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Development of WHO guidelines for indoor air quality: dampness and mould

Report on a Working group meeting
Bonn, Germany, 17-18 October 2007

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ABSTRACT

Microbial pollution is one of the key constituents of indoor air pollution. It consists of hundreds of species of bacteria and fungi, and in particular filamentous fungi (moulds) growing indoors when sufficient moisture is available. Health problems associated with moisture and biological agents include increased prevalence of respiratory symptoms, allergies, and asthma as well as perturbation of the immunological system. Based on the extensive review of the scientific evidence, this WHO working group identified the main health risks due to excess moisture, associated with microbial growth and contamination of indoor spaces. It also formulated WHO guidelines for protecting public health, recommending that persistent dampness and microbial growth on interior surfaces and in building structures should be prevented (or minimized) as they may lead to adverse health effects.

Keywords

AIR POLLUTION, INDOOR – PREVENTION AND CONTROL
HUMIDITY - ADVERSE EFFECTS
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Introduction

Background

Problems with indoor air quality are important risk factors for human health in both developing and developed countries. The substantial fraction of time that populations spend in buildings underlines the importance of indoor air. In special indoor environments, such as day-care centres and homes for elderly people, and in residences to a lesser extent, indoor air pollution affects population groups that are especially vulnerable due to their health status or age.

Microbial pollution, one of the key constituents of indoor air pollution, comprises hundreds of species of bacteria and fungi, and particularly filamentous fungi (moulds), which grow indoors when sufficient moisture is available.

Dampness is regularly observed in residences and other buildings. Moisture problems are estimated to affect more than half of buildings during their life-cycle. For example, health problems associated with moisture and biological agents affect people with asthma, especially children, in whom the prevalence of asthma has increased to about 20% in some countries. Exposure to microbial contaminants is clinically associated to respiratory symptoms, allergies and asthma, as well as perturbation of the immune system.

In 2005, the working group for the global update of the WHO guidelines for air quality recommended that WHO develop health-based guidelines for indoor air quality. The planning meeting for this task, held in Bonn, Germany in October 2006, recommended addressing the issues under three subcategories: pollutant-specific guidelines, dampness and mould, and indoor combustion of fuels.[1]

Scope and purpose

A WHO working group on dampness and mould met in October 2007 to identify the main health risks due to excess moisture and associated microbial growth and contamination of indoor spaces, and to formulate WHO guidelines for protecting public health. The guidelines should address various levels of economic development and climates, cover all relevant population groups, and enable the design of feasible approaches to reduce health risks from dampness and microbial contamination. The group was asked:

- to agree on the text of the recommended guidelines/guidance;
- to identify the changes needed in the background documents summarizing the scientific evidence that supported recommendations; and
- to define the process of finalizing the assessment.

Based on the recommendation of the planning meeting in 2006, a steering group was created in April 2007 to support and guide the process.[2] It recommended potential authors and reviewers for the first draft of the background material. Annex 1 provides the list of chapters of this draft

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[1] *Development of WHO guidelines for indoor air quality. Report on a working group meeting, Bonn, Germany, 23–24 October 2006*. Copenhagen, WHO Regional Office for Europe, 2006 (http://www.euro.who.int/Document/AIQ/IAQ_mtgrep_Bonn_Oct06.pdf, accessed 30 August 2007).

[2] Steering group members are Ross Anderson, Aaron Cohen, Séverine Kirchner, Lars Mølhave, Aino Nevalainen, Bernd Seifert, Kirk Smith and John Spengler (see Annex 2).

and their authors. The draft chapters were submitted to WHO in August 2007 and, after compilation, distributed for review. Comments from the reviewers were collected by the end of September and distributed to the meeting participants.

The working group on developing WHO guidelines for indoor air quality, dampness and mould comprised 32 experts from 16 countries (Annex 2). Dr Aino Nevalainen and Dr Bernd Seifert co-chaired the meeting, and Dr Lidia Morawska acted as rapporteur. The group evaluated the scientific evidence using the background material prepared for the meeting and the comments gathered during the review. Then it summarized its evaluation and made recommendations. The group also agreed on the process of finalizing the background material based on the comments gathered before and during the meeting. Before publication of this report on the meeting, drafts were circulated twice for the comments and approval of all working group members.

The meeting was supported by funds received by the WHO European Centre for Environment and Health, Bonn from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany.

Discussion

The plenary discussion addressed the format and scientific basis of the guidelines. The working group agreed that the formulation of WHO guidelines supporting the protection of public health in both developed and developing countries required a systematic evaluation of the health effects of indoor exposure. Although some health-based recommendations for indoor environments may specify concentration levels not to be exceeded, recommendations identifying indoor air quality problems using qualitative indicators, such as the existence of dampness in the building structures leading to microbial growth or the use of solid fuels indoors, were also needed to protect health. Feasible action to identify and prevent the health risks was also needed.

The working group was divided into four small groups to conduct detailed and focused discussions and make specific recommendations on the chapters of the draft guidelines. The subgroups had two tasks.

The first was to draft a section for the guidelines to identify the main environmental conditions or exposures that lead to health effects and to recommend efficient ways to interrupt this route of progression based on the evidence. The working group decided that the guidelines should identify and describe the difference between a healthy/non-hazardous and a hazardous state of the indoor environment, and avoid recommendations on risk management or remediation. Providing guidelines was one step of the process (and the focus of the guidelines being developed by the working group), while risk management was the next step of the process (and beyond the scope of the working group's task). The outcome should be formulated in a few sentences that, linked with the paragraphs based on other chapters, would form the first draft of the guidelines.

The subgroups' second task was to discuss the critical points from the review and finalize the corresponding chapter texts, ensuring that the evidence presented supported the guidelines. The outcomes from the discussions were to be recorded as succinctly as possible but give specific recommendations on the revision of chapters and specify which experts, besides the original authors, could contribute to the revision if needed.

Scope of the guidelines

The working group concluded that the introductory chapter (Chapter 1) should define the scope of the guidelines and the terminology used. In particular, it should explain why the guidelines would either address certain important issues (such as allergies and house dust mites) briefly or not cover them. The group extensively discussed the need for definitions of central terms such as dampness and moisture. It concluded that, while the guidelines must use the terms consistently, their explicit definition had limitations. The scientific studies reviewed used various definitions, but the subtle differences between them were hard to recognize. Thus, the selection of terms used had to be separately evaluated in each context.

Chapter 1 needed to introduce the causal chain of events in the formation of a health hazard, linking events from sources of water, through existence of excessive moisture, to biological growth and physical and chemical degradation, and further to emission of hazardous biological and chemical agents. It should also acknowledge factors related to allergens, although a separate evaluation of indoor aeroallergens was planned. Because dampness is one of the causes of increased exposure to allergens (such as *Aspergillus* spp. and house dust mites), however, the two evaluations may overlap. The guidelines include evidence on exposure to fungi as damp-associated allergens in the exposure chapter, but exclude other dampness-related indoor allergens from such sources as dust mites, cockroaches and rodents.

The guidelines would cover not only mould but also, to some extent, other biological agents, such as bacteria associated with the presence of excess moisture in indoor environments. Nevertheless, listing all potential exposure factors in the title was not feasible, so the working group accepted "dampness and mould" as a good compromise between the need for a title that was both brief and precise about the content of the publication, particularly as Chapter 1 would specify the actual scope of the work.

As the guidelines should consider conditions and situations affecting the whole range of climates and/or socioeconomic settings, the reviewers, particularly those from developing countries, should assist in including relevant issues. The guidelines would cover both private and public buildings (for example, offices or nursing homes), as dampness and mould were risks everywhere. As stated at the planning meeting in 2006, the guidelines would not consider occupational settings where exposure is related to the occupants' work or hospitals with high-risk patients and potential sources of pathogen exposures.

A WHO report prepared in 2000[3] acknowledged each person's right to a healthy indoor environment, including safe indoor air. The working group recommended that Chapter 1 mention this work and a related journal publication[4], stating some of the relevant principles where they applied.

The guidelines needed to acknowledge links between indoor air quality, excess moisture and biological agents, and several well-acknowledged global factors that contribute to the conditions associated with increased exposures to moisture and mould. Following a detailed discussion, the working group identified:

- climate change: variability of extremes, shifting of climate zones;

[3] *The right to healthy indoor air*. Copenhagen, WHO Regional Office for Europe 2000 (http://www.euro.who.int/document/e69828.pdf, accessed 13 January 2008).
[4] Mølhave L, Krzyzanowski M. The right to healthy indoor air: status by 2002. *Indoor Air*, 2003, 13(S6):50–53.

- urbanization: migration, building type and density, urban degradation, housing availability and social inequity;
- improperly implemented energy conservation measures: tightened building envelopes, ventilation deficits, improper insulation; and
- the quality and globalization of building materials and components, and construction concepts and techniques.

The guidelines did not need to quantify the population risk due to exposure to biological agents in indoor air (expressed, for example, as years of life lost), although it would be important in setting priorities for policy formulation.

Critical review of draft chapters

The reviewers of the first draft of the background material made a number of recommendations on the possible inclusion of additional material in the text of the guidelines. They also identified the need to ensure coherence between the different chapters.

The review of Chapter 3, "Ventilation in relation to mould and dampness", identified two main issues that had not been sufficiently covered:

- the overall role of ventilation in the guidelines, which was restricted to its effects on indoor dampness and mould in the current text; and
- moisture control in buildings, which is barely covered by the first draft of the text.

The working group acknowledged that, while the current guideline text focused, not on ventilation itself but on its role in controlling moisture, ventilation had a far greater role in building operation and occupant health. These additional aspects needed to be covered in another part of the guidelines. Specifically, ventilation was an important issue in formulating the guidelines on indoor combustion.

The group agreed that, while health-based quantitative guidelines on concentrations of many of the biological agents could not be provided, recommendations, guidance or guidelines (to be called "guidelines") could be formulated to protect health and identify health risks. Thus, the working group would advise on problems and the circumstances in which risk was likely to occur, although its remit did not include recommending action to manage indoor air quality. The guidelines' main purpose was to define indicators of a safe indoor environment.

Conclusions

Based on texts formulated by the subgroups, the working group extensively discussed, revised and agreed on the text of a summary of the health risk evaluation and the recommended guidelines. The group agreed that the guidelines on dampness and mould would be published as soon as they were ready, rather than waiting for the completion of the remaining parts of the guidelines on indoor air quality, related to pollutant-specific issues and indoor combustion.

Summary of the health risk evaluation

1. Sufficient epidemiological evidence from studies conducted in different countries and climatic conditions shows that occupants of damp or mouldy buildings, both homes and public buildings, are at increased risk of experiencing respiratory symptoms, respiratory

infections and exacerbations of asthma. Some evidence suggests an increased risk of developing allergic rhinitis and asthma. Although not many intervention studies are available, their results show that remediation of dampness problems leads to a reduction in adverse health outcomes.

2. There is clinical evidence that exposures to moulds and other dampness-related microbial agents increase the risk of rare conditions, such as hypersensitivity pneumonitis/allergic alveolitis, chronic rhinosinusitis and allergic fungal sinusitis.

3. Toxicological evidence in vivo and in vitro supports these findings by showing diverse inflammatory and toxic responses after exposure to specific microorganisms isolated from damp buildings, including their spores, metabolites and components.

4. While groups such as atopic and allergic individuals are particularly susceptible to exposures to biological and chemical agents in damp indoor environments, adverse health effects have also been widely demonstrated in non-atopic populations.

5. The increased prevalence of asthma and allergies in many countries increases the number of people susceptible to the effects of dampness and mould in buildings.

6. The prevalence of indoor dampness ranges widely within and among countries, continents and climate zones. It is estimated to be in the order of 10–50% of the indoor environments in Europe and North America, as well as in Australia, India and Japan. In some specific settings, such as river valleys or coastal areas, conditions of dampness are substantially higher than national averages.

7. The amount of water available on/in materials is the most important factor triggering the growth of microorganisms, including fungi, actinomycetes and other bacteria.

8. Microorganisms in general are ubiquitous in all general environments. Microbes propagate rapidly whenever water is available. The dust and dirt normally present in most indoor spaces provide sufficient nutrients to support extensive microbial growth. While mould growth is possible on all materials, appropriate material selection is nevertheless important to prevent dirt accumulation, moisture penetration and mould growth.

9. Microbial growth may result in elevated levels of spores, cell fragments, allergens, mycotoxins, endotoxins, ß-glucans, and microbial volatile organic compounds (MVOCs) in indoor air. The causative agents of adverse health effects have not been conclusively identified, but excessive levels of any of these in the indoor environment indicates a potential health hazard.

10. Microbial interactions and moisture-related physical and chemical emissions from building materials may also play a role in dampness-related health issues.

11. Building standards and regulations on comfort and health do not sufficiently emphasize requirements to prevent and control excess moisture and dampness.

12. Besides occasional events – such as water leaks, excess rain, floods, etc. – most moisture enters buildings through incoming air, including that infiltrating though the envelope, or is due to occupants' activities.

13. Allowing surfaces to become cooler than the surrounding air may result in unwanted condensation. Thermal bridges (such as metal window frames), inadequate insulation and unplanned air pathways, or cold water plumbing and cool parts of air conditioning units can result in surface temperatures below the dew point of the air that contribute to dampness problems.

14. The problem of excess moisture and dampness can be tackled by controlling the quality of the building envelope regarding air infiltration, exfiltration, and pathways of water intrusion, by ensuring adequate thermal insulation and by avoiding condensation indoors through the control of moisture sources and of temperature, humidity and velocity of the air in the proximity of the surfaces.

Recommendations

1. Persistent dampness and microbial growth on interior surfaces and in building structures should be avoided or minimized, as they may lead to adverse health effects.

2. Indicators of dampness and microbial growth include the presence of condensation on surfaces or in structures, visible mould, perceived mould odour and a history of water damage, leakage or penetration. Thorough inspection and – if needed – appropriate measurements may be used to confirm indoor problems related to moisture and microbial growth.

3. Currently, the relationship between dampness, microbial exposure and health effects cannot be precisely quantified, so no quantitative health-based guideline values or thresholds can be recommended for acceptable levels of specific microorganism contamination. Instead, it is recommended that dampness and mould-related problems be prevented. When they occur, they should be remediated because of the increased risk of hazardous microbial and chemical exposures.

4. Well-designed, -constructed and -maintained building envelopes are critical to the prevention and control of excess moisture and microbial growth by avoiding thermal bridges and preventing intrusion by liquid or vapour-phase water. Management of moisture requires proper control of temperatures and ventilation to avoid high humidity, condensation on surfaces and excess moisture in materials. Ventilation should be distributed effectively in spaces, and stagnant air zones should be avoided.

5. Building owners are responsible for providing a healthful workplaces or living environments free of excessive moisture and mould problems by ensuring proper building construction and maintenance. Occupants are responsible for managing water use, heating, ventilation, appliances, etc. in a proper manner that does not lead to dampness and mould growth.

6. Local recommendations in different climatic regions should be updated to control dampness-mediated microbial growth in buildings and to ensure the achievement of desirable indoor air quality.

7. Dampness and mould may be particularly prevalent in poorly maintained housing for low-income people. Remediation of conditions related to adverse exposures should be given priority to prevent additional contributions to poor health in populations already living with an increased burden of disease.

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