Microbial Growth and Secondary Emissions – Their Main Causes in Swedish Problem Buildings

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***Summary**: In Scandinavian buildings, moisture related problems are a dominating factor in explaining "sick buildings". This study comprised 113 Swedish cases during the period 1993 to 2002. The occupants had pronounced health complaints and/or suffered due to abnormal odours. The results showed that in 92 % of the cases, the problems were mainly caused by emission sources due to different kinds of harmful moisture. The remediation strategy resulted in an improved health situation as well as removal of abnormal odours.*

***Keywords:** Micro organisms, Secondary emissions, Moisture damage, Investigation*
***Category:** Case studies*

1 Introduction

In Scandinavia it has been amply demonstrated that some types of construction sustain mould growth while in others abnormal chemical emissions also occur. Both types of damage are due to harmful moisture. It is also well known that occupants sometimes have pronounced health problems associated with living or working in damp buildings. In contrast, outside the group of professional investigators, there is a lack of knowledge as to which components are damaged and how often this occurs. These professional investigators have also learned by experience that when a well performed investigation has identified new or old moisture damage, followed by a well performed remediation process, the result is almost always significant improvement in the health situation and also removal of abnormal odours.

The causality between bad health and measurable pollutants in the indoor environment is largely unclear. Investigators are therefore trying, without a scientific foundation, to solve problems in buildings where the occupants complain of SBS. This is unsatisfactory and has also resulted in scepticism on the part of scientists, allergists and others about the approach employed by the investigators to solve these problems.

It is also important for the whole building sector to learn from earlier mistakes that had caused damage and a deterioration in indoor air quality. This will help the remediation processes and help avoid the same mistakes in the future.

One way to improve knowledge about these and to help sectors outside the professional investigators to better understand the situation is to describe examples and the results of indoor air investigations in buildings with SBS.

2 Aim

The aim of this work has been to compile and to disseminate the experiences of professional investigators concerning damage in buildings which have given rise to indoor environment related problems.

3 Methods

Written documentation relating to about 300 commissions carried out by a firm of consultants in Central Sweden during the period 1993 – 2002 has been studied. The clients, who were mainly the owners of the buildings to which the commission referred, represent a mixture of property firms of different sizes, municipal and national authorities and private owners of single family houses. The common factor leading to the engagement of the firm of consultants was that the problems encountered needed expert assistance for their solution.

Only indoor environment investigations relating to problems due to abnormal odours or problems where the occupants referred to some form of complaint/ symptom due to living or working in the building were chosen for the study. Damage investigations concerning the causes of faults such as visible damage were not included.

The methods used to characterise the SBS depended upon the number of occupants. In larger buildings, with more than 20 occupants, in most cases a standardised questionnaire was used to assess the scope of complaints before and after the remedial measures.

The MM Questionnaires [1] developed at Department of Occupational and Environmental Medicine, Örebro University Hospital were used in this case. The occupants in the building answered how they had perceived the environment and if they had health symptoms which they associated with staying in the building.

The question about the indoor environment was: -Have you been bothered during the last three months by any of the following factors at your work place? The question included the following factors: draught, room temperature, stuffy "bad" air, dry air, and unpleasant odour (see figure 1).

The question about the symptoms was: -During the last three months have you had any of the following symptoms? The question included the following factors: fatigue, feeling heavy headed, headache, dizziness, difficulties concentrating, and irritation of the eyes and nose (see figure 2).

One of following three answers could be given: “Yes, often (every week)”, “Yes, sometimes” or “No, never”. The answers were then collated and displayed in graphs according to figure 1 and 2 below.

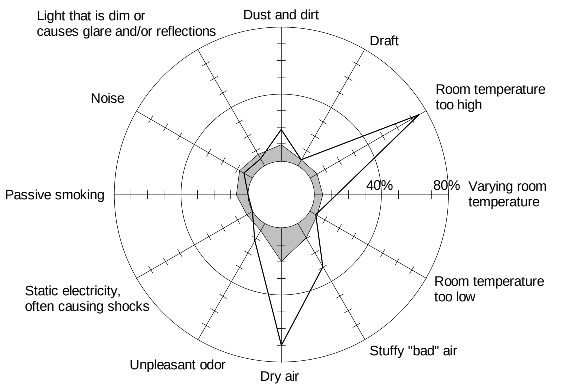

Fig. 1. Example on results of the questionnaire relate to the environment (often bothered) %.

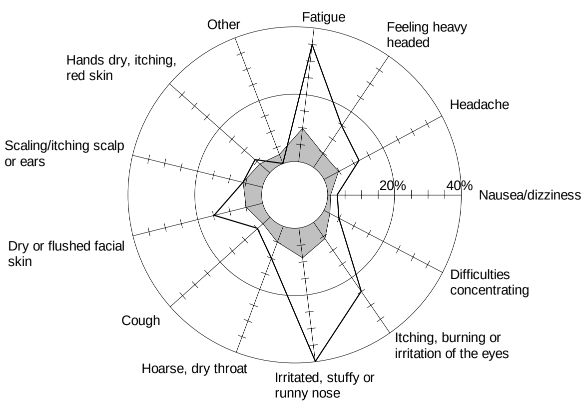

Fig. 2. Example on results of the questionnaire relate to the symptoms (yes, often) %.

The shaded area in figure 1 and 2 represents reference data from non problem buildings.

In smaller buildings and in single family houses SBS was usually characterised by conducting interviews with those who were most affected. Only those cases where the questionnaires or interviews confirmed that the measures had remedied the problems were included in the study.

Another requirement was that the building should have been investigated and the suspected fault or defect identified [3, 4]. In the buildings included in the study, the sources of elevated undesired emissions were in all cases identified [2] and also remedied.

The emissions were of two types:

A. Microbial:
The microbial biomass was measured as total acridine orange stained cells and a viable count [7] from growth of mould and bacteria.

B. Chemical:
The chemical emissions were analyzed through GC-MS technique [5] and were divided into primary and secondary emissions, depending on causal relationship of its production [5].

Primary emissions are emissions of substances present in materials already from their production. Secondary emissions are emissions of substances from materials where chemical reactions or mould growth have created new substances. Here, secondary emissions are defined as secondary chemical emissions only. Secondary emissions from mould growth are characterized as emissions from microbial biomass.

Chemical emissions from building material and/ or constructions were in some cases measured with the emission chamber FLEC (Field and Laboratory Emission Cell) [10]. In some cases simpler methods were used to assess the emission. These were an exsiccator lid applied against the material combined with either an ordinary VOC-sampling over an adsorbent [8] or a gas monitor Brüel&Kjær 1302 [11].

Another requirement for the commissions to be selected was that the extent and type of remedial technical measures should be known.

To sum up, the criteria for the cases selected for the study were that

- the occupants had health symptoms and/or experienced pronounced abnormal odours,
- the building had been thoroughly investigated [3],
- remedial measures had been taken,
- the health situation and also the abnormal odours had improved.

Of the total of 300 cases, 113 satisfied these criteria and were selected for the study. The cases represent a wide range of building technologies. While the buildings are grouped in five categories by field of application, Figure 3, some general similarity in building technology can be seen in each group.

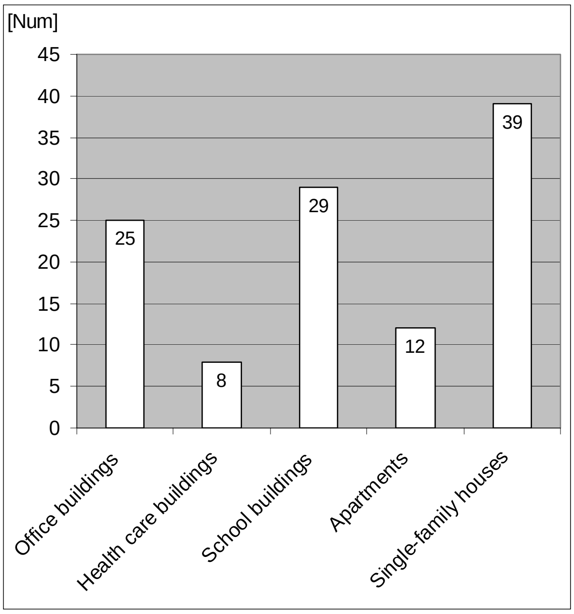

Fig. 3. Number of selected building breakdown in five categories.

Office, healthcare and apartment buildings are dominated by multi-storey buildings with frames and intermediate floors of concrete, with the floor finish consisting of flooring bonded to the concrete. Few of these have ventilated crawl space foundations; most have basement storeys. The school buildings comprised in the study, including nursery schools, was built with frames of concrete or timber. Among these buildings, some have foundations in the form of slabs on the ground; some had ventilated crawl spaces and some basement storeys. The building technology for single family houses was dominated by timber frames with different types of foundations.

Among the cases of damage which satisfied the criteria for the study, an endeavour was made to judge whether the occupants mentioned only complaints/symptoms or only abnormal odours, or both of these. However, this is not clear from the material in all cases. Many of the buildings comprised in the study are single family houses where the complaints referred to odours. If there were any health problems, these were often not discussed, since the investigator was an engineer and not a doctor. For some other buildings in the study also, health problems, if any, were not clarified, only generally mentioned. If an abnormal odour was also complained of, the investigator looked into this. The commission was then concluded when, after some time, it was reported that all problems had been remedied. There was in such cases some uncertainty if, apart from odour problems, there had also been occupants who associated health symptoms with working or living in these buildings.

In Figure 4, the principal complaints mentioned by the occupants have been summarised as ”Only SBS” or ”Abnormal odour”. SBS refers to cases where the occupants complained of some of the symptoms characterised as the Sick Building Syndrome [1]. In the group of buildings characterised as ”Abnormal odour”, the principal problem had been abnormal odour. According to the observation made above, in this group there may also have been health symptoms.

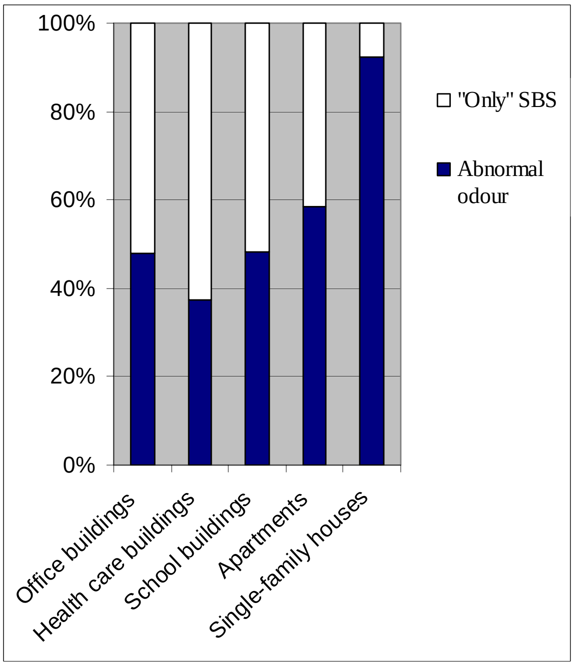

Fig. 4. Breakdown of the principal complaints in the five building categories.

As seen in Figure 4, not many of those living in single family houses stated that health problems were the principal cause of their complaints. This need not mean that there had been no health symptoms. This compilation shows only that the documents relating to these cases do not say whether there had been another reason apart from an abnormal odour for the indoor environment investigation and remedial measures.

4 Results

The main cause of the problems, in 75 % of the selected cases, was microbial growth [6]. This was followed by damage due to secondary emissions [5] in 17 % of the cases. These two damage types are mainly caused by harmful moisture (Figure 5).

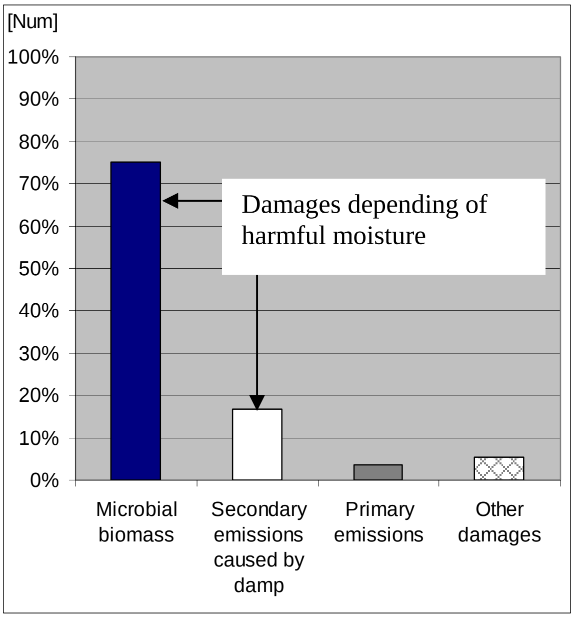

Fig. 5. Breakdown of emission sources for all cases in the study.

In six of the cases more than one dominant cause has been identified. In this compilation, only the cause regarded as the most significant has been included.

Figure 5 gives the percentage breakdown of damage types for the different building categories. It was considered that a breakdown based on percentages would present a more realistic idea of the breakdown, since the number of buildings in the categories varies (Figure 3). It must however be noted that there are only a few buildings in the categories ”Health Care Centres” and ”Apartments”, 8 and 12 buildings respectively, and the breakdown of damage types for these is therefore not as representative as for the other categories which comprise 25, 29 and 39 buildings respectively.

As can be seen in Figure 6, the differences in the types of damage between the building categories were due to differences in building construction.

The largest single cause of damage in all categories was microbial growth. For the single family houses this applied to almost 100 % of the cases and for school buildings in 80 % of the cases.

The next largest cause of damage was secondary emissions. For all categories except single family houses, this damage was the most dominant in 20-40 % of cases in the study.

The breakdown of the principal damaged components in the different building categories is set out in Figure 7.

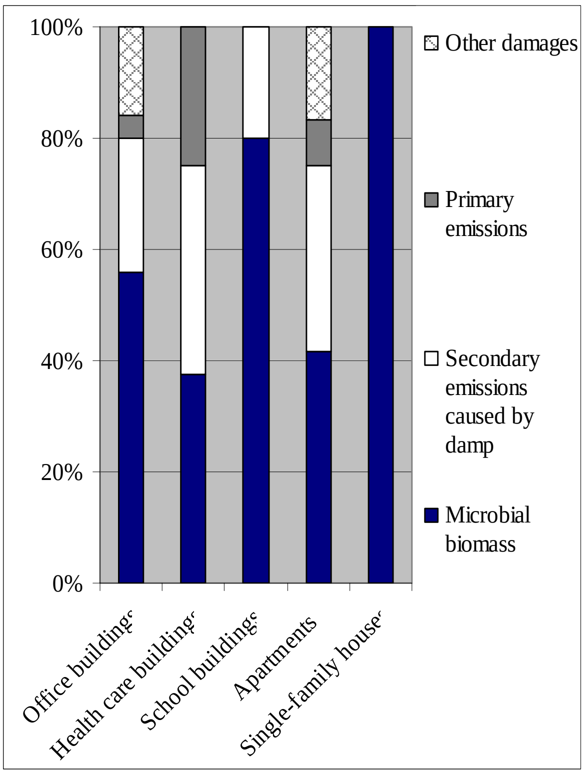

Fig. 6. Breakdown of the emission sources in the five building categories.

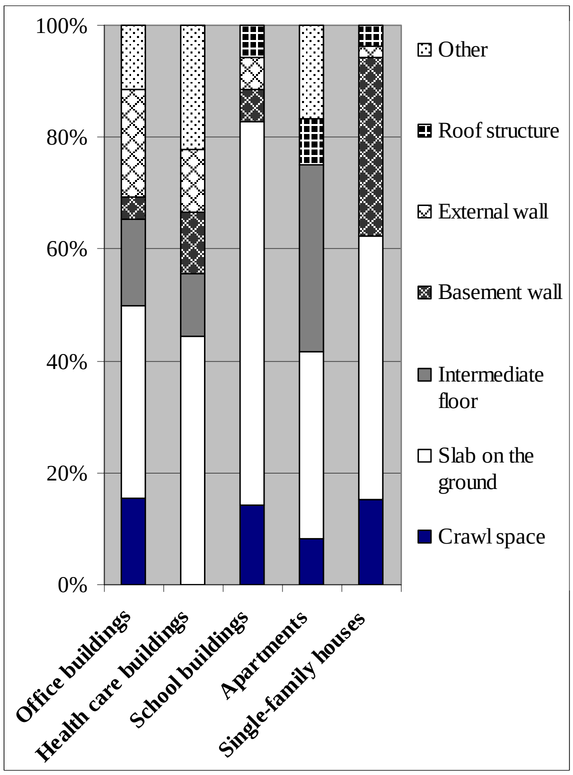

Fig. 7. Breakdown of the damaged components in the different building categories.

Most of the damage, in 50 % of the selected cases, was due to the foundation being constructed as a slab on the ground. Damage to the floor construction, represented by this, the crawl spaces and the intermediate floors, was seen in 82 % of the total number of cases.

5 General building technological faults

In all the cases of damage included in the study, some significant general building technological faults can be identified.

Slab on the ground with thermal insulation on top

The common cause of damage to floor constructions with a slab on the ground is harmful moisture. In cases where mould growth was found, organic material such as timber had been laid directly on the concrete slab which was moist over an extended period. Since the thermal insulation was placed on top of the concrete slab, the temperature difference between the concrete slab and the underlying ground was small. After some time, this caused moisture from the ground to migrate upwards due to vapour pressure equalisation. Where the drainage system had been faultily constructed, there was also capillary moisture migration. Soil moisture in combination with organic material was therefore the cause of microbial growth. The source of emission in these cases was microorganisms deep in the wooden floor construction which was laid on top of the concrete slab.

Concrete slab with bonded floorings

In those cases where damage of the type secondary emissions occurred, flooring had been bonded to the moist concrete slab. In cases where damage occurred in a foundation with a slab on the ground, the thermal insulation had been laid on the bottom side of the concrete slab, which protected the slab from moisture migration from the ground. However, these concrete slabs and/or the screed, in the same way as in the case of damage to intermediate floors, were not allowed to dry out sufficiently before the flooring was bonded to the concrete. The cause of damage was therefore excess building moisture in combination with bonded impervious flooring materials. In these cases, the emission source was the glue and/or the degradation of the flooring which caused increased chemical emission.

Crawl spaces

In the case of damage to crawl spaces, the common cause was excessive humidity over an extended period. Generally, the cause was that the crawl spaces which had cooled down during the winter months were ventilated with warm air with natural high absolute moisture content during the summer months. This gave rise to such high levels of humidity that organic material, mainly on the bottom side of the floor construction, was attacked by microorganisms.

Other faults

In older buildings problems were found in crawl spaces after renovation, when the original natural ventilation in the building was replaced by mechanical extract ventilation. In these cases, far too much contaminated air entered the building via the crawl space which had been free of problems prior to renovation.

Damage to the external walls of basements with internal thermal insulation is due to moisture and microbial problems similar to those in slabs on the ground with insulation laid on the top.

The cause of damage which was dominant in external walls and roof constructions was in most cases increased moisture content due to precipitation.

Apart from these general faults, the cases of damage represent a large number of different causes.

6 Conclusion

To sum up, this study shows that it was possible to identify and remedy faults in buildings where the occupants associated health problems of the SBS type with living or working in these buildings.

The endeavour had been to use correct methods of measurement to find damaged material which was suspected of causing abnormal emissions into the indoor environment, instead of trying to measure technical parameters in the indoor air and try to couple them with threshold limit values for bad health.

These emission sources could be identified by comparing a moisture history perspective with the occupants’ perceptions in time and space. Generally, the remedial strategy was to reduce or eliminate emissions to the indoor environment from the damage considered to be most significant.

It appears that the most important parameter in creating buildings free from emission sources that have a deleterious effect on health is to concentrate on effective moisture exclusion during design and construction.

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