AGENCE DE LA SANTÉ
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Evaluation by international experts of the methods used by the Direction de santé publique to assess the health impacts of water damaged buildings

Proceedings of the audit held in April 2013

Québec

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Evaluation by international experts of the methods used by the Direction de santé publique to assess the health impacts of water damaged buildings is a production of the Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal.

1301, rue Sherbrooke Est
Montréal (Québec) H2L 1M3
514 528-2400
dsp.santemontreal.qc.ca

Participating international experts (by alphabetic order)

Harriet Ammann, toxicology and public health, Department of environmental and occupational health sciences, School of public health, University of Washington

Scott Armour, environmental health and industrial hygiene, remediation of water and mold damaged buildings, Institute of Inspection, Restoration, and Cleaning Certification (IICRC)

Tony Colantonio, Architecture, building science and infrared thermography, Public Works Canada

Jean Cox-Ganser, Epidemiology, National Institute for Occupational Safety and Health, USA

Anne Hyvarinen, environmental health and microbiology, Department of environmental health, National institute for health and welfare, Finland

Eckardt Johanning, environmental and occupational medicine, Fungal Research Group Foundation, Columbia University

Philip Morey, environmental hygiene and microbiology, ENVIRON International Corporation

Team of the Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal

Louis Jacques[1,2,3,4], Noémie Savard[1,3], Yves Frenette[1,3], Stéphane Perron[1,2,3], Stéfanie Gauthier[1,3], Geneviève Hamelin[1]

[1] Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal
[2] Clinic in Occupational and Environmental Medicine
[3] Montreal University
[4] McGill University

Dr. Louis Drouin, head of the Urban environment and health sector, Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal and Norman King, assistant to Dr. Drouin

Traduction

Anne-Marie Mesa, certified translator

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MOT DU DIRECTEUR

Chronic water damage in buildings and the resulting contamination of structures by mould is a major public health concern. The Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal (DSP de Montréal) has been actively intervening on this problem for several years now in collaboration with multiple partners. Due to the complexity of issues involved in assessing the health impacts of a mould contaminated building, building assessment and risk evaluation, remediation and prevention the DSP decided to organize a two day international audit with expert panelists from the United States, Canada and Finland in order to evaluate the methods used and the recommendations made by the DSP and its partners. The current proceedings present the content and conclusions of the discussions that took place during the two days and end with a series of consensus statements aimed at guiding future interventions in this field. I would like to warmly thank the personnel of the DSP who organized and took part in the audit and the seven expert panelists without whom such an event could not have taken place. We would also like to thank the ministère de la Santé et des Services sociaux du Québec (MSSS) for its generous financial support which greatly facilitated the organization of this event.

Richard Massé

EXECUTIVE SUMMARY

On the 25th and 26th of April 2013, experts from various backgrounds and countries were convened in Montréal, Québec, Canada, to discuss and evaluate the methods used and recommendations made by the Urban environment and health sector of the Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal (DSP de Montréal) regarding health impacts of chronic water damage in buildings. This was deemed necessary due to the existence of important differences of opinion among the various professionals involved concerning the methods which should be used for the investigation of this problem, the interpretation of the data and the recommendations made to address building and health issues.

The objectives of this two day session were to evaluate the methods used and the recommendations made by the DSP de Montréal regarding health impacts of chronic water damage in buildings and to make recommendations aimed at improving the following aspects:

1) Evaluation of water damaged buildings and the health of building occupants;
2) Interpretation of data and the conclusions drawn from the investigations;
3) Recommendations made;
4) Evaluation of the effectiveness of the remediation.

A panel of seven scientists selected according to their background and expertise in the fields of interest was invited to review the methods and the recommendations made by the DSP de Montréal. Professionals from the health, municipal and education sectors as well as consultants working in this area of water damage in buildings were invited to participate in this two day meeting. After a general overview of the problem given by Dr. Louis Jacques of the DSP de Montréal, real cases of schools (2) and apartment buildings (2) affected by chronic water damage were selected for the discussion by the panelists. Each discussion was followed by a general discussion open to all participants.

The state of a building can have an impact on health, and the health effects of chronic water infiltration are well recognized. There are several sources of moisture within a building and water infiltration that is not caught and fixed within 24-48 hours can lead to excessive growth and amplification of mold and other microorganisms. A variety of microbial fragments and products, and not only spores, are associated with health effects which include respiratory problems (irritant, allergic and other types of reactions) and effects on other systems and will vary according to the type and extent of exposure and a host of individual factors (age, atopy, etc.).

Building investigation relies on an integrated approach where many elements (history, observations including visual inspection of the inside of the building and the exterior envelope, various tests, health assessment of occupants) are taken together to allow evaluating risk and proposing remediation actions.

There are many useful tools that should be part of any building investigation. The most important is a moisture meter (humidity detector) which is used to identify humid material, to confirm the findings of infrared thermography, and to point the areas for intrusive inspections.

An infrared thermographic camera detects temperature differences across a relatively large surface area. The reason it can assist in detecting moisture is that evaporation at the surface of a moist material results in cooling of that surface. However, it is an instrument requiring specialized training and experience.

Intrusive inspections, that is opening in the structures (wall, ceiling or floor …), from the inside or outside, where present or past water damage or excess humidity are suspected, should be performed more systematically and early to confirm or exclude the presence of a contamination, to identify its source and to guide the remediation. Hence, intrusive inspections are necessary when there has been chronic water infiltration. Bulk or surface sampling, and opening of the structures in the case of a wall problem, all come before air sampling.

Air sampling is a complex issue and is often not recommended because the results are difficult to interpret. There is no established quantitative relationship between health effects and air sampling results. This being said, there are certain specific situations where air sampling could be part of a building investigation, and if air sampling is to be done, care must be taken with the methods, analysis, and interpretation. Finally, experts warn against reaching conclusions based on air sampling results alone, and place much greater importance on the overall building assessment for evidence of dampness and microbial contamination as well as the health assessment of the occupants.

Health assessment is another tool that can complete a building investigation. At the clinical level this is complex and requires experience, due to the variety of associated pathologies, the non-specificity of many symptoms, and the complexity of medical tests and interpretations. At the group level, using standardized and validated health questionnaires is a common and recognized approach both in research and intervention. Although there may be biases in health questionnaire results, the health effects of damp environments are well recognized, and actions should be undertaken whether there are health effects or not – their presence only making the situation more unacceptable. The use of clinical and epidemiologic data and follow-up at the clinical and group levels, as is often done by the DSP de Montréal, provides a combination of data that improves the health assessment.

When designing a remedial solution, one must first think of what caused the water damage in the first place. If the condition causing water intrusion is still present, one has not solved the problem; and if one does not solve the water problem, it does not matter how well the cleaning is done, as the mold will come back.

The guiding principle of all remediation efforts is removal of the contaminated material. All molds must be removed, whether they are active, dormant, or dead, and whether they are visible from within the occupied spaces or concealed in a cavity. Clean-up is also a key factor, because remediation strategies create a lot of particles and dust that can affect health. It is therefore important to insure appropriate dust suppression and containment during remediation to avoid contamination of occupied areas.

The decision to completely remove, clean, or otherwise control contaminated structural building elements will depend on the type of material, the structural integrity of the contaminated elements and whether the mold growth is accessible for removal or cleaning. Encapsulation is only used in exceptional circumstances after one has gone out of one's way to clean the material first, in order to contain the fine dust that cannot be controlled otherwise. It must be followed by monitoring and other options must be adopted if it fails.

Removal of occupants from the milieu is primarily a medical decision that could apply to one or some individuals, or a whole group. Affected people should be further evaluated by a physician and removed from the environment or relocated as needed. This could involve a contaminated environment requiring major works or temporary removal from an area undergoing decontamination or adjacent to such an area.

The best way to guarantee the success of a remediation process is to do the required work properly and clean up well. Assessment of the effectiveness of the remediation process involves visual assessment of what was done. There must also be a written protocol for decontamination, a check list so that the contractor knows what to deliver, a paper trail of what was done and implementation of strict and clear quality control and quality assurance measures. Air sampling is typically not recommended for assessment of remediation unless it is part of a research program or required in exceptional situations such as a hospital. In this latter case, it should be done one to two weeks after the HVAC system has been running normally. Finally, medical follow-up is also important in order to assure that health effects have resolved subsequent to remediation or affected people have received proper medical care and treatments.

During the closing discussion, the panelists generally felt that the DSP de Montréal approach follows most basic principles recommended by existing expert organizations, from investigation of the building, to health assessment and recommendations to protect public health. The panelists also raised the following points:

- It is important to address moisture problems; acting early can prevent health problems;
- Structural damage is costly but the human cost related to indoor air quality is probably higher. The net benefits of dealing with moisture problems are a more durable building, increased productivity and prevention of disease and lower health costs;
- If you see a problem, fix it. Don't approach the problem by saying «The contamination can't be removed» but «it must be removed». If not possible, examine the possibility of using other options;
- Rely on building assessment, evidence of dampness and microbial contamination, and building science, not air sampling unless there are very good reasons and know how to interpret results. Air sampling should not be done for evaluation of remediation, except in special circumstances;
- Communication is important, both among experts and authorities and with building occupants and those with health concerns or complaints. Problem solving requires collaboration and negotiation;
- Verify a consultant's knowledge and work methods. Methods and conclusions should be presented with consensus-based references. If the consultant does not want to discuss and explain methods, interpretations and conclusions, change consultants. Quality control for work done by a consultant is important; a check list can be helpful.

A series of statements was drawn up based on the cases presented, the discussion held over the two days of the audit and the scientific literature. These statements represent a consensus reached by scientific experts that should be used to guide future actions in the field.

CONTENTS

INTRODUCTION

On the 25th and 26th of April 2013, experts from various backgrounds and countries were convened in Montréal, Québec, Canada, to discuss and evaluate the methods used and recommendations made by the Urban environment and health sector of the DSP de Montréal regarding health impacts of chronic water damage in buildings. This document contains the proceedings of this two day meeting. It is a summary of the discussions and the consensus reached with the experts. It is hoped that this document will serve to improve the way these problems are addressed in Montréal and elsewhere.

Origin of the meeting

Water damage in apartment buildings, schools, day care centers, hospitals and other types of building is a major concern because of its frequency, its impact on health and the sustainability of buildings and the costs involved in repairs. Chronic water damage in these buildings is mainly caused by lack of maintenance but poor design and construction methods also contribute to the problem.

Over the past years, the Urban environment and health sector of the DSP de Montréal carried out hundreds of epidemiological investigations which involve the environmental evaluation of water damaged buildings, the assessment of associated health impacts and the elaboration of public health advisories. These advisories can include recommendations aimed at carrying out or implementing:

- Further investigations to identify the source of the problem;
- Corrective measures to eliminate water infiltration and to control other sources of dampness;
- Decontamination measures;
- Relocation of susceptible individuals or all occupants as required.

We have observed important differences of opinion among the various professionals involved concerning the methods which should be used for the investigation of this problem, the interpretation of the data and the recommendations made to address the building and health issues. This has prompted the organization of this meeting.

Objectives of the meeting

The objectives of this two day session were to evaluate the methods used and the recommendations made by the DSP de Montréal and its partners regarding health impacts of chronic water damage in buildings and to make recommendations aimed at improving the following aspects:

1) Evaluation of water damaged buildings and the health of building occupants;
2) Interpretation of data and the conclusions drawn from the investigations;

3) Recommendations made;
4) Evaluation of the effectiveness of the remediation.

The consensus reached will thereafter be communicated to public and private organizations involved and to the public.

The process

A panel of scientists from three countries was invited to review the methods and the recommendations made by the DSP de Montréal regarding this issue. The experts were selected according to the fields of expertise needed to cover the various aspects to be discussed, including the evaluation of the building and the health of the occupants as well as the remediation process. The experts were individually selected based on their background and publications or identified by their organization as representative of the domain of expertise needed.

The organisations in Montréal and the province of Québec directly involved in the issues discussed were also invited to participate in the discussions. These include administrators and professionals from different organizations (public health, municipal, school board, housing authority) and private consultants from the Montréal region.

Real cases of school (2) and apartment buildings (2) affected by chronic water damage were selected for the discussion. In total, four cases were discussed, followed by a general discussion.

Prior to the meeting, experts received documentation in English concerning the evaluation of these buildings and their occupants' health and the remediation process.

During the meeting, a general overview of the problem was first presented by Dr. Louis Jacques of the DSP de Montréal. Then, for each case, professionals from the DSP de Montréal first presented the data to the audience, with photos and a summary of the results of the building investigations, the health surveys and the remediation process. Two schools were presented and discussed during the first day, and two apartment buildings during the second. Additional information was given when needed by professionals from the organizations involved (School board, municipal inspectors, private consultant …). For each case, a discussion with the experts followed, according to the questions raised and the most relevant issues which were selected before the meeting by the DSP de Montréal. A period of questions from the audience was allowed after the discussion with the experts, for each case. Finally, the experts were invited to present their general comments and recommendations at the end of the meeting.

The time frame did not allow the experts to visit and inspect the buildings, nor to review the medical files and the completed health questionnaires of the many hundreds of persons evaluated.

All the discussions were recorded and a transcript was produced based on the recordings and the notes taken by two professionals during the meeting. A first draft was produced by Noémie Savard, a 4th year resident in Public health and preventive medicine. It was reviewed and completed by the professionals of the DSP de Montréal before it was circulated to all invited experts, and then revised according to their comments.

Overview of the problem by Louis Jacques, MD, MOH, CSPQ, FRCPC

Lack of maintenance but also poor design and poor construction are the main causes of chronic water damage in buildings. Lack of maintenance of flat roofs is especially important. Other sources of water infiltration and dampness come from the building envelope, plumbing, windows and foundations.

The proportion of buildings affected by water damage is high, varying from 10% to 50% according to the World Health Organization (WHO), depending on the country and the methods of measure used (WHO, 2009). It is estimated to be around 50% in USA (Mudarri, 2007). Approximately 40% of residences in Montréal are estimated be affected by some water damage, dampness or molds, but the proportion varies significantly depending on the borough from roughly 30% to more than 50% (Jacques, 2011).

In Europe, the proportion of schools affected by water damage varies from 20% to nearly 50% depending on the country and the method used (Haverinen-Shaughnessy, 2012; Simoni, 2011). In USA, water damage in schools is the main cause of IAQ complaints notified to the National Institute for Occupational Safety and Health (NIOSH) (CDC NIOSH). The Center of Green Schools has estimated that it would cost more than 270 billion dollars just to get public elementary and secondary school buildings back to their original conditions and twice that amount to get them up to date (Center for Green Schools, 2013).

A report of the Québec's acting auditor general in 2012, regarding primary schools in Québec, concluded that risk factors related to IAQ, including the envelope of the building and its maintenance, are poorly mastered by the school boards undergoing verification (Vérificateur général du Québec, 2012). The Montréal School Board (one of the five School Boards in the Montréal region and the largest School Board in the Province of Québec) owns and operates about 220 public primary and secondary schools and has estimated that it would cost about 1,6 billion dollars to restore these buildings because of their dilapidated state (CSDM, 2012). In recent years, many schools have been investigated in Montréal and some have been closed because of health effects caused by water damage and mold growth affecting the majority of the occupants.

The public health impacts of water damage in public and private buildings are very important and considered a priority by many countries in America and abroad. Many reports have been published by various groups of experts around the world in the last 15 years or so (see the list in the references under *Main health reports since late 1990*). These show that there are many and important health effects caused by water damage, molds and other bio aerosols associated with dampness. These include a long list of diseases affecting the upper and lower respiratory tract and many other systems, reduced performance among personnel, learning difficulties among students and direct and indirect mental health effects, all affecting a significant proportion of children and adults, students and personnel in the whole population. The persistence of exposure to these contaminants can also lead to chronic diseases.

According to recently published reviews in the scientific literature (Fisk, 2010, 2007; Jaakkola, 2013; Mendell, 2011; Quansah, 2012), there is sufficient evidence of an association between indoor dampness-related factors and a wide range of health effects affecting the respiratory tract and other systems, including development and exacerbation of asthma (including ever asthma, current asthma, uncontrolled, severe and persistent asthma), upper and lower respiratory tract infections, lethal fungal infections among immunocompromised patients, allergic rhinitis and chronic rhinosinusitis, respiratory symptoms such as cough, wheeze and dyspnea, hypersensitivity pneumonitis, and eczema. There are many other associated health effects for which there are fewer studies published in the scientific literature but for which a physiopathological basis does exist, including chronic fatigue and diffuse chronic pain (Brewer, 2013; Chester, 2003; Dennis, 2009; Gray, 2003; Husman, 1996; Johanning, 1996 & 1999), neurocognitive complaints and neurological effects (Anyanwu, 2003; Crago, 2003; Campbell, 2003 & 2004; Empting, 2009; Karunasena, 2010; Kilburn, 2003 & 2009), inflammatory arthritis and autoimmune diseases (Bengtsson, 2005; Campbell, 2004; Hirvonen, 1999; Luosujärvi, 2003; Myllykangas-Luosujärvi, 2002; Roponen, 2001), eye problems (conjunctivitis, infections and others) (Gray, 2003; Mendell, 2011), various dermatitis, ear problems (otitis, vertigo and others) (Derebery, 2000, 2000A), aggravation of chronic pulmonary disease, obstructive sleep apnea syndrome (Koinis-Mitchell, 2012; Redline, 1999; Singh, 2013), digestive problems and environmental hypersensitivity. This list is not complete but it shows the diversity of effects associated with the diversity of contaminants produced in a water damaged building.

In a meta-analysis, researchers have estimated that 21% (95% confidence interval: 12-29%) of asthma cases among children and adults in USA would be attributable to this problem and that the annual costs associated with this disease alone are 3,5 billion dollars (95% confidence interval: $2.1–4.8 billion) (Mudarri, 2007). They also estimated that the proportion of respiratory infections attributable to this problem range from 9-20% according to the types of respiratory infections and populations considered (children or adults) (Fisk, 2010). Among children living in Montréal, aged from 6 months to 12 years old, it was estimated that 17% of active asthma cases, 26% of upper and lower respiratory tract infections and 14% of winter allergic rhinitis could be attributable to this problem (Jacques, 2013). These numbers are probably underestimated for various reasons and only take into account exposure at home.

Despite the evidence accumulated in the literature as to the importance of this public health problem and its cost for the society, and despite documents written by groups of experts describing how this problem should be dealt with, the experience in the field has shown that there is wide variation in the way these problems are addressed, that the problem is often denied or poorly managed, leading to persistence of exposure to these contaminants in the residential setting as well as in the public buildings. The principles of evaluation and remediation in this field are poorly mastered or respected, creating much discussion and conflict, delayed actions, persistent health problems and increased complexity in the intervention. The costs are obviously the major obstacle to remediation.

The DSP de Montréal has often been involved in these discussions and has had to justify the methods used to assess the problem, the conclusions drawn and the recommendations made. Arguments against our methods, conclusions and recommendations include the following: there are wide variations in the way the problem is addressed, among various experts; the science is said to be controversial, the DSP de Montréal has a very different approach compared with Public Health Departments of other regions in terms of methods of assessment and recommendations to protect the public; why intervene if nobody or very few persons have officially complained; why intervene if the mold counts are low; why intervene if mold growth is not visible; some stating that only a minority of the occupants can be affected (the most vulnerable or most susceptible); the symptoms and health problems can be caused by many other factors, and some arguing that it is not possible to determine which factors are really responsible; we cannot reconstruct the buildings; there are no other buildings for relocation anyway.

Issues selected for discussion

Based on our public health practice and the points raised by the preceding overview, the DSP de Montréal selected for discussion at the meeting some of the most controversial or relevant issues which can be summarized as follows:

- The health risk assessment associated with water damage, dampness, and molds should be based on a set of data, including the history of the building (present and past water damage, repeated water infiltrations), actions taken, the inspection of the building, the measures of humidity, the health complaints and identification of sentinel cases, the critical analysis of sampling results and the health evaluation based on clinical cases and epidemiological surveys;
- The health risk assessment should not be based solely on the results of air sampling;
- The necessity to act promptly in case of flooding or other water accidents and the necessity to proceed to remediation without delay once water infiltrations and dampness are observed, without the need to rely on air tests or proof of health effects;
- The importance of a thorough inspection of the exterior and interior of the building in relation to water damage and dampness;
- The use of infrared thermography and a humidity detector, as a basic and fundamental step in the evaluation of the problem;
- The relevance to look for hidden mold growth and its contribution to health effects;
- The indications of intrusive inspections and the interpretation of observations;
- The indications of air and surface sampling for molds, the importance of good sampling strategies and the interpretation of data according to the AIHA, ACGIH and New York City guidelines;
- The wide range of contaminants associated with dampness, and the wide range of health effects, based on the relevant scientific literature;
- The relevance of health data, from clinical cases and epidemiological surveys, before and after remediation, and the methods available and recommended to assess health;
- The indications and criteria for relocation of individuals affected by mold growth and dampness, versus the relocation of all the occupants of a building;
- The methods of remediation and decontamination, especially in the following cases: large surfaces of contamination, hidden molds, attic, masonry, stone, concrete blocks, wood block construction, and the use of blasting, biocides, mechanical ventilation;
- The need to follow-up the health of individuals and the whole group when needed, to assess the effectiveness of remediation.

This situation has led to the organization of the meeting where experts in the various aspects of the problem were invited to discuss and evaluate these issues, using four typical cases related to schools and apartment buildings.

A note to the reader

The following sections constitute a narrative of the two-day discussion that took place during the audit. The panel discussion was based on several things: the review of case documents, the presentation material by the DSP de Montréal and questions from the audience members. The expert panel had limited time during the symposium to thoroughly address all the issues and concerns. Therefore, some of the discussion was incomplete. The narrative cannot identify those issues, nor does the narrative attempt to add or expand on those issues that were cut short by time and require more in-depth discussion.

However, the consensus points have been reviewed by the panel and all agreed that they accurately reflect the general approach to mold and moisture in buildings. These statements should not be considered absolute, as situations and conditions are indeed case-specific and responses and approaches can be modified to meet the needs of the particular occupants, building factors, and available resources.

Following this narrative, a series of statements is presented starting on page 31. These statements which are based on the cases presented, the discussion held over the two days of the audit and the scientific literature represent a consensus reached by scientific experts that should be used to guide future actions in the field in the following areas: health aspects, building evaluation and risk assessment, remediation and prevention.

Two schools (school A and school B) and two apartment buildings (building C and building D) affected by chronic water damage were selected for the meeting. These were investigated and followed during a period varying from approximately two years to more than ten years. A document containing the description of each case, with summary tables is annexed to this final document.

Reference to the examples that were discussed during the audit is presented in italics.

FROM BUILDING TO HEALTH

General approach

The literature shows that chronic water infiltrations are associated with health problems. The primary association that has been clearly documented is between dampness and health effects (IOM, 2004; Fisk, 2007; WHO, 2009; Mendell, 2011). As cited by Fisk (2007), "The Institute of Medicine (IOM) of the National Academies of Science (of the United States) concluded that "excessive indoor dampness is a public health problem" and noted that dampness problems are common, and require corrective actions." Water itself is not the agent directly causing health problems, but it promotes growth and amplification of microorganisms, including molds (IOM, 2004, Fisk, 2007, WHO, 2009; Mendell, 2011; Quansah, 2012). Molds themselves release various products in the environment, many of which have been shown to affect health. However, it is not necessary to identify the causal agents before taking action (Hill, 1965). A building with chronic water damage is considered a public health problem, and public health recommendations are that repairs be done. This approach is exemplified in Finland's Protocol for Health Housing and the New York City Department of Health Guidelines.

Furthermore, health risk assessment is based on exposure assessment. The presence of exposure is sufficient to act and there is no need to wait for symptoms. A condition that may bring health effects, such as water damage and mold contamination should be corrected before the appearance of these health effects. *In School A, for instance, the exposure is very probable, and this alone suffices to trigger action. One may also have decided to take a sample of the building structure. With a positive sample, and knowing that there is air leakage, then we know there is potential exposure, and air sampling is not necessary before taking remedial actions.*

The objectives of building investigation for water damage and mold contamination are twofold: we don't want the building to self-compost and collapse, and we want to avoid health problems. Ultimately however, buildings are there for people, and the role of public health department and agencies is to protect the health of the occupants.

From building deficiency to water damage and mold growth

From a building perspective, it is important to understand the sources of moisture and water damage. Moisture can come from water leaks and infiltrations. Water infiltration that is not caught and fixed within 24-48h can lead to mold growth. Moisture can also come from wintertime condensation, including the moisture that the occupants breathe out and from natural disasters. Moist air can also come from the outside in the summertime. The use of ventilation affects the moisture conditions. For instance, turning off ventilation when the building is unoccupied – such as during summer vacation in a school – may create a humid environment that promotes mold growth. In such a case, the recommendation would be to leave the ventilation or air conditioning on in order to keep the relative humidity or the equilibrium relative humidity in room materials from consistently exceeding 70%. (Morey, 2011; ACGIH, 1999)

From water damage and mold growth to production of microbial components

We consider health effects regardless of the condition or activity of the mold – active, dormant, or dead – or the current condition of humidity. It is not only growing mold that can affect health; the history of moisture, water damage, water penetration and related mold growth in the building are also important. For instance, Stachybotrys releases fragments when it is dry and it is disturbed, whereas it does not tend to aerosolize when it is alive and wet (Sorenson, 1987).

Molds produce spores that can have very variable half-lives according to the species. For instance, many *Penicillium* and *Aspergillus* species remain culturable for 5 to 10 years, whereas *Cladosporium* and *Stachybotrys* remain culturable for less than a year (AIHA Field Guide, 2005).

It is not only spores that should be taken into account when considering health effects. Research shows more and more that health effects come from small microbial fragments and other small particles (fine particles). Microbial fragments, that is, very small pieces of fungi and bacteria, are often more numerous than spores (Gorny, 2002 & 2004; Cho, 2005; Reponen, 2007). Fragments of spores and mycelia can have allergenic properties and can carry irritants and mycotoxins. In addition, when thinking of fine particles, one should not only think of fragments in the air, but also of dusts, on which mold products are deposited. Fragments and other small particles are also important because, being smaller than spores, they have a larger total surface area per mass, which allows for greater absorption of other air contaminants; their small size then allows them to be carried to parts of the lungs where clearance mechanisms are not efficient.

Exotoxins are to be considered as well. In the environment, molds typically grow in a mixed milieu, and produce exotoxins (or mycotoxins) as they are fighting against other microorganisms for survival. They stop producing exotoxins when they are in a single culture. ß-1,3-glucans, another mold product, have irritant properties. In a mouse model, exposure to ß-1,3-glucan and mycotoxin concentrations found in damp building led to mucus production and inflammatory cytokine increase, through a non-allergic mechanism (Miller, 2010; Rylander, 1999). Molds produce other compounds, such as microbial volatile organic compounds (MVOCs) and ergosterols, but what abnormal levels would be is not known – but neither are they known for glucans and toxins. Bacteria also live in damp environments, but again, what constitutes abnormal levels of gram-negative and gram-positive bacteria is not known.

In summary, what constitutes "safe" levels of exposure to mycotoxins, ergosterols, β-D-glucans, MVOCs, enzymes and other microbial products has not been determined, because individual susceptibility varies widely especially with respect to allergic agents, and the necessary long-term studies of critical effects of low level exposures are not available (IOM, 2004; Rao, 2005; WHO, 2009). The general recommendation is therefore to keep exposure levels as low as possible in indoor spaces.

From production of microbial components to exposure

Exposure to microbial components depends on where the mold contamination is, and whether the air from that space can contaminate the air of occupied spaces. This in turns depends on pressure differentials and on the presence of openings allowing air to go through. It has been shown that spores from mold growth in wall cavities can enter and degrade indoor air (Morey et al, 2003; Miller et al, 2000). Very small pressure differences (6-20 Pascals) have been shown to move particles in the respirable size fraction through cracks in walls, floors and ceilings (WHO, 2009). *Such considerations may be relevant when mold is found in cavities, for instance in the wall cavity in School B, and in non-occupied spaces such as School A's attic and School B's crawl space.*

Air movement can be caused simply by wind pressure against a building, which create positive pressure inside the wall and drives the air into the occupied space. Such a situation was found in a California dormitory, where one side was exposed to both wind and rain. The rain caused water infiltration problems and contamination with *Penicillium* and *Aspergillus* in the wall, and the wind pressure was sufficient to drive the contaminated air into the rooms. The rooms on the other side of the building had little or no growth in the wall cavity and exhibited mold profiles similar to the outdoors. In general, there is probably a high correlation between openings in walls and air leakage from wall cavity to occupied areas, and moisture deposition, water accumulation, and mold contamination.

Temperature changes can also cause air movement through the building. For instance, when the air in the building cools down, it contracts and air moves in. There are also air movements up and down. Mechanical ventilation also influences air pressure and movement. For instance, in a California school (previously mentioned), where there was as much mold as in the dormitory, the air conditioning created positive pressure so that the spores were not coming out of the wall cavity into the occupied area.

From exposure to health effects

The health effects have not often been related to environmental measures of spores, fragments, or measures of various suspected agents, primarily due to the inability of current short term measurement techniques to determine continuing or long-term exposure. It is also important to note that what is breathed in is a complex mixture whose individual and combined effects have not been determined. Notably, for rhinosinusitis and asthma, there are both allergic and irritant mechanisms. Irritative reactions are thought to be more dose dependent, whereas allergic reactions depend more on the individual and on the level of sensitization. Furthermore, the effects on the immune system can be both allergic (IgE-and non-IgE mediated) and non-allergic (Mendell, 2011).

Susceptibility to the various suspect agents varies widely. Exposed individuals have different ages, detoxification systems, immune systems, behaviors, breathing patterns, and genetic components, such that health effects can vary for a similar exposure. In addition, there may be interactions with other contaminants in the environment. Therefore, no blanket statement can be made relative to the health effect of a given level of exposure to molds for a whole population. As the saying goes: “The dose plus the host makes the poison”.

BUILDING INVESTIGATION

General approach

Building investigation relies on an integrated approach where many elements (history, observations, and tests) are taken together to allow evaluating risk and proposing remediation actions. Experts warn against reaching conclusions based on air sampling results alone, and place much greater importance on the overall building assessment for evidence of dampness and microbial contamination.

History taking is very important. To properly investigate a building, one must gather knowledge about the building's activities, sources of past and present water infiltration and moisture, maintenance, and remediation actions that have been undertaken in the past. This involves bringing in all the people who have the best knowledge of the building, such as the custodian, the janitor and, in the case of a school, the school board and school staff.

Visual inspection is also important, to identify both signs of potential or actual water damage and mold growth. Visible mold is not only mold that can be seen when being in a room. Concealed mold may be visible, although inside a cavity, for instance a wall cavity. As Terry Brennan, a building scientist who worked on the New-York guidelines, puts it, visible refers also to **"**what is visible to rats, bats, and cockroaches." Visible mold means visible to the naked eye, not microscopic. Only when millions of mold cells are aggregated in a colony does mold become visible. Hence, intrusive inspections are necessary when there has been chronic water infiltration. *In School B, mold was found inside the wall cavity of room 130; however, damage to the envelope appears to be consistent for the whole building, and what was found in this room is likely to be found elsewhere. Therefore, that which prompted intrusive inspections in this room should lead to similar investigations in other rooms.* As for odor, it indicates that there is active growth, because it is the result of metabolism. "If it smells, it's living" (however, the absence of mold odor does not exclude the presence of mold).

To distinguish between mold and dust, a simple test would be to apply transparent tape to the surface and then observe this tape under a microscope (AIHA Field Guide, 2005). Surface and bulk sampling can also be performed, to identify spores and, if there is growth, hyphae and fruit bodies. Before sampling, however, one needs to know what is normal and abnormal, and needs to assess whether the results will help the decision making. For instance, if there is clear mold contamination, negative results on sampling may be considered as false negative and may not provide useful information.

In addition to visual inspection, infrared thermography and moisture meter can be used to help identify likely areas of dampness and mold growth. Air sampling is often performed in building investigation to assess mold contamination, although interpretation of the result is often difficult. Finally, health assessment of the occupant is important in completing a building investigation. These three elements are further discussed.

Moisture detection - Special techniques

An infrared thermographic camera detects temperature differences. The reason it can assist in detecting moisture is that evaporation at the surface of a moist material results in cooling of that surface. Therefore, any material that does not allow water to evaporate through it will not allow a thermographic camera to detect moisture behind it. Furthermore, moisture and evaporation are transient phenomena. In order for interior evaporative cooling to exist, the absolute environmental humidity is required to be substantially lower than the humidity level within the wet surface areas being observed. Infrared inspections are not recommended in interior environments greater than 70% relative humidity. A thermographic camera can only identify current moisture, and cannot detect past water infiltration or recurrent water problems that are not presently ongoing. Neither can it detect mold. The technology is good when it is used at the right time and the right place.

Infrared cameras have a number of specifications, including spatial and thermal resolution. Thermal resolution is the most critical specification. Most cameras have a resolution under 100mK, medium range cameras are between 60-80mK, and better cameras are at 25 mK. Better thermal resolution allows for better detection of differences in evaporation cooling, so it is recommended to use a camera with the best resolution possible.

A correct methodology was exemplified in the School B case. The infrared camera was used to identify colder areas on the walls and ceiling of the rooms that were investigated, where water infiltration was possible or suspected. The shape and location of the colder areas influence the probability that they reflect a humid area, as opposed to other phenomena such as thermal bridges. Results were then confirmed with a moisture meter, as they always should be to differentiate between thermal bridges and evaporative cooling due to the presence of humidity. The assessment was done during the spring, when there is an abundance of moisture in the walls and the roof, and when there is thermal transfer between the outside and inside. It is a good time to use thermography, when moisture is likely to be present. Doing it, for instance, in the middle of June when everything is dry, one would have likely not found anything.

A thermographic camera can usually detect moisture from the inside of a building all year round, because of the effect of evaporative cooling on the surface. Detecting moisture problems from the outside may be more difficult, particularly when it is cold, although it is feasible given the right conditions. If there is moisture in the wall assembly, it can be detected in the wintertime since there will still be differences in the thermal resistance value between the wet and dry material – although the difference will depend on the type of material (and provided that the material is not frozen). Wet insulation, for instance, has a much lower thermal resistance value; thermography should be able to pick it up both from the inside and outside in the wintertime. For outside, however, one would have to do it at night, once the solar heat gain has dissipated from the cladding. This could take 8 hours for masonry, but less for wood. Thermography is also useful on the roof to assess the presence of moisture in the insulation, which is likely eventually to percolate and affect the rest of the building.

Not everyone gives the same importance to thermography. Some consultants will identify the most likely locations of moisture problem and where to do intrusive inspection without placing much emphasis on thermography. On the other hand, professionals from certain sectors such as insurance companies and restoration firms may also use infrared thermography, to determine when the structure is dry. The usefulness of thermography depends on the business needs.

A moisture meter (humidity detector) is used to identify humid material and to confirm the findings of infrared thermography. The moisture meter should not be used to test surfaces indiscriminately. Rather, part of the moisture evaluation is first to assess where the greatest potential for high moisture (and mold growth) is, and to test there with the moisture meter.

The correct way to use a moisture meter was exemplified in the School B case. The readings should be interpreted relative to the normal background humidity level found in the same material when dry. Areas of high humidity were identified where the humidity level was higher than the level in the same material elsewhere in the room. One should not rely on the absolute humidity number for interpretation. As for the scale used, it modifies the sensitivity of the detector, and different scales are typically suggested on the meter for different materials. However, any scale can be used for a given material, to facilitate differentiation between humid and dry area: interpretation of the results remain valid irrespective of the scale.

The initial result of the humidity assessment should be interpreted as either normal (background humidity) or abnormal. One then needs to inspect further and look at the state of the material. If the humidity level is normal, the components stay in good shape; if abnormal, there may be destruction of the material – for instance, moisture content in the high 20s will lead to destruction of wood – and there is a probability that mold will grow as well. However, there is no set number that we can put on a single humidity measurement that will be associated with mold growth, notably because water problems are cyclical. Furthermore, negative readings do not mean that the material has not been affected in the past and that there is no mold present or currently growing. [1]

Air sampling

Air sampling for mold spore detection is often done in building investigations, or often asked for. Air sampling was done in all cases presented, sometimes on multiple occasions and by different consultants[2]. Yet, air sampling is generally not recommended, or recommended only in specific situations, after other factors are taken into account. More specifically, NIOSH recommends not relying on air samples, particularly short term air samples, for assessing the possibility of health effects. In Finland's Protocol for Healthy Housing, air sampling is only a late measure, if used at all. Before getting to air sampling, if there is water damage, it should be repaired. Bulk or surface sampling, or opening of the structures in the case of a wall problem, come before air sampling. Air sampling is only a last resort measure, such as if occupants are reporting health problems and no visible problem is found.

Air sampling is often not recommended because the results are difficult to interpret due to several factors including background sources (outdoors, etc.). There is no established

[1] A small increase of the level of humidity on the surface of gypsum board can be sufficient to promote mold growth.

[2] In the experience of the Montreal Public Health Department, air sampling for mold spores is often asked for and done as the first or only step of building investigations by consultants.

quantitative relationship between health effects and air sampling results. A numerical guideline for what is normal had been produced in the past by the ACGIH, but it has been retracted since. To use numerical guidelines today is to be out of touch with the literature, and it is not currently accepted. The ACGIH withdrew the numerical value because small volume, short term sampling cannot be representative of the mold contamination of a building. Multiple environmental factors, as well as the cyclical biological activity of the mold itself, create important variability in the air spore concentrations. For instance, a study concluded that in order to statistically estimate the air spore contamination of a building, one would have to repeat sampling on 11 different occasions. Similarly, investigation in a building showed huge variation in the spore concentration, going from 30,000 colony-forming units per meter-cube (CFU/m^3) to <1000 CFU/m^3 within a few weeks.

If air sampling is to be done, care must be taken with the methods, analysis, and interpretation. Before sampling, one needs to assess whether the results will help decision making. One needs to use other observations and techniques, and needs to know what is happening to the building, including the presence of symptoms in the occupants. Sometimes (if not often, considering information from history, visual and intrusive inspection, and health) one will know enough that sampling is not required. If one sees visible mold, there is no need to sample (New York City, Department of health, 2008). *In School A, for instance, much of the air sampling was not necessary, since enough information was known on the potential exposure. Still, every sample indicated that there was an actual or potential problem, and that one ought to do more in the building.*

Before sampling, one also needs to define the question that will be answered by the sampling. This will allow choosing the proper sampling methodology. The specifics of the methodology will depend on what environment one wants to characterize, and under what conditions – so the environment needs to be defined before it can be characterized with air sampling. For instance, windows can be open if we want normal living conditions, or closed if we want accumulation. Typically, sampling would be done during normal activity, without waiting for everyone to be gone, but without stopping and stirring up the dust either. It is important to remember, however, that in order to find the signature of the building, one would need to know its variability – and that itself would require research. As for sampling volumes and other technical specifications, they are detailed in the ACGIH guidelines. Roughly, volumes around 200 liters for culture and 150 liters for spore trap are recommended (ACGIH, 1999).

Laboratory analysis of air samples should be done up to the species, as was done, for instance, in Building C. To interpret the results, one should look at the predominant species, not at the numbers of CFUs themselves, and compare that with outdoor air species (ACGIH, 1999).

The outdoor air sample should be taken to represent the outdoor ambient air that has an impact on indoor air quality (ex.: on the roof facing into the wind or at the heating, ventilation and air-conditioning inlet or in a space where the outside air, along with its contaminants, enters the building). Taking it in dusty streets or a bush, for instance, should be avoided (ACGIH, 1999). Comparison can be done with rank order assessment: listing what are the most numerous taxa indoors and outdoors and comparing the two. *For example, when interpreting the sample from apartments Building D, the importance is not that the indoor samples are similar in numbers to outside concentrations, it is that they differ in types of molds present. Similarly, in Building C's pre-remediation sample, indoor air differed from outdoor air: there was a high level of yeast* *which indicates a moist environment, and Penicillium species were present in a profile that is clearly abnormal. On the other hand, the Cladosporium species from the post-remediation samples appeared normal and similar inside and outside.* A good discussion of post remediation sampling is found in ACGIH, 1999, Chapter 15.5 (Judging remediation effectiveness).

One should also look at indicator species, knowing what is typical and atypical for indoor air – there are existing guidelines for this. *In Building D, the Stachybotrys species and some of the Aspergillus species should not normally be in indoor air.*

It is important also to mention that if a sample is negative, the results may be inconclusive. One cannot necessarily infer that the situation is normal or acceptable from one negative sample (or a set of negative samples), especially when there are other indications that a problem exists. This also applies in a clinical context, when a clinician tries to infer causal relationship between a suspected exposure and a diagnosis. If a patient has symptoms thought to be related to mold contamination of the building and sampling results are positive, then interpretation is relatively easy. However, if the sampling results are negative, these results might be inconclusive and more investigation could be necessary, especially when there are other indications that a problem exists.

In any case, interpretation of air samples often remains difficult. Only with a good hypothesis can sampling results be interpreted. A good discussion of this subject can be found in chapter 5 of ACGIH, 1999. Furthermore, the person who knows the building should interpret the data, not the laboratory that has not seen the building. In the cases discussed, different people have drawn different conclusions on the same data. Even experts may disagree on the interpretation of some samples. *For instance, for the post-remediation sample of apartments Building C, the expert panel disagreed on the interpretation, some considering it as typical and comparable to outdoor air, some considering that one of the Aspergillus species was abnormal*[3]. Therefore, if there is disagreement between panel experts, it is easy to imagine that there would be disagreement elsewhere – hence the warning against relying solely on an air sample to draw conclusions.

Finally, spore sampling does not take into account other mold products or microbial contaminants that have or may have an effect on health, such as fragments, ergosterols, proteins (ex.: enzymes), MVOCs, ß-1,3-glucans, toxins, and contaminants from gram positive and gram negative bacteria. This reiterates the fact that a negative spore count might not preclude health effects. However, measuring these various contaminants in the context of a building investigation would not be useful, since we would not know what the results mean. On the other hand, they could be measured in research to develop knowledge, which highlights the importance of distinguishing between research objectives and building investigation objectives. Of note, although MVOCs can be used for other indoor air problems, there is an agreement that they should not be used currently for mold detection.

[3] Air tests were done by different consultants and the MPHD. The last air tests done by the MPHD after remediation showed the presence of 29 different species, of which 16 were absent in outdoor air, despite all windows opened during the weekend before the air sampled. These results clearly show an indoor mold amplification

Apartments Building C provides an example of how measuring contaminants without a basis for interpretation does not provide useful information. One of the reports mentions that "bacteria and particles should be addressed rather than dormant mold." However, measurements seem to have been done with a particle counter only, and there is no notion of what types of bacteria are being referred to. We know that bacteria grow in humid environment, but pathogenic bacteria are rare in such huge numbers in the air. At any rate, this is not something for which we have good documentation or foundation for measurement. The significance of these results is not clear.

To conclude, air sampling is often not recommended in the context of building investigation, because of the high inter-measurement variability and the difficulty in interpretation. If one is to do air sampling, one cannot usually do it only once, and one cannot rely on that alone. Furthermore, air samples are costly. "They are the most expensive way of getting the least amount of information. If you see it, smell it, you have it."

Health assessment

Although health risk assessment is based on exposure assessment – that is, exposure to a mold contaminated environment is sufficient to trigger remedial action whether symptoms have been reported or not – health assessment remains an important part of a building investigation. Buildings may initially come to the attention of Public Health Departments because occupants have developed health problems. Importance should be given to such sentinel cases, as they often seem to be the tip of the iceberg: when one investigates, one will tend to find many other occupants with symptoms. Furthermore, the most specific estimate of the health effects of an environment remains the report of these health effects.

The questionnaire-based approach used in Montreal to assess the occupants' symptoms is not unusual, as experts in several countries have used a similar approach. Symptoms reporting, especially respiratory symptoms, is quite sensitive and specific. For example, Laney and colleagues (2009) reported that pulmonary function test results supported reports of respiratory symptoms and diagnoses. Although it is recognized that health questionnaires have some biases, these can be reduced or taken into account to some extent, for instance by comparing results to population surveys or to a control building, or by including questions about symptoms not thought to be related to mold contamination, in order to pick up any systematic answering pattern[4]. Repetition of questionnaires is useful to assess evolution of symptoms over time, in which case the same standardized questionnaire should be used. Standardized questionnaires would also allow compiling data from different building investigations.

Information from the clinical follow up of patients may also be integrated in the health assessment of a building's occupants, as is often done at the DSP of Montreal. The questionnaire-based approach could also be improved by following up on parameters such as peak flow or pulmonary function studies, and implementing intervention studies. In a research

[4] In the experience of the DSP de Montréal, it has become very difficult to find a suitable control group given the extent of the problem in the schools for instance; but a control group was available and was used in the first health survey at School A. To our knowledge, there is no set of frequent symptoms not related to mold that can be used.

perspective, tests such as lung function studies, non-specific challenges, and skin-prick test or other measures of exposure markers could also be used in the health assessment.

An epidemiological approach to health assessment does not, however, allow reaching conclusions regarding the causal relationship between exposure and health at the individual level[5]. Establishing causality at the individual level is a clinical matter, with a differential diagnosis approach. A clinician first characterizes the diagnosis and the exposure, and then evaluates the likelihood of a causal relationship. Symptom variation related to removing from, and returning to, the environment usually gives a good indication of causal role of the environment (WHO, 2009; Kercsmar, 2006). These "N of 1" trials (not meant in an epidemiological way), considered as a natural challenge, are well accepted in clinical medicine with randomized drug trials, environmental exposures and animal laboratory assessments of infectious disease (Hodgson, 1993; Janosky, 2005). When caring for individual patients, one also needs to reflect on the level of certainty needed to presume a causal relationship with a given exposure. The threshold might be different from a practitioner point of view than from a policy maker or worker compensation board point of view.

A difficulty with health assessment, from a clinical perspective, is that more than one health problem in the same person can be caused by damp and mold contaminated environments. Notably, mold contamination can cause health problems through both allergic and irritant (non-allergic) mechanisms, both for asthma and rhinosinusitis. Another difficulty is that most symptoms are not specific to these health problems. Fatigue, for instance, is a very common non-specific symptom in many health problems unrelated to mold; however, with unexplained fatigue and living or working in a moldy environment, one may think of mold exposure.

Another difficulty is that although immunoglobulin testing may be used as a marker of exposure – for example, IgE may be followed over time as is done with usual allergens – it cannot form the basis of the diagnosis. Negative immunoglobulin tests carry little information, because IgE or IgG production depends both on the person and on timing relative to exposure. Many allergists do not use immunoglobulin testing anymore. Furthermore, immunoglobulin testing would not detect non-allergic irritant health problems. Non-allergic mechanisms are important even for asthma, which was traditionally thought to be all allergic. For instance, a study of a much damaged office building revealed that post occupancy-onset asthma was associated with less atopy than preoccupancy-onset asthma (Cox-Ganser, 2005). In another study, mice exposed to ß-glucans and mycotoxin concentrations found in damp building had increased mucus and inflammatory cytokine production through non-allergic mechanisms (Miller, 2010). An extensive review of the literature suggests that only 50% of asthma is IgE-mediated and that 50% is non-allergic (Pearce, 1999; Douwes, 2002). The prevalence of IgE-related asthma varies among countries, being higher in more developed than developing countries that have high helminthic infection rates (Moffat, 2010; Weinmayr, 2007). These non-allergic mechanisms may however

[5] The DSP de Montréal may use the questionnaire on a group or individual basis. The questionnaire can be used to produce a portrait of a group, possibly comparing with a control group (use in the epidemiological sense). It can also be used as an individual screening test: the result of each test is classified as probably, or possibly attributable to IAQ problem, or probably unrelated, or undetermined. In our experience, the confirmation test (evaluation by an expert clinician) has shown that probable and possible cases were confirmed in all but rare instances.

not be recognized by work compensation boards: in Quebec, for instance, work-related asthma is presumed to be related to exposure to a sensitizing agent.[6]

Regarding building-related health problems, the term “mass hysteria” (mass psychogenic illness) was often brought up 20 years ago. Some argue that when a building occupant reports a symptom, others start reporting. In the experience of the health experts on the panel, this is not typically the case. Rather, workers do not start reporting until the problem gets severe. Epidemiologically speaking, we cannot say that there is no bias. *However, in cases such as School A, elements suggest that it is not just bias. For instance, symptoms seemed associated with certain areas of the building, not everybody reported symptoms, and people were followed at a medical clinic.*[7] *Furthermore, the exposure at School A was very probable, so bias is really not an issue since actions would have been required even if there were no symptoms.* Besides, it is important to acknowledge that mass psychogenic illness too requires a diagnosis, and that to make a psychological diagnosis, one should do a medical and psychological assessment. In addition, any disease has a psychological component. Losing a home due to mold contamination, for instance, is a traumatic experience, creates stress and fear, and can cause a psychological reaction. Finally, in psychogenic situations there is not necessarily a history of water damage, dampness and visible mold contamination.

To summarize, health assessment at the clinical level is complex and requires experience, due to the variety of pathologies, the non-specificity of many symptoms, and the lack of definitive diagnostic tests. At the group level, using health questionnaires is a common approach. The existence of biases in health questionnaires is acknowledged. However, the health effect of damp environments is well recognized, and actions should be undertaken whether there are symptoms or not – the presence of symptoms only making the situation more unacceptable.

[6] In a study published by Piipari (2005), it was shown that during the period of 1988-1997, occupational asthma caused by moulds was very frequent in Finland (and has become the most frequent cause since 1995) while no compensated case was reported in the Province of Québec.

[7] In fact, those followed at the clinic were diagnosed with illnesses that had nothing to do with mass hysteria or psychological complaints. Many waited a long time (years) before consulting. Mass hysteria has a very different mode of presentation than the cases under study, is a rare event and was never found in the mold cases studied by the DSP of Montreal.

REMEDIATION

General approach

The general principle of remediation is to **remove** the contamination. It must be done in a safe way for the building occupants and workers and in accordance with bylaws and regulations that apply. It may be sometimes impossible (for instance economically or logistically) to remove or clean the contaminated materials: then the question becomes whether the contamination can be controlled. However, when talking about feasibility, one should not approach the problem with the question "can we not remove it?" but rather with the principle that "it must be removed." Only if the contaminated materials cannot be removed, can one start looking at other options. Such a principle is the rule in Finland, where only those kinds of structures that are not removable – which may include concrete or brick walls in certain cases – should be mechanically cleaned. *In School A, for instance, the first option recommended by the DSP de Montréal would have been to replace the contaminated materials. If this could not have been done, an option would have been to verify for mold growth on the materials after cleaning.*[8]

In general, the mold growth and related fragments must be removed, whether they are active, dormant, or dead, and whether they are visible from within the occupied spaces or concealed in a cavity. Both the IICRC S520 Standard and Reference Guide for Professional Mold Remediation and the NYC guidelines state that concealed mold must be addressed. General principles of water damage and remediation guidelines have been recently reviewed by an expert group based on a conference meeting prompted by the Superstorm Sandy in New York and New Jersey (Johanning, 2013).

Clean-up is also a key, because remediation strategies create a lot of particles and dust where the hazard then lies. It is therefore important to insure appropriate dust suppression (Morey, 2011) and containment during remediation to avoid contamination of occupied areas.

When designing a remedial solution, one must also think of what caused the water damage in the first place. If the condition causing water damage is still present, one has not solved the problem; and if one does not solve the water problem, it does not matter how well the cleaning is done, as the mold will come back. *For instance, in Building D, causes of moisture were in part addressed, by changing windows, sealing gaps, stopping leakage of the skylight, and installing fans in the washrooms. However, the skylight shaft can be a continuous source of moisture and contamination, as ventilation in bathrooms can pull air from the shaft and from all other apartments connected to that shaft.*

It is also important to consider the effect of ventilation when planning remedial action. In *School B, there were high CO_2 levels suggesting that the building is poorly ventilated through natural ventilation, and that installation of mechanical ventilation would be required. However, this*

[8] Indeed, this was verified for instance for the stone foundation which was shown to be still contaminated, damp and producing VOC odors after two decontaminations.

change is likely to influence pressure differentials in walls and thus potentially influencing exposure to mold-contaminated air.

Finally, there may be building issues larger than the immediate mold issues: for instance, if the building is not air tight, one will be living with the neighbors' problems. Unless there is major remediation to make the building up to code (which is typically not the area of expertise of the contractor dealing as best as possible with the health issue at hand), one will live with the building one has. Larger building issues are also financial issues.

Surface cleaning

There are many ways to clean a contaminated surface, such as sanding, power brush, or blasting, whose appropriateness depends on the situation. *For instance, in School A, dry ice blasting was used to clean the timbers in the attic*. *Dry ice blasting does a great job at removing contamination, but one can raise the question of whether it was excessive*[9]*. Blasting creates lots of particles that are difficult to clean up afterward. Maybe a cleaning brush would have been enough, although there appears to be no conclusive research favoring one over the other. In Finland, however, the recommendation would have been to remove, rather than to clean, those timbers*.[10]

Of note, HEPA vacuuming alone of a surface, when the contamination is not only deposited on the surface, is not considered cleaning of that surface. As for fungicides, they may lead to other health problems, such as ammonium irritation or sensitization. Applying biocides on growing molds is the worst, since they will start producing more mycotoxins because they are trying to stay alive. In Finland, biocide use indoors is recommended in rare cases only.

Contaminated structural elements and encapsulation

The decision to completely remove, clean, or otherwise control contaminated structural building elements will depend on a number of factors.

Structural 2x10 or 2x12 wood timbers may be contaminated with mold on the surface or mold that has penetrated deeply. There is an important difference between a sap stain (blue stain) mold – mold that runs through the rays where the sap runs – and water damage related mold. If

[9] The video and the inspection showed that the contamination was partly (not completely) removed by dry ice blasting.

[10] Here it is worth quoting the IICRC S520 standard which states the following: «*These techniques should be used with caution, especially those involving abrasive blasting. By definition, abrasive blasting methods have a strong tendency to aerosolize particles they remove from surfaces. This can lead to extremely high levels of contaminants in air, potentially creating unacceptable exposure for workers or occupants, or allowing contaminants to spread into previously unaffected areas. Some media can also create a difficult cleanup problem (e.g., sand, soda, sponge corn husks, and rice hulls) or lead to the development of unacceptable worker exposure (e.g. dry ice blasting in an enclosed space creating excessive levels of* CO_2 *in the work area). Abrasive blasting techniques should be limited to situations in which aerosolization is not a critical factor (e.g., outdoors), or can be adequately controlled (e.g., high-volume, laminar airflow cleaning chambers).*

you have a sap stain only, the wood can still be sound. Although there may be debate in the IICRC as to what wood can be saved, the general idea is that if the wood is solid, not water damaged, and not structurally damaged, it can be saved. There would be many ways to clean it – one possibility would be to sand it – and it would need to be done carefully. On the other hand, rotten wood needs to be removed. However, even if the mold contamination is only on the surface, cleaning would be complicated if there is water and mold between the pieces that are not accessible without taking down the wall, for instance on timbers facing each other. *Such was the case in Building D, where the wood was contaminated on all sides.* In such a case, it would be up to someone such as the environmental hygienist to evaluate whether that inaccessible mold will contaminate occupied spaces. *One option would be to tear down the contaminated structure, as was done partly in Building D; another could be to try and seal it off with zinc oxide, which stops mold growth but does not kill it*[11].

Masonry may also be contaminated with mold. Mold can grow on the surface of bricks, as well as inside hollow blocks. With clean water infiltration only[12], the surface of these materials alone does not provide enough bioload for mold to grow on. However, dirty water infiltration can leave debris for microorganisms to live on. *How to approach remediation of contaminated masonry can be complex, as exemplified by Schools A and B*.

In School B, the wall is made of hollow concrete blocks, in which mold may grow. The first step of the approach is to determine where the water problem can be and the scope of the contamination. The second step is to determine the likelihood of the air from the contaminated area (here, inside the wall, assuming mold growth in the hollow blocks) contaminating the occupied space. Various air movement mechanisms need to be considered, as were described above. Then one can decide on the remediation measures to be taken. The principle of mold remediation remains to remove the contamination. Only if neither removal nor cleaning is possible, one may try other options, depending on the extent of contamination and the likelihood of contaminating occupied spaces. Such options may include partial replacement[13].

School A, with its wall composed of three layers of bricks, represents another challenge, particularly if one was asked to save the wall. Mold can grow on the dust between the brick layers, where it is not accessible. The primary problem of the wall that would need to be fixed is wetness. To dry the wall, one would need to dig up the foundations. An *encapsulant may be used to show which parts of the wall are wet, as these parts will eventually turn darker. Encapsulation*

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[11] Zinc oxide has been used in HVAC systems to prevent future mold growth. Potentially it is useful to prevent future mold growth on other structural materials that can't be removed from the building. Zinc oxide should not be used to cover up mold growth on materials like wall board that can be removed during remediation (Yang, 2004). Since molds do not grow under extreme alkaline conditions it may be useful for preventing future mold growth on materials that are located in chronically damp areas.

[12] In our experience, this is rare, water infiltrations being often recurrent from the roof and other sources.

[13] In School B, recent investigations after the meeting have allowed to better assess the contamination in the exterior walls of the entire building. The walls are made of bricks, air space, concrete hollow blocks, black paper, insulation wool between wood studs and wood finish panel. There are important air spaces between the concrete hollow blocks, partly filled with wood (shim). The back of wood finish panels, the studs, the insulation and the wood filler between the concrete hollow blocks for instance were contaminated by molds in many walls which contributed to contaminate the air in the classrooms. Water infiltration tests showed that the building envelope was pervious to water infiltration in many places. The architect recommended to completely rebuild the exterior walls.

can sometimes prevent aerosolization of dust; isolation of those air spaces may be on the way to protect the rest of the building. In this case, however, it is not so simple considering the three layers of brick. One may also try liming the bricks. During remediation, one would need to ensure that the air does not go elsewhere and does not contaminate occupied spaces, for instance using negative pressure. One would need to continue monitoring regardless of the remediation strategy adopted. In any case, it is important to evaluate what is the risk of exposure following the remediation strategies undertaken. [14]

Encapsulation

Encapsulation may sometimes be used as part of a remediation strategy. *In Building D, for example, there is a structural beam that cannot be removed: it could be a candidate for encapsulation or sealing with zinc oxide.* Before using encapsulation as part of remediation, one needs to think of what kind of encapsulation is considered and why. There is sometimes confusion with the terminology that varies according to the hazard. For instance, with asbestos and lead paint, encapsulation means that the contaminant remains under the encapsulant. It is different with mold, since mold can and should be removed. Encapsulation is used only after one has gone out of one's way to clean the material first, to contain the fine dust that cannot be controlled otherwise. Furthermore, the water problem needs to be fixed first; otherwise, the mold will grow back. In any case, encapsulation certainly does not mean painting over visible mold. (Refer again to footnote no 14)

Contaminated non-occupied spaces

Non-occupied spaces may be contaminated with mold, such as the attic and the crawl space. Whether this contamination will affect the air in the rest of the building depends on the presence of air flow between these areas. *In School A, for example, it was assumed that there was such air movement.*[15]*. Wood timbers in the attic were decontaminated by dry ice blasting, but maybe one could have instead prevented air penetration between the attic and the working space.*[16] *Similarly, crawl space contamination in School B can be a source of contamination for the rest of the building if there is a physical opening, and if the pressure in the rooms of the first floor is negative compared to the crawl space.* However, even if negative pressure is achieved in the crawl space, a problem can come up as to how good and consistent this negative pressure is. For instance, it may be turned off during weekends or vacations to save energy – which would not be recommended. There is an example of a school, in USA, that filled up the crawl space with concrete in order to solve this problem, but the outcome is not known.

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[14] In the IICRC S520, 2008 document, *Standard and reference guide for professional mold remediation*, at section 12.2.7, it is stated: *Deviation from removal processes*: "*The principles of mold remediation state that mold contamination should be controlled as close to its source as practical. Further, mold should be physically removed during remediation. Attempts to kill, encapsulate or inhibit mold instead of proper source removal generally are not adequate*." Given the recommendations of the ACGIH, the AIHA and the IICRC for the decontamination of a semi-porous material such as masonry, the extent of contamination of the brick walls and stone foundations in School A and the persistence of dampness in these structures and the need for a sustainable solution and the protection of public health, the DSP de Montréal has not recommended encapsulation. The decision of the Montréal School board, based on this recommendation, is to re construct the building.

[15] In fact, there is an open door in the floor of the attic and this floor is made of boards, which may have some space between.

[16] Again, the basic principle remains to remove the mold contaminants.

PROTECTION AND RELOCATION

Removal from the milieu is primarily a case-by-case medical decision. Affected people should be further evaluated by a physician and removed from the environment as needed; for instance, if a physician thinks that someone working in a mold contaminated space has work-related asthma, this person should be relocated.

At the population level, if our job is defined as protecting public health, we have to make our recommendations based on what we know about the health effects of dampness and mold contaminated buildings, from a perspective of precaution and prevention. However, the building owner and worker representatives often need to be involved as well – so relocation is very complex. NIOSH does not get involved in closing building and moving whole populations, but state or local public health departments may according to their responsibilities.

We should also ask ourselves if we can protect the people present during the remediation process, and we should be able to evaluate whether there is a problem. These necessary protection methods may sometimes be very expensive.

In a California dormitory where there was no other place to relocate, extensive cleaning with HEPA vacuuming was done every week. This was a fallback approach that seemed to work, but was not going to work forever or for everyone. In addition, students coming to the dormitory had to sign a waiver saying that they did not have asthma. Eventually, the building envelope was torn off.

In School B, if there is somewhere to relocate the occupants, it would be sensible to do so while the corrections are being made. If this is not possible, there needs to be very good containment of the remediation process so that the occupants are not exposed. However, a summary of the case does not provide enough information to tell whether it is safe to stay in the building. Telling the occupants of the facts known and allowing for informed consent are important.

ASSESSMENT OF REMEDIATION

Standards and tests

There is not a very good way of making sure that building is safe, other than doing the required work properly and cleaning up well. We may think of a silver and a gold standard for assessing remediation. The silver standard is composed of visual assessment of the remediation process. There has to be a written protocol for the decontamination, a check list (such as from the S520 guidelines) so that the contractor knows what to deliver, a paper trail of what was done and identification of quality control measures. The cleanup process and completion need to be verified by an experienced hygienist or other indoor environmental professional for instance regarding the proper use of HEPA filter cleaning. The AIHA 2008 Green Book and the AIHA 2001 report of the Microbial Task Force present guidelines that can be followed. For wall contamination, it must be ensured that mold is removed while the wall is still open. How this can be demonstrated can be complicated – for example, how to differentiate between a water stain, a blue stain, and mold growth. Air sampling does not do it; surface sampling may help. In most cases, the silver standard is sufficient to assess remediation. *In Building D, for instance, it is probably appropriate.*

The gold standard comes from Health Canada (2004). It consists of the silver standard plus an indication that if clearance air sampling is carried out it should occur one to two weeks after the HVAC system has been running normally. It is recommended in special cases only. For instance, in a luxury hotel in Honolulu, it was used to prove that the work was well done, for legal protection. In a hospital, air sampling was done both before and after build back, which appears to be a reasonable approach for a hospital – although air sampling is not sufficient to show that mold was removed before build back. Nonetheless, the gold standard is really impractical and not recommended in most situations.

AIHA emphasizes avoiding air sampling for assessment of remediation. Air sampling is essentially for investigation – with all the caveats discussed earlier – and is not recommended for assessment of remediation unless it is part of a research program. Positive air samples post-remediation may indicate a number of situations. One would need to differentiate between remaining growth and residual dust. Fine dust might not have been removed. One could repeat sampling after the dust has settled down, and could test the dust as well. White glove or black glove test may be used to test for residual dust (AIHA, 2008). In addition, although there might be less fine dust, its composition could remain the same in terms of species – i.e. buildings have a “memory.” This refers to the difficulty in removing all of the contaminating spores (such as *A. versicolor*) from a building during mold remediation (Morey, 2011A). It takes time for a building to equilibrate with the outdoor environment, namely it takes time for a “normal” profile of spores to build up in a building after remediation.

Finally, if there is no containment, the contaminated air may be coming from elsewhere. One may perform surface sampling before cleaning to compare the species with those in the air.

In Building D, there was a positive air sample post-remediation. The sample indicates that the situation is abnormal, but one time air sampling cannot tell the story about the building. There may be remaining dust, but the question is whether there is remaining growth. Something may be left from clean up, and/or a contaminated part might have been missed completely. The decontamination work seem to be very good and thorough – what should then be done is to finish being thorough. One should re investigate, look at surfaces and cavities, possibly getting a third party to verify. There may be something outside that was missed. There may be a cavity that can be sealed. Meanwhile, HEPA cleaning should be continued, while keeping all materials dry. Waiting for a couple of weeks may allow air to equilibrate indoor and outdoor. [17]

In Building C, the panel experts disagreed on interpretation of post remediation sample, as was described earlier. This highlights difficulties in interpretation, and cautions against relying on air sampling for remediation assessment. (Refer again to footnote no 3, section on air sampling)

Clinical follow-up

It is also important to follow people's health when they reintegrate a building post-remediation. Ultimately, the most sensitive test is that people can live in the space (although we do not want to do this experimentally). They can also be followed using health parameters such as pulmonary function testing and see how these parameters were affected by the intervention.

Evaluating whether the building is now safe for the occupants may be difficult in a clinical context. In most cases, people return to buildings that were "cleared" with tests; however, one should refrain from reaching conclusions regarding the health risk for the occupants based on air sampling, without knowing the health condition of the occupants themselves. Interpretation of such tests in terms of health risks should be a team approach, such as between the hygienist and the physician who knows the patients and their susceptibilities. From a clinical perspective, one may also want different remediation standards: for instance, while a given remediated building may be safe for most people, a clinician may want higher confidence in the remedial process for some atopic or other high risk patients, i.e. a "platinum standard."

Social and legal context

Recognition of the problem is an important step towards solving it. One should not deny the obvious: there are lots of data and solid evidence for the health effects of damp and mold-contaminated buildings. Yet, many are still denying it. In some places, the problem is recognized and is not debated anymore. In Finland, everyone agrees that moisture is a problem. In

[17] In the months following this meeting, we have re inspected the building; many wood blocks which were not removed seemed to be still contaminated. Openings were made in the walls up to the brick in every apartment (taking off pieces of wood beams and pieces of black paper between the wood and bricks), and surface samples were taken for molds on those pieces of wood beam and black paper, but not on bricks. It was found that most pieces of wood and black paper were contaminated, with spaces between the wood beams allowing the contaminants to access the indoor air. The contamination was determined by the visual aspect (deteriorated wood and visible molds) and by culture of many samples (20 bulk samples and 7 surface samples) with analysis up to the species level which showed the presence of many molds including *Aspergillus versicolor*, *Chaetomium*, various species of *Penicillium*, *Stachybotrys*, *Ulocladium* and *Alternaria*. The building may be re built because the costs of remediation are close to those of reconstruction - it is impossible to remove and decontaminate the wood beams of the exterior walls without removing the bricks and these have to be repaired anyway.

Germany also, there is a general acceptance of these problems. The government took initiatives and there are regulations defining responsibilities of various stakeholders. Owners know that they have something to do about it.

It is important to deal with the problem from a regulatory perspective. *Building C is a classic example of what happens in the private sector: the building owner has limited resources to address the problem and is trying to limit economic consequences, and there are limitations from the borough perspective. This highlights the importance of adopting a regulatory approach.*

Many people out there may see mold as an entrepreneurial opportunity; hence the need to ensure competence. The Health Canada document (2004) discusses qualification of building experts, and the AIHA makes recommendations on protocols used by mold inspectors and mold remediators (AIHA, 2001 & 2008). Many documents also recommend separating inspection and remediation, that is, they recommend having a third party inspection. In Finland, in addition to the many guidelines and recommendations, there is also mandatory training and qualification for building investigators. In the United-States, Florida and Texas require state-licensing in order to be a mold inspector or remediator – and one cannot be both on the same job. The states approve the training but do not provide it. A caveat is that many small organizations offer credentials, as it is easy for one to become a mold investigator, so care must be taken before choosing who can offer certification.

Moisture and mold associated with structural damage is a costly issue, although a bigger component is the human cost. There is a net benefit of dealing with the moisture problem, as it leads to more durable buildings and more importantly increased productivity of its occupants. There are also potentially cost savings to be made, from a health care perspective, by bringing in more stringent regulation – the problem should therefore be further discussed from a savings perspective. To that effect, there is a 7:1 benefit-to-cost ratio for following US-EPA regulations.

Finally, as was discussed earlier, decisions regarding relocation may be complex. The answers are often there, but it is often difficult to make them happen. It is almost a social decision.

Communication

Communication is very important when working with people who feel there is a problem with their building. Addressing the problem requires a trust relationship. People are angry when they do not know what is happening. Collaboration and discussions are important between all people involved, and dispute resolution and negotiation skills are often required.

Communication also involves education. It means educating the stakeholders so they can make better decisions. It involves giving people the correct information, for example when they ask for an air sample to "prove that the air is clean," when our recommendation would be not to perform such a sample. It can also involve educating consultants, as they often have time and resources to use only one source of information, while there are many sources out there with many similarities but some differences – some of which are possibly more relevant for the case at hand.

Finally, informed consent is important. We must tell the occupants of the risks, and tell people of our limitations.

CONCLUSION

The panelists were asked to give their general comments and conclusions following the two day exercise. As already mentioned, this sort of peer review is limited by the fact that the panelists have not seen the buildings.

It was generally felt that the DSP de Montréal approach follows most basic principles recommended by existing expert organizations, from investigation of the building, to health assessment and recommendations to protect public health. Much discussion was about the use of air sampling (see below). One commented on the fact that there are similarities between this approach and that of NIOSH in their field investigations.

There were few general recommendations. Someone suggested that the diseases associated with water damage and molds should be reportable to the Public health officer, and the interventions that follow should be evaluated. Another one suggested setting up a peer review group to discuss ongoing issues with Canadian experts.

The following general points were raised as well:

- It is important to address moisture problems; acting early can prevent health problems;
- Structural damage is costly but the human cost related to indoor air quality is probably higher. The net benefits of dealing with moisture problems are a more durable building, increased productivity and prevention of disease and lower health costs;
- If you see a problem, fix it. Don't approach the problem by saying «It can't be removed» but «it must be removed. If not possible, test other options.»;
- Rely on building assessment, evidence of dampness and microbial contamination, not air sampling unless there are very good reasons and know how to interpret results. Sampling should not be done for evaluation of remediation;
- Communication is important, both among experts and authorities and with building occupants. Problem solving requires collaboration and negociation;
- Verify a consultant's knowledge, if he doesn't want to talk about it, change consultant. Quality control for work done by a consultant is important; a check list can be helpful.

CONSENSUS STATEMENTS AIMED AT GUIDING FUTURE ACTIONS IN THE FIELD

Based on the cases presented, the discussions during this meeting and the scientific literature, we have summarized a series of statements in collaboration with the panelists present at the two day meeting. These statements represent a scientific consensus reached by scientific experts that should be used to guide future actions in the field. This would greatly improve the way these problems are managed, facilitate the process of investigations and allow adequate remediation to proceed without delay, thereby contributing to reduce this important public health problem.

Health aspects

1. It is important to fully appreciate the global impact of water damage, dampness and moulds in buildings, in terms of public health and sustainable development, in order to assess the problem comprehensively, to allocate adequate resources to solve this problem, and to use various outcomes to evaluate the success of remediation;
2. The public health impacts of water damage in public and private buildings are important and are considered a priority by many countries in North America and abroad. These include a long list of diseases affecting especially the upper and lower respiratory tract and other systems. Other effects can include reduced performance among personnel, learning difficulties among students and direct and indirect mental health effects, all affecting a significant proportion of children and adults, students and personnel in the whole population;
3. Chronic water infiltrations and dampness will almost inevitably lead to the growth of molds and other microorganisms, including bacteria and mites. It also promotes the proliferation of insects such as cockroaches and of rodents. All these may contribute to alter indoor air quality and cause health effects;
4. There are various mechanisms by which these health effects are produced. As Mendell and colleagues have pointed out: *The wide variety of health effects cannot be explained by a single mechanism… Epidemiologic evidence suggests involvement of both allergic and non-allergic mechanisms, as both atopic and non-atopic individuals are susceptible to adverse effects of dampness or mold… The inflammatory responses demonstrated in many microbiologic exposures include histamine release by non IgE-mediated mechanisms, providing plausible mechanisms for the occurrence of allergy-like symptoms in non-sensitized individuals.* Accordingly, it should not be concluded that patients are not affected by molds or are not allergic to molds if the skin test for allergy is negative or if the serum dosage of immunoglobulins E for molds is negative;
5. Clinical investigation of the index cases (first notified cases in a building) provide very useful information to suspect the presence of health problems associated with a water damaged

building. A survey may also be conducted to investigate the prevalence of health problems associated with a water damaged building of all the occupants. The aim of this survey could be to determine the extent of the problem or the need for more protective measures. A validated questionnaire is a valid means to obtain such information which can be compared with a suitable reference population when feasible. The use of both clinical and epidemiological data provides useful means to investigate an IAQ problem within a milieu, to monitor the situation and to contribute to assess the success of remediation;

6. Moulds and bacteria associated with dampness in the buildings produce a wide variety of bio-contaminants (fungal fragments, ergosterol, glucans, enzymes, other proteins, fungal and bacterial toxins, volatile organic compounds, etc) which are mainly found in free fine particles in dust and the air, rather than in the spores. All these contaminants can contribute and interact in a complex way to cause the health effects. Because these are very fine particles (less than 1 µm), they can propagate through small openings in the building (cracks, electrical outlets, joints, etc), be inhaled, and penetrate deeply in the lungs where they can be absorbed into the blood. It is important to note that these bio-contaminants are not directly measured in the usual tests performed in the field and are not well reflected by the spore count;
7. Hidden molds (or molds which are not visible from the inside of the room without openings in the wall or ceiling …) matter in terms of health. Studies have definitively shown a link between damp structures, hidden molds and health. As previously explained, fine particles emitted by molds and bacteria can penetrate through small openings in the walls, ceilings and floors and then be inhaled by the occupants. The presence of water damage and dampness is the most consistent and predictive variable of health effects in the epidemiological studies published;
8. Past mold growth as well as present mold growth matter in terms of health. Some of the bio-contaminants emitted are very persistent and difficult to inactivate, and they can continue to cause health effects once water infiltration has stopped. In addition, molds can re-grow under favourable conditions.

Building evaluation and risk assessment

9. The history of water damage, the inspection of the exterior and interior of the building, the measurement of humidity in the air and in materials using the appropriate specialized equipment and techniques (ex.: a moisture meter and an infrared thermographic camera), the findings from intrusive inspections, and the health data (clinical data and epidemiological survey) are all important and considered the most relevant elements for the evaluation of the problem in a water damaged building;
10. Once water damage has occurred, especially persistent water damage or dampness (unrepaired incident of water damage or chronic water damage), and obviously when moulds are visible on or inside the structures (during intrusive inspections) which are or were affected by dampness, actions should be taken immediately, without further tests, to

find the cause of dampness and to proceed to remediation. When the above conditions are found, there is no need of air sampling in the vast majority of situations because the risk of health effects from water damage and hidden or visible molds is well established, and because air sampling for molds has many limitations and has produced divergent results. Pursuing the air tests would only delay the work to be done, prolong the health effects among the occupants and waste money. Intrusive inspections should be more regularly performed, if needed, to confirm the problem and to find its source. Air tests should be the last tests to perform, if indicated, rather than the first as is often done. A negative air test does not exclude the presence of a mold problem, especially in presence of other positive findings as indicated above. The health risk assessment in a water damaged building should not be based solely on the results of an air sampling evaluation.

Among the limits of air sampling, we can mention the followings:

a. As mentioned above, many of the fine particles most relevant from the health point of view are not directly measured by the usual tests and are not well reflected by the spore count. Spore analysis should rather be viewed as a *proxy* measure of molds and other associated bio-contaminants;
b. Typically, the air is sampled for some minutes in a day while there are important variations of the types and concentrations of molds in the air in a day or week. Therefore, the results of the sampled air may not adequately represent the variety and concentrations of molds present during the whole period of exposure;
c. The sensitivity of air sampling (ability to detect a mould problem) may be affected by various factors such as: the sampling may have been performed after days of non-occupation (the spores in the settled dust will not be reflected in the sampled air), or after HEPA vacuuming of dusts, or after windows have been opened (diluting the concentrations of contaminants), or after biocides have been applied, all of which may give false negative results. The outdoor sample may have been cross contaminated, producing a false comparison. The air volume sampled may have been too small, which reduces the probability of detecting a variety of molds and underestimates the real concentrations (lower sensitivity), especially if the concentration of molds in the air is low, for instance after remediation, or if windows have been opened. If the analyses are not made at the species level, the indoor and outdoor mold profiles may look similar while in reality there are important differences in species which would have indicated an indoor mold amplification. It should be noted that analysis to species level is accomplished by a competent mycologist in conjunction with sampling such as direct impaction onto a culture plate. Spore trap air samples cannot be accurately identified to the species level;
d. There are also problems in the interpretation of the results: if the recommended criteria set by the expert groups are not considered (for instance, one compares with a threshold level which has not been yet established), and if the other essential elements of the investigation (history of the building, visual inspection, humidity measurements, intrusive inspections and health data) are not taken into consideration, one may falsely conclude that the sampling results suggest that there is no mold problem.

If air sampling is to be done, care must be taken with the methods, analysis, and interpretation. Before sampling, one needs to assess whether the results will help decision making. In the interpretation of air sampling, it is the profile of species that matters rather than the mold count. The presence of many mold species in indoor air which are absent in the outdoor, or the presence of *indicator species* (species known to be associated with water damage or dampness or health effects) are indicative of an indoor mold amplification phenomenon. There is no mold threshold value established and there will probably never be such a threshold because it is scientifically very difficult to take into account the interaction between the vast numbers of bio-contaminants produced by dampness and their effects on health.

Remediation

11. The goal of remediation is to remove all the mold contamination, including hidden growth, produced in the past or present. The source of water infiltration or dampness must be corrected in order to prevent continued growth or regrowth. The methods of remediation vary according to the type of material and the extent of the contamination. Wood beams (wood block construction), masonry and concrete blocks (with empty cells), must be addressed on a case by case basis; in some cases the surface growth is easy to remove; in cases of gross contamination and water damage or contamination throughout the material, removal of whole components may be required. Encapsulation of a component with a coating is an acceptable solution only if and after the surface is thoroughly cleaned; coating may be useful or efficient only for limited size surfaces, such as a structural beam. As stated in the IICRC S520 standard: «Abrasive blasting techniques should be limited to situations in which aerosolization is not a critical factor (e.g., outdoors), or can be adequately controlled (e.g., high-volume, laminar airflow cleaning chambers).» Use of biocides is not recommended: it is not an established method of decontamination, it may trigger the production of mycotoxins (Audenaert, 2011; Peitzsch, 2012) and may cause direct and indirect health effects. Clean-up is also a key, because remediation strategies create a lot of particles and dust; therefore containment and dust suppression are important.
12. The question should not be *how can we find a way not to remove the contamination (e.g., encapsulation)*, but *what is the best way to remove it (most sustainable)*. If, for important reasons, it is impossible to remove all the contaminated material, one must find the best way to control the release of contaminants and to monitor the situation in order to find a better solution if needed;
13. The success of remediation is mainly evaluated by looking at the process of remediation itself, which means that one must be able to verify that the recommended methods of remediation have been respected, according to the extent of the contamination and the type of material affected. In certain circumstances, such as in a hospital or in a ventilation system, surface and air sampling may be a useful complement to assess the remediation before re-entry of the occupants, provided that the validity of sampling is maximised according to the above mentioned factors. A positive result will indicate that the

contamination persists; however a negative result from surface and air sampling should not be determinant over all other information. It is even more important to make sure that all dust and debris associated with remediation have been removed by HEPA vacuum cleaning. The health of the occupants is very important to consider following re-entry; health can be assessed following re-entry in the same way it was done to document the problem, using all available epidemiological and clinical information. The presence of a group of persons who react is a strong indication of the persistence of contamination. Although a sensitized person may react to a low level of contamination, it still is an indication of a persistent contamination somewhere in the building. When persistent contamination is suspected, one must reassess the situation to find the cause, which can be related for instance to insufficient vacuuming of accumulated dusts, persistent contamination in the ventilation system or other hidden contamination.

Prevention

14. Buildings should be well maintained to prevent water infiltration. Buildings should also be designed and constructed to minimize water infiltrations and excessive moisture. Special attention should be paid to flat roofs and other frequent sources of water infiltration, including regular inspection and maintenance (annual), use of special investigative techniques when needed and prompt repair. Finally, regular cleaning and preventing accumulation of dust are also important in terms of preventing health effects among building occupants.

ANNEX

Description of the cases

Four real cases of investigation and intervention, in two schools and two apartment buildings, were chosen to evaluate the methods used and the recommendations made by the Public Health Department of Montréal regarding the health impacts of chronic water damage in buildings. These were all affected by water damage and mould contamination and were followed-up, on the building and health aspects, over a period ranging from 2-14 years.

The general characteristics of these buildings are described in Table 1. Each case is further described in a chronological summary presented in a table (Tables 2 to 5).

Table 1. Background information on the four cases

Case	Year of construction	General description	Main building materials	Type of roof	Type of heating	Number of occupants or of apartments	Cause of intervention
School A	1911	Two storeys building with basement	Rubble stone foundation, outdoor walls made of 3 courses of bricks, wood and plaster indoor walls	Flat roof, presence of an attic	Water radiant stove	240 students, 40 employees	Health complaints
School B	1953	Two storeys building with crawl space	Brick outdoor walls, concrete blocks inner wall, wood studs, insulation and indoor wall wood finish	Flat roof	Water radiant stove	558 students, 105 employees	Security hazard (deteriorated masonry)
Apartment building C	1930	Three storeys building with basement	Brick outdoor walls, wood beams inner walls and plaster and wood indoor walls	Flat roof	Electrical baseboards	12 apartments	Notification by city inspector (health complaints)
Apartment building D	1958	Three storeys building with basement	Brick outdoor walls, wood beams inner wall, plaster and gypsum indoor walls	Flat roof	Water radiant stove	29 apartments	Notification by city inspector (health complaints)

Table 2. School A, chronological summary

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
1999, Spring			Water infiltration from the roof down to the basement mainly through the West stairway, causing major flood		
1999, 2000	Contractor				Repair of the roof
1999-2000 Winter	School, School Board		Health complaints from the personnel	Assess indoor air quality	
2000, April	Consultant 1	Air sampling (Andersen impactor, 85L, culture on TSA and MEA media, 1 outdoor sample, 5 indoor samples)	Total count higher in the West stairway and in one room next to it, compared with the outdoor sample	Further assessment to locate the sources of moulds; clean the contaminated area with non-toxic detergent	
2000, August	Contractor				Cleaning of the surfaces in the contaminated area (mainly the West stairway)
2000 until 2007	School	Written complaints, Observations	Many employees report symptoms. Water infiltrations from the roof, plumbing, heating system, windows…		Repairs according to the problems notified (no detailed record available)
2007, Summer	Consultant 2	Visual inspection and moisture detector; air sampling (SAS Super 180; culture; 200 L; 1 outdoor sample, 5 indoor samples, analysis up to the genus level, school unoccupied)	Inspection: dry materials, musty smell and minor signs of water damage near the West stairway Outdoor air: *Cladosporium* sp. (500 UFC/m^3) Indoor air: *Aspergillus* sp., *Penicilium* sp., *Trichoderma* sp., *Cladosporium* sp. (total count goes up to 340 UFC/m^3)	Further assessment to locate the sources of moulds; decontamination of the affected structures	
2007, Fall	Doctor	Clinical evaluation	Sentinel case: a teacher who works near the West stairway (room 142) was hospitalised 3 times for pneumonias in less than a year		Notification to Public Health Department. The teacher was relocated to another school (health gradually improved afterwards)

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2007, December	School Board	Intrusive inspection	Multiple openings in the walls of the West stairway confirmed widespread mould contamination in this area		
2008, January	Public Health Department	Visit (December) and 1st health survey among employees with a detailed questionnaire	Inspection: signs of water damage in the classroom of the sentinel case (room 142), and in other rooms; Health survey: response rate of 100% (N=41) Results: 51% possibly affected by IAQ; employees working close to the West stairway are almost all affected. Compared with a control group, significantly more symptoms related to several systems	Further assess the extent of contamination, and decontaminate	
2008, January	Consultant 3	Visual inspection and moisture detector; bulk sampling; air sampling (Andersen impactor, culture medium MEA, 1 outdoor sample, 13 indoor samples, every sample duplicated, analysis up to the species level)	Inspection: no visible mould nor odour, dry materials, openings left from prior removal of contaminated materials Bulk samples: low or absence of fungal contamination Outdoor air: *Penicillium* sp. Basidiomycetes, *Exophisia* sp., *Mycelia sterilia* Indoor air : usually «low concentration» of species not found outdoor such as *Acremonium* sp., *Aspergillus* sp., *A. ustus*, *A. versicolor*, *Cladosporium* sp., *Phlalophora* sp., *Phoma* sp. Room 225: *Aspergillus sydowii* (55 UFC/m^3) Consultant conclusion: «*No significant air contamination except for room 225*»	Further assessment to locate sources of moulds in room 225	
2008, Spring	Consultant 4	Visual and intrusive inspection with moisture detector; Bulk/tape-lift sampling (59 samples)	Inspection: signs of water damage on various components and visible mould during intrusive inspection. Spores and/or fungal growth of: *Stachybotrys* sp., *Chaetomium* sp., *Ulocladium* sp., *Aspergillus* sp., *Penicillium* sp., *Memnoniella* sp., *Acremonium* sp., *Ophiostoma* sp., *Cladosporium* sp., *Oedocephalum* sp.	Remove and replace contaminated materials; clean materials goods	

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2008, Summer and Fall	Contractor				Repair of the roof; decontamination of the attic with dry ice blasting; decontamination of the walls in the stairways and in some rooms in the basement
2008, July	Consultant 4	Air sampling right after some remediation works on 3 days (150L, analysis up to the genus level): July 7, 8 and 16	July 7: indoor concentration of *Aspergillus/Penicillium* higher than outdoor air; presence of *Chaetomium* and *Stachrybotrys* which are absent in outdoor air July 8: indoor concentration of *Aspergillus/Penicillium* higher than outdoor air July 16: presence of *Chaetomium*, *Stachrybotrys, Memnoniella,* and *Scopulariopsis* which are absent in outdoor air; indoor concentration of *Aspergillus/Penicillium* and other unidentified spores higher than outdoor air	No report, only laboratory data.	
2009, March	Public Health Department	2nd health survey among employees with the same detailed questionnaire	43% renewal of personnel since first survey. Response rate: 100% (N=44) Results: 18% (8 employees/44) were found to be affected by IAQ		
2009, March	Consultant 4	Air sampling after remediation works (N-6 impactor, 141.5L, culture medium MEA, 2 outdoor samples, 10 indoor samples, analysis up to the species level)	Outdoor air: *Cladosporium herbarum*, *Peniciliium* sp. Indoor air: low concentration (<40 UFC/m^3) of moulds not found outdoor such as *Alternaria alternata*, *Aphanocladium* sp., *Aspergillus ustus*, *Penicillium brevicompactum*, yeasts. Consultant conclusion: «*Indoor air quantitatively and qualitatively similar to outdoor*»		
2009, fall	Public Health Department	Report from clinical evaluation of the cases and health survey with a detailed questionnaire	Degradation of the health of the 8 employees identified in March 2009, following their return to work after Summer vacation		

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2010, November	Public Health Department	Report from clinical evaluation	A healthy young recently employed teacher got sick after few weeks of work in classroom 142 which had been closed for more than 2 years.		The teacher was put on sick leave by her doctor and relocated to another school. Classroom 142 closed.
2010, November	Consultant 5	Visual inspection; air sampling (Andersen impactor, 280L, culture medium MEA, 2 outdoor samples, 21 indoor samples, analysis up to the species level, school unoccupied)	Inspection: no sign of water damage, no visible mould, no odour Indoor samples: low concentration (<40 UFC/m^3) of moulds not found outdoor such as *Aspergillus niger, Penicillium chrysogenum*, *Rhizopus solonifer*. Gymnasium: *Aspergillus ochraceus* (84 UFC/m^3), *Aspergillus sydowii* (14 UFC/m^3), and *Eurotium herbarum* (4 UFC/m^3). Room 202: higher concentration of *Geotrichum candidum* than outdoor Consultant conclusion: «*no significant air contamination excepted in gymnasium and classroom 202*»	Further assessment to locate the sources of moulds in gymnasium and classroom 202	
2011, Spring	Public Health Department	3rd health survey among employees; survey among students identified by the school nurse based on sick leaves (parents interview)	Many complaints and high turnover of employees. Results: 24 employees surveyed, 88% of whom were found to be probably affected by IAQ. Students: 7/8 probably affected by IAQ		
2011, May to June	Consultant 6	Visual and intrusive inspection with moisture detector; bulk/tape-lift sampling (total of 47 samples)	Inspection: dry materials, numerous traces of water damage from various sources, efflorescence on brick walls Spores and/or fungal growth of *Aspergillus* sp., *Penicillium* sp, *Ulocladium* sp, and *Acremonium* sp Consultant conclusion: widespread contamination in the structure of the building, including the attic, the insulation material in the wooden floors, and behind the gypsum boards in walls and ceilings in many rooms	Repair every source of leaking water; remove and replace contaminated materials; clean materials goods and ventilation system	

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2011, Summer	Public Health Department	Risk assessment and public health advisory		Relocate all occupants, based on the findings of the assessment by consultant 6 and health survey of the occupants in Spring 2011	Relocation in another school; beginning of major repairs
2012, Summer	Consultant 6	Intrusive inspections from inside and outside (73 openings), visual inspection, moisture detector and bulk/surface sampling (over 150 samples)	Inspection: excess humidity on all peripheral walls on the 3 courses of bricks, particularly under the windows, crumbling and blackened mortar, missing joints, efflorescence on every course of bricks, musty odour of the rubble stone and high humidity in the basement Sampling: active fungal growth on the 3 courses of bricks Consultant conclusion: active mould growth in the masonry on all 4 sides of the building causing potential indoor air contamination; excess humidity in the structure of the building	Repair every source of water infiltration, isolate brick walls from indoor air, and install a ventilation system to assure a good indoor air quality	School board decided to keep the structure of the school, to repair sections of the walls where bricks are crumbly, to control moulds with encapsulation of brick walls, then to rebuilt the inner structure
2012, Summer	Contractor and consultant 6	Decontamination of the basement	Persistence of musty odor 2 weeks after decontamination of the rubble stone in the basement		1st decontamination of rubble stone by aspiration of dust with HEPA vacuum and 2nd decontamination with a fungicide and HEPA vacuum
2013, March	Consultant 7	Visual Inspection; air sampling (RCS Plus Air sampler, 100L, 4 outdoor samples, 11 indoor samples, analysis up to the genus level)	Inspection: no sign of water damage Outdoor air: *Penicillium* sp., *Geotrichum* sp., *Aspergillus* sp., yeasts (10 to 80 CFU/m^3) Indoor : low concentration (10 to 60 CFU/m^3) of moulds not found outdoor such as *Alternaria* sp., *Cladosporium* sp., and *Engyodontium* sp. Consultant conclusion: normal conditions and weak fungal contamination levels.		

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2013, April	Public Health Department	Public health advisory		Based on the results of all building and health investigations and based on the recommended methods of decontamination, the use of encapsulation was not recommended to control the exposure to fungal contaminants in this school	
2013 Fall	School Board				Decision to rebuilt the school, given the extent of damage and contamination, the cost of remediation, and the impossibility to guaranty the results of the remediation process

Table 3. School B, chronological summary

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2010 June	Consultant 1	Visual inspection	Falling debris from masonry. Advanced deterioration of precast concrete under windows (sills, lintels, legs) which cause an immediate security hazard and may lead to water infiltration	Replace elements of immediate security; eventually rehabilitate other elements and brick walls	
2011	Contractor				Repair of most problematic precast concrete elements
2011	School	Written complaints	Many employees report symptoms or diseases possibly related to school IAQ		
2012, February	School Board	IAQ program initiated	School flagged due to health complaints and relocation of employees		School prioritized and notified to Public Health Department

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2012, February	School Board	Short questionnaire among employees	24/40 respondents report symptoms associated with IAQ		
2012, February	Consultant 2	Air sampling (Andersen impactor, culture medium MEA, 198L, 29 indoor samples, analysis up to the species level)	Outdoor: no outdoor air sample, weather under 0°C Crawl space: low contamination (<40 CFU/m^3) by *Aspergillus* sp., *Penicilium* sp., *Beauveria* sp., and *Cladosporium* sp. Indoor: low concentration (<40 CFU/m^3) of *Aspergillus* sp., *Penicilium* sp., *Cladosporium* sp., *Eurotium herbarum*, *Mucor racemosus,* yeasts, except high concentration of *Aspergillus sydowii* (545 CFU/m^3) in room 130	Further assessment to locate the sources of moulds in room 130	
2012, March	Public Health Department	Visual inspection, infrared camera and moisture detector	Outside: many defects affecting the integrity of the building (efflorescence under nearly all windows, important deterioration of window ledges, mortar and bricks in many places, cracks), roof has no gravel cover in some areas and has many puddles of water, important accumulation of water near the foundation. Inside: signs of water damage and high humidity on the walls and floors of several classrooms. Crawl space: flooded in many sectors, efflorescence and visible mould Conclusion of the Public Health Department: «we suspect significant water infiltrations probably from the roof and foundation, favouring mold growth throughout the building»	Repair the roof; do intrusive inspections in the walls; dry out and ventilate crawl space	
2012, Spring	Contractor				Crawl space: drainage and negative pressure with ventilation system
2012, Spring	Public Health Department	1st health survey among employees, with a detailed questionnaire	Results: 66% of teachers (22/28) probably affected by IAQ (82% possibly or probably affected)		

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2012, May	Consultant 2	Intrusive inspection in room 130 (6 openings in exterior wall, moisture detector) and bulk/swab sampling, (direct microscopy, culture media MEA and DG18, 35 samples)	Intrusive inspections: water stains and humidity detected on the inner structures. Samples: contamination of the various components of the walls (MDF, plywood, insulation wool, vapour barrier, wood stile, concrete blocks) by spores and/or fungal growth (*Aspergillus* sp., *Penicillium* sp., *Chaetomium* sp., *Stachybotrys* sp., *Cladosporium* sp., *Rhizopus* sp., *Geotrichum* sp., *Ulocladium* sp., *Scopulariopsis* sp., *Fusarium* sp., *Trichoderma* sp., yeasts) Consultant conclusion: contamination caused by persistent excess humidity probably coming from the roof, windows and the walls.	Room 130: remove all contaminated components of the exterior wall and of the floor to reach concrete, and decontaminate it by sanding and brushing; clean all surfaces, especially with HEPA-filter	
2012, May until October	Contractor				Room 130: repairs made according to recommendations by consultant 2
2012, Fall	Public Health Department	2nd Health survey among employees, short questionnaire produced by the School Board	82% of employees (32/39) possibly affected by IAQ. 13 teachers who also answered the 1st questionnaire were similarly affected. Conclusion of the Public Health Department: «Significant proportion of teachers has health problems associated with IAQ and the proportion has not changed since Spring 2012. Corrections made to the building during Summer 2012 are not sufficient.»		
2013, January	Consultant 3	Visual inspection, CO_2 level and air sampling on 2 different days (BIOTEST, model SCR Plus Air Sampler, 100L, culture Agar, analysis up to the gender level)	Crawl space: leaks from sewage canals Inside: signs of water damage, sewer smell in many toilet rooms CO_2: too high while school is occupied Air sampling on January 3 (19 samples): low concentration for 11 samples, 8 without fungal growth (no lab data available) Air sampling on January 21 (6 samples): 5 without fungal growth, 1 with 20 UFC/m^3 of non-sporulating isolates Consultant conclusion: no significant air contamination	Correct/repair water infiltration, sewage and air movement problems; Control CO_2 and biological contaminant concentration with windows opening	

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2013, March	School Board & contractor				Remediation works planned to start soon (walls, windows, roof, floors, etc.)

Table 4. Apartment building C, chronological summary

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2011, October	Public Health Department	Evaluation of apartment 8509**:** visual inspection, infrared camera, and moisture detector	Visit follows notification to PHD by a city inspector. Outside: many signs of water damage (efflorescence, deterioration of several bricks, cracks, moulds), negative slope. Inside: excess humidity on several walls, floors and ceilings, signs of water damage (cracks, paint peeling off)	Repair the outside envelope of the building; do intrusive inspections; decontamination by a specialised firm	
2012, April	Consultant 1	Apartment 8521: visual inspection, moisture detector. Air sampling: spore traps (Z5, 25L, 2 indoor samples, 1 outdoor)	Outside: façade «appears serviceable» Inside: Illegal marijuana growth was located in the basement; no visible mould; no signs of water infiltration Air samples: total indoor count higher than outdoor (840 vs 320 spores/m^3), indoor concentration of *Penicillium*/*Aspergillus* (520 spores/m^3) higher than outdoor (240 spores/m^3), indoor conc. of *Cladosporium* >5 times that of outdoor, and types of basidiospores absent in outdoor air. Consultant conclusion: satisfactory results, no further remediation is necessary		
2012, April	Public Health Department	Assessment of 9/12 apartments (without 8509) Visual inspection, infrared camera, and moisture detector	Outside: mortar joints deteriorated or absent, paint peeling off on the foundation Inside: excess humidity on several walls, floors and ceilings, visible moulds, VOC odour, many signs of water damage (paint peeling off, holes, stains)	Repair the roof; do intrusive inspections; decontamination by a specialised firm	

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2012, June	Public Health Department & Local health and social services	Health survey among tenants	13/15 tenants evaluated (5/6 apartments evaluated) had health problems probably caused or aggravated by IAQ. Evidence of cockroaches and mice	Apartments can't be rented once the tenants leave. Additional investigations and remediation	2 families were first relocated for health reasons
2012, July	Consultant 2	Apartments 8505 & 8509: spore traps (Quick Take 15, 75L, 2 indoors sample for each apartment, 1 outdoor sample)	Apartment 8505: indoor concentration of *Pencillium/Aspergillus* (1170 spores/m^3) higher than outdoor (427 spores/m^3) Apartment 8509: *Pithomyces* (53 spores/m^3), absent in outdoor air. Consultant conclusion: concentration of *Pencillium/Aspergillus* higher than «acceptable» (>750 spores/ m^3); no problem in apartment 8509	Apartment 8505: remove contaminated materials; decontamination by a specialist Apartment 8509: no fungal contamination; do intrusive inspection where water damage has occurred	Roof repaired
2012, Summer	Borough, Public Health Department, consultant 2, and the owner	Round table	Report on what was done and discussion on what remains to be done	Elaboration of a decontamination protocol: major intrusive investigations, starting in apartments 8501 to 8511	
2012, Fall	Consultant 2	8501: bulk sample (direct microscopy, DG18 and MEA culture media; sample of wood)	DG18 medium: *Penicillium* spp. (over 31 isolates/plate), *Aspergillus niger* and yeasts (1-10 isolates/plate) MEA medium: *Penicillium* spp. (11-30 isolates/plate), *Paecilomyces variotti* and yeasts (1-10 isolates/plate) Consultant conclusion: «In both culturable fungal bulk tests, *Penicillium* spp. was identified in high or moderate relative amounts, which is a conclusive indication of mould present on the collected sample.»	Further assessment is necessary	Beginning of major remediation works
2013, April	Consultant 2	Air sampling after remediation work in the building (200L, culture medium MEA, 1 outdoor sample, an indoor sample in 6 apartments)	Outdoor: *Aspergillus fumigatus, Scopulariopsis brumptii, Eurotium herbariorum* (5 to 10 CFU/m^3) Indoor: *Penicillium* spp, *Cladosporium* spp., *Aspergillus* spp., *Stachrybotrys* spp., *Eurotium* spp. (5 to 15 CFU/m^3)		

Table 5. Apartment building D, chronological summary

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2010, October	Public Health Department	Visual inspection, infrared camera, and moisture detector, in 7 apartments	Visit follows notification to PHD by a physician. Outside: many signs of water damage (efflorescence, deteriorated mortar joints and foundation, cracks), negative slope; thermal anomalies on the infrared camera. Roof: accumulation of water, loose flashing. Inside (various apartments): visible mould (2 apartments), excess humidity on several walls and ceilings (most apartments), condensation in windows (1 apartment)	Repair the roof; repair the outside envelope of the building; do intrusive inspections; decontamination by a specialised firm;	
2010, November	Public Health Department	Public health advisory	Advisory based on the results of the building assessment and medical evaluation of the tenants of some apartments	Apartments 104 and 304 unfit for living; relocation of tenants. Problem in the whole building which needs further investigations and remediation	
2010, November	Contractor				Roof repaired, walls painted
2010, December	Consultant 1	Spore traps (1 indoor sample)	No evidence of mould contamination (no laboratory data available)		
2010, December	Public Health Department	Air sampling in 11 apartments (Air ideal 3P impactor, 250L, culture medium MEA, 11 indoor samples, analysis up to the species level)	No outdoor air sample, weather under 0°C. Indoor: total of 26 species, of which 24 are indicators of excess humidity and indoor fungal growth; concentration above 100 CFU/m^3 of *Aspergillus* spp., *Cladosporium* spp., *Penicilium* spp. and yeasts. Mean total concentration (winter) for the 11 samples is 334 CFU/m^3	Repair the roof; decontamination by a specialised firm. Building is judged unfit for living	
2011, February	Public Health Department and Local health and social services	Health survey among tenants (detailed questionnaire by a physician or nurse in the apartment, or evaluation at the clinic or phone interview)	Among 27 apartments, 11 had at least 1 tenant with health problems probably caused or aggravated by IAQ and/or vermin. Evidence of cockroaches and bed bugs	Remediation works need to be done as soon as possible	Tenants of apartment 304 had been relocated and those of 104 were going to

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2011, February	Consultant 2	Visual inspection	Inside: high condensation in windows, signs of water damage under the windows, dirtiness (dust or grease), defective plumbing, and exhaust fans not functional. Consultant conclusion: «Tenants also share the blame for the environmental contamination. Condensation is the major cause of environmental degradation.»	Removal of surface mould that affected the walls and ceilings; rebuilt the bathrooms; install kitchen hood; address the issue of cleanliness. Consultant conclusion: «*It shouldn't be necessary to eliminate all the mould already present […]. The building can be made reasonably healthy and safe by pursuing the more modest goals and priorities set out [resolving the source of moisture problems rather than eliminate all the dormant mould]*».	
2011, Spring to Summer	Contractor and Consultant 2		All work was done while tenants were living in their apartment. Also asbestos exposure caused by the openings in the plastered walls.		According to the consultant report: visible sources of mould removed; sources of mould growth addressed; both inside and outside cleaning; ongoing maintenance program with a pest-control manager.

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2011, Summer	Consultant 2	Post-remediation: damp sponge sampling (direct microscopy, culture) and air sampling (culture, analysis up to the genus level)	August 02, air and surface samples: 21/40 judged «unacceptable» by the consultant (indoor count or genus different from outdoor) with presence of *Aspergillus spp.*, *Epicoccum*, *Chaetomium*, *Penicillium* spp., *Phoma*, *Stachybotrys chartarum,* *Trichoderma*, and yeasts August 29, surface samples: *Cladosporium* (80 CFU/m^3) in 1/10 samples, no mould detected for 9/10 samples. Air samples: *Penicillium* spp. (300 CFU/m^3) in 1/10 samples, 9/10 samples showed the same species as outdoor (*Cladosporium,* *Trichoderma*, yeasts) Consultant conclusion: satisfactory results for IAQ, decontamination successful		
2011, September	Public Health Department	Air sampling (Air ideal 3P impactor, 300L, culture medium MEA, 16 indoor samples, 1 outdoor sample, analysis up to the species level)	No visible mould Outdoor: 14 species Indoor: 29 species, of which 16 were absent outdoor, especially *Pitomyces chartarum*, *Aspergillus* spp., *Penicillium* spp., *Paecilomyces variotii* and *Rhizopus stolonifer* PHD conclusion: despite the work done, there is still significant contamination in the whole building.	Decontamination by a specialised firm	
2012, May	Consultant 3	Air sampling (RCS Biotest, 160L, culture medium Agar, indoor sample in 13 apartments, 2 outdoor samples, analysis up to the species level)	Outdoor: 5 species Indoor: no contamination in the 12 apartments. In apartment 107, indoor concentration of *Penicillium cyclopium* (>100 CFU/m^3) higher than outdoor (13 CFU/m^3); species not found outdoor are *Aspergillus versicolor, Mucor* sp, and *Ulocladium chartarum* at concentrations <40 CFU/m^3 Consultant conclusion: contamination only in apartment 107	Further assessment to locate sources of moulds in apartment 107	

Date	Organization	Methods	Observations or results	Recommendations	Actions or remediation
2012, June	Consultant 3	Further assessment in apartment 107: visual inspection and moisture detector. Dust (1 sample), swab (1 sample) and air sampling (RCS Biotest, culture medium Agar, 160L, 2 indoor and 1 outdoor samples, analysis up to the species level)	Indoor: no visible mould; stains and damp spot around the bath, plumbing leaks Dust sample: no detection of yeast or mould Swab sample (bath): yeasts (>100 CFU/m^3) and *Cladosporium cladosporoides* (<40 CFU/m^3) Air sample: *Aspergillus versicolor* (13 CFU/m^3) not found outdoor. Consultant conclusion: results of air samples show the presence of yeasts. The source is probably the bathroom. Damp materials have been found.	Remove and replace contaminated materials in the bathroom; fix the plumbing	Bath walls has been removed; Contaminated wood has been treated;
2012, July	Consultant 3	Post-remediation, apartment 107, bathroom: spores trap (3 different days, 1 outdoor and 1 indoor sample each day) and tape-lift sampling (2 different days, total of 5 samples)	July 20: presence of *Aspergillus/Penicillium* sp., and *Pithomyces* sp., not found in outdoor air July 25: presence of *Aspergillus/Penicillium* sp., and *Coprinus* sp., not found in outdoor air; no spores detected in surface sample July 31: indoor air genus similar to outdoor air; presence in low concentration (all <10 CFU/m^2) of *Aspergillus/Penicillium* sp., *Cladosporium cladosporoides*, *Chaetomium* sp., *Stachybotry chartarum*, and *Ganoderma* sp. Consultant conclusion: «mould removal work has been effective in the bathroom.»		
2012, Fall	Public Health Department	Evaluation of apartments 101 and 103 (now used as a daycare): visual inspection, infrared camera, and moisture detector	Outdoor: roof and outside envelope are still suspected of water intrusion Indoor: excess humidity on the walls, floors and ceilings of every room in the two apartments	Decontamination by a specialised firm	Apartments 101 and 103 are closed by the City
2013, January	Public Health Department, city inspector, consultant 4 and owner	Visual inspection, infrared camera, and moisture detector	Outside: many signs of water damage (efflorescence, deterioration of mortar joint, cracks), negative slope Inside: visible mould, excess humidity on several walls, floors and ceilings, mostly in the basement and the 3rd floor	Repair the outside envelope of the building including the roof; do intrusive inspections; decontamination by a specialised firm	

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