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Development of WHO Guidelines for Indoor Air Quality

Report on a Working Group Meeting

Bonn, Germany

23-24 October 2006



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ABSTRACT

Indoor air quality has a special role as health determinant, and management of indoor air quality requires different approaches than outdoor air. Therefore the working group of the recently published Global Update of the WHO Guidelines for Air Quality (WHO, 2006), recommended development of WHO guidelines for indoor air quality.

Based on this recommendation World Health Organization convened a working group meeting for the development of indoor air quality guidelines representing scientific expertise in epidemiology, toxicology, exposure assessment, developing country issues, indoor combustion, biological agents, building construction, ventilation and indoor air quality management. The working group outlined the tasks required for the guideline development in 2007-2009 and recommended a list of special chemicals for which numerical guidelines can be prepared. It also proposed ways to define guidelines allowing for reduction of health risks due to biological contamination of indoor air and due to indoor combustion of solid fuels.

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Background

The WHO Air Quality Guidelines (AQG) are designed to offer guidance in reducing 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 (World Health Report, 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 Environmental 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 for, and importance of, healthy indoor air has been emphasized also by the World Health Organization (WHO, 2000a).

Importance of indoor air is magnified by the substantial fraction of time populations spend within buildings. Indoor combustion is a source of pollution causing severe burden to health, especially for children and women in developing countries. In residences, day-care centres, elderly people homes and other special environments, indoor air pollution affects population groups that are especially susceptible due to their health status or age. Well established evidence on health effects of air pollution comes from outdoor air studies, but health effects of same pollutants are expected to be similar also indoors. There is also a substantial body of research on health effects of indoor exposures. There are many potentially hazardous compounds released indoors due to combustion, emissions from building materials, household equipment and consumer products. Microbial pollution comes from hundreds of species of bacteria, fungi, and moulds growing indoors. Indoor air quality management is made difficult not only by the large number and variation of indoor spaces but also the complex relations of indoor air quality and the building design, materials, operation and maintenance, ventilation and behaviour of the building users.

The recent update of the WHO AQGs (WHO, 2005, 2006) for particulate matter, ozone, nitrogen dioxide, and sulfur dioxide specified that the AQGs applied in all non-occupational environments, including indoors in households, schools, vehicles, etc. Although, such traditional AQGs in the form of concentrations for specific pollutants based on scientific review and assessment of health effects have been widely used in outdoor air quality management, they have had relatively little impact on management of indoor air quality in most countries. Recognizing that management of air quality indoors requires different approaches to those applicable to outdoor exposures, the recent AQGs update recommended that WHO explore development of AQGs specifically designed to facilitate management of indoor air quality around the world.

Scope of the meeting

In response to the recommendation by the global update working group (WHO, 2005), the European Centre for Environment and Health convened this planning meeting with the objective to discuss the role of WHO guidelines in reduction of health risks due to pollution of indoor air,

and to agree on the recommended scope and format of the WHO guidelines for indoor air quality. The meeting was also requested to recommend the background material to be developed before the guidelines are formulated as well as to discuss the most efficient organization of the process of the guidelines formulation.

WHO took as a starting point the principles that the guidelines should address various level of economic development, cover all relevant population groups and enable feasible approaches to reduce health risks from indoor air pollutants. Existing national and international experiences in indoor air quality regulation and conclusions of completed international projects provided the background information to the discussion of the working group. The target date for publication of the guidelines for indoor air quality was set for the years 2008-9 and would depend on the availability of funds for project coordination and implementation.

Process

Based on the recommendations of the steering group of the global update of the WHO Air Quality Guidelines, as well as following informal consultations with several experts involved in assessment and management of risks due to indoor air quality, WHO invited ca. 50 experts to join the Working Group. The experts were asked to identify existing national guidelines or standards, as well as reports from projects addressing indoor air quality regulations. Copies of these documents were made available through the restricted-access web page, and a summary of most of them was distributed directly to the experts in advance of the meeting. The list of the background materials is presented in Annex 1.

In October 23-24, 2006, the working group meeting in Bonn gathered 38 experts, representatives of International Agency for Research on Cancer, European Commission and WHO, as well as observers from US-EPA and the Shell Foundation. Annex 2 presents a full list of the meeting participants. Dr Matti Jantunen and Dr Ross Anderson co-chaired the meeting, and Dr Kwok Wai Tham acted as the meeting rapporteur.

In a series of plenary discussions and small drafting group sessions, the Working Group reviewed the general approach to the guidelines' formulation, discussed their scope and format, and agreed on the general contents of the background material. Initial recommendations were proposed by sub groups addressing:

- A. Guidelines for specific agents / substances (chaired by B. Chen)
- B. Biological agents (chaired by A. Nevalainen)
- C. Combustion of fuels indoors (chaired by K. Smith).

The final recommendations concerning the guideline development were made in plenary by consensus. This report summarizes the Working Group discussions and presents the work plan for developing the guidelines for indoor air agreed by the Working Group. It includes the corrections received from the WG members resulting from their review of the first version of the report distributed after the meeting.

The meeting was supported by the funds received by the WHO European Centre for Environment and Health, (Bonn Office) from the, German Federal Environment Ministry, which is gratefully acknowledged.

Summary of the discussion

The meeting started with introductory presentations to mediate the discussion on the current knowledge on health effects of indoor air pollution (Isabella Annesi-Maesano and Kurt Straif), exposures (Matti Jantunen, Kalapana Balakrishnan, and Lidia Morawska), and existing work on indoor air guideline development (Paolo Carrer, Jarek Kurnitski, Bingheng Chen, and Heather Walton).

Presentations

Health effects. Air pollution increases premature mortality caused by lung cancer and other respiratory and cardiovascular diseases. Subjects with respiratory conditions experience symptoms due to exposures to air pollution, leading to increased medication use, sick leaves, and lowered performances in learning and working. In the World Health Report, 2002, it was estimated that 1.6 million premature deaths are caused annually by indoor air pollution (WHO, 2002). Certain population groups, like women and small children, are vulnerable to the effects of indoor air pollution because their daily activities include exposure to cooking fumes from unvented combustion of solid fuels for most of the day. This applies to a large fraction of homes in the developing world. International Agency for Research on Cancer recently classified smoke from indoor combustion of coal as carcinogenic for humans, and indoor emissions from household combustion of biomass fuel (primarily wood), as probably carcinogenic for humans (IARC, in press, Straif et al., 2006).

Indoor exposures. A substantial fraction of mankind is exposed to levels of a number of chemicals and pollutants which are higher indoors than outdoors. While most of the air pollution epidemiology is based on using outdoor measurements of pollutant levels in the analysis of the association between exposures and health outcomes, there is no reason to assume that health effects would be associated with exposures to these pollutants only when outdoors. Available studies on effects of indoor exposures confirm this assumption. The enclosed nature of indoor spaces leads easily to very high indoor exposures when indoor sources are present. Even substantial part of exposures to air pollution from outdoor air occurs indoors as outdoor air enters indoors via infiltration and ventilation. Review of the occurrence of indoor sources of various chemicals and the chemicals' toxicity leads to identification of certain compounds for which indoor sources and exposures are driving the health risks of specific population groups in Western countries.

Developing countries. Indoor exposures in the developing world are affected especially by the use of solid fuels. It has been estimated that at least 3 billion people are exposed to smoke from coal and biomass in their homes. Use of such fuels affects also the outdoor air quality and therefore merely venting the smoke outdoors may not be a sufficient long-term solution, even though it effectively reduces pollutant levels indoors. 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 (e.g. chimneys, hoods; use of clean fuels). Such situations have been linked with a wide range of health effects including mortality, 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.

Biological agents. Biological factors of health relevance exhibit enormous heterogeneity, ranging from spores emitted outdoors to fungal growth indoors and across a wide variety of microbes and allergens spreading from person to person. Due to this heterogeneity and the difficulty of accurately estimating exposure levels, it is difficult or impossible to attribute the burden of disease to single factors like species of microbes. However, microbial growth in indoor environment is dependent on the availability of moisture and on temperature. Therefore the use of correct building design and ventilation procedures to remove dampness from surfaces has been shown to be both the most efficient technique reducing the health risk associated with biological factors, and the moisture is the best indicator of the increased risk.

Building codes and ventilation. Building codes and building material classification systems provide tools to reduce building material emissions and improve indoor air quality especially in developed country settings. Sufficient mechanical or natural ventilation is a key element in removing humidity, carbon dioxide, bioeffluents and other pollutants from indoor air. Requirement for 2-way mechanical ventilation, driven mainly by energy efficiency reasons, ensures adequate ventilation rates for all rooms and provides also opportunity to apply air filtration. but it also can be a source of some indoor air quality problems. Unfavourable combinations of air humidity and temperature differences in building structures may lead to condensation of water on surfaces and microbial growth with the potential of building material decomposition. When mechanical ventilation is applied, ventilation ductwork and filters contaminated by deposited materials may become sources of mineral fibres, volatile organic compounds, other emissions and odours if not properly maintained.

Prioritization of compounds. The European Commission project for critical appraisal of the setting and implementation of indoor exposure limits (INDEX) applied a three-tiered risk assessment for prioritization of single chemical pollutants present in indoor air. From the 41 potentially hazardous first phase pollutants 14 compounds were selected for a more detailed analysis and based on the exposure and toxicity data 5 priority compounds were identified: formaldehyde, nitrogen dioxide, carbon monoxide, benzene, and naphthalene. Recommendations listed for indoor air quality management included indoor air quality guidelines, building codes and ventilation standards, equipment standards and permits, mandatory maintenance and inspections, labelling and reporting of the contents of, or releases from building products, furnishing materials, equipment, and consumer products, and raising public awareness on the emissions and the importance of good indoor air quality.

National standards. In countries of fast development like China and India, fast urbanization changes the environment rapidly by increasing traffic, energy consumption and crowding. Economical development, usually associated with improvements in environmental health, may in such situations lead also into deterioration of indoor air quality because of the use of new materials such as the use of chipboard in China leading to high emissions of formaldehyde in modern homes. In some countries, including China, Singapore, Canada, United Kingdom and Germany, air quality guidelines have been developed or suggested also for indoor air, however exhibiting a large heterogeneity of compounds and factors considered and in some cases using not only health-based approaches, but also technical approaches and feasibility.

Relationships of guidance, guidelines, and standards

Existing recommendations for indoor air guidelines list a number of pollutants that may require attention. Some of the existing guidelines are, however, not health based and do not belong to the scope of this WHO work. Furthermore, some national assessments reflect national or regional (e.g. continental) conditions and do not necessarily include settings that need to be covered by the global WHO guidelines.

Development of the WHO guidelines for indoor air quality must be based on systematic review of the scientific evidence on health relevance of various pollutants in the indoor air and factors affecting indoor air quality. The principles of such a systematic review for health impact assessment are presented in the WHO guideline document (WHO, 2000b). Indoor combustion of solid fuels and dampness in building structures have been consistently associated with indoor air quality problems and consequently well documented health hazards. These factors cannot be fully characterized using a concentration-based approach in the guideline formulation that has been used in the previous WHO guidelines (WHO, 1987, 2000c, 2005, 2006). Therefore the indoor air guideline work needs to consider also qualitative indicators of health hazards and address them using guidance based on indicators of the hazards. Interim targets introduced in the Global Update of the WHO Guidelines for Air Quality (WHO, 2005, 2006) may also be a promising tool in supporting policy development in especially developing areas of the world.

WHO guidelines are recommendations based on scientific evidence on health effects of certain exposures. Formulation of guidelines as exposure levels gives an objective measure of health risk that can be used as a reference point for design and maintenance of safe indoor environments. The use of the guidelines to create national and international legislation and standards needs to consider feasibility of various approaches besides direct control of indoor concentrations, including taxation of fuels and products, product and equipment use, maintenance, product composition, labelling, building construction, ventilation and education of professionals and the public to account for the importance of the indoor air quality for public health.

Work in small groups

To select the specific agents and factors to be included in the guidelines and to define the format of guidelines for various groups of agents, the working group was divided into three subgroups for more detailed and focused discussion and formulation of specific recommendations. The discussions and recommendations of each of the sub groups are summarized below. The tasks of the sub groups were 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
2. Recommend formats of the guidelines, including for example guideline concentrations levels, interim targets or technical solutions
3. Recommend actions needed to develop the guidelines for these agents, including the needs for systematic reviews of the scientific evidence and existence of relevant published reviews.

Group A. Air pollutant specific guidelines

Traditional approach to setting guidelines for air quality has been based on identification of specific compounds, assessment of exposures, determination of dose-response relationships, and evaluation of the overall health risks. The task of the sub group was to identify those specific pollutants and agents that would require specific attention due to the characteristics of indoor environments.

A.1 Identification of pollutants

The group specified the following criteria for selection of compounds for the development of WHO guidelines for indoor air

- Existence of indoor sources
- Availability of toxicological and epidemiological data (e.g. NOAEL, LOAEL¹)
- Indoor levels exceeding the levels of NOAEL and/or LOAEL

Based on these criteria, pollutants considered by the sub group were divided into two categories (Table 1). Group 1 includes pollutants for which WHO guideline for indoor air is needed and WHO should plan their development. Group 2 includes pollutants of potential interest but the group concluded that further investigation would be needed before it was clear whether there was sufficient evidence to warrant their inclusion in the guidelines. According to publication of new evidence their role may need to be reconsidered at a later stage of the process.

The group concluded that the WHO guidelines for environmental tobacco smoke (ETS) published in WHO Air Quality Guidelines for Europe, 2nd Edition (WHO, 2000c) and stating that there is no evidence for safe exposure level are clear and still valid. Therefore ETS does not need to be included in the current work. Plenary discussion concluded that the guidelines for other pollutants should be developed based on the assumption that ETS is eliminated from the indoor spaces.

A.2 Format of the guidelines

The group recommended the following outline for the format of each of the pollutant specific chapters:

For each pollutant

1. General description of the compound
2. Indoor sources and pathways of exposure
3. Current indoor levels and relationship with outdoor levels
4. Kinetics and metabolism
5. Health effects (non-cancer and carcinogenic effects) (for general population and identified susceptible groups)
6. Evaluation of human health risk
7. Guidelines and guidance
8. References

¹ No observed adverse effect level; Lowest observed adverse effect level.

A.3 Work plan and existing systematic review

The group identified a number of relevant systematic reviews and risk assessments of pollutants present in indoor environments, some of which are listed in Table 1. These reviews should be used as inputs to the development of the indoor air quality guidelines. One of the issues to be considered is the use of information from epidemiological studies based on ambient pollutant levels as exposure indicator.

Table 1. Identification of pollutants recommended for guideline development (group 1) and those with not sufficient scientific evidence and corresponding systematic reviews (group 2).

(+ indicate the source of the evidence identified by the WG)

	<i>WHO AQG</i>	<i>IARC</i>	<i>INDEX</i>	<i>US-EPA</i>	<i>IEH UK</i>	<i>Germany</i>
Group 1 pollutants: Development of guideline recommended						
1.1	Formaldehyde	+	+	+	+	+
1.2	Benzene	+	+	+	+	
1.3	Naphthalene			+		+
1.4	Nitrogen dioxide (NO ₂)	+		+	+	+
1.5	Carbon monoxide (CO)	+		+	+	+
1.6	Radon (Rn)	+				+
1.7	Particulate matter (PM _{2.5} and PM ₁₀)	+		+	+	
1.8	Halogenated compounds (tetrachloroethylene, trichloroethylene)				+	+
1.9	Polycyclic aromatic hydrocarbons (PAH), especially Benzo-a-pyrene (BaP).	+			+	
Group 2 pollutants: Current evidence uncertain or not sufficient for guidelines						
2.1	Toluene	+		+	+	+
2.2	Styrene	+		+	+	+
2.3	Xylenes	+		+		
2.4	Acetaldehyde			+	+	
2.5	Hexane					
2.6	Nitric oxide (NO)					
2.7	Ozone (O ₃)	+				
2.8	Phthalates					
2.9	Biocides, Pesticides					
2.10	Flame retardants					+
2.11	Glycol ethers					
2.12	Asbestos					

Group 2 pollutants: Current evidence uncertain or not sufficient for guidelines (continued)

2.13	Carbon dioxide (CO ₂)			+
2.14	Limonene, pinene		+	+
2.15	General recommendations TVOC			+

WHO AQG: WHO Air Quality Guidelines, 2000, 2006

IARC: International Agency for Research on Cancer; monographs 29 and 88

INDEX: Critical appraisal of the setting and implementation of indoor exposure limits in the EU.

US-EPA: US Environmental Protection Agency;

IEH UK: www.silsoe.cranfield.ac.uk/ieh/publications/airpoll.html

Germany: recommended guideline values listed in <http://www.umweltbundesamt.de/uba-info-daten/daten/gesundheits/irk.htm>

Group B. Biological agents

B.1 Identification of factors

Exposures to biological agents in indoor environments were identified as a significant health hazard causing a wide range of health effects. There is vast evidence on hazards of several biological agents listed in Table 2. However, the group concluded unanimously that it is not possible to identify individual species of the microbes or other specific biological agents responsible for the health effects. The exceptions are some common allergies, which can be attributed to specific agents or exposures, such as house dust mites or pets.

Biological agents in the indoor environment are attributable to dampness and inadequate ventilation. Excess moisture on any material leads to growth of microbes such as moulds, fungi and bacteria, which subsequently emit spores, cells, fragments and volatile organic compounds into the indoor air. Moreover, dampness initiates chemical and/or biological degradation of materials which also causes pollution of the indoor air. Dampness has been therefore suggested to be the strongest and most consistent indicator of risk for asthma and respiratory symptoms (e.g. cough and wheeze).

Inadequate ventilation is strongly associated with adverse health (sick building syndrome, inflammation, infections, asthma, sick leave, etc.) and reduces work performance in office buildings and learning capacities of students in schools. Proper ventilation is an important control for humidity, and prevention of condensation.

The group recommended guidelines to be developed for the following factors related to biological agents:

- a. Dampness and mould
- b. Ventilation
- c. Allergens
 - i. Allergens from house dust mites
 - ii. Allergens from pets

It was pointed out that ventilation system may act as a source of health hazard e.g. in case of microbial growth and VOC emissions from accumulated sediments in the ventilation systems, but that overall ventilation should be seen as the solution for most indoor air quality problems, including those associated with biological agents.

B.2 Recommendations for the format of the guidelines

Various technological and lifestyle recommendations and guidance were identified as effective measures available to control health risks caused by biological agents. Concentration based guidelines cannot be given at this time. Individual susceptibility was identified as an important issue in the formulation of the guidelines.

The sub group discussed the formatting of the guidelines especially regarding biological agents as guidance, or as qualitative identification of risk factors and giving recommendations on indicators and actions to avoid/reduce the health risks. Traditionally air quality guidelines have been formatted as acceptable concentration levels of specified pollutants or other measures of air quality. Expansion of the air quality guidelines for biological agents as well as indoor combustion related issues warrants widening the formats of the WHO recommendations as defined as guidance related to indicators, risk factors and feasible actions.

The sub group discussed the outline of the guidelines by e-mail after the meeting and recommended the following structure:

Dampness and mould

- 1 General description
- 2 Effects of dampness on sources of exposure
- 3 Health effects associated with mould and dampness
- 4 Evaluation of human health risks
- 5 Guidelines
- 6 References

Ventilation

- 1 General description
- 2 Ventilation as a solution for indoor air quality problems
- 3 Ventilation as a source of exposures
- 4 Health effects associated with ventilation
- 5 Evaluation of human health risks
- 6 Guidelines
- 7 References

Allergens

- 1 General description
- 2 Sources and routes of exposure
- 3 Kinetics and metabolism
- 4 Health effects
- 5 Evaluation of human health risks
- 6 Guidelines
- 7 References

B.3. Work plan and existing systematic reviews

Guidance can be developed based on re-evaluation and updates of the existing scientific evidence. Development of quantitative guidelines requires further research for all agents evaluated. The existing draft for WHO Guidance on Biological Agents compiled in 2003 is useful background material for development of the guidelines.

Table 2. Identified sources of systematic reviews and recommendations for biological agents.

Agent	Systematic reviews existent	Evidence Needs systematic re-evaluation	Guideline can be proposed	Guidance can be provided
Pathogenic agents e.g. viruses & bacteria	Y	Y	N	Y
Bacteria (non pathogenic)	N	Y	N	Y
Fungi	Y	Y	N	Y
Toxins & other microbial products (e.g. MVOCs), microbial components	N	Y	N	Y
Algae and amoebae etc.	N	Y	N	Y
Mites (e.g. HDM, storage mites)	Y	Y	N	Y
Pet allergens (e.g. cats, dogs)	Y	Y	N	Y
Pest allergens (e.g.. Cockroaches & other insects, rats)	Y	Y	N	Y
Pollen	N	Y	N	Y
Fungal allergens (e.g. Alternaria, Cladosporium)	Y	Y	N	Y
Birds	N	Y	N	N
Ventilation (Humidity control, Pollutant removal)	Y	N	Y	Y
Ventilation (Components – as sources of contamination (e.g. filters, ductworks, coils, condensation pans, etc...))	N	Y	N	Y
Dampness & Health	Y	Y	N	Y
Moisture control (envelope & building systems and components)	N	Y	N	Y
Condensation	N	Y	Y	Y
Chemical degradation and microbial growth	N	Y	N	Y
Hygiene & cleanliness (Lack of) Cleaning	Y	Y	N	Y
Use and mis-use of cleaning & disinfection products	Y	Y	N	Y
Air fresheners	Y	N	N	Y

Group C. Combustion of solid fuels and kerosene

C.1 Identification of factors

Particulate matter (PM₁₀ and PM_{2.5}) as well as carbon monoxide (CO) are good indicators of a large group of pollutants emitted in combustion of solid fuels. The group recognized that the current air quality guidelines for PM provide targets which are also valid for indoor environments. However the current guidelines for carbon monoxide (WHO, 2000c) need to be updated to reflect new information on chronic effects and to assure sufficient protection against acute poisoning in solid-fuel using households.

There are big differences in exposure levels to pollutants from solid fuel use between developing and developed countries. The group recognized that measurements of indoor air quality are difficult to be performed especially in developing countries, and that substantial improvements in reducing exposures can be achieved merely using indicators like “use of solid fuels indoors without proper ventilation / chimney” for identification of the need for action and formulation of corresponding technological recommendations regarding fuels, stove types, venting etc. However, when available, measurements of indoor air quality provide quantitative information on the exposures, and in case of interventions allow assessing the efficiency of the selected actions. There is much room left for technological solutions in exposure reduction (particularly for cooking) as relatively few resources have yet been applied.

The group set the focus of the development of indoor air quality guidelines on exposures to emissions from household use of solid fuels and kerosene, not just for heating and cooking but including also e.g., lighting and small commercial activities in households. The group also recognized that the health relevant exposure to combustion products is affected also by the outdoor air quality. While moving pollution emitted indoors to the outdoor air with venting radically improves indoor air quality, it still causes harmful exposure to people both outdoors as well as via outdoor pollution infiltrating back indoors. Therefore the reduction of the emission should be an objective of the health relevant actions. In some areas processed solid fuels, e.g., charcoal and “clean coal” may be part of the solution. Control of household use of “poisonous coals”, i.e. those contaminated with S, F, As, Pb, Hg, etc. needs to be considered as an important aspect as well.

C.2 Recommendations for the format of the guidelines

The group deliberated on plausible technical solutions to effectively control the sources and exposure pathways and listed the following processes/solutions to be considered in the guidelines for indoor air quality:

- Stove Venting
 - Flues
 - Hoods
- Household ventilation
 - Natural
 - Forced
- Combustion quality, particularly to improve technology of combustion of biomass and coal
 - Stove types
 - Burning temperature
 - Air to fuel ratio
 - Fuel consumption (smoke=unburned biomass, lost energy)
- Cleaner fuels
 - Processed biomass
 - Liquid fuels
 - Gas fuels
 - Electricity

The review of each option should include:

- Short description of the purpose of the process
- Possible technical solutions
- Evidence on impacts on indoor air quality (PM, CO, other pollutants)
- Evidence on total exposure reduction for various population groups
- Comments on practical limitations (costs, feasibility).

C.3. Work plan and existing systematic reviews

The recommended main effort in guidelines preparation is the review and evaluation of the technical options available. The effects of the application of these options on indoor air quality, total exposures, and health risk reduction must be documented by the systematic review of the literature and based on studies using scientifically sound validation methods and field measurements. Many completed studies were not reported in peer reviewed journals so the evidence from “grey literature” should be critically reviewed and evaluated.

Conclusions

The working group agreed on the role of indoor air quality as a significant determinant of population health. The development of WHO guidelines specific for indoor air quality are recommended for several reasons:

- Wide range of sources of air pollution specific to indoor spaces;
- Specificity of some exposures in indoor spaces in terms of pollution composition and exposure levels;
- Large fraction of time spent indoors affects population exposures;
- Separation of indoor and outdoor spaces which modify the exposures to a number of pollutants;

Formulation of WHO guidance or guidelines supporting protection of public health in both developed and developing world will require systematic evaluation of the health effects of the indoor exposures. 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.

Definition of indoor spaces to be included

The working group discussed how to define the indoor spaces that should be covered by the guidelines. It was concluded that the WHO guidelines for indoor air quality should cover indoor settings in which the general population or especially susceptible population groups like children, elderly, asthmatics etc. are potentially exposed to indoor air pollution. These include homes, schools, day care centres, public places as libraries or institutionalized settings like nursing homes. However, conditions that are specific to exposures in industrial settings, agriculture, mining and in other occupational settings where the exposure is related to the occupational activity of the occupants cannot be adequately addressed in the general guidelines for indoor air quality. Such settings are typically covered by work safety legislation or guidance.

Relationship to existing AQ guidelines

The working group acknowledged the existence of air quality guidelines for a substantial subset of the chemicals and factors identified. It was unanimously agreed that the existing air quality guidelines and recommendations are potentially applicable for indoor air and should be applied and accounted for as such in the development of the WHO guidance specific to the indoor air settings.

Selection of issues to be covered by the Guidelines

The recommendations for pollutants, agents, and factors to be included in the WHO guidelines for indoor air were discussed in detail in the sub groups for agent specific guidelines, biological agents, and combustion of solid fuels. The recommendations of the small groups were presented in the plenary, discussed and finally agreed on. The pollutants and factors to be included in the guidelines are presented in Table 3. The discussion has also decided that inclusion of all factors in one, comprehensive document (and not in several parts covering selected issues only) is advisable. The review of individual issues will be preceded by a short introductory section addressing:

- Differences in the approaches to management of indoor and outdoor air quality
- General recommendations for indoor air quality.

Table 3 Summary of factors to be included in the Guidelines on IAQ.

Group A	Group B	Group C
Pollutants	Biological agents	Indoor combustion
Formaldehyde	Dampness and mould	Stove venting
Benzene		- flues
Naphthalene		- hoods
Nitrogen dioxide (NO ₂)	Ventilation	Ventilation
Carbon monoxide (CO)	- natural	- natural
Radon (Rn)	- forced / mechanical	- forced
Particulate matter ¹		Combustion quality
Halogenated compounds	Allergens	Fuels
PAH ² , especially BaP ³	- from house dust mites	- solid
	- from pets	- processed solid
		- liquid
		- gas
		- electricity

¹ PM_{2.5} and PM₁₀, ² Polycyclic aromatic hydrocarbons, ³ Benzo[a] pyrene

The structure of the chapters should follow recommendations presented in reports from the subgroup discussion.

Follow up activities

The working group agreed that the development of the guidelines is an ambitious task and will require a substantial effort from the scientific community as well as WHO coordination. The following steps were recommended by the working group:

- A small steering group should be established to guide WHO through the process of Guidelines development and assure its scientific reliability and relevance to the public health needs.
- WHO was requested to search for relevant funding enabling implementation of the process, covering costs of the working group meetings as well as man-power required by the secretariat for the process coordination.
- After the necessary fundraising (6 months), the scientific work for the actual development of the guidelines should be planned for ca. 18 months, followed by process to publish the guidelines as an official WHO document.
- Recommendations of the working groups formulated at various stages of the process should be published electronically before the actual guidelines are published.

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- US EPA. An introduction to indoor air quality. Respirable particles.
<http://www.epa.gov/iaq/rpart.html>
- US EPA. Benzene. <http://www.scorecard.org/chemical-profiles/benzene.html>
- US EPA. Technology transfer network. Air toxics website. Naphthalene.
<http://www.epa.gov/ttn/atw/hlthef/naphthal/html>
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- IARC. IARC Monographs on the evaluation of corcinogenic risks to humans., Volume 95. Household use of solid fuels and high-temperature frying. Lyon, International Agency for Research on Cancer (in press)
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- WHO, 2005. *Air Quality Guidelines Global Update*. Report on a working group meeting Bonn, Germany, 18-20 October 2005. <http://www.euro.who.int/Document/E87950.pdf>
- WHO, 2006. *Air Quality Guidelines Global Update, Executive summary*. World Health Organization, Geneva, Switzerland. <http://www.who.int/phe/air/aqg2006execsum.pdf>

Annex 1

LIST OF BACKGROUND MATERIAL

The summary column¹ below refers to a 151-page compilation of executive summaries, conclusions, key tables and tables of contents of the documents.

Documents by Countries

- Canada Health Canada, 2006. Residential Indoor Air Quality Guideline: Formaldehyde. 3 pp. Available at http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/air/formaldehyde_e.pdf (300 kB)
- Health Canada, 1987 (revised 1989). Exposure guidelines for residential indoor air. 28 pp. Available at http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/air/exposure-exposition/exposure-exposition_e.pdf (155 kB).
- China Chinese indoor air quality guidelines, tables in English (2 pp.)
- Finland Finnish Building Code section D2: Indoor Climate and Ventilation of Buildings Regulations and Guidelines 2003. 41 pp. Available at <http://www.ymparisto.fi/download.asp?contentid=33667&lan=en> (300 kB)
- Finnish Society of Indoor Air Quality and Climate (FiSIAQ), 2001. Classification of Indoor Climate 2000; Target Values, Design Guidance and Product Requirements 40 pp. Available at <http://www.tervetalo.net/lataa/siy5-1.pdf#search=%22classification%20of%20indoor%20climate%202000%22> (1.1 MB)
- Germany Umwelt Bundes Amt, 2005. Options for legal regulations concerning indoor pollution – Do we need a “TA Innenraum”? (9 pp)
http://www.umweltbundesamt.de/uba-info-daten-e/daten-e/health/TA-Innenraum_en.pdf
- Singapore Singapore, 1996. Guidelines for good indoor air quality in office premises. 47 pp. Available at http://www.nea.gov.sg/cms/qed/indoor_air.pdf
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Documents by International Organizations

- EFA EFA, 2004. Towards Healthy Air in Dwellings in Europe. The THADE Report. European Federation of Allergy and Airways Diseases Patients Association. 97 pp. Available at <http://www.efanet.org/activities/documents/THADEReport.pdf> (1.9 MB)
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- EU European Commission, JRC, 2004. The INDEX Project: Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits in the EU. (331 pp). Available at http://www.jrc.cec.eu.int/pce/documentation/eur_reports/INDEX%20%20EUR%2021590%20EN%20report.pdf (2.6 MB).
- European Commission, JRC, 2004. The INDEX Project: Summary of recommendations and management options (27 pp, 630 kB).
- PCIA Partnership for Clean Indoor Air (PCIA), Household Energy, Indoor Air Pollution and Health Country Overviews for the following countries: Guatemala (50 pp, 1 MB), India (58 pp, 880 kB), South Africa (48 pp, 550 kB), China (108 pp, 1.9 MB), and Nepal (48 pp, 550 kB) reports available at <http://www.pciaonline.org/resources.cfm>
- WHO WHO, 2006. Air Quality Guidelines, Global Update: Chapter 9, Indoor air quality issues associated with domestic solid fuel use in developing countries. Draft 4, September 2006.
- WHO, 2003. Guidance on Biological Agents in indoor air. Draft. 162 pp.

UPDATE 1 OF THE BACKGROUND MATERIAL

The following documents were added to the original set of background documents according to the recommendations of the working group members. Documents sorted first by country, then by topic, and finally last sections by the international organizations.

Japan

Ministry of Health, Labour and Welfare, Office of Chemical Safety / Pharmaceutical and Food Safety Bureau, Committee on Sick House Syndrome: Indoor Air Pollution: Progress Report No.1 - Summary on the discussions from the 1st to 3rd meetings - 26 June 2000. 9 pp., 39 kB.
<http://www.nihs.go.jp/mhlw/chemical/situnai/kentoukai/rep-eng1.pdf>

Ministry of Health, Labour and Welfare, Office of Chemical Safety / Pharmaceutical and Food Safety Bureau, Committee on Sick House Syndrome: Indoor Air Pollution: Progress Report No 3 - Summary on the discussions at the 6th and 7th meetings - 5 July 2001. 6 pp., 26 kB.
<http://www.nihs.go.jp/mhlw/chemical/situnai/kentoukai/rep-eng3.pdf>

Japan Electronics and Information Technologies Industries Association (JEITA), 2006: VOC Guidelines for Personal Computers (Ver. 1). 13 pp., 332 kB.
http://it.jeita.or.jp/infosys/committee/environ/0601VOCguideline_en/0601VOCGuideline_final.pdf

Legislation in Japan (Chemicals): <http://www.nihs.go.jp/law/elaw.html>

Germany

Seifert B, Englert N, Sagunski H, Witten, J, 1999. Guideline values for indoor air pollutants. In Proceedings of the 8th International Conference on Indoor Air Quality and Climate held in Edinburgh, Scotland, 8–13 August 1999. 8 pp., 590 kB.

Indoor air hygiene: <http://www.umweltbundesamt.de/uba-info-daten-e/daten-e/health/indoor.htm>
(Summary with links).

Carbon Monoxide

Volans, G., *et al.*, 2006. Neuropsychological effects of chronic exposure to carbon monoxide in the indoor air. Final Report to the Department of Health 22 July 2006. 48 pp., 570 kB.

WHO 1999. Carbon Monoxide, 2nd edition. Environmental Health Criteria 213. 492 pp., 2.7 MB
http://whqlibdoc.who.int/ehc/WHO_EHC_213.pdf

Building codes and standards

EN standard, preliminary, prEN15251 under the EPBD Energy Performance in Buildings Directive. 50 pp., 417 kB.

UK, Office of the Deputy Prime Minister, 2000. Building Regulations, Explanatory Booklet. 65 pp., 1.2 MB.

UK, Office of the Deputy Prime Minister, 2000. Building Regulations, F - Ventilation. 24 pp., 5.5 MB.

UK, Office of the Deputy Prime Minister, 2000. Building Regulations, J – Combustion appliances and fuel storage systems. 78 pp., 620 kB.

World Bank documents on indoor air quality

Dasgupta S, Huq M, Khaliquzzaman M, Pandey K, Wheeler D., 2004. Who Suffers from Indoor Air Pollution? Evidence from Bangladesh. World Bank Policy Research Working Paper 3428. 24 pp., 708 kB. http://www.cleanairnet.org/baq2004/1527/articles-59204_dasgupta.pdf

Dasgupta, Susmita, Huq, Mainul, Khaliquzzaman, M., Pandey, Kiran and Wheeler, David, "Indoor Air Quality for Poor Families: New Evidence from Bangladesh" (September 2004). World Bank Policy Research Working Paper No. 3393. 48 pp., 702 kB. <http://papers.ssrn.com/sol3/Delivery.cfm/38254.pdf?abstractid=625270&mirid=3>

WHO documents, developing country settings

WHO, 1995. Jonathan E. Sinton, Kirk R. Smith, Hansheng Hu, and Junzhuo Liu, *Indoor Air Pollution Database for China*, WHO/EHG/95.8, Human Exposure Assessment Series, Office of Global and Integrated Environmental Health, Geneva, 120 pp, 3.1 MB (scanned). http://whqlibdoc.who.int/hq/1995/WHO_EHG_95.8.pdf

WHO, 2002. Health effects of indoor air pollution in developing countries. 41 pp., 266 kB (id 69515) http://whqlibdoc.who.int/hq/2002/WHO_SDE_OEH_02.05.pdf

WHO, 2003. Sumeet Saksena, Lisa Thompson, Kirk R. Smith, *Indoor Air Pollution and Exposure Database*. School of Public Health, University of California, Berkeley, WHO site http://www.who.int/indoorair/health_impacts/databases_iap/en/index.html
Documentation file <http://ehs.sph.berkeley.edu/heh/hem/documents/iapi.pdf> 13 pp., 540 kB).
Database site <http://ehs.sph.berkeley.edu/hem/page.asp?id=33>

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Annex 2

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