



# Interventions and actions against damp and mould

**Report on a WHO working group  
meeting**  
28-29 February 2008, Bonn, Germany



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## ABSTRACT

The presence of dampness or biological agents such as mould in indoor air or building structures is largely attributable to occupant behaviour and building characteristics, and in particular to condensation, inadequate ventilation and structural failures.

To review practical interventions and their effectiveness in reducing exposure, WHO has collected case studies on actions and interventions against damp and mould in indoor settings. Case studies were reviewed and discussed by international experts during a review meeting aiming at an assessment and evaluation of damp and mould remediation actions carried out in indoor settings.

Various successful remediation examples indicate that removal of dampness and mould are effective measures to protect health, although it is difficult to assess the effectiveness of specific interventions. Main aspects to be considered for the prevention of damp and mould are adequate building structures and especially ventilation, thermal insulation and occupant behaviour, while remediation efforts need to be based on proper technical removal measures and moisture control.

The review meeting identified a variety of conclusions and recommendations on scientific, remediation-oriented and process-related aspects of damp and mould actions. Further work will be carried out on the policy dimension of approaches and recommendations against damp and mould.

The project is co-funded by the European Commission (DG Sanco, grant agreement 2005156).

### Keywords

AIR POLLUTION, INDOOR - prevention and control

HUMIDITY - prevention and control

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### NOTE:

The case studies discussed during the meeting can be accessed at

[http://www.euro.who.int/Housing/support/20080403\\_1](http://www.euro.who.int/Housing/support/20080403_1)



## Context and objectives of the meeting

Exposure to biological agents in indoor environments is a significant health hazard, causing a wide range of effects. The presence of biological agents such as mould in the indoor air is attributable to housing characteristics, particularly dampness, condensation, inadequate ventilation and structural failures. Signs of dampness and/or mould are considered strong indicators of risk for asthma and respiratory symptoms (e.g. coughing and wheezing). Ventilation and temperature, on the other hand, are important control mechanisms for humidity and the prevention of condensation. In addition, ventilation plays an important role in reducing concentrations of microbial and chemical pollutants in the air.

A WHO working group on indoor air quality guidelines has made recommendations on dampness and mould in indoor spaces, but the implementation and evaluation of specific actions is difficult due to the great variety of indoor spaces, fragmentation of responsibilities and, in the case of private residences, a limited mandate for interventions by public authorities.

To review practical interventions and their effectiveness, WHO collected case studies on actions and interventions in indoor settings. The meeting participants discussed a selected set of the studies, and identified elements of good practice based on the actions and technical measures described in them.

This meeting was part of a larger work package on “Addressing policy implications of actions to reduce health risks due to indoor air pollution with biological agents” carried out by the WHO European Centre for Environment and Health (Bonn Office) and co-funded by the European Commission (DG Sanco, grant agreement 2005156). With the overall objective of formulating policy briefs on effective approaches against damp and mould, the review meeting aimed at assessing and evaluating actions carried out in indoor settings in order to:

- learn about practical actions of involved parties
- categorize actions and approaches
- scientifically assess methodologies
- identify elements of good practice.

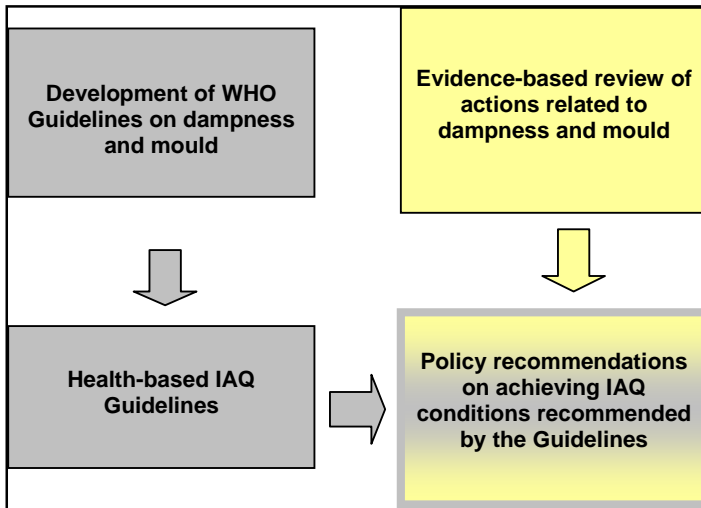
The results of this meeting are thus background material for a future meeting to discuss policy options and recommendations on actions to prevent, reduce or mitigate damp and mould exposure in indoor and built environments.

The policy advice on damp and mould actions provided by this work package will also complement the WHO guidelines on damp and mould<sup>1</sup> that were discussed in 2007 and will be published in 2008. As the WHO guidelines on dampness and mould are restricted to a health risk assessment based on scientific evidence, risk management options are not addressed. Therefore, the work package’s risk management aspect – along with the European Commission’s policy advice – will also provide mechanisms and practical recommendations for implementing WHO guidelines on dampness and mould. Together, both projects are expected to provide strong scientific and policy-related foundations for national and international measures (Figure 1).

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<sup>1</sup> WHO (2008): Development of WHO guidelines for indoor air quality: dampness and mould. Report on a working group meeting, October 2007. Available at: [http://www.euro.who.int/air/activities/20070814\\_1](http://www.euro.who.int/air/activities/20070814_1)

**Figure 1: Science and practice – towards policy-making on dampness and mould**



The feasibility of actions and interventions was emphasized, and their potential utility in preventing the problems related to damp and mould in the first place.

## Case study collection and pre-selection

As a first step towards the development of policy advice on actions against damp and mould, a case study collection was carried out to compile an evidence base of risk management actions in different countries. The collection of case studies aimed at projects targeted at the prevention, reduction or mitigation of damp and mould problems, such as:

- reduction of indoor relative humidity
- reduction of dampness/condensation
- removal/prevention of mould
- improvement of ventilation.

Due to special regulations in work places and health care institutions, they were excluded. The case study review therefore included residential buildings, schools and child and elderly centres with a focus on non-care elements.

The collection of case studies was carried out through a variety of mechanisms and information channels, including information from the WHO network and collaborating national and international expert networks, calls for case studies at conferences and public expert meetings, appeals to national building and engineering research institutions and searching the proceedings and abstract books of relevant international conferences. In total, several hundred sources were addressed and a more detailed follow-up was carried out with 60 experts who received the case study template for submission of case studies. Out of the 60, 21 contributed a total of 30 case studies.

The 30 case studies received were subject to a first review and pre-selection carried out by WHO in collaboration with the advisory group of the project<sup>2</sup> and the WHO Collaborating Centre for

<sup>2</sup> Dr De Cuyper, Belgium; Dr Kelly, UK; Dr Kurnitski, Finland; Dr Szewzyk, Germany

Housing and Health.<sup>3</sup> The pre-selection focused on the scientific validity and completeness of case studies in relation to the three main parameters (measurement of exposure, measurement of health effects, description of actions undertaken) and selected 17 case studies for discussion at the meeting.<sup>4</sup>

A summary of the selected case studies, the review process and the overall rating of all case studies is available in Annex 1, which also describes gaps and weaknesses such as:

- few case studies from schools and institutional settings
- lack of studies from warm climates
- difficulty relating health effects to specific measures
- lack of reliable exposure and health measurements in many case studies.

All case study templates discussed at the meeting can be accessed at [http://www.euro.who.int/Housing/support/20080403\\_1](http://www.euro.who.int/Housing/support/20080403_1).

## **Approaches against damp and mould**

Before the discussion of individual case studies, the variety of approaches and action mechanisms to prevent, reduce or mitigate damp and mould problems were highlighted and shortly introduced by focus presentations. The following mechanisms were all reflected by the case studies, and provided reasonable evidence of relevance and utility.

### **Impact of remediation activities**

Remediation activities include removal of dampness and mould problems and repair of dysfunctional building structures, with removal of damaged or contaminated material. The key to remediation success is identifying the source of the problem, rather than merely addressing the consequences. Essentially, this means preventing the accumulation of moisture.

### **Impact of thermal insulation**

There has been a trend in recent years toward increased insulation and energy efficiency in buildings, which may diminish indoor air quality due to reduced air exchange rates and increased humidity and condensation due to higher temperatures. Several case studies based on thermal insulation projects and interventions have shown that insulation can inhibit the reduction of dampness and mould if not accompanied by adequate ventilation.

### **Impact of ventilation**

Ventilation is the main mechanism of removing pollutants, dampness and humidity from buildings. Although the effectiveness of ventilation depends a lot on the outside conditions (ventilation is much more effective in cold and dry climates), it is a controlling factor for indoor conditions in any climate. Case studies show that the ventilation capacities of buildings, as well as ventilation behaviour of their occupants, are frequently associated with problems of dampness and mould. Mechanical ventilation, which is the only means for controlling and optimizing ventilation rates, is becoming more important as natural air change becomes less prevalent in modern buildings.

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<sup>3</sup> Dr Kompauer / Dr Link, Germany

<sup>4</sup> Four additional case studies were suggested for discussion by a specific working group on processes.

### **Impact of education**

Many companies are actively involved in the remediation or removal of indoor mould and mould-damaged material. Some case studies have targeted the education or certification of professional staff to assess compliance with national guidelines and recommendations on mould removal, and training has been offered on regional or municipal levels to maximize the health impacts of remediation activities.

### **Information campaigns / capacity building**

In addition to professional services, which often are called to deal with large problems, untrained building occupants and others also undertake mould abatement and removal activities. To support such do-it-yourself activities, information campaigns disseminate practical guidance on work procedures, via a variety of materials and media. Informational activities targeting the public also increase general awareness and knowledge, thereby reducing dependence on professional services.

### **Municipal action**

Public authorities are directly responsible for protecting the health of users and occupants of public buildings and institutions. Therefore, regular inspections and hygiene checks are mandatory. In private homes and dwellings, there is no such obligation. However, several municipalities or authorities have supported the development of public or semi-public services aimed at protecting private homes and rental units from damp and mould.

Due to the restricted number of relevant case studies, a comparative assessment of the described approaches is not possible. Also, many case studies have considered various approaches in parallel, combining technical, informational and procedural mechanisms, generally concluding that these approaches are valid and potentially effective when adapted to specific building and climate conditions.

## **Conclusions and recommendations by working groups**

Three working groups were charged with consolidating a list of good practice elements from the selected case studies and making recommendations on their basis. The format for each working group (with a chairperson and rapporteur) was a first afternoon group discussion followed by a presentation of the group's findings to the plenary group on the morning of the second meeting day. Each working group then reconvened for a final discussion and drafting of a condensed set of conclusions and recommendations, taking into consideration the comments of the plenary group. The final recommendations were then presented to and shortly discussed at a final plenary session.

### **Working Group A: Good practice elements and recommendations from scientific perspective**

Chair: Kurnitski; Members: Davies, Emenius, Kolb, Kompauer, Molhave, Slotova

Working Group A assessed the case studies from a scientific perspective, trying to identify which showed the most reliable intervention result for purposes of the meeting discussion. The strengths and weaknesses of each case study were discussed, leading to an overall assessment of

the results' reliability. Of the 17 case studies, the group identified 9 as having sufficient information on the relevant parameters for assessment. The main reasons for non-selection were:

- lack of adequate health measurements
- retrospective measurements of health by questionnaire only
- inadequate measurement of dampness or mould exposure
- lack of information on remedial actions undertaken
- weakness of study design (lack of control group, comparison of different buildings, etc.)
- lack of integration of relevant confounding factors.

Although non-selected studies may still be scientifically valid and reliable, they were considered less appropriate or not sufficient for the meeting discussion requirements. The group noted that the unselected case studies may also contribute useful elements for damp and mould mitigation or prevention. In addition, the group cautioned that there is a large body of scientific evidence that has to be considered in preparing final recommendations.

The case studies provided reliable scientific evidence supporting the recommendations below. As a key conclusion, the group highlighted that moisture control is essential because dampness and mould problems basically are consequences of inadequate moisture control. In mitigation, the removal of contaminated material is equally essential. Therefore, the group made separate recommendations for general prevention and for remediation of existing problems.

Working Group A identified the following lessons and recommendations concerning prevention:

- Preventive measures are essential in avoiding mould and dampness problems.
- Occurrence of mould is a result of inadequate moisture control resulting from one or (most often) more factors such as incorrect design, construction errors, inadequate building maintenance or use and natural disasters.
- Building design should consider climate, culture and location as well as the intended use of the building.
- Regulations, codes, standards and guidelines should require effective control of moisture in buildings, including sources of moisture and ventilation as well as the hygrothermal quality of the building envelope.
- New buildings should be designed to meet a broad range of functions and occupant behaviours.
- Measures that reduce humidity below (nationally) specified values should include consideration of the moisture balance and ventilation consequences.
- Ventilation systems and devices can be effective moisture control measures, as they have the potential to reduce indoor humidity.

The group derived the following recommendations for remediating existing problems:

- Proper remediation can solve indoor mould and dampness problems.
- Proper remediation includes both moisture control and mould abatement.
- Remediation work should be done promptly and rapidly.
- To be successful, remediation must remove or mechanically clean all mould and contaminated materials as appropriate, and enable better moisture control.
- Targeted or partial renovation can also produce significant results.

- Remediation measures should be selected according to the nature of the problem; several parallel interventions may be needed.
- Building designs may have to be adapted to obtain better moisture control.
- New insulation, air tightening or changes in building function should be compensated by appropriate design or technical measures to keep humidity below specified (national) values.
- Remediation should take into account building use and occupant behaviour and health status.
- Installation of ventilation systems and devices can be effective moisture control measures as they have the potential to lower the indoor humidity.
- Occupants should be made aware of their potential role in causing dampness and mould problems, so that they do not counteract the remediation results.

Many case studies show that remediation and removal of contaminated material lead to a significant reduction in exposure, but do not always include assessments to show that this is reflected in health improvement. Although it is desirable that health impact measurements be performed, the main objective interventions must be the removal of the sources of exposure, as scientific evidence shows that the reduction or termination of exposure is a key requirement for associated health improvement.

### **Working Group B: Good practice elements and recommendations from problem perspective**

Chair: Haverinen-Shaughnessy; Members: Becker, Bogs, Buzyte, Hofbauer, van Loenhout, Walusiak, Wolz

Working group B approached discussion of the case studies from a pragmatic and problem-oriented perspective, looking in more detail at the interventions in relation to the described problem and indoor setting. Contrary to group A, which based its recommendations on more general scientific criteria, group B was more interested in technical solutions to the problem. Although the large majority of case studies referred to private dwellings, they were still considered relevant for all indoor spaces as the setting does not play a major role in remediation measures.

The working group first identified the types of problems that were described by the selected case studies, and identified – aside from problem of mould growth – a number of problems that needed to be addressed by building interventions.

<b>Technical problem description</b>	<b>Case studies</b>	<b>%</b>
Mould growth	17	100
Higher indoor relative humidity	10	59
Rain water seepage	7	41
Lack of ventilation	7	41
Inadequate heating	6	35
Damaged construction materials	5	29
Increasing dampness	3	18
Internal moisture sources	2	12
Unventilated crawl spaces	2	12
Plumbing leakage	1	6
Spread of contaminants by HVAC system	1	6
Major flooding effects	1	6

It seems reasonable to expect that these types of problems are typical and provide a rough overview of the technical challenges in dampness and mould remediation. The main problems associated with mould exposure in the selected case studies were higher indoor humidity levels, leaks and lack of adequate ventilation and heating.

The group noted that there are a variety of technical problems that may additionally be associated with mould problems, but are not reflected in the case studies, including moisture inside building structures, interstitial condensation, construction moisture, aging materials and the exposure to high outdoor humidity.

Key elements of successful actions were listed by the group during the review of the case studies, and are summarized below. However, due to the variety of project objectives and remedial action taken, most case studies only covered a few of these practices. No case study implemented more than five of the suggested elements, which are:

- examination of buildings by experts with proper tools
- resolution of moisture problem causes
- removal of mould as well as damaged material (mechanical or chemical cleaning)
- drying remaining structures
- improvement of ventilation and thermal insulation
- use of proper materials that do not promote mould growth
- protection of workers
- prevention of cross-contamination by separating clean-up areas from non-infected areas  
initiating remediation work as soon as possible
- minimizing the remediation period to prevent occupant discomfort
- relocation of occupants to reduce exposure and health complaints
- follow-up of remediation and quality control.

In addition, the group stated that from a pragmatic perspective, it may be necessary to set priorities, as not all remedial action can be performed at once. Based on the case studies, it seems that with the right priorities, partial remediation can be successful.

The working group observed that high-occupancy buildings are more prone to health problems from dampness and mould, and that geographical location may be a factor (e.g., northern exposures may be associated with more humidity problems). The relevance of thermal conditions and indoor surface temperatures for the prevention of condensation was highlighted as well as the necessity of adequate ventilation in relation to the climate. Finally, it was stated that ventilation systems should be quiet to make their use acceptable to building occupants.

The group acknowledged the key relevance of occupant behaviour, which – depending on the building – may be able to compensate for minor constructional failures, or to trigger damp and mould problems in well-constructed buildings. It was considered necessary to educate building owners as well as occupants about the impact of their behaviour, and to provide adequate information on the consequences of building changes and renovation activities. Main objectives of any kind of information campaign should be to help the occupants to avoid technical problems and observe good practices (not hanging laundry to dry indoors, open flue heaters, excessive water use in cleaning, excessively low temperatures, misuse of ventilation, etc.). It was recommended that specific advice be given to occupants of problem buildings.

A number of open questions still remain, such as the loose qualification requirements of housing professionals in general and remediation workers in particular, the lack of cost-benefit studies of remediation, the uncertainty about if or when building occupants need to be relocated and the frequent conflict between ventilation and energy-saving requirements. Evidence-based answers to these questions will help improve the actions taken against dampness and mould, and increase the health benefits of the interventions.

Merging all elements from the case studies, the working group put together a generalized summary of actions in relation to specific building-related causes, distinguishing between hygrothermal problems, outdoor and indoor moisture sources and catastrophic events. In addition to actions related to the causes of problems, subsequent actions should adequately address damage already caused, via cleaning or replacement of contaminated materials, drying of wet materials and protecting occupants and construction workers from contaminated materials.

The working group suggested a need for policy guidelines on technical issues, but acknowledged that these can only be very broad and need to be supplemented by specific technical norms and codes of practice on national or regional levels.

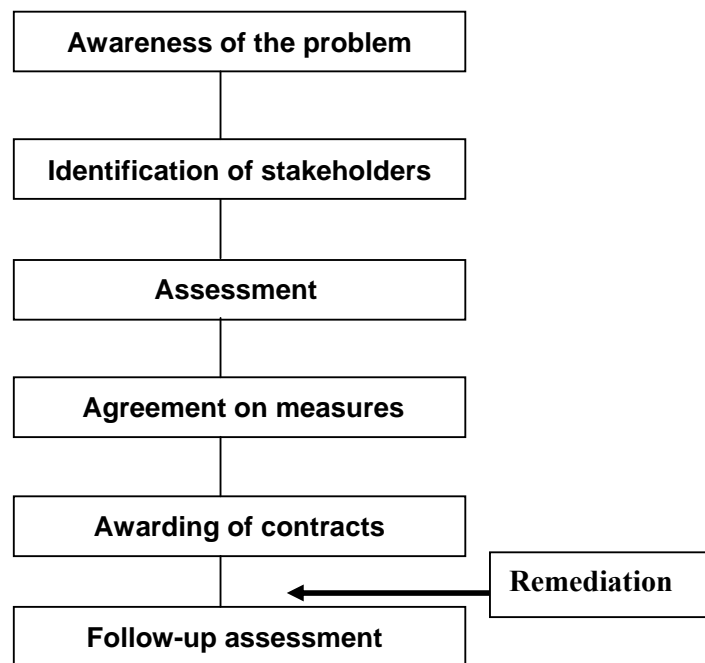
<b>Hygrothermal problems</b>	<b>Remedial action</b>
Increased relative humidity indoors	Addressing indoor moisture sources, control of ventilation and HVAC systems, increasing temperature as necessary
Surface condensation without increased indoor humidity	Addressing thermal insulation, including local thermal bridges and defects
Combined problem	Measures starting with relative humidity indoors
<b>Outdoor sources</b>	<b>Remedial action</b>
Outdoor sources and rising damp	Diagnosis of moisture path, necessary actions addressing drainage, sealants, water-membranes, flashings, water stops, capillary layers etc. If accessibility is limited and repair works must be done from the inside, consultation with an expert may be recommended.
<b>Indoor sources</b>	<b>Remedial action</b>
Plumbing	Inspection, repairs and replacements
Occupants	Addressing exact moisture source, educating occupants to change occupant behaviour
<b>Catastrophic events</b>	<b>Remedial action</b>
Flooding, storm water intrusion, fire fighting efforts, major water/sewage line breaks, etc.)	Temporary relocation occupants, immediate remedial actions

### **Working Group C: Good practice elements and recommendations from process perspective**

Chair: Hasselaar; Members: Charpin, Follin, Gallo, Heuberger, Kelly, Kopf, Link, van den Hazel

Working group C discussed the case studies from a process viewpoint, considering the actors, mechanisms and institutional context of the actions in the case studies. This group discussed four additional case studies that mainly focused on the mechanisms and processes and suggested strategies for municipalities and/or non-governmental organizations to become involved. The number of case studies discussed was therefore 21.

Drawing from the review discussion of the case studies, the group first developed a “good practice” process example which emerged from the case studies and their individual approaches. As working group B was discussing the technical aspects of mould and moisture removal actions, Group C did not cover this point and therefore the step of “remediation work” has only been indicated in the process line below. Clearly, not all case studies followed this process and often some steps were not relevant or implemented in a modified way. The good practice example below can therefore be considered a synthesis of steps that were deemed useful and effective. However, it is important to note that the process example described below is based on large-scale remediation requiring professional expertise. A wide variety of other scenarios can be considered in which one or several steps presented below may be left out – one example could be the realization of small and basic repair and remediation work by building occupants, which would ignore the steps of identifying adequate actors and appointing contractors. Depending on the building type and the specific housing market mechanisms, different process lines will be valid.



The group’s first recommendation was of the need for prevention in order to avoid problems in first place. Prevention includes making indoor humidity, ventilation and temperature control focal areas of policy-making.

When problems do arise the mechanisms of the case studies suggest the following steps and actions:

### Stage 1: Awareness of the problem

Description	This first stage is the identification of the presence of mould/dampness in a building. It could also be a medical complaint registered by a physician, environmental health or local authority.
Actors or stakeholders involved	<p><b>Occupants</b> should be provided with information for identifying and preventing mould.</p> <p><b>National health organizations</b> should provide advice on the symptoms and conditions associated with mould and the preventative measures to be taken.</p> <p><b>Medical professionals</b> should be made aware of the conditions and symptoms of mould.</p> <p><b>Facilities managers</b> should be encouraged to act promptly and effectively when a problem is presented. An initial check of the building operations, condition and occupant behaviour should be carried out.</p> <p><b>Inspectors</b> should identify, as far as possible, the risk factors related to specific complaints, make building occupants aware of them and suggest measures to be taken.</p> <p><b>Building professionals</b> should provide relevant information on the prevention of mould/dampness to legislative and regulatory bodies.</p>

### Stage 2: Identification of stakeholders

Description	<p>The second stage looks at identifying the stakeholders involved in dealing with the complaint. These individuals or organizations should be focussed on identifying the magnitude of the problem, the affected persons and the remedial measures to be considered.</p> <p>All stakeholders should be made aware of the process of intervention, as described here.</p>
Actors or stakeholders involved	<p><b>Occupants</b> should be made aware of other stakeholders and the next steps in the investigation.</p> <p><b>Homeowners</b> may be tasked with dealing with mould/dampness issues.</p> <p><b>Building owners</b> should be aware of problems in their buildings, the processes to follow and the steps involved in interventions.</p> <p><b>Tenant organizations</b> should be made aware of problems when necessary.</p> <p><b>Local authorities</b> should take responsibility for following and monitoring the process and make sure adequate solutions are found to protect the residents.</p> <p><b>Funding agencies</b> who may be able to support inspections should be identified and invited to these discussions.</p> <p><b>Government agencies</b> may be asked to provide support in cases of financial constraint that could hamper the investigation.</p>

### Stage 3: Assessment

Description	<p>Mould/dampness problems should be fully investigated to determine their causes. The assessment can be carried out on medical grounds, building physics investigation and tenant/occupant interview.</p> <p>Guidance can be given to the tenant/owner as to the level of intervention that may be required.</p>
Actors or stakeholders involved	<p><b>Occupants</b> should be encouraged to clean small areas of mould as an initial step.</p> <p><b>Building owners</b> should assess the extent of affected areas and determine the need to appoint a dedicated professional.</p> <p><b>Inspectors</b> should be qualified and trained to a suitable level, as determined by a third-party organization where possible. Guidelines should be provided on how to carry out an investigation in a structured and effective manner. A directory of approved inspectors could be provided to ensure quality.</p> <p><b>Medical professionals</b> should carry out examinations where a patient referral has been requested. Any diagnosis provided should be presented by specialized professionals.</p> <p><b>Tenant organizations or local authorities</b> could carry out interviews.</p> <p><b>Funding agencies</b> relevant to the situation should be involved in these discussions.</p>

### Stage 4: Agreement on measures

Description	<p>After the investigation has been completed, remedial measures should be identified and presented to stakeholders for discussion and agreement.</p>
Actors or stakeholders involved	<p><b>Occupants</b> should be made aware of findings from the inspections and approved remedial measures.</p> <p><b>Building owners</b> should discuss the findings of the investigation with all other parties involved. They should recognize their limitations and consult with professionals as required. The building owners should recognize their financial role in the remediation process.</p> <p><b>Inspectors</b> have the primary role of presenting their findings and suggesting remedial work. They should recognize their limitations and consult with other professionals as required. These proposals should be discussed with all parties involved.</p>

### Stage 5: Awarding of contracts

Description	<p>When the remedial work has been agreed, a competent contractor who has a good history in work of this kind should be appointed. A clear scope of work should be agreed, including procedures and a contract should be presented for all parties follow. The contractor should be made aware of safe working and handling procedures before work is initiated, and should provide a plan describing how the work will be undertaken so as to minimize risk of further contamination.</p>
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Actors or stakeholders involved

**Occupants** should be informed of the processes and duration of the remedial work. They have to be protected from exposure to contamination, including relocation under special circumstances

**Building owners** should provide safe access to the areas.

**The building industry** is encouraged to provide available technical solutions for remediation work.

### Remediation (see Working Group B)

#### Stage 6: Follow-up assessment

Description

When the remedial work has been completed, a follow-up assessment should be carried out, including, as a minimum, an inspection of the remedial work, but could also be extended to a medical examination and tenant interview.

A standardized template for questioning tenants should be developed to ensure continuity of approach and measurement of effectiveness.

Actors or stakeholders involved

**Occupants** should independently request evaluation action.

**Building owners** should carry out such follow-up actions out of own interest.

**Local authorities** should monitor the success of remediation for public buildings and possibly expand this to (or initiate the process for) private buildings.

**Remediators and inspectors** should take interest in evaluating their work and performing adequate measures for quality control.

**Medical professionals** can use health survey and research methods to assess the effect of remediation.

### Meeting conclusions

From the final discussions and comments of the working groups, based on their prior discussions, the following main conclusions on technical actions and policy implications were derived:

#### Technical actions and interventions against damp and mould

There is more evidence available than that found in the case studies discussed. Although the case studies provide an impression of how theoretical knowledge on dampness and mould interventions can be carried out in practice, they also provide restrictions as they do not reflect the full scope of potential actions and interventions. Therefore, for further progress of the project, additional review activities of actions and projects are recommended.

Adequate assessment of the magnitude of the problem, as well as a thorough identification of the root causes of damp, moisture or mould occurrence, are considered the key measures for sustainable remediation and prevention. This includes not only building parameters, but also the occupants' behaviour.

The physical removal of mould and mould-affected materials is considered the main strategy for remediation and various case studies have proven its effectiveness. However, the exact measures strongly depend on the given problem and building. There was consensus among the participants that although complete removal and remediation is desirable, focused remedial action targeting the main problems can be a successful first measure as well.

The balance between moisture, air change rate and surface temperatures (both indoor surfaces as well as surfaces within the building structure) has been identified as the main objective for both remediation and preventative measures. Therefore, applicable and affordable solutions are needed to either reach such balanced conditions in damaged buildings, or prevent unbalanced conditions in general terms. Assuming that buildings are healthy in most situations, the preventative dimension of this balance is a key objective for technical actions.

As the case studies were strongly focused on the remediation of existing problems, the actions undertaken did not provide direct information on the value of preventive approaches. Nevertheless, actions taken to ensure that conditions do not reappear after removal help to reach balanced indoor conditions in relation to dampness, ventilation and temperature.

### **Policy dimensions of the case study review**

To eliminate subsequent problems from dampness and mould, preventive measures must be intensified already from the design and construction of new buildings. This is particularly relevant in combination with measures to reduce energy consumption. The meeting participants strongly felt that for a variety of conditions and parameters, such as a threshold level for relative humidity or thermal insulation values, national and international guidelines and standards need to be developed. However, technical guidance on exact values may be more appropriate on the national level, adapted to the pertinent climatic and building characteristics. International work could rather be focused on the overall content and requirements for such guidance, leaving the practical implementation to the country level. The development of WHO Indoor Air Quality Guidelines for Dampness and Mould was considered the appropriate process for suggesting such guidance tools and values.

One key component that is currently missing in the protection of the population is the lack of mould monitoring and identification of exposure problems in private homes. While there are clear mandates of local authorities and regular assessments and inspections for publicly owned buildings, there is no public responsibility for private homes. In the rental sector, however, there is a clear responsibility of building owners to provide adequate housing conditions, but in practice this is mostly restricted to legal implications after a problem has been identified, and very little is done of a preventative nature. Future policies need to improve this situation, and enable private residents to identify problems and act accordingly. This also includes the provision of quality control measures for remediation work, which can usually not be assessed and evaluated by residents.

As main options to protect the health of private residents, the meeting suggested increased involvement of municipal services and implementation of inspections in relation to new rental or purchase contracts. In addition to such general approaches, there could be identification of buildings with specific dampness and mould problems. In most countries, there is sufficient knowledge on the quality problems of the housing stock to allow for national campaigns – possibly supported by grants and incentives – to address those buildings as a first priority.

Parallel to approaches targeting specific elements of the housing stock, the education of housing practitioners and craftsmen is relevant. As professionals involved in building work and rehabilitation have direct access to the building, they could, with proper training, become a major factor in the protecting the population. In addition to the identifying problems (which may be unknown to the occupants), such housing practitioners could also inform and advise occupants about adequate action. Additionally, the building industry is encouraged to take part in the development of practical solutions for remediation work.

From a policy perspective, little is known about the regulations and policies on handling dampness and mould and their elimination in different countries. A review of policies and regulations would be helpful to compile national practices and approaches, and would provide suitable background information for the development of policy recommendations.

Finally, and with much emphasis, the meeting participants concluded that policy approaches need to address both buildings and occupants, and especially empower the occupants to identify problems and take appropriate action. However, this requires increased awareness of the problem as a first measure, as well as basic awareness of the technical relationship between humidity, temperature and ventilation by the residents. It was suggested that information campaigns be less focused on mould – which is rather a symptom, not a cause – and instead send a clear message that the ultimate problem is excessive dampness, moisture and condensation. This would help to avoid activities undertaken by private actors with the objective of removing mould (sometimes using hazardous chemical substances to do so), and redirect the actions to address the root causes of dampness and moisture.

## **Project perspectives**

Reviewing case studies on interventions against dampness and mould is one element of a larger project addressing the policy implications of actions to reduce health risks due to indoor air pollution with biological agents. Complimenting the development of indoor air quality guidelines on damp and mould, this project aims at delivering policy advice on adequate tools, actions and mechanisms. Therefore, the conclusions and recommendations developed at this meeting will provide one of the background documents for a future project meeting focusing on the development of policy briefs, informing policy-makers about the main challenges, appropriate actions and adequate policies to prevent, mitigate and reduce the exposure of the population. The recommendations in this meeting were directed to the general population. The consideration of people with special needs or with special risks should be done in a further step.

In addition to the policy meeting, additional work will have to be carried out to identify evidence for both technical and policy measures against dampness and mould. Working steps should aim at providing information on areas identified as insufficiently covered by the review of case studies and technical actions. Main elements of future work as a preparatory step for a policy meeting could include:

- compilation of technical and case studies from southern Europe and warmer climates
- review of measures undertaken in public or institutional settings
- review of projects, standards and guidelines related to policy approaches to prevention and mitigation.

Based on the conclusions of the case study review and some additional background documents, the policy meeting would then gather a number of European experts and policy-makers to discuss appropriate interventions and their translation into political action and policy tools.

## *Annex 1: Case study summary*

WORLD HEALTH ORGANIZATION  
REGIONAL OFFICE FOR EUROPE

WELTGESUNDHEITSORGANISATION  
REGIONALBÜRO FÜR EUROPA



ORGANISATION MONDIALE DE LA SANTÉ  
BUREAU RÉGIONAL DE L'EUROPE

ВСЕМИРНАЯ ОРГАНИЗАЦИЯ ЗДРАВООХРАНЕНИЯ  
ЕВРОПЕЙСКОЕ РЕГИОНАЛЬНОЕ БЮРО

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### **WHO expert meeting on interventions to reduce health effects of dampness and mould**

**Bonn, Germany, 28 - 29 February 2008**

## **Case study summary**

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## **General information about received studies**

In total, 30 case studies on dampness and mould interventions were submitted to the WHO European Centre for Environment and Health, Bonn Office. Countries of origin were Belgium (4 studies), Denmark (1), Finland (4), France (1), Germany (6), Israel (3), New Zealand (1), Slovakia (1), Sweden (4), the United Kingdom (3) and the United States (2). Twenty of these studies were conducted in residential buildings, four in schools, one in residential buildings and schools, one in a child centre, one in a child centre and residential buildings, one in an elderly centre, one in an office building and one (an information campaign) targeted all kinds of buildings. Seventeen were intervention studies, seven information campaigns, one was a laboratory experiment and five were miscellaneous activities.

## **Methodology of case study selection**

Case studies were evaluated by the WHO Collaborating Centre for Housing and Health, according to criteria for intervention studies on mould remediation established by the Centre (Drs Gabrio, Kompauer, Link) together with Dr Szewzyk. In parallel, each of the four members of the advisory group evaluated 15 studies for eligibility for the WHO expert meeting on interventions to reduce health effects from damp and mould. The studies were categorized as: useful for discussion, limited but still useful and those selected by each reviewer. Finally, all rankings were merged, with 17 studies reaching at least a 2 in the overall ranking considered appropriate for further discussion. The other 13 studies were not considered for the meeting mainly for the following reasons:

- no intervention study / before-after design
- out of scope
- weak practical evidence
- no systematic evaluation.

The results of this review process are summarised in Table 1 at the end of this document.

## Description of the case studies

On the following pages the interventions and, where available, measured exposures and health outcomes of the 17 studies are summarized. For this summary, the submitted case study descriptions and additional publications or drafts for publication were considered.

**Lorenz et al. (Germany) (3)** gave advice on mould remediation for 249 residents of 114 residential buildings and 6 months later investigated by a telephone interview if the damage had been repaired and if the ailments of the inhabitants had decreased following renovation. After removal or after renovation of all damage with complete removal of the damaged material, roughly 87% reported amelioration of the respiratory and skin symptoms and in 73% and 47%, respectively, the joint pain decreased or disappeared completely. After repair of all damage without removal of the damaged material, 39% of the previously suffering people reported amelioration of respiratory and skin symptoms and 20% a decrease or disappearance of joint pain. After repair of only a part of the mould damage with complete removal of the damaged material, 74% reported amelioration of respiratory and skin symptoms and 54% a decrease or disappearance of joint pain. Without repair, 17% of the previously suffering people reported amelioration of the respiratory and skin symptoms and 19% a decrease or disappearance of joint pain.

In **Dearborn et al. (United States) (4)**, interventions were directed at reducing water infiltration, removal of water-damaged building materials and altering heating, ventilation and air conditioning units and environmental cleaning in the houses of 62 moderately severe asthmatic children or families with young infants where there was visible water damage and/or a mould source. In the control group only house cleaning information was given. In total, 104 residential buildings were included in this study. Children in both groups showed improvement in asthma symptomatic days during the pre-remedial period of the study. The remediation group had a significant decrease in symptom days ( $p = 0.003$ , as randomized;  $p = 0.004$ , intent to treat) after remodelling, whereas these parameters did not significantly change in the control group. In the post-remediation period, the remediation group had a lower rate of exacerbations compared to control asthmatics (as treated: 1 of 29 vs. 11 of 33, respectively,  $p = 0.003$ ; intent to treat: 28.1% and 10.0%, respectively,  $p = 0.11$ ).

**Wilson et al. (United States) (7)** distributed a video providing guidance on flood clean-up and mould control for houses in an urban area (New Orleans) affected by multiple days of flooding after Hurricane Katrina. Preliminarily, they conducted a very well-documented pilot study in three single-family houses. The intervention included disposal of damaged furnishings and drywall, cleaning surfaces, drying the remaining structure and treatment with a biostatic agent. Before the intervention, they measured culturable fungi, fungal spores, PCR and endotoxin in indoor air in all three houses; fungal spores in indoor and outdoor air at all three houses; culturable fungi, PCR, and endotoxin in outdoor air at one house and moisture content of the

wood studs. Additionally, they visually inspected the extent of mould on walls, cabinets, floors, doors, trim, appliances, equipment and ductwork. After the intervention, they measured culturable fungi, PCR and endotoxin in indoor and outdoor air at all houses and fungal spores in indoor and outdoor air at one house. The intervention resulted in a reduction of very high concentration of colony-forming units and spore counts and (except for one house) endotoxin levels. The authors reported an underestimation of some species in culture-based analyses. Average workplace protection factor against fungal spores for elastomeric respirators was higher than for the N-95 respirators. The authors found that intensive dry cleaning followed by the application of borates appears to control mould growth. Unfortunately, no health outcomes were measured.

In epidemiological studies, **Herbarth et al. (Germany) (8)** wanted to find out changes in load depending on activities like remodelling or mould removal and associated health effects in approximately 3000 dwellings and 50 child centres with approximately 6200 people. In the cohort studies, at every time of investigation (around birth, after 7 weeks, 0.5 years old, 1 year old and at every birthday until the 6<sup>th</sup>, 10<sup>th</sup> or 14<sup>th</sup>), volatile organic compounds (VOC) and microbial volatile organic compounds (MVOC) were measured using passive (4 weeks) and active sampling methods. The mould was measured using sampling devices (and agar plates). Lifetime prevalence of physician-diagnosed eczema and allergy-associated symptoms were assessed by questionnaire. In the repeated cross sectional studies the authors found a strong link between renovation activities around birth and incidence of atopic diseases in later life. The risk was approximately two times higher than in the control group (no renovation). The earlier in a child's life renovations were carried out, the greater the risk of developing allergic disorders later on.

In the second contribution by **Herbarth et al. (26)**, based on the results of measurements in approximately 500 apartments, the subjects were given information about reducing or removing mould with reference to the "Mould remediation guide" [*Schimmelpilzsanierungs-Leitfaden*]. No measures were prescribed with consideration to legal problems. Before and after the intervention, indoor mould spores and VOC were measured. Allergic disorders, airway diseases and indoor associated syndromes like sick building syndrome or chronic fatigue syndrome were assessed by questionnaire, specific immunoglobulin E (IgE) and immunoglobulin G (IgG) were measured. The following measures were undertaken conducted by the participants or owners of the apartments: mould remediation by a specialized company; mould remediation by the participant using anti-mould chemicals and/or remodelling; changing apartments or doing nothing. The measures are not described in detail (the chemicals used, etc.). For all participants who had taken any measure the load caused by mould was lower than before or not further detectable. Preliminary results suggest that typical indoor mould spores such as *Penicillium* (-30%) and *Aspergillus* (-70%) were reduced, and this is reflected in symptom load reductions. This effect was observed with regard to non-specific symptoms like headache or fatigue as well as specific symptoms of the respiratory tract (irritation, itching nose, cough), epidermis and eyes

(irritation, dry eyes, skin rash). All in all the number of affected persons was decreased by 15–30%. Changes of laboratory parameters were also observed (generally improving), for example specific IgE and IgG. The improvement in symptoms was more pronounced than that in the laboratory parameters.

**Haverinen-Shaughnessy et al. (Finland)** forwarded four studies (10, 11, 28, 29). In their first study (11), they conducted improvements in drainage, rainwater sewer systems and water barriers of basement walls in a school. Additionally, replacement of moisture-prone materials improperly used in locations subjected to high moisture loads, improvement in ventilation of crawl spaces and replacement of all damaged material was done. Areas where damage was observed were left unused and isolated to avoid air exchange between the damaged areas and other areas before and during the repairs. An extensive cleaning after the removal of damaged materials included wiping of all surfaces and disinfecting materials prone to microbial contamination. The data were analyzed both in cross-sectional design including all respondents, and longitudinally including paired observations of those individuals who had responded both before and after the repairs. After the repairs there was significant improvement of most of the 20 symptoms studied among the cross-sectional study populations. However, improvement was not so clear in the paired analysis and generalized estimating equation (GEE) analysis among the students who responded to three repeated questionnaires. The results indicate that the repairs succeeded in the sense that new cases of symptomatic students were no longer expected. Both technical and microbial follow-up measurements made after one year and partially repeated at three years suggested that the repairs were satisfactory and microbial contaminant levels were reduced.

In a second study, **Haverinen-Shaughnessy et al. (10)** followed-up effects of remediation (including renewal of roofing, improved drainage system, remediation of balconies and renewal of damaged ceiling tiles) in an elderly centre. Before and after the intervention, they measured surface moisture and temperature, as well as culturable (and non-culturable) fungi from air, surface and bulk samples. After the intervention they measured culturable and non-culturable fungi in air. The employees responded to a health questionnaire based on Örebro-Questionnaire (MM40) and the Tuohilampi questionnaire, and also kept a symptom diary during the process. The health questionnaire included 70 questions on irritation, respiratory and general symptoms, respiratory infections, acute and chronic respiratory diseases and allergic diseases as well as questions on changes observed between the questionnaires. After remediation, water leakage through roof and balcony structures had stopped, and no more *Stachybotrys spp.* fungi was observed in the indoor air samples. However, low concentrations of other indicator microbes were still observed. Occupants reported significantly fewer nasal symptoms, hoarseness, sore throat, and eye symptoms. Symptom association with work decreased significantly for facial eczema and cough. The prevalence of sinusitis was significantly decreased after the remediation.

In the third study on a row house complex including 51 apartments with 145 residents (28), **Haverinen-Shaughnessy et al.** recommended the improvement of ventilation and drainage,

drying of wet materials and improving moisture protection in bathrooms. Before and after the intervention, surface moisture, temperature, CO<sub>2</sub>-concentration, pressure differences, air flow measurements were performed. Only technical evaluation was done in the course of the study. Microbial and health effects studies were also included in the process, but the results have not been analyzed collectively due to the research project ending. The technical monitoring indicated improved and more controlled ventilation. However, some of the floor structures still had elevated moisture content. Occupant reports and complaints of poor IAQ had diminished. This data was not systematically collected, but was based on assessment by the environmental health officers of the city records of occupants' spontaneous contacts.

The fourth **Haverinen-Shaughnessy et al.** study (29) was conducted in a school and consisted of ventilation system improvements and roofing renewal, air leakage sealing, windows repair, drainage improvements and remediation of wooden ground floor structures. Before the intervention, culturable and non-culturable fungi from air, surface and bulk samples were measured. Technical follow-up measurements included visual observation, and measurements of relative humidity and temperature from structures. Culturable and non-culturable fungi in air, and culturable fungi from surface or bulk samples were measured yearly during the three years of the remediation. In the follow-up phase annual questionnaires were given to the personnel, based on Örebro-Questionnaire (MM40) and the Tuohilampi questionnaire, including 70 questions on irritation, respiratory and general symptoms, respiratory infections, acute and chronic respiratory diseases and allergic diseases. Additionally, questions on changes observed in between the questionnaires were asked. Students responded to a similar questionnaire, including 44 questions on respiratory and general health, 12 questions on background information and 16 questions about the school. Repairs could not be implemented immediately due to budgetary constraints and were extended over three years. Large spatial and temporal variations were observed in the airborne microbial concentrations. Hence, no conclusion could be drawn based on these results. Occupant health status remained similar or even deteriorated during the remediation process. Therefore, the remediation did not have positive effects on occupant health.

**Becker R et al. (Israel) (13)** established adequate minimal thermal insulation requirements in new Israeli dwellings to reduce the risk of surface condensation in bedrooms and living rooms in regular size dwellings under normal use conditions, surveying 250 dwellings before implementation of the standards and 100 (different) dwellings after implementation. The first survey indicated that only 45.5% of the dwellings had no condensation-related mould growth; 19% had severe mould growth attributed to surface condensation and 29.5% had observed surface moisture due to condensation. After implementing the new standard, the level of condensation-related mould growth was reduced to less than 30% and severe mould growth related to surface condensation to less than 9%, appearing only in dwellings in the north of the country with an insulation level almost equal to the new minimum.

**Oreszczyn T et al. (United Kingdom) (15)** reported installation of draught stripping, thermal insulation and gas central heating systems in roughly 3000 low-income residences. Before and after the intervention, living room and main bedroom temperatures and relative humidity were measured. Additionally, visual inspections of the occurrence and extent of mould were done and quantified on a mould severity index (MSI). The authors found that standardized relative humidity increased with the size of the household and that there was a clear relationship between standardized relative humidity and presence of mould. The risk of mould is very small if the standardized relative humidity is below 40%. Overall, the project was successful in increasing thermal comfort and indoor temperatures while humidity and mould problems were reduced.

**Emenius et al. (Sweden) (16)** measured air change rates, indoor air humidity, mite allergen levels in mattress dust and total VOCs in 59 one-storey single-dwelling houses to study the impact of mechanical ventilation on various indoor parameters. In 22 out of the 59 houses a balanced mechanical ventilation system was installed; the others had the originally installed natural ventilation (29) or improved natural ventilation (8). Increased indoor air humidity  $\geq 7$  g/kg air was only observed in naturally ventilated houses (8 of 29). The authors found an inverse correlation between the air exchange rate per hour and absolute indoor humidity ( $r=-0.64$ ) and a weak inverse correlation between air exchange rate per hour and mite allergen in mattress dust ( $r=-0.31$ ). No significant correlation between indoor humidity levels and mite allergen in mattress dust, but significantly lower levels of mite allergen in mattress dust and concentrations of VOC in mechanically ventilated houses was reported by the authors. Absolute humidity levels were significantly lower than in a previous study, likely due to different times of year (October vs. March).

**Matthews et al. (United Kingdom) (17)** conducted a randomized controlled trial on houses of patients with asthma consisting of 81 intervention and 83 control houses. The intervention included removal of indoor mould, application of fungicide and installation of exhaust fans in lofts. Before the intervention, air temperature and relative humidity, ergosterol in air samples, outdoor mould and house dust mites were measured, and mould presence was confirmed by trained observers. After 12 months, measurement of air temperature and relative humidity was conducted again and mould was visually inspected. After 6 and 12 months, morning and evening peak expiratory flow (PEF) variability declined in both the intervention and the control groups, with no significant differences between them. Also, an improvement in wheezing, rhinitis, rhinoconjunctivitis and a reduction in medication use were observed in the intervention group. The reduction in humidity was small but significant. Visible indoor mould was eradicated in all houses in the intervention group, but 12 months later it had reappeared in 40% of them, mostly at new sites. Some residents of the control houses also took their own actions to remove mould, so that by 12 months mould was present only in 78% of them.

Activities of the WHO housing programme reported by **Braubach et al. (Germany) (19)** included the assessment of thermal insulation of facades, building roofs and basement ceilings,

replacement of single-glazed with double-glazed insulation windows, exchange of doors to staircases and exchange of the heating system in some dwellings. The intervention group consisted of 212 residential buildings, the control group of 162. After the intervention, data on indoor temperature and relative humidity for 189 dwellings, dust samples for 102 dwellings, VOC measurements for 22 dwellings and measurement of inside and outside wall temperature and humidity for bedrooms and living rooms for all dwellings were collected. Peak flow and NO in exhaled air were measured and prevalence of selected diseases was assessed by questionnaire. The residents of the intervention dwellings reported greater thermal comfort. Indoor temperatures were higher and relative humidity was slightly reduced in the intervention dwellings, compared to the control dwellings. For visible mould growth, very little change was found a few months after the intervention. For several diseases (asthma, cold, bronchitis), the prevalence increased for residents of control dwellings while there was no change or a slight decrease for intervention dwelling residents. Stronger results were found for the number of acute respiratory diseases during the last three months (i.e., winter), which increased for the control group and decreased for intervention group.

The intervention of **Bladt et al. (Belgium) (21)** consists of an environmental diagnosis of a dwelling where indoor exposure to mould, other organic substances or chemicals pollutants is suspected to contribute to reported health problems. Reports were sent to physicians, who would advise subjects and then assess their health after 12–18 months. Starting in 2000, the programme was conducted for approximately 150 dwellings each year, with chemical (VOCs, benzene, toluene, xylene, formaldehyde and pesticides) and biological sampling (mould contamination of surfaces and air and dust mite allergens) of each room. The diagnoses include a search for sources (bad ventilation, condensation, humidity, building problems). A questionnaire on health improvement was sent to every patient and doctor. After 12–18 months, 57% of physicians reported real improvements in patient health and 80% of the patients felt an improvement in their health. In 30% of cases, the doctors' advice had not been implemented by the respondents.

The intervention of **Howden-Chapman et al. (New Zealand) (22)** consisted of ceiling insulation in 1400 dwellings with approximately 5000 residents, draught stopping around doors and windows, under-floor insulation and under-floor polythene to reduce rising moisture, as appropriate. Before and after the study, indoor temperature, energy consumption and relative humidity were measured. Additionally, speciation and mass of mould, endotoxins, beta-glucans and dust mite allergens were measured, but not reported. Data on self-reported health, wheezing, school and work sick days, visits to general practitioners and admissions to hospital were collected using a questionnaire. The insulation caused a small increase in bedroom winter temperatures (0.5°C) and a decrease in relative humidity (–2.3%), exposure to temperatures below 10°C was reduced by 30%. Fair or poor self-rated health, self-reported wheezing in the last three months, self-reported school and work absence were reduced. GP visits and hospital admissions for respiratory conditions were less often reported by occupants of insulated buildings.

The study of **Pieckova et al. (Slovakia) (25)** included a public information campaign on avoiding objectively identified factors that increase indoor dampness and mould. The authors compared 148 dwellings and 3 schools of the same construction type in the same area with (cases) or without (controls) complaints about dampness and mould. At the beginning of the study, construction type, indoor temperature including dew point and surface temperature were measured. Information on household style (ventilation, cleaning regimen, internal sources of dampness, furnishings, economic status, subjective health conditions – respiratory illnesses, discomfort etc.) were collected using a questionnaire. Very early results (half a year after the information campaign) include a reduction of complaints about indoor dampness/moulds (further statistical validation needed) in dwellings. Statistical analysis of the relationships of indoor fungal contamination to hygrometric conditions, household characteristics and construction defects is in process. The inhabitants of mould-affected buildings mostly behaved differently in terms of heating/ventilation modes, cleaning and maintenance practices and indoor moisture sources, factors that seem to affect indoor moulds even more than construction or insulation failures.

## **Review of selected case studies**

### **1) Main elements: interventions, exposure assessment and health impacts**

#### **I. Actions and interventions to prevent, remove or mitigate damp and mould**

##### **Mould removal**

- removal of indoor mould
- appliance of fungicide
- replacement of all damaged material

##### **Change of ventilation**

- installation of a fan
- exhaust ventilation system
- improved ventilation in crawl spaces

##### **Reduction of water infiltration**

- ceiling and roof repairs
- under-floor polythene
- drainage improvements
- rainwater sewer systems
- water barriers for basement walls
- replacement of moisture-prone materials in high-moisture locations

##### **Thermal insulation**

- under-floor insulation
- thermal insulation of facades, roofs and basement ceilings
- replacement of single-glazed with double-glazed windows
- draught stopping around doors and windows
- heating system replacement

##### **Further activities**

- remediation of wooden ground floor structures
- isolation of affected areas to avoid air exchange before and during the repairs
- extensive cleaning after removal of damaged materials, including wiping of all surfaces and disinfecting materials prone to microbial contamination.

#### **II. Exposure assessment**

To assess the exposition before and after interventions, data on the following risk factors were collected:

- dampness and relative or absolute humidity measured by the study or reported by residents
- visible mould determined by the researchers or reported by the residents
- dampness or mould determined by the researchers or reported by residents

- spore microscopy and/or polymerase chain reaction (PCR) to identify fungi
- concentrations of mould spores and culturable fungi
- related microbial agents

### III. Health impact assessment

#### **By medical examination**

- Spirometry for forced expiratory volume in one second (FEV<sub>1</sub>), forced vital capacity (FVC), peak expiratory flow rate (PEFR)
- NO in exhaled air
- skin prick test, total IgE, specific IgE, IgG
- peripheral blood eosinophil counts

#### **By questionnaire**

- prevalence of allergic, respiratory and other diseases
- indoor-associated syndromes like sick building syndrome or chronic fatigue syndrome
- general symptoms, health
- use of medication
- amelioration of ailments
- quality of life.

## **2) Settings for damp and mould interventions**

Twelve of the studies were conducted exclusively on residential buildings, two exclusively on one school building each and one on an elderly centre. One study included residential buildings and schools, one residential buildings and child centres (8). The numbers of investigated residential buildings ranged from 3 single-family houses in the pilot study on mould removal after hurricane Katrina (7) to approximately 3000 in the studies of Herbarth et al. (8) and Oreszczyn et al. (15). The DVD on the mould removal campaign after hurricane Katrina was also distributed to at least 3000 residents of the affected buildings, but this was not evaluated further.

Unfortunately, the results for the 50 child centres that were mentioned by Herbarth et al. (8) were not listed separately. In the elderly centre (10), mainly the outer parts of the building were renovated or repaired (roofing, drainage system, balconies and damaged ceiling tiles), other possible damage sites within the building were not included. This partial measure stopped water leakage and improved microbial status of the building and occupant health as assessed by questionnaire. However, because of the very limited information on child and elderly centres, conclusions on these institutional settings can hardly be drawn.

### **3) Actors and project contexts**

Eight were conducted by universities, four by a public health institute, one by WHO, one was an initiative of an environment ministry and the remainder were from other institutes or consumer initiatives. The studies mainly had research objectives; only four mainly aimed at pragmatic improvement of indoor conditions for the good of the residents. In one project, a research group primarily conducted a study on mould removal in highly affected buildings (three houses in New Orleans after Hurricane Katrina) to produce a DVD for a mould removal campaign.

### **4) Measurements on exposition or health conducted in the studies**

Nine of the studies measured indoor mould concentrations before and after the intervention, mostly in the air and surfaces of building materials. Other compounds or metabolites of microorganisms measured were endotoxins, beta-glucan, ergosterol and volatile organic compounds. All studies that analysed the differences between concentrations of mould and compounds of microorganisms found a reduction or complete disappearance after the interventions.

Eight studies measured moisture in the air and on building surfaces. In the limited number of studies where the changes in humidity after the intervention were reported, there was at least a small reduction of moisture. Interventions conducted to reduce humidity were mainly changes in ventilation, reduction of water infiltration and thermal insulation. Oreszczyń et al. (15) improved insulation and heating systems in low-income households, leading to a reduction in relative humidity and mould growth. Also, thermal insulation resulted in a reduction of condensation-related mould growth in the study of Becker et al. (13). In the studies of Braubach (19) and Howden-Chapman et al. (22), relative humidity was also reduced by thermal insulation. Installation of a fan in the loft resulted in a significant reduction of humidity in the intervention houses 12 month later. Comparing mechanically ventilated vs. naturally ventilated houses, Emenius et al. reported that high indoor air humidity ( $\geq 7$  g/kg air) was only found in naturally ventilated houses and that there was an inverse correlation between air exchange rate per hour and absolute indoor humidity ( $r=-0.64$ ). Reduction of water infiltration by repairing or exchanging building structure was also successful in the studies.

To summarize these results, each of the single methods to reduce humidity seems to be successful, but it is not clear which of these measures is the best to resolve the problem or whether a combination of improved ventilation and thermal insulation is much better than applying only one of these measures.

In health status reporting, all studies found an improvement of symptoms after the intervention (it is not possible to assess publication or contribution biases). However, in some studies questionnaires were handed out to the participants both before and after the intervention and differences in health outcomes were assessed, whereas some studies only asked if symptoms had improved after remediation. The latter technique is most likely less valid for assessing health

status because of the possibility of a placebo effect. Generally, it is not possible to blind the residents to the intervention; they inevitably know if mould has been removed and if actions to reduce dampness have been taken, and might feel better only because they see that the condition of their dwelling has improved.

Medical examinations were less frequently implemented than questionnaires on health status. In six studies (4, 8, 17, 19, 26, 28) the authors stated that they conducted medical examinations, but the results were presented in only three of them. In their case-control study, Dearborn and Kercksmar reported better measurements of pulmonary function (FVC, FEV<sub>1</sub>, PEF) six months after the remediation in the remediation group, but no differences at the beginning of the study and after 12 months in a limited number of study participants (n=33). Levels of total IgE or total eosinophil counts did not change between the first and the last clinical visits in either group. Matthews et al. (17) found a decline in the PEF both in the intervention and in the control group after the intervention, but no differences between the groups. Herbarth et al. (26) wrote that “together with the symptoms also changes of laboratory parameters have been observed (as a rule an improvement), for example specific IgE, IgG. The improvement in case of symptoms was more pronounced than in the laboratory parameters.”

From these limited results on medical and laboratory examinations conclusions can hardly be reached. Generally, if effect sizes of health improvement were measured, they were greater for self-reported data than for the results of medical examinations.

### **5) Selection of the study population**

Two studies included only asthmatic children (4, 17), whereas one study (16) excluded people suffering from allergic diseases on the grounds that they could take other allergen-avoidance measures than changing the ventilation system. Two studies were conducted with people suffering from health complaints suspected by physicians to be related to indoor exposure (3, 21). In the latter studies, improvement of health status was asked 6 and 12–18 months after the remediation activities had finished. However, the physicians' suspicion that indoor exposure might have been a cause and patients' assumptions that remediation activities themselves might cause amelioration could have induced placebo effects.

### **6) Adverse health effects of remediation activities**

In the study of Herbarth et al. (8) a strong link between exposure to renovation activities in early life and incidence of atopic diseases in later life was found. The risk of illness was approximately twice as high in such cases as in the control group. The Odds Ratio for allergic symptoms was 1.85 (1.31-2.61; p=0.0004) and for eczema 1.95 (1.43-2.67; p<0.0001). The prevalence of allergic symptoms was 9.3% without renovation and 16.8% after all three renovation activities. Consistently, the prevalence of eczema was 11.5% without renovation and 20.3% after all three activities. The authors concluded that the earlier in a child's life renovations were carried out, the

greater the risk of developing allergic disorders later on. Unfortunately, mould was not investigated in that study. A preliminary study on the respiratory health of children during remediation activities after hurricane Katrina conducted in February/March 2006 showed an increase in the proportion of children with symptoms and a lower limit of normal lung function, compared to before the hurricane and after the remediation activities finished in April/May. Most families in that study had limited flood damage, and half of them reported having renovated their residence. Indoor mould levels were not significantly associated with symptoms, and therefore the authors concluded that “exposure to other respiratory irritants could be a factor triggering symptoms”. However, the authors also considered that winter colds and exposure to rotting debris, diesel exhaust or other factors outside might have elicited the respiratory symptoms (Rabito et al., *Journal of Allergy and Clinical Immunology*, 2008). Haverinen-Shaughnessy et al. (29) reported that occupant health status in a school remained similar or even deteriorated during the remediation process, which lasted for three years. The authors remarked that the remediation did not have positive effects on occupant health. In a study on an elderly centre (19) the same author reported that personnel expressed concerns about the health of the elderly people during the remediation.

Because several measures were conducted in parallel in these studies, the impact of any single measure on health outcomes cannot be assessed.

**Table 1: Results of the review**

Nr	Country	Title	Overall result	Selected for discussion
1	Denmark	Climate chamber damaged buildings	3.00	
2	Sweden	Day care center mould removal Sweden	2.33	
3	Germany	Dwelling mould removal NRW Germany	1.33	X
4	USA	Dwelling mould removal USA	1.00	X
5	Belgium	Housing inventory list Flemish Government	3.00	
6	Germany	Mould remediation education Germany	2.66	
7	USA	Mould removal campaign Katrina USA	2.00	X
8	International	Mould studies International	1.33	X
9	Israel	Mould-resistant paints Israel	3.00	
10	Finland	Remediation in elderly homes FinlandB	1.33	X
11	Finland	School moisture damage repair work Finland	1.00	X
12	Sweden	Sick building offices Sweden	2.66	
13	Israel	Thermal insulation standard change Israel	2.00	X
14	Belgium	Ventilation measures Belgium	3.00	
15	UK	Warm Front thermal housing improvement UK	1.33	X
16	Sweden	Dwelling ventilation changes Sweden	1.66	X
17	Wales/UK	Dwellings mould eradication Wales	1.00	X
18	Sweden	Dwellings mould removal Sweden	2.66	
19	Germany	Dwellings thermal insulation Germany	1.00	X
20	France	Dwelling environmental inspection and counselling France	2.33	
21	Belgium	Green ambulance Belgium	1.66	X
22	NZ	Housing insulation effects New Zealand	1.00	X
23	Belgium	IAQ and health tool Belgium	2.66	
24	Germany	Mould consultation and mediation Germany	2.66	
25	Slovakia	Mould problems in dwellings and schools Slovakia	1.66	X
26	Germany	Mould removal dwellings Leipzig	1.66	X
27	UK	Purifan air cleaning system in schools UK	2.66	
28	Finland	Remediation in dwellings FinlandC	1.33	X
29	Finland	Remediation in schools FinlandA	1.33	X
30	Israel	Ventilation system change Israel	3.00	

*Annex 2: List of participants*

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**Original: English**