Development of WHO guidelines on indoor air quality

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SUMMARY
Indoor air quality has a special role as a health determinant, and the management of indoor air quality requires different approaches than outdoor air. Therefore WHO initiated the preparation of guidelines for indoor air quality, which will address selected chemical pollutants, biological contaminants of indoor air and pollutants due to indoor combustion of solid fuels. Exposures to dampness and mould were considered as the first group of indoor air quality problems for which the guidelines were prepared. Based on a review of the scientific evidence, a 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 – prevention and control, Environmental exposure, Risk assessment, Guidelines

INTRODUCTION
The WHO air quality guidelines (AQG) are designed to offer guidance in reducing the adverse health impacts of air pollution based on expert evaluation of current scientific evidence. An assessment of the global and regional burden of disease due to air pollution organized by WHO focused attention on the geographic distribution of the problem and its scale: more than 2 million premature deaths each year are attributed to urban outdoor air pollution and indoor air pollution from the burning of solid fuels, and more than half of this burden is borne by the populations of developing countries (WHO, 2002).

Various problems in indoor air quality are recognized as important risk factors for human health in both developing as well as developed countries. One of the regional priority goals of the Children’s Environment and Health Action Plan for Europe (CEHAPE), adopted by the Fourth Ministerial Conference on Environment and Health in Budapest in June 2004, is the reduction of adverse effects of air pollution on children’s health. The basic right to, and importance of, healthy indoor air has also been emphasized by the World Health Organization (WHO, 2000).

Recognizing that the management of air quality indoors requires different approaches to those applicable to outdoor exposures, the recent update of the WHO AQG (WHO 2006a) recommended that WHO explore the development of AQG specifically designed to facilitate the management of indoor air quality around the world. In response to this recommendation, WHO convened a planning meeting to discuss the role of WHO guidelines in reducing health risks due to polluted indoor air, and to agree on the recommended scope and format of the WHO guidelines for indoor air quality (IAQ).
The working group met in Bonn, 22–23 October 2006, and set the framework for the IAQ guidelines. It agreed that formulation of WHO guidance or guidelines supporting the protection of public health in both the developed and the developing world would require systematic evaluation of the health effects of indoor exposures. The meeting also discussed the potential role of the guidelines in the assessment and management of health risks related to indoor air pollution, and agreed on the scope and format of the IAQ guidelines. This paper summarizes the results of this discussion, published in a WHO report (WHO 2006b), and presents the progress of work on the guidelines on dampness and mould.

METHODS
According to the agreement of the working group meeting, besides the health-based recommendations for concentration levels not to be exceeded, the guidelines may formulate recommendations concerning indoor air quality problems using qualitative indicators, such as existence of dampness in the building structures leading to microbial growth or use of solid fuels in indoor spaces.

For a substantial subset of the chemicals and factors relevant to indoor air quality, the air quality guidelines exist. It was unanimously agreed that these guidelines and recommendations are potentially applicable to indoor air and should be applied and accounted for as such in the development of the WHO guidance specific to the indoor air settings.

The WHO guidelines for indoor air quality will cover indoor settings in which the general population, or especially susceptible population groups such as children, elderly people, or people with asthma, are potentially exposed to indoor air pollution. These include homes, schools, day care centres, public places such as libraries or institutionalized settings such as nursing homes. However, the general guidelines for indoor air quality cannot adequately address conditions that are specific to exposures in industrial settings, agriculture and mining or in other occupational settings where the exposure is related to the occupational activity. Such settings are typically covered by work safety legislation or guidance.

WHO established a small steering group\(^1\) to guide WHO through the process of guidelines development and assure its scientific reliability and relevance to public health needs.

The development of the guidelines starts with the preparation of background material based on a systematic review of the accumulated evidence on the patterns and levels of population exposure to the analysed substance/factor in indoor spaces and on the health effects of the exposure (based on epidemiological, toxicological and clinical studies). This evidence is then summarized to provide a health risk evaluation of the substance/factor. The background material is prepared by experts invited by WHO based on the steering group recommendation. After initial review by the steering group, this material is subject to external review by a broader set of reviewers, submitting their written comments to WHO. The background material and the comments are then discussed by the WHO working group meeting, gathering together the authors, reviewers and steering group members. The main tasks of the discussion are clarification of the scientific issues identified by the review and formulation of the recommended guidelines. Following the working group meeting, the authors finalize the background material considering the comments received from the reviewers and submit the

\(^1\) Members of the steering group: R. Anderson (United Kingdom), A. Cohen (United States of America), S. Kirschner (France), L. Mølhave (Denmark), A. Nevalainen (Finland), B. Seifert (Germany), K. Smith (United States of America), J. Spengler (United States of America) (and, from March 2008, E. Lebret (Netherlands)).
text for final peer review. The final text, accepted by the steering group and edited, is evaluated by WHO before the official WHO guidelines are issued.

RESULTS

Issues to be covered by indoor air quality guidelines
To select the specific agents and factors to be included in the guidelines and to define the format of guidelines for various groups of agent, the experts gathered at the WHO meeting in October 2006 had to:

1. confirm the health relevance of the group of agents or factors for which the scientific evidence on the relationships between exposures and adverse health effects attributable to these factors is well established, warranting their inclusion in the WHO guidelines; and

2. recommend the formats of the guidelines, including for example guideline concentrations levels, interim targets or technical solutions.

In the result of the discussion, the working group agreed that the IAQ guidelines should cover three groups of issue: specific pollutants, biological agents and indoor combustion products (Table 1).

Table 1. Summary of factors to be included in IAQ guidelines.

<table>
<thead>
<tr>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pollutants</strong></td>
<td><strong>Biological agents</strong></td>
<td><strong>Indoor combustion</strong></td>
</tr>
<tr>
<td>Formaldehyde</td>
<td><strong>Dampness and mould</strong></td>
<td>Stove venting</td>
</tr>
<tr>
<td>Benzene</td>
<td></td>
<td>- flues</td>
</tr>
<tr>
<td>Naphthalene</td>
<td></td>
<td>- hoods</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>Ventilation</td>
<td>Ventilation</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>- natural</td>
<td>- natural</td>
</tr>
<tr>
<td>Radon</td>
<td>- forced/mechanical</td>
<td>- forced</td>
</tr>
<tr>
<td>Particulate matter (PM$<em>{10}$ and PM$</em>{2.5}$)</td>
<td></td>
<td>Combustion quality</td>
</tr>
<tr>
<td>Halogenated compounds</td>
<td>Allergens</td>
<td>Fuels</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons (PAH), especially benzo[a]pyrene</td>
<td>- from house dust mites</td>
<td>- solid</td>
</tr>
<tr>
<td></td>
<td>- from pets</td>
<td>- processed solid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- liquid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- gas</td>
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<td></td>
<td></td>
<td>- electricity</td>
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</table>

The structure of reviews for each group may vary, to correspond optimally to the needs for the presentation and analysis of the relevant evidence. However, in each case it will address the exposure and its sources, health effects and evaluation of human health risks.

Development of guidelines on dampness and mould
Considering the interest of WHO’s Member States in the health effects of biological agents as well as the limited resources available for the guidelines development in 2007, WHO initiated the process of IAQ guideline formulation by preparing guidelines on mould and dampness.
The structure, authors and reviewers for the first draft of the background material were proposed by the steering group (Table 2). The draft chapters were submitted to WHO in August 2007 and, after compilation, distributed for review. The working group composed of 32 experts from 16 countries evaluated the evidence at a meeting convened in Bonn on 17–18 October 2007. The meeting recommended the guidelines and agreed on the process to finalize the background documentation, allowing publication of the results of the work in 2008 (WHO 2008).

Table 2. Structure of the background material for the WHO guidelines on indoor air quality: dampness and mould.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>WHO</td>
</tr>
<tr>
<td>Building dampness and its impacts on indoor exposures to biological and</td>
<td>J. Douwes</td>
</tr>
<tr>
<td>non-biological pollutants</td>
<td></td>
</tr>
<tr>
<td>Moisture control and ventilation</td>
<td>O. Seppanen, J. Kunitski</td>
</tr>
<tr>
<td>Health effects associated with dampness and mould</td>
<td>M. Mendell, T. Sigsgaard, J. Bonløkke, H. Meyer, M-R Hirvonen, M. Roponen</td>
</tr>
<tr>
<td>Evaluation of human health risk and recommended guidelines</td>
<td>Whole working group</td>
</tr>
</tbody>
</table>

Based on the accumulated evidence, the working group formulated the following 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 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 and appliances, 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.

The final editing and processing of the background material are progressing, as is the clearance process in WHO to issue the guidelines based on the above recommendations.

**Development of guidelines on specific pollutants**

Preparation of the review of the evidence on health hazards of specific pollutants started in spring 2008. The steering group recommended the inclusion in the review of all pollutants listed in the first column of Table 1 except particulate matter. This was based on the agreement that the WHO guidelines on particulate matter updated in 2005 (WHO 2006) apply also in indoor spaces and that there is no evidence allowing the creation of separate health-based guidelines for indoor and outdoor exposures. The working group reviewing the evidence has been established and the work will proceed in 2008-2009.

**Development of guidelines on indoor combustion**

Exposures to products of the combustion of fuels in indoor environments are a significant health hazard causing a wide range of health effects. It has been estimated that at least 3 billion people are exposed to smoke from coal and biomass in their homes. More than 1.5 million premature deaths each year are attributed to indoor air pollution from the burning of solid fuels, and this burden is almost exclusively borne by the populations of developing countries (Rehfuess, 2006; WHO, 2002). Especially developing countries seek WHO guidance in setting priorities and recommending the most effective feasible ways to reduce health risks. In these countries, indoor air quality problems are attributable to the lack of technology necessary to eliminate indoor air pollution (such as cleaner-burning and more fuel-efficient stoves and chimneys, and the use of clean fuels). Such situations have been linked with a wide range of health effects, in particular morbidity and mortality due to acute lower respiratory infections among children and chronic obstructive pulmonary disease among adults, and therefore the formulation of feasible and effective guidelines must not be limited to setting concentration limits for selected pollutants, but may also include guidance on the use of appropriate fuels, pollution control and exposure reduction.

It is expected that the work on the guidelines on indoor combustion will start in 2009.

**CONCLUSIONS**

The systematic review of the evidence on the health hazards of indoor air pollutants necessary to prepare the WHO guidelines allows the formulation of conclusions supporting the prevention and reduction of the risks to health associated with poor indoor air quality. However, the guidelines are only one of the instruments that might be used to construct an effective strategy to improve indoor air quality. It may indicate a target to be reached with the application of a wide range of tools, such as building design, selection of materials used indoors and their emission standards, ventilation standards or limit/action levels for selected indicator pollutants. In some cases, it may also mean a ban on certain materials being used or on activities to be performed indoors. Though the technical and practical problems regarding
those tools may be substantial, application of the guidelines should focus actions on the indoor air quality aspects that are most relevant for health.

ACKNOWLEDGEMENT
A full list of the experts involved in development of the WHO indoor air quality guidelines is available in WHO reports (WHO, 2006b; 2008). WHO gratefully acknowledges the financial support for development of the guidelines from the German Federal Environment Ministry, from the Department of Health, England, United Kingdom and from L’agence française de sécurité sanitaire de l’environnement et du travail (AFSSET).

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