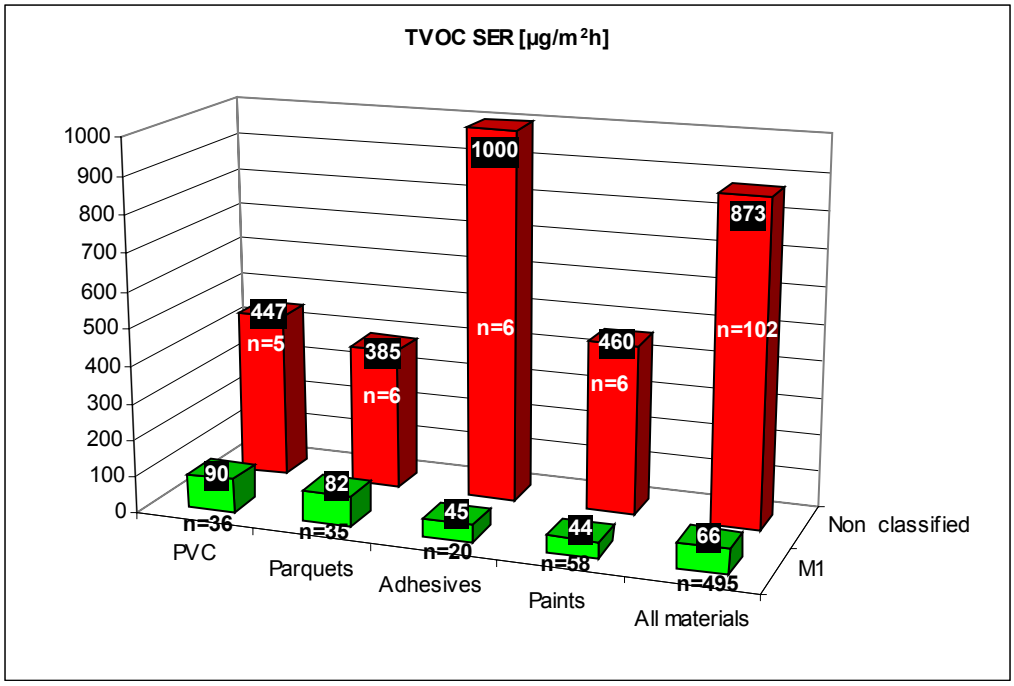

Figure 1 TVOC emission rates of classified materials and common materials on market.

Detection and verification of an indoor air problem. A reliable verification of an indoor air problem, source detection and verification, remedial actions and their validation have been the core subject for three projects in the Healthy Building Technology programme.

A reliable measuring technique is the core for tracing and verifying the source material. A FLEC-based technique (Nordtest) was established for emissions from structures underneath tight floor coverings. This method is based on the fact that the diffusion process of the emission of chemical compounds reaches equilibrium only after at least 3 days after removing the tight covering material (Figure 2).

Reference values for emissions from structures. The study showed that as reference values for evaluation of the defect structures emission values from new buildings can be used.

The effect of inhabitants. The study showed that when the inhabitants were removed from the problem building, the indoor air TVOC value was halved, except the VOC emission of the defect material, in this case TXIB-viscosity modifier from a poor quality PVC flooring.

Remedial actions to remove the emissions caused by humidity. The most typical pollutant emission from structures caused by excess humidity is the emission of ammonia. The most frequent source is the casein containing mortars. The casein is hydrolysed due to long lasting dampness and degrades giving off ammonia, amines, alcohols, aldehydes and sulphuric compounds as degradation products. Today the use of casein in emission labelled products in Finland is not accepted. There are still, however, complaint buildings built in the 1980s and the beginning of the 1990s where the above degradation products are causing indoor air complaints. The studies using different ways to cure the structures showed that the TVOC content of the indoor air rose as a result of the repair works, the ammonia concentration level were not reduced substantially, but levels of carbonyl compounds and esters diminished. The

complaints were, however, continuing in most cases. Only in one case the inhabitants were satisfied when the PVC flooring was substituted with parquet.

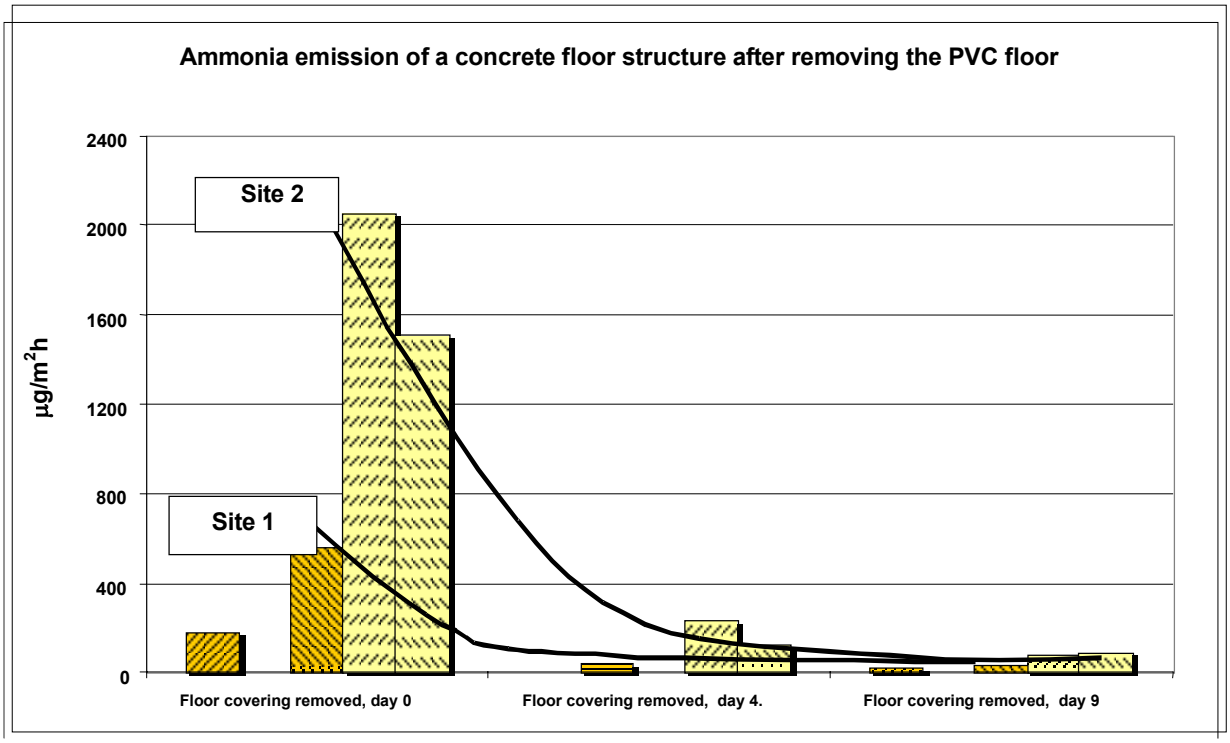

Figure 2 Example of ammonia emission decay in two sites after removing the floor covering. The twin columns indicate parallel samplings. Site 1 is a new building and Site 2 a problem building.

Poor quality materials. Today, as emissions from materials, especially the low boiling solvent residues, have diminished substantially, some higher boiling processing aids have become commonly used. Of these, TXIB, a viscosity modifier in PVC products, but also used in, e.g. glues, has been commonly causing indoor air complaints. In another research programme, it was revealed to correlate with clinical findings (Villberg, 2003). Different remedial actions to remove the problem were tested. The cheapest alternative is to install a new tight floor covering on the old, which diminished the emission in the beginning, but later the emissions diffused through the covering. Removal of the original floor covering and emission measurements under the removed cover revealed strong TXIB emission from the structure due either to contamination from the floor covering or the glue. The emission of the floor structure did not disappear after a 2-week heating period indicating that a bake out is not able to remove high boiling compounds with slow diffusion rate. The only reliable remedial action seemed to remove the flooring material and the levelling mortar and install a M1-class PVC flooring. In these cases the symptoms disappeared.

SUMMARY

New Buildings

- The use of low emission materials has halved the indoor air concentrations.
- The indoor air quality S1 design values are not reached in buildings equipped with only exhaust ventilation within the first year and S2 values are reached from half a year to 1 year.

- The indoor air quality S1 design values are reached in office and residential buildings equipped with supply air ventilation within a few weeks after completing the building.
- The effect of indoor air humidity on indoor concentrations of secondary emissions such as ammonia, formaldehyde and other aldehydes and esters are confirmed.
- Emissions from materials in structures in real buildings are for several months higher than in the laboratory emission measurements.
- A modelling technique for emission from structures was developed.

Complaint Buildings

- Today's building codes, guidelines and the Indoor Climate 2000 Classification contain the necessary information for design, building works and maintenance for avoiding the humidity defects.
- No sure remediation technique was found for ammonia emitting structures.
- Bake out with elevated temperature does not, within a 2-week period, lower the emission from structures polluted with high boiling contamination.

Practical Applications

- A measurement method for reliable verification of material emissions from structures was presented.
- Reference values for normal emissions from structures were taken out and they can be used in quality assurance of new and source disclosure and verification in problem buildings.
- Reference values for indoor air quality in new buildings were attained.

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