Toxic Mould Remediation and Testing – Experiences from Scandinavia

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Summary: This paper starts with a short explanation of how sick buildings and mould were, brought to the focus of the general public in 1993. The media have played a major role in publicizing problems with damp and run-down buildings. Due to this massive media bombardment the general public in Denmark is, compared to the rest of Europe, well aware that damp buildings are not good for your health! Several new ideas regarding mould removal without chemicals and rapid testing techniques have been invented during this period.

Keywords: Background of mould events in Denmark, Mould removal without chemicals, testing.

1 Introduction
In recent years there has been growing awareness and concern over the very serious health problems that can be caused by mould in buildings. Occupants and even casual users of affected buildings may typically suffer headaches, fatigue, and sickness as a direct result of the toxins and particulates produced by mould. Although it has long been accepted that habitation in damp and mouldy buildings is generally undesirable and ‘sick building syndrome’ (particularly in relation to modern office buildings) has been under discussion for some time, significant problems specifically associated with the presence of mould in buildings first came to general public attention in Scandinavia during the 1990’s. American public interest in the subject then arose and, unsurprisingly, legal actions involving massive claims followed there. Professional Indemnity Insurers in the UK have now started warning their clients about the risks associated with mould and imposing exclusions in cover.

2 PROBLEMS AND REMEDIES
“Mould - the new asbestos?” has been typical of many recent headlines in the US and the UK. The same type of headline first hit Denmark back in 1992, when I was involved in the investigation of a school building with suspected ‘indoor air’ problems. Pupils, teachers, and even the cleaners who spent relatively little time there, were complaining of a variety of health problems whilst in the building. The building was a single-storey structure with a flat roof, comprising eight large classrooms, toilets and boiler room, etc., and had been built by the local Council in 1972.

A multi-disciplinary team including a building engineer, a heating and ventilation consultant, a doctor, and led by Danish microbiologist Suzanne Graversen, was assembled to investigate the reasons for the reported ill health of the occupants.

At first sight this looked to us much like any other well-maintained school building awaiting the start of a new academic year. Over the previous summer holiday period, the local Council had commissioned internal refurbishment and redecoration works, furniture had been replaced, and linoleum flooring had been laid throughout the building in place of wall-to-wall carpeting.

During the initial superficial visual inspections, the only things that I noted as being unusual were a “musty” smell in certain areas of the building (otherwise fresh with the smell of new paint, linoleum, etc.) and a few seemingly minor defects in the felt roofing. If there was something within the building causing its occupants to become sick, it was well hidden. Dampness and mould were naturally suspected as potential causes, amongst other possible factors, but neither was evident at the outset of our investigations.

Interviews with janitors, local Council staff, teachers, pupils and others using the building were carried out to assemble data, including the incidence of sickness and the history of building maintenance, which might be useful in identifying possible causes. These interviews revealed a history of poor or non-existent maintenance of the building fabric by the local
Council. Complaints of sickness from teachers, pupils, and others at the school had been made over several years. Such complaints had periodically resulted in visual inspections of the premises being made by the Council but, invariably, no defects had been evident and no remedial action was taken.

Many people complaining of ill effects were simply moved from the subject building to other parts of the school premises. The majority of these people then found that their symptoms such as headaches, itchy skin, rashes, tiredness and breathing difficulties seemed to disappear.

People with asthmatic problems found that their need for medication declined after being moved away from the building, and their general well-being increased.

Whilst this anecdotal information was being gathered, my team of building specialists concentrated on identifying and investigating areas of the building that might be at significant risk of moisture-related problems.

Non-destructive investigations were carried out first, using moisture meters and electronic probe type moisture meters. This work provided the following findings:

- Most of the non-load bearing partition walls between classrooms and toilet areas, built of timber studwork and gypsum plasterboard, were found to be damp from floor level up to about 1.5m height.
- The felt roofing was scanned and found to be damp, especially in areas around rooflights and joints.
- The new linoleum flooring was also scanned and found to be damp, mainly around the toilet areas.

On the basis of these findings we started destructive investigations, including the removal of finishes to expose the building structure and underlying fabric, to find the extent and origin of the moisture problems.

Mould (mainly Stachybotrys chartarum) was found growing on most of the wet gypsum plasterboard and on the underlying timber stud walling. Other mould types, including Aspergillus versicolor and Trichoderma viride, were found growing under the linoleum and within the roof construction behind timber rooflights.

The investigations revealed several reasons for this mould growth in the building, including:

- Drainage (combined system) of insufficient capacity under the building, leading to overflow and flooding within the structure during periods of heavy rain.
- Leaks in the felt roofing.
- Damaged and leaking water service and heating pipes. As was common in Denmark at the time, the Architect’s original design had included many water and drain pipes concealed within internal partitions and ducts built of timber framing and plasterboard. This approach might be aesthetically pleasing but, consequently, minor leaks are unlikely to be detected early on and extensive damage may occur before such defects become evident.

The results of our combined building and health investigations provided clear evidence to the local Council that the school building was in need of extensive renovation work. This presented several difficulties for them, such as accommodating staff and pupils elsewhere in time for the start of the new school year, how best to remedy the building defects, and whether poor maintenance or other factors had caused or contributed to these problems. In due course, the remediation of the defects included extensive demolition and removal of mould-affected parts of the structure, and subsequent partial reconstruction of the building.

The Danish media, including national television and newspapers, took an interest in the unfolding events at the school, especially due to the fact that the local Council involved was well known as having the lowest council tax levels in Denmark. Due mainly to the massive press coverage that followed, the Danish population at large were made aware that there is a definite link between “sick buildings” with mould growth, and the health of those who use them!

Further cases and investigations of similar ‘hidden’ mould causing ill health in a number of school buildings soon followed. This was no doubt due to the dawning realisation amongst the public that a cause had been identified in this first well-publicised case that was probably common to others.

The next large case in which I was involved concerned a large social housing estate, located on the outskirts of Copenhagen, of 628 terraced houses, together with a kindergarten, supermarket, etc., on site. The estate was built in the 1960’s using non-traditional methods, as an experimental ‘rapid building’ system. Rather than construct more multi-storey apartment blocks that were typical of the period, the idea was to build affordable terraced houses each with a small garden courtyard and, by doing so, create a greater sense of community than that found in high-rise projects.

Again, most occupants of this estate were experiencing significant and chronic ill health with the symptoms now becoming typically associated
with sick buildings and mould growth in the indoor environment.

Our initial investigation of five houses chosen at random revealed, within each, extensive hidden mould growth in the roof construction and in the crawl space under the suspended timber ground floor, together with visible mould in the bathroom, on the badly insulated outer walling, and behind cupboards, beds and sofas.

Our subsequent report, based on non-destructive and destructive testing throughout these five houses, predicted that all of the 628 terraced houses would have mould problems of similar nature and extent because of the repetitive design and construction techniques. Subsequent investigation of other houses on the estate proved this assertion to be correct.

An investigation by Danish Public Health Authorities into the health of the inhabitants was then carried out. This reported a much higher-than-normal asthmatic tendency in the tenants, the majority of whom also had allergic reactions and other health problems attributable to mould growth in the indoor climate. It was clear that the inhabitants were suffering ill health as a direct result of living in badly designed housing which allowed extensive mould growth.

The press again reported extensively on this case throughout 1996-7, and the building owners and the local authority were forced into taking the drastic step of demolishing approximately 80% of the house structures, together with the estate shops and the kindergarten. Only the foundations and a small part of the concrete shell were re-used.

The eventual remediation cost for this project exceeded £100,000 per house. This should be compared with the initial construction cost in 1966 of only £6,000 per house.

The huge cost of demolition and rebuilding work, necessary to remove the mould, on the two aforementioned projects led indirectly to the invention of the simple yet extremely effective microclean® mould removal technique that uses only superheated steam. This is now an industry-standard method throughout Scandinavia and extensively patented worldwide.

2 Testing Mould

There are essentially two approaches in use today for assessing the growth of mould on building surfaces. The first approach is based on the cultivation of viable mould collected from a given surface, whilst the second involves determining the biomass of live mould actually present on a surface.

The first approach of testing by cultivation of mould collected from building surfaces has been widely used in Scandinavia; however it is, in fact, unsuitable for the quantification of fungi. The reason is that these cultivation methods were originally used for the quantification of bacteria, which are unicellular organisms i.e. one bacteria forms one colony. Fungi are multicellular organisms consisting of 95-100% mycelia and 0-5% spores. While one fungal spore (one cell) gives rise to one colony, a mycelium leads to one colony even though it consists of tens of thousands of cells. Cultivation methods, therefore, dramatically underestimate the amount of fungi present. Thus these methods have been shown to be merely a measurement of sporulation.

The initial mould tests available in Denmark in the 90`s, such as rodac contact or pressure plates combined with air testing devices, were very limited in their application and not at all suitable for use in building investigations. The typical first reaction of clients on seeing the results of these tests, which normally comprise a long list of unpronounceable Latin names of mould genus and species, was one of panic! When then confronted with an explanation that not all the mould types mentioned in the report were actually growing on the inspected building surface, but only on culture plates that had been carefully nurtured in an oven to encourage the growth of spores, there was a mood change to one of total confusion! Headlines such as “Killer mould Stachybotrys chartarum found in School” were frequent, and totally misleading.

These expensive and time-consuming testing methods are seldom used today because it is now realised that being able to identify the particular species of mould present in a building is, under normal circumstances, largely irrelevant, although this can be done in special cases by DNA analysis. There are several thousand species of mould, and no information is available about the possible ill-health effects for humans of the vast majority of them. A few species are commonly found in buildings where indoor climate problems have been identified, but there may be many that are potentially harmful. It is safe, and not over-cautious, to assume that any significant mould growth may pose a health risk to building occupants. All live mould and dead biomass must be removed.

It is also important to appreciate that mould spores are ever-present, and that low level ‘background’ mould presence is normal and generally not harmful to our health. Therefore, rather than harvesting and deliberately cultivating any viable spores, money and
time are far better spent in properly identifying whether mould growth in situ is raised above normal background levels and, if so, identifying its full extent and cause(s) to facilitate effective eradication of the mould and remediation of the damaged building.

The second approach to mould testing, that of simply estimating the mould biomass, has been developed in the economical and rapid Mycometer Test method that is widely used in Denmark today. This test has been produced by Dr. Morten Reeslev and Dr. Morten Miller, who are both researchers from the Department of General Microbiology at the University of Copenhagen, in response to the demand from Building Surveyors for a quick and reliable mould testing method that can be performed on site. The test is rapid, taking approximately 30 minutes from sampling to result, and can be used on site. Alternatively, test swabs can be sent to a laboratory technician to be analysed.

The reason for estimating mould biomass on building surfaces is to help detect sources of fungal growth and heavy accumulation of fungal spores. The presence of fungal growth is related to the amount of mould biomass present, irrespective of the species/genus of the mould present. It is not possible to directly measure the amount of mould biomass present on a building material as fungi may grow inside porous and semi-porous materials making separation of fungal biomass from the substrate impossible. Therefore methods to indirectly estimate the fungal biomass are necessary. The Mycometer Test is based on the detection and quantification of an enzyme that is present in both mycelium and spores of all moulds. The enzyme activity is measured using a highly sensitive fluorescence technology. The fluorescence signal is proportional to the amount of mould present on the tested sample or surface.

The natural background level of mould on clean surfaces in well-maintained buildings has been determined using the Mycometer Test. Test results from areas under investigation are compared with these ‘baseline’ values, to determine whether there is a mould growth problem. Raised values would normally indicate that cleaning and remediation measures were necessary. The effectiveness of mould removal and cleaning can be checked by using the Mycometer test at completion. Properly cleaned surfaces should result in baseline values.

The Mycometer test has been documented in publications in peer-reviewed scientific journals. The patented method is commonly used throughout Scandinavia, Europe and U.S.A.

3 Removing Mould

Experts in the field of indoor climate assessment agree that, typically 70% of mould growth in buildings is hidden from view, often in floor voids, roof voids, behind dry-linings, etc. Mould growth seen during a superficial visual inspection is often merely the “tip of the iceberg”. It is not sufficient to treat only this visible mould because, of course, hidden mould also gives off the toxins that cause health problems. It is essential to identify and expose the full extent of any mould outbreak.

The treatment of mould in buildings throughout Scandinavia was, until relatively recently, typically undertaken in the ‘traditional’ manner involving either the physical removal of mould-affected elements or by using a range of chemicals sprayed onto affected surfaces to kill the live mould. Removal of defective elements and, at worst, demolition are clearly very expensive options, as discussed above. The alternative approach of using chemical treatment has been proved to be ineffective because it removes neither the live mould nor the dead biomass which is left behind, and which can be just as prejudicial to the indoor climate as live mould. It is also not an ‘environmentally friendly’ technique, something which has been a concern for many years in Scandinavia and which is gaining ground in the rest of Europe and the USA.

Both approaches have been recently superseded by the micro clean® mould removal method. The micro clean® method was invented by Consulting Engineers in Denmark in 1994 specifically in response to the need for a better, environmentally friendly treatment. It utilises only tap water with no chemical additives whatsoever throughout the removal process. Apart from its sound environmental basis, it has two more very significant benefits over the traditional chemical treatment:

• It not only kills the live mould but also removes the resulting dead biomass.
• It uses only thermal energy from high-pressure steam to kill the live mould. Chemical treatments carry the risk of further pollution of the indoor climate through both fumes and residues left on treated surfaces.

4 Typical Case Procedure

Public awareness in Scandinavian countries of sick buildings and detrimental health problems due to mould growth is much higher than most other countries. Many cases here start when people recognise visible mould growth or connect their health problems with the possibility of hidden mould within their house, workplace, etc.
A Specialist Building Surveyor with experience in dealing with indoor climate problems would be contacted. Following the initial superficial inspection, and where necessary, the building fabric would be opened-up and insulation, etc., removed so that the full extent of any mould could be seen and, of equal importance, the cause of mould growth identified.

At this stage, the affected parts of the building need to be sealed to prevent transmission of spores to other areas.

The Surveyor’s report would normally contain:
- Identified reason(s) for mould growth
- Assessment of the extent of the problem
- An initial estimate of the areas of mould growth to be removed
- Detailed plan of remedial action

Remediation should then start under strict expert supervision. Firstly, the cause(s) of mould growth (e.g. leaking pipes, condensation, faulty design or detailing of the building fabric, etc.) must be remedied, and the structure allowed to dry out.

Samples of suspected mould growth may, if necessary, be taken and analysed. The Mycometer test, as described above, is normally used.

Mould removal then starts. The micro clean® removal process itself begins with thorough vacuum cleaning (with HEPA filtration) of all affected surfaces to remove loose material, spores, dust and dirt etc.

The micro clean® superheated steam cleaning system is then used to kill and remove the mould from the treated surface. The process, using different cleaning heads for different surfaces, is being continuously developed to encompass all types of construction surfaces and joints. The specially designed cleaning heads range from scrubbing heads to cotton cloths, which are used to remove the dead biomass. The amount of steam required for cleaning is so small that the local level of humidity will revert to normal within 24 hours without the need for special dehumidifying measures.

Lastly, vacuum cleaning (with HEPA filtration) is repeated.

The effectiveness of the micro clean® process is always internally Quality Assured after completion by repeated testing of the cleaned surface using the Mycometer technique. A Quality Assurance report is then sent to the client. Mould testing can also be undertaken by the Specialist Building Surveyor, so that the client has an ‘independent’ quality control as well as the aforementioned internal control.

The micro clean® method of dry steam cleaning can be used on all types of hard surfaces, for example:
- All types of wood and chipboard
- Concrete and other cellular blocks
- Steel
- Brickwork
- Tiles
- Plaster
- Painted and polished surfaces

A proper appraisal of the suitability of a particular surface needs to be done before treatment. The system cannot be used on insulation or textiles that, if affected by mould, must be removed from site.

5 Summary

Mould spores are present all around us and, at ordinary background concentration levels, are not normally prejudicial to human health. Design or construction defects in buildings, usually involving damp problems, may allow significant mould growth to occur. Such mould growth within buildings is likely to cause ill-health effects in occupants. The mould may be visible or hidden.

Our preferred approach is to identify the full extent of any significant mould growth within buildings, to remedy the causal defect, and to kill and remove the live and dead biomass. Except in special cases, it is not necessary to identify the species of mould – we treat all mould as potentially harmful to health. The rapid Mycometer test is normally used to assess the degree of mould problems and, subsequently, to check the effectiveness of mould removal. The industry-standard micro clean® method is used as an economical, non-destructive technique for killing and removal of mould avoiding the use of chemicals and the need for renewal of affected building structure or fabric.