Why Do People Get Sick in Damp Buildings?

LIST OF REFERENCES

Compiled by:
Wane A. Baker, P.E., CIH
MICHAELS ENGINEERING
La Crosse, Milwaukee, St. Paul, Green Bay

In order by year published.

C. G. Bornehag, G. Blomquist, F. Gyntelberg, et al (2001), "Dampness in Buildings and Health: Nordic Interdisciplinary Review of the Scientific Evidence on Associations Between Exposure to 'Dampness' in Buildings and Health Effects (NORDDAMP)", *Indoor Air [The International Journal of Indoor Environment and Health]*; 11: 72–86

ABSTRACT
Several epidemiological investigations concerning indoor environments have indicated that ''dampness'' in buildings is associated to health effects such as respiratory symptoms, asthma and allergy. The aim of the present interdisciplinary review is to evaluate this association as shown in the epidemiological literature. A literature search identified 590 peer-reviewed articles of which 61 have been the foundation for this review. The review shows that "dampness" in buildings appears to increase the risk for health effects in the airways, such as cough, wheeze and asthma. Relative risks are in the range of OR 1.4–2.2. There also seems to be an association between "dampness" and other symptoms such as tiredness, headache and airways infections. It is concluded that the evidence for a causal association between "dampness" and health effects is strong. However, the mechanisms are unknown. Several definitions of dampness have been used in the studies, but all seem to be associated with health problems. Sensitisation to mites may be one but obviously not the only mechanism. Even if the mechanisms are unknown, there is sufficient evidence to take preventive measures against dampness in buildings.

PRACTICAL IMPLICATIONS
''Dampness'' in buildings appears to increase the risk for a number of health effects such as cough, wheeze, asthma, airways infections, tiredness, and headache. However, with the exception of mite-exposure, it is not known which humidity related agents in indoor air that are responsible for the health effects. Both chemical and microbiological exposures are suspected. Thus, even if it is a great challenge to science to explain the associations, the practical advice is "avoid dampness in buildings". This means that there is not enough scientific knowledge today to do health relevant evaluations of dampness related exposures indoors.

"State of the Science on Molds and Human Health", Statement of Stephen C. Redd, M.D., Chief, Air Pollution and Respiratory Health Branch, National Center for Environmental Health, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services. Statement for the Record, U.S. House of Representatives, July 18, 2002

Link confirmed September 16, 2009: www.cdc.gov/MOLD/pdfs/moldsci.pdf

SELECTED EXCERPTS

- "…molds can cause illness when people are exposed to extensive mold growth indoors."
- "…airborne fungal allergens were most often associated with allergic diseases…"
- "In its 2000 report…[the] IOM concluded that there is sufficient evidence of an association between exposure to mold and exacerbations of asthma."
- "In a 5-year CDC initiative on work-related asthma in offices and schools, significant relationships have been found between:
    - Respiratory disease, and visual assessment of water and mold damage
    - Respiratory symptoms, and endotoxin and ultra-fine particles
    - Respiratory symptoms, and indicators of mold in chair and floor dust"
- "We do not know whether molds cause…pulmonary hemorrhage, memory loss, or lethargy."
- "…measures should be taken to prevent mold growth indoors because some people are, or may become, allergic to it."
- "Linkages between indoor airborne exposures to molds and…bleeding from the lung, or memory loss, have not yet been scientifically substantiated."

Institute of Medicine, The National Academies, Committee on Damp Indoor Spaces and Health, Board on Health Promotion and Disease Prevention (2004) "Damp Indoor Spaces and Health", National Academy Press, Washington, DC

Read the entire 370 page report on-line (free), or download the 29-page Executive Summary in PDF. Link confirmed September 16, 2009: http://www.nap.edu/catalog.php?record_id=11011

SUMMARY OF FINDINGS

Table ES-1: Summary of Findings Regarding the Association Between Health Outcomes and Exposure to Damp Indoor Environments

Sufficient Evidence of a Causal Relationship
- (no outcomes met this definition)

Sufficient Evidence of an Association
- Upper respiratory (nasal and throat) tract symptoms Wheeze
- Cough Asthma symptoms in sensitized asthmatic persons

Limited or Suggestive Evidence of an Association
- Dyspnea (shortness of breath)
- Asthma development
- Lower respiratory illness in otherwise-healthy children

Inadequate or Insufficient Evidence to Determine Whether an Association Exists
- Airflow obstruction (in otherwise-healthy persons)
- Skin symptoms
- Mucous membrane irritation syndrome
- Gastrointestinal tract problems
- Chronic obstructive pulmonary disease
- Fatigue
- Inhalation fevers (non-occupational exposures)
- Neuropsychiatric symptoms
- Lower respiratory illness in otherwise-healthy adults
- Cancer
- Acute idiopathic pulmonary hemorrhage in infants
- Reproductive effects
- Rheumatologic and other immune disease

Table ES-2: Summary of Findings Regarding the Association Between Health Outcomes and the Presence of Mold or Other Agents in Damp Indoor Environments

Sufficient Evidence of a Causal Relationship
- (no outcomes met this definition)

Sufficient Evidence of an Association
- Upper respiratory (nasal and throat) tract symptoms Wheeze
- Asthma symptoms in sensitized asthmatic persons Cough
- Hypersensitivity pneumonitis in susceptible persons

Limited or Suggestive Evidence of an Association
- Lower respiratory illness in otherwise-healthy children

Inadequate or Insufficient Evidence to Determine Whether an Association Exists
- Dyspnea (shortness of breath)
- Skin symptoms
- Airflow obstruction (in otherwise-healthy persons)
- Asthma development
- Mucous membrane irritation syndrome
- Gastrointestinal tract problems
- Chronic obstructive pulmonary disease
- Fatigue
- Inhalation fevers (non-occupational exposures)
- Neuropsychiatric symptoms
- Lower respiratory illness in otherwise-healthy adults
- Cancer
- Rheumatologic and other immune diseases
- Reproductive effects
- Acute idiopathic pulmonary hemorrhage in infants

C. G. Bornehag, J. Sundell, S. Bonini, et al (2004) “Dampness in Buildings as a Risk Factor for Health Effects; EUROEXPO: A Multi-disciplinary Review of the Literature (1998–2000) on Dampness and Mite Exposure in Buildings and Health Effects”, *Indoor Air*; 14: 243–257

ABSTRACT
The scientific literature on health effects from dampness in buildings, including mite exposure over the period 1998–2000 has been reviewed by a European group (EUROEXPO) of eight scientists in experience from medicine, epidemiology, toxicology and engineering. Forty studies deemed relevant have been the foundation for the conclusions. Dampness in buildings is a risk factor for health effects among atopics and non-atopics both in domestic and in public environments. However, the literature is not conclusive in respect of causative agents, e.g. mites, microbiological agents and organic chemicals from degraded building materials. There is a strong need for more multidisciplinary studies including expertise from all relevant areas. A general conclusion from the work was that there is a strong need for multidisciplinary reviews in scientific journals of articles dealing with associations between indoor environmental factors and health effects.

PRACTICAL IMPLICATIONS
There is good evidence for a true association between dampness in buildings and health. As the causative factors behind this association are not known, the main focus in practical investigations should be on finding out and remediate the reasons for the humidity problem.

D. Mudarri and W. J. Fisk (2007) “Public Health and Economic Impact of Dampness and Mold”, *Indoor Air*; 17: 226–235

ABSTRACT
The public health risk and economic impact of dampness and mold exposures was assessed using current asthma as a health endpoint. Individual risk of current asthma from exposure to dampness and mold in homes from W.J. Fisk, Q. Lei-Gomez & M.J. Mendell [(2007) *Indoor Air* 17: 284–296], and asthma risks calculated from additional studies that reported the prevalence of dampness and mold in homes were used to estimate the proportion of US current asthma cases that are attributable to dampness and mold exposure at 21% (95% confidence internal 12–29%). An examination of the literature covering dampness and mold in schools, offices, and institutional buildings, which is summarized in the Appendix, suggests that risks from exposure in these buildings are similar to risks from exposures in homes. Of the 21.8 million people reported to have asthma in the USA, approximately 4.6 (2.7–6.3) million cases are estimated to be attributable to dampness and mold exposure in the home. Estimates of the national cost of asthma from two prior studies were updated to 2004 and used to estimate the economic impact of dampness and mold exposures. By applying the attributable fraction to the updated national annual cost of asthma, the national annual cost of asthma that is attributable to dampness and mold exposure in the home is estimated to be $3.5 billion ($2.1–4.8 billion). Analysis indicates that exposure to dampness and mold in buildings poses significant public health and economic risks in the USA. These findings are compatible with public policies and programs that help control moisture and mold in buildings.

PRACTICAL IMPLICATIONS
There is a need to control moisture in both new and existing construction because of the significant health consequences that can result from dampness and mold. This paper demonstrates that dampness and mold in buildings is a significant public health problem with substantial economic impact.

World Health Organization (2009) "WHO Guidelines for Indoor Air Quality: Dampness and Mould", WHO Regional Office for Europe, Copenhagen, Denmark

Link confirmed September 16, 2009:
http://www.euro.who.int/InformationSources/Publications/Catalogue/20090629_4

ABSTRACT
Microbial pollution is a key element of indoor air pollution. It is caused by hundreds of species of bacteria and fungi, in particular filamentous fungi (mould), growing indoors when sufficient moisture is available. This document provides a comprehensive review of the scientific evidence on health problems associated with building moisture and biological agents. The review concludes that the most important effects are increased prevalences of respiratory symptoms, allergies and asthma as well as perturbation of the immunological system. The document also summarizes the available information on the conditions that determine the presence of mould and measures to control their growth indoors. WHO guidelines for protecting public health are formulated on the basis of the review. The most important means for avoiding adverse health effects is the prevention (or minimization) of persistent dampness and microbial growth on interior surfaces and in building structures.

EXCERPT FROM CHAPTER 4 "HEALTH EFFECTS ASSOCIATED WITH DAMPNESS AND MOULD"

Section 4.4: Synthesis of Available Evidence on Health Effects

In this chapter, we have presented several types of evidence – epidemiological, clinical and toxicological – relevant to answering the question of whether dampness or dampness-related exposures cause adverse human health effects. This summary is based initially on the epidemiological and clinical evidence for causal relations between dampness-related factors and specific human health outcomes. Then, the available toxicological evidence is considered as either supporting or not supporting the biological plausibility of any potentially causal association. The epidemiological evidence is based on qualitative assessments of dampness related factors, such as visible dampness, mould, water damage or mould odour, as the epidemiological findings based on quantitative measurements of specific microbial agents were too inconsistent and, for specific outcomes, too few for clear conclusions.

The epidemiological evidence is not sufficient to conclude causal relationships between indoor dampness or mould and any specific human health effect, although the findings of one strong epidemiological intervention study, in conjunction with the other available studies, suggest that dampness or mould exacerbates asthma in children.

There is sufficient epidemiological evidence of associations between dampness or mould and asthma development, asthma exacerbation, current asthma, respiratory infections (except otitis media), upper respiratory tract symptoms, cough, wheeze and dyspnoea. There is sufficient clinical evidence of associations between mould and other dampness-associated microbiological agents and hypersensitivity pneumonitis, allergic alveolitis and mould infections in susceptible individuals, and humidifier fever and inhalation fevers. This is the only conclusion that is based primarily on clinical evidence and also the only conclusion that refers explicitly to microbial agents, as opposed to dampness-related factors.

Limited or suggestive epidemiological evidence of an association between indoor dampness or mould and allergic rhinitis and bronchitis is available.

The evidence for effects on lung function, allergy or atopy and "asthma, ever" is inadequate or insufficient. The evidence does not suggest that any specific measure of microorganisms or microbial substances results in a demonstrably more specific or sensitive assessment of a particular dampness-related exposure relevant to health effects. Nonetheless, although specific causal agents have not been identified conclusively, microbial exposure is often suggested to play a role. Further studies with valid, quantitative exposure assessment methods are required to elucidate the role of fungi and other microorganisms in damp-induced health conditions. The available epidemiological and clinical evidence suggests that both atopic and nonatopic people are susceptible to adverse health effects from exposure to dampness and mould, even if some outcomes are commoner in atopic people. Therefore, both allergic and non-allergic mechanisms may be involved in the biological response.

The mechanisms by which non-infectious microbial exposures contribute to adverse health effects associated with indoor air dampness and mould are largely unknown. It is clear, however, that no single

mechanism can explain the wide variety of effects associated with dampness and mould. Toxicological studies, by investigating the ability of microbial agents associated with damp buildings to activate certain toxicological mechanisms, provide insight into the multiple biological mechanisms that might underlie the observed associations between health effects and dampness and mould. In vitro and in vivo studies have demonstrated diverse inflammatory, cytotoxic and immunosuppressive responses after exposure to the spores, metabolites and components of microbial species found in damp buildings, lending plausibility to the epidemiological findings.

Many dampness-associated conditions are likely to involve inflammation, as inflammatory responses to many microbiological agents have been found. These include histamine release by mechanisms other than those mediated by IgE, indicating a plausible mechanism for the occurrence of allergy-like symptoms even in non-sensitized people. Dampness-associated asthma, allergic sensitization and associated respiratory symptoms may result from repeated activation of the immune defences, exaggerated immune responses, prolonged production of inflammatory mediators and tissue damage, leading to chronic inflammation and inflammation-related diseases, such as asthma.

Although fungal spores associated with damp buildings produce metabolites with demonstrated acute cytotoxicity, the spores also have toxic effects other than those caused by the inflammatory reaction. The observed increase in the frequency of respiratory infections associated with damp buildings might be explained by the immunosuppressive effects of damp building-associated microbes in experimental animals, which impair immune defences and thus increase susceptibility to infections. An alternative explanation might be that inflamed mucosal tissue provides a less effective barrier, increasing the risk of infection. Demonstration of such effects in cells or experimental animals at levels of microbial exposure similar to those in indoor environments would allow extrapolation of these results to human beings.

Various microbial agents with diverse, fluctuating inflammatory and toxic potential are present simultaneously with other airborne compounds, inevitably resulting in interactions in indoor air. Such interactions may lead to unexpected responses, even at low concentrations. Therefore, the detection of individual exposures, such as certain microbial species, toxins or chemical agents, cannot always explain any associated adverse health effects. In the search for causative constituents, toxicological studies should be combined with comprehensive microbiological and chemical analyses of indoor samples.

The synergistic interactions among microbial agents present in damp buildings suggest that the immunotoxic effects of the fungal and bacterial strains typically found can be potentiated during concomitant exposure, leading, for instance, to increased cell death or cytotoxic or inflammatory effects. Such interactions can give rise to unexpected responses, even at low concentrations of microbial (or chemical) agents, so that it is difficult to detect and implicate specific exposures in the causation of damp building-associated adverse health effects. Thus, microbial interactions must be carefully considered when evaluating the possible health effects of exposure in damp buildings. Differences in the concentrations used in studies with cell cultures or experimental animals and those that may be reached by human beings should also be kept in mind when interpreting the findings.

Most of the relevant toxicological data from studies in experimental animals refer to the immunotoxicity of fungi, especially the species *S. chartarum* and its toxins. The role of other microbial exposures, including dampness-related bacteria, requires more study. For the identification of causative constituents and risk assessment, toxicological and epidemiological data should be combined with microbiological and chemical analyses of indoor air samples. In interpreting the results of studies in experimental animals in relation to human exposures, it is important to consider differences in relative doses and the fact that the exposures used for experimental animals may be orders of magnitude higher than those found in indoor environments.

The available estimates, based on the assumption that the associations found in the epidemiological studies are unbiased and causal, suggest that dampness related risk factors are associated with a large proportion of human respiratory disease. For instance, residential dampness is associated with a 50% increase in current asthma and substantial increases in other respiratory health outcomes, suggesting that 21% of current asthma in the United States may be attributable to residential dampness and mould (Fisk, Lei-Gomez, Mendell, 2007; Mudarri, Fisk, 2007). These estimates, for imprecisely defined risk factors, cannot indicate true causal relationships and must be interpreted with caution, but they suggest that some dampness-related risk factors contribute substantially to the burden of human respiratory disease.