Moisture control in cold climates—the report of ISIAQ Task Force IX

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ABSTRACT
The work of Task Force IX started in 1997 at a workshop in Washington Healthy Buildings conference. It continued at the Indoor Air '99 conference in Edinburgh, Scotland, and the following workshops took place at Healthy Buildings '00 in Helsinki, Finland and at Indoor Air '02 in Monterey, California, USA. The objective has been to produce a practically oriented document dealing with the principles of moisture control of buildings in cold climates. The document consists of a multidisciplinary approach using the viewpoints of civil engineering, HVAC technology, medicine, and environmental hygiene practice. It has been produced by contributors from various disciplines related to building, indoor air and environmental health sciences. This paper presents a summary and few insights of the report.

INDEX TERMS
Task Force IX; Moisture control; Document; Cold climate

INTRODUCTION AND DEFINITIONS

Excess moisture in building environment may lead to microbial growth on building materials or chemical destruction of building materials, and subsequent contamination of indoor air. In epidemiological studies, excess moisture induced exposures have been associated with a number of health effects. These health effects seem to be consistent in different climates and geographical regions. However, the causal agents or cellular mechanisms of the health effects are still poorly understood.

While indoor air contamination and health effects are consequences, the common nominators for them are different forms of undesired moisture behaviour, which is often connected to the climate. The prevailing temperature, humidity and rain conditions regulate much of the principles and practices of building construction and maintenance. Therefore, the whole problem parameters may vary according to the climatic zone. Cold climate is defined here as a region where heating and thermal insulation is needed in the buildings due to harsh winter temperatures. Although the definition is not precise, typical to cold climates are winters with permanent snow cover at least occasionally, winter temperatures under freezing point, and a heating season of a minimum of 6 months a year.

In the literature, various moisture-related terms are also used without a clear definition. In the report, the most commonly needed definitions are summarized. The definitions include 'moisture physical terms', such as moisture content (MC), relative humidity (RH), and water activity (a_w). The definitions also include 'moisture problem terms' such as dampness, moisture damage, water damage, frost damage, microbial growth, mould, visible mould, and microbial VOC (MVOC).

CONTENTS

Moisture and Humidity in Cold Climates

Whereas all building materials contain water in different forms, a distinction should be drawn between those situations when the presence of moisture can be regarded as 'normal', and when the material contains excess moisture such that it can be regarded as 'harmful'.

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Therefore, basic understanding on moisture physics is needed. This chapter explains the principles of moisture dynamics: forces acting on water that result in migration, pressure caused by moving air and partial pressures, and how water vapour travels along as part of the air mixture. It also contains information on indoor water sources and their relative strength, summarizes causes of water accumulation on building materials, and gives rough estimates on what are the critical humidity levels above which risk of damage resulting indoor air pollution is increased. Seasonal and regional variation should be taken into account also in prevention of moisture damage; the preventive actions including analyses of structural design, construction moisture drying out time, and selection of material. If the prevention and moisture control action fail, excess moisture in buildings may result in damage and consequently, indoor air polluting emissions from building materials and organisms growing on them.

Indoor Pollutants and their Sources Associated with Moisture

Indoor air pollutants can be classified as microbial or chemical pollutants, or particulate matter, based on their origin or composition. Microbial pollutants include fungi, bacteria and mites. In damaged materials, also protozoa, nematodes, algae and insects are found, but the information related to their relative importance on indoor air quality is currently very limited. In the report, information on microbial aerosol is given on the following subjects: factors regulating microbial growth; temperature, RH, and time, and in what manners microbes can be considered as indicators of moisture damage. In addition to microbial processes, excess moisture in buildings may also result in chemical processes. Both microbial growth and chemical processes may be sources of emission of volatile organic chemicals (VOCs). Specifically, indoor air may be contaminated by the destruction of vinyl floorings, carpet glues, or casein-containing flooring compounds due to high MC and pH in newly cast concrete floors. Both microbial and chemical processes may contribute to odours, which is a common reason for decreased indoor air quality perceptions. A phenomenon called powdering has been associated with floor treatments during winter, due to fast drying of the floor surface.

The Role of Air Flows and Ventilation Systems in Moisture Problems

Ventilation is required to remove the moisture produced by human activity in buildings. In cold and moderate climates, the MC of outdoor air is lower than that of indoor air for most of the year. Thus, the MC indoors can be reduced by sufficient air change. A critical parameter is the risk for condensation of water to interior surfaces or inside of the structures. In cold and moderate climates, the most critical season the time when outdoor temperature is between 0 and+10°C and the MC of outdoor air is high. The minimum ventilation rate required to remove the moisture produced by persons and activities in residential buildings is in the order of 0.35 air changes per hour. However, increased ventilation is needed, for example, during showering. In addition to ventilation, prevention of moist air from entering structures includes use of vapour barrier on the interior (warm) side of the building envelope. Other than from the moisture control point of view ventilation is also important in terms of diluting the concentrations of indoor air pollutants. In the worst case, HVAC systems themselves may become sources of pollutants. Ingress of rain and snow to the system, condensation on system surfaces, or badly maintained humidifiers are examples of this problem, also introduced in the report.

Typical Signs of Moisture Damage in Different Environments

There are a variety of sources accounting for the introduction of water from the exterior of a building to its interior, although most relate to above or below ground-level building envelope deficiencies. Primary sources of water in buildings from above ground include roof leaks due to

roof membrane deterioration, defective or inadequate roof flashing and drainage, and inadequate roof pitch; wall leaks due to inadequate wall flashing, cracked wall surfaces, plugged weeps, deteriorated sealant around windows and door frames; defective window and door frames; and condensation and moisture adsorption by building materials. Leakage of water from exterior is commonly first detected from inside the building by the occupants long after the building envelope has failed, which can increase the repair costs considerably.

Excess moisture in buildings can be derived from a variety of internal sources. In summary, in newly constructed buildings elevated moisture content can be due to wet building materials. Moisture content can also be elevated due to cooking, washing clothes, bathing, and from keeping living plants indoors. Respiration and perspiration by building occupants contribute to moisture levels, as does the use of poorly maintained humidifiers. In improperly ventilated building spaces, these sources of water can account for significant problems. Signs of excess moisture inside buildings due to these problems include mould growth in areas supporting highest moisture levels as well as condensation on cold surfaces and wetting of materials.

Water can also accumulate in buildings as a consequence of plumbing leaks, or from window, peripheral wall and ceiling plenum pipe condensation problems. Plumbing leaks are usually manifest by the wetting of building materials or the appearance of water stains on porous materials. Ceiling plenum pipe condensation problems are often detected due to the appearance of water stained ceiling material immediately under and following the same direction of the overlying pipes. Improperly insulated windowpanes often support condensation problems. These are manifest as window frame discoloration and deterioration due to water staining and mould growth. Wicking along wall surfaces from poor wet mopping practices is a common problem. Signs typical of this problem include discoloration and microbial growth. Baseboard detachment from wall surfaces may also be a sign of wet mopping or flooding by water overflow problems.

Exposure and Health Aspects Related to Moisture and Microbial Contamination

Occupants of buildings are exposed to indoor air pollutants via air. Several factors including temperature, RH, draught and odours affect the perception of indoor air quality and modify the effects of chemical and microbiological contaminants. In moisture damaged buildings, the exposure is always a complex mixture of particles and volatile chemicals. Therefore, it is practically impossible to measure all possible components and to distinguish between the effects of various exposures, and the exposure is often estimated by limited number of surrogates such as microbial counts in material samples or VOC-measurements in the air.

In order to perform risk assessment, it is necessary to quantify both the exposure and the effect, and still a certain amount of uncertainty will remain when cause and effect relationships between the exposure and the health outcomes are estimated. Health effects associated with moisture damage related exposures include irritative and non-specific symptoms, respiratory infections, and, in a long-term or massive exposure situation, chronic bronchitis, allergic diseases, alveolitis and ODTS. Typically, the human body reacts to a number of exposing agents in a non-specific way, and the reactions can be similar no matter if the exposure in question is a chemical, inorganic dust or biological agent, such as microbes. Only in limited number of exposures, the response is specific to certain microbes or chemical components. These specific responses can be proved only by experimental exposure or specific tests of immunological and inflammatory reactions. Some information can also be derived from animal studies.

Investigation Techniques

The purpose of the building investigation is to analyse the occurrence and extend of moisture damage in a building and the causes of moisture damage. On the basis of the results of the investigations, advice should be given about how to remove and replace the damaged

structures and how to improve the resistance of the structures against moisture. If necessary, environmental samples can be taken to locate the sources of indoor air pollution, and to characterize the pollution for exposure assessment. For most of the sampling methods, results vary with time, place and circumstances of sampling and the methods used, and so far the determinants of exposure are poorly known. Therefore, exposure assessment or building investigations alone may not lead to independent conclusions, but both may be needed in evaluating the situation.

In such cases where occupants' health concerns play an important role, it may be necessary to conduct health effect studies. In general, discussing about the health symptoms of the occupants should be avoided without a consultation of a health professional. Occurrence of the symptoms has usually been assessed by questionnaires or interviews, or clinical diagnoses have been used. Certain limitations have to be taken into account, related to, for example, the methodology, the sample size required to make reliable conclusions, and confidentiality. A step-wise approach on how to conduct a thorough building investigation and the related measurements, how to draw conclusions based on the analyses of the results, and how to include aspects of risk communication during the process is presented in the report.

Repair Measures

In principle, all damaged or contaminated material should be removed. Covering the damaged area by a new finishing layer and thereby making the damage invisible is not enough. Also all accessible odorous materials should be removed. Cleaning of odours is difficult, and therefore it often less expensive in practise to remove all the contaminated materials at once. Some post-remediation techniques introduced in the report include controlling air pressure, sealing, airing and heating (baking out) and chemical treatment.

A comprehensive approach on the management of indoor air problems associated with moisture and mould includes follow-up of effectiveness of the repairs for quality assurance. Only after carrying out a sufficient follow-up scheme, it will be possible to assess the effect of the erasing of the exposure on the decrease of the illness. Therefore, follow-up is an important part of the repair process.

Occupational and Working Safety

Occupational and working safety issues become important after moisture problem with possible consequences on indoor air quality has been detected. It is a necessity to avoid the building occupants' exposure to the indoor air pollutants before and during the repair process, and to provide sufficient protection for the construction workers working in the contaminated area. Protection is also needed to avoid further contamination of the facilities and material surrounding or connected to the damaged area before and during the repair process. Topics included in this chapter include protection techniques under different circumstances and handling damaged or contaminated materials.

References

The complete list of references includes over 100 documents related to moisture control in cold climates.

Acknowledgements

The Task Force wishes to thank Dr Carl-Gustaf Bornehag, Mr. Terry Brennan, Dr Brian Flannigan, Dr Tuula Husman, Dr Phil Morey, Dr Tom Rand, Prof. Olli Seppänen and Dr Jorma Säteri for their contributions.