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The Indoor Air Quality Programme of the WHO Regional Office for Europe

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Abstract

The indoor air quality (IAQ) programme of the World Health Organization Regional Office for Europe was initiated in the mid-seventies when it was realized that over 70% of the general population spends its time indoors in homes, office buildings, schools, hospitals, transportation means, etc. The first meeting of experts on health aspects related to IAQ was convened in 1979, being probably the first international meeting on IAQ with participation from eastern and western Europe as well as from North America. Seven meetings followed between 1982 and 1990, at which the "sick building" syndrome, IAQ research, formaldehyde and radon, organic pollutants, biological contaminants, combustion products, and mineral fibres were discussed. A ninth meeting on sources, control and mitigation is planned for 1991.

KEY WORDS:
Indoor air quality (IAQ), Health effects, "Sick building" syndrome, IAQ research, Formaldehyde, Radon, Organic pollutants, Biological contaminants, Combustion products, WHO/EURO.

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Introduction

The indoor air environment, as a subject, can be conveniently divided into two components:

a) indoor climate, which deals with temperature, humidity and ventilation (including air conditioning), and determines human comfort; and
b) indoor air quality (IAQ), which includes physical (e.g., radon), chemical and biological pollutants, and relates to human health.

This paper describes the development by the World Health Organization Regional Office for Europe (WHO/EURO) in Copenhagen of its programme on IAQ.

WHO/EURO consolidated in the late sixties its traditional environmental sanitation activities, undertaken for many years, and converted them into a new and elaborate long-term programme on environmental health. This programme included a component on atmospheric air pollution and control. By 1974 it was recognized that IAQ was another subject with a serious impact on human health yet untouched by WHO. Prior to that time there were very few published reports and research papers available on IAQ, no international forum addressed this subject, and no national health authority paid any attention to it. Yet it had become obvious that, at least in the highly developed and industrialized countries such as those in Europe, the majority of the general population was spending most of its time indoors ("indoors" in the broadest meaning of the word), within enclosed spaces, such as in homes, in educational and cultural structures (i.e., schools, theatres, museums), general working places (i.e., offices and professional buildings), medical, health and sports facilities (i.e., hospitals, clinics, gyms, closed swimming pools), and most transportation means (i.e., cars, buses, aeroplanes, trains, ships, and respective land, air and sea terminals). When dealing with IAQ from a public health viewpoint (in contrast to the industrial hygiene situation), one is also concerned with people working in enclosed spaces, where the air quality is not directly affected by the nature of their work.

IAQ activities were proposed for inclusion in WHO/EURO's programme of work in 1974 and the first planning meeting took place in 1978.

Health Aspects related to IAQ

The planning meeting was followed by the first WHO/EURO working group of experts on health aspects related to indoor air quality, convened in the Netherlands in April 1979. The experts recognized that two major developments had made an assessment of the health aspects of IAQ a matter of urgency. The first was the rapid increase in the price of energy for heating buildings and the consequent need to reduce energy use, which had led to measures to reduce the rate of natural and forced ventilation in buildings.

The second development of great concern was the introduction of building materials, furnishings and consumer products which released harmful contaminants to the indoor atmosphere. The Group discussed the effects of soil surfaces and building materials which emit radioactive radon gas, asbestos-containing materials which can release asbestos fibres, and insulation materials and processed wood which release formaldehyde. The Group also considered the wide range of consumer products such as personal hygiene products, cleaning agents, biocides, air fresheners, solvents and adhesives, as well as hobby and home craft materials, all of which can discharge a large number of harmful contaminants in appreciable quantities and high concentrations to the indoor environment.

The Group reviewed certain aspects of IAQ which have always been of concern but which have an even more serious impact with drastically reduced ventilation, such as body odours and those produced by cooking and tobacco smoking. The health consequences of increased respirable suspended particulate matter (RSP) and CO from tobacco smoke and of increased NO_2, CO and aldehydes from the use of unvented combustion of gas for cooking and water heating were also discussed. CO_2 and water vapour produced by man and his activities in a low ventilation indoor environment can have direct and indirect effects on the health of occupants. Lowered ventilation rates affect the concentration of viable particles indoors and thus the transmission of infectious disease, especially in cases of high density occupancy such as in schools and other public buildings. A final report, including conclusions and recommendations, was published the same year (WHO, 1979).

Exposure and Health Effects

The second working group was convened in the Federal Republic of Germany in 1982 to review recent work on exposure to indoor air pollutants and to assess adverse health effects. The Group paid particular attention to a problem of great importance called, for no better term, the "sick building" syndrome. Some people in such buildings feel some kind of sickness, a phenomenon which has not yet been well enough understood. The meeting also dealt with the assessment of health effects on the basis of animal toxicological studies, appropriate occupational studies (which serve as a basis for comparison, but refer to much higher concentrations of pollutants), controlled exposure studies in man, designs of sequential studies and epidemiological studies. The methodology and priorities of future studies were also discussed.

The Group assessed the adequacy of current knowledge concerning the nature and strength of the sources of indoor air pollution and their distribution. It considered the status of available measuring equipment and the adequacy of current knowledge regarding population exposure. It also reviewed the adverse health effects that have been reported in conjunction with indoor air pollutants and the current level of knowledge concerning the exposure-response relationships for each of the pollutant categories of interest.

The state of knowledge on population exposure to a number of pollutants was considered. The pollutants were environmental tobacco smoke (ETS), NO_2, CO, radon and daughters, formaldehyde, SO_2, CO_2, O_3, asbestos, non-asbestos mineral fibres, organic substances and allergens. For each of the pollutants the Group estimated the fraction of the population exposed to low and to excessive concentrations. It also rated the adequacy of knowledge about sources, their characteristics and distribution, the adequacy of available measuring equipment and of actual monitoring data. The health effects associated with each of the pollutants were considered, as was the adequacy of knowledge concerning the exposure-response relationships and the population exposed. Based on current though inadequate levels of knowledge, an attempt was made to identify the concentration level below which exposures would not be of substantial public health concern, as well as the concentration level above which serious public health concern would exist. This assessment was made for most, but not all, of the pollutants. Much of the information accumulated during this exercise was compiled into three tables, becoming a major achievement of the working group, and a basis for repeated reviews and updating in future meetings (see Appendix 2).

Attention was given also to methods and priorities for further research on assessing exposure. An evaluation was made of the rapid increase in a number of countries of the "sick building" syndrome in which occupants of large non-industrial buildings complain of a set of symptoms, the underlying cause of which is usually difficult to establish. Consideration was given to the factors that would have to be taken into account if criteria, guidelines and standards for outdoor air, or for the occupational environment, were to be applied to the non-occupational indoor environment. Finally, ways of assessing the health effects of indoor air pollutants were considered and priorities for future work on the assessment of exposure-response relationships and on the impact of indoor air pollution on health were identified. A final report, including conclusions and recommendations, was published in 1983 (WHO, 1983).

Indoor Air Quality Research

The third working group was organized in Stockholm in conjunction with and immediately following the Third International Conference on Indoor Air Quality and Climate, held there from 20 to 24 August 1984. The purpose of this third group was to review recent work on IAQ and to examine new developments in research methodology. A full report, including conclusions and recommendations, was published in 1985 (WHO, 1985).

The "Sick Building" Syndrome

Although considerable progress has been made in recent years in this investigation, the methodology is not adequate to clarify the mechanisms of the reactions that occur under such conditions. There is a growing feeling that the number of instances of "sick building" syndrome is much greater than was originally thought. A Working Group discussed methodological approaches to be chosen for investigating the problem. It examined the extent of the problem, the population groups that would be at risk, how health outcomes should be measured, how practical investigations should be conducted and how studies should be designed, and finally, proposed some remedial measures (WHO, 1985).

Radon and Formaldehyde

The fourth working group met in 1985 in Yugoslavia to assess the risk to health and recommend air quality guidelines for radon and formaldehyde, two pollutants that may adversely affect IAQ. They have already become well-known issues, and a lot of questions have been raised at different governmental levels. The case of formaldehyde from home insulation in Canada is well known, and radon has been identified as a pollutant prevailing in more situations than originally expected.

Aspects discussed with respect to radon were its sources (soil, building material, tap water, and cooking gas), observed levels, routes of exposure (drinking-water, food and air), health effects, evaluation of human health hazards, strategies for identification and control and characterization of sites for future homes.

With regard to formaldehyde, the experts dealt, again, with sources, occurrence in air, roots of exposure (drinking-water, food and air), occupational exposure, smoking, skin absorption and blood exchange. Also discussed were the kinetics and metabolism (including absorption, distribution, biotransformation and elimination), health effects, organoleptic properties, and evaluation of human health hazards.

In the case of radon, levels are mostly determined by site characteristics and secondarily by characteristics of the structure. In the case of formaldehyde, the level is determined by the building characteristics and the presence of sources of formaldehyde in the structure or its furnishings, or by occupant activities. For both pollutants the rate of air exchange with the outdoors is important and, for both, the control or avoidance of the sources is the most effective way of reducing exposure to them. The Group devoted considerable effort also to identifying available remedies for the reduction of exposure to both these pollutants. The final report includes conclusions and recommendations (WHO, 1986). It was also included as a shorter version in a volume on air quality guidelines (see last section).

iety of aerosols and odours with biological activity which in turn produces adverse health impacts in occupants, a subject dealt with in the previous chapter.)

The Group considered the state of knowledge concerning the adverse health effects of indoor air contaminants from vented and unvented combustion occurring indoors. These considerations were limited to the range and distribution of the concentrations of different indoor air pollutants produced by indoor combustion. The major pollutants considered were CO, NO_2, SO_2, CO_2, water vapour and RSP. A number of other combustion products produced in lower concentrations were also considered, such as benzene, benzo[a]pyrene, formaldehyde and dimethylnitrosamine. Water vapour occupies a special role as a combustion product in that the optimum relative humidity in the indoor environment is between 30% and 60%. Relative humidities below 20% will aggravate irritation of mucous membranes of the eyes, nose and throat, and relative humidities above 70% will promote microbiological growth which, in turn, is likely to produce biological air contaminants in the indoor space. Vented combustion appliances will normally introduce only small amounts of combustion products into the indoor space. Under certain conditions, including high wind velocities and mechanical malfunctions, it is possible for even a vented heating appliance to discharge substantial amounts of combustion products into the indoor space it serves. The Group found that the level of protection from such events by current standards, codes and practices required review and, where necessary, improvement.

Exposure to combustion products indoors in the absence of indoor sources is generally lower than outdoors. Whenever unvented combustion sources occur, there is a strong likelihood that the total human exposure to combustion products will be dominated by indoor exposures. The Group's conclusions and recommendations are given in Appendix 3.

Inorganic Fibres

The eighth working group, organized in Kingston, ON, in conjunction with the 5th International Conference on Indoor Air Quality and Climate in Toronto, Canada, concentrated on particulate matter from asbestos, man-made mineral fibres (MMMF), rockwool and the like, which are of interest in common, non-industrial environments (WHO, 1991). Mean respirable fibre concentrations of MMMF in residences and public buildings have been reported at 40-200 F/m^3 of air. Outdoor air has been reported to contain MMMF at concentrations of 400-1700 F/m^3 in urban environments, and 40 F/m^3 in rural air. Asbestos fibres longer than 5 μm can be found in the indoor air in buildings at mean concentrations in the range of 70-200 F/m^3; if all asbestos fibres of any length are counted, then mean concentrations of $(0.5\text{-}1.0) \times 10^6$ F/m^3 can be obtained.

The Group considered the state of knowledge concerning the associated adverse health effects. Potential effects are interstitial pulmonary fibrosis (IPF), lung cancer and mesothelioma. The Group reviewed the recent toxicological data obtained in animal testing, and also the status of the major epidemiological studies involving cohorts of industrial workers. New toxicological studies using improved methodologies are showing animal carcinogenesis for ceramic fibres and for other MMMF when the length is more than 5 μm and the fibre diameter is 1 μm or less.

Epidemiological studies have been limited in number, and are based on cohorts of workers in different mineral-fibre industries. The exposure/effect relationships are difficult to establish because the exposures are very poorly documented. With the best estimates of exposure it appears that different industrial processes produce different slopes for the exposure/effect relationship for a given mineral fibre. In the asbestos-cement industry, the risk for a given exposure is considerably lower than the same exposure in the asbestos-textile industry. The risk of mesothelioma seems to be much lower for chrysotile and anthophyllite than for crocidolite and amosite, and even for crocidolite the risk appears to depend on the percentage of fibres with a diameter of 1.0 μm or less.

For an asbestos fibre concentration indoors of 100 F/m^3, the lifetime excess risk of cancer is estimated to be in the order of 1 in 10^5 to 1 in 10^7. The Group considered different methods of prevention of exposure in indoor environments, ranging from recommending against the use of carcinogenic mineral fibres in buildings to implementation of detailed administrative procedures to assure effective containment. Such approaches should begin with a documented inventory, inspection and maintenance schedules aimed at preventing releases of fibres, and education and training of responsible personnel in the safeguards required. It is sometimes advantageous to enclose the asbestos-containing material, or to encapsulate it with a bonding agent or a sealer. The most extreme form of asbestos control is to remove it completely from a building using suitably safe methods, and to dispose of it in an approved manner.

Future Activities

Almost a routine, the opinion of the participants of most past working groups was polled as to the need for future meetings to resolve important still outstanding IAQ issues. While most proposed subjects have already been discussed, two more meetings are still in the planning stage. One is supposed to concentrate on sources, control, mitigation and legislation related to indoor air pollution, discussing both the elimination, if possible, of pollution sources and the means and measures for the reduction and control of pollutants, the sources of which cannot be eliminated.

It is intended to update the material presented in past reports and conclude the work on IAQ by compiling a monograph, which will put the discussions of the various working groups into proper order and perspective. In this connection, use will also be made of the results from some other past WHO/EURO meetings on legionella and man-made mineral fibres. For this purpose, a second meeting may be convened to serve for the review and editorial finalization of the draft monograph.

WHO Air Quality Guidelines

In 1984, WHO/EURO embarked on a project to study and establish air quality guidelines for Europe for close to 30 organic and inorganic air pollutants. The basic principles that guided the project were: the guidelines would describe the latest state of scientific knowledge; the information provided would be condensed, describing only the essential factors leading to the final conclusions; the description of scientific findings would be understandable to a broad and rather heterogeneous group of readers; the rationale for the guideline recommendations would also contain a description of uncertainties in the evaluation process due to missing, inadequate or equivocal data; a basic common structure for the description of pollutants and the rationale for guidelines would be enforced; and the draft guidelines would undergo several intensive reviews.

The guidelines consider various toxic (carcinogenic and noncarcinogenic) substances, and for a few substances also their ecological effects. The guidelines do not differentiate between indoor and outdoor exposure (with the exception of exposure to mercury) because, although the sites influence the type and concentration of chemicals, they do not directly affect the basic exposure-effect relationship. The guidelines apply to the exposure of the general population, and do not relate to occupational exposures, even though the latter have been considered in the assessment process. For those compounds that were not reported to induce carcinogenic effects and on which data regarding such effects were lacking to insufficient, a threshold assumption was made and guideline values were proposed. For carcinogenic substances, the guidelines provide an estimate of lifetime cancer risk arising from exposure to those substances.

The project was completed with the publication of the guidelines at the end of 1987 (WHO, 1987). These guidelines will be reviewed and revised, as necessary, and new pollutants will be considered for addition. The enlarged and revised publication is expected for reissue in the mid 1990s.

Acknowledgements

This paper was prepared on the basis of the reports on the respective WHO IAQ working groups. As such, it draws on the texts drafted for WHO/EURO by Dr J.A.J. Stolwijk, USA, in his capacity as working group rapporteur (with the help of participating colleagues, too many to be named here), and edited by WHO/EURO staff before publication. Thanks and appreciation are due to all of them for years of effort and faithful support.

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Appendix 1

International Participation in the WHO IAQ Working Groups

Traditionally, WHO working groups include experts from several countries who usually represent a variety of scientific disciplines, professional experience and institutional backgrounds (i.e., academia, government, industry).

A list of the working groups, discussion subject, location, dates and report reference is given in Table 1; a list of the 20 countries and 3 international governmental organizations that provided participants to one or more meetings is given in Table 2, and a detailed analysis of the body of participants is presented in Table 3.

Table 1 List of WHO IAQ working groups and respective reports (1979-90)

WG No.	Title of working group report	Location of meeting	Date of meeting	Publication reference[1]
1	Health aspects related to IAQ	Bilthoven, Netherlands	03-06 Apr 1979	ERS 21 (1979)
2	Indoor air pollutants: exposure and health effects	Nördlingen, Federal Republic of Germany	08-11 Jun 1982	ERS 78 (1983)
3	IAQ research	Stockholm, Sweden	27-31 Aug 1984	ERS 103 (1986)
4	IAQ: radon and formaldehyde	Dubrovnik, Yugoslavia	26-30 Aug 1985	EHS 13 (1986)
5	IAQ: organic pollutants	Berlin (West)	23-27 Aug 1987	ERS 111 (1989)
6	IAQ: biological contaminants	Rautavaara, Finland	29 Aug -02 Sep 1988	ES 31 (1990)
7	IAQ: combustion products	Charleston, SC, USA	31 Oct -04 Nov 1989	Summary Report (1990)
8	IAQ: inorganic fibres and other particulate matter	Kingston, ON, Canada	24-27 Jul 1990	Summary Report (1991)

[1] See also list of references.

Table 2 Countries and organizations providing participants to WHO IAQ working groups (1979-90)

Northern Europe	Western Europe	Eastern Europe	North America	International governmental organizations
Denmark[1] Finland Norway Sweden[1]	Belgium France F.R. of Germany and Berlin (West)[1] Italy Netherlands[1] Switzerland United Kingdom[1]	Bulgaria Czechoslovakia German Democratic Republic Hungary[1] Poland USSR Yugoslavia[1]	Canada[1] USA[1]	Commission of the European Communities[1] International Agency for Research on Cancer WHO[1, 2]
4	7	7	2	3

[1] Countries and organizations that have provided participants for four working groups or more.
[2] WHO/EURO has provided the secretariat for the working groups.

Table 3 Composition of expert participation in the WHO IAQ working groups

Total expert participation in all eight meetings			152
Total number of individual experts involved			86
Expert participation in[1]:			
All 8 meetings	7 meetings		4-5 meetings
AJ Stolwijk (USA)[2] MJ Suess (WHO)[2]	MD Lebowitz (USA) B Seifert (Berlin (West))		JSM Boleij (Netherlands) I Farkas (Hungary) M Fugas (Yugoslavia) H Knöppel (CEC) T Lindvall (Sweden) DJ Moschandreas (USA)
2-3 meetings			
15 individual experts from:			
Belgium	Denmark	Norway	United Kingdom
Canada	Finland	Sweden	United States
Czechoslovakia	Netherlands		

[1] The ten named experts served as the essential nucleus of the WHO IAQ working groups and the scientific continuity, which is important when a series of activities on the same subject is being undertaken. Also, this has helped the easy and smooth absorption into the work of 65 additional experts, whose specialty was required for the discussion of a certain topic at one specific meeting.
[2] Respectively, permanent Rapporteur of the IAQ working groups, and convener and Scientific Secretary on behalf of WHO/EURO.

Appendix 2

Assessment of Levels of Knowledge concerning IAQ

At the second working group in 1981, the experts attempted for the first time to consolidate levels of knowledge concerning IAQ in the form of three tables (WHO, 1983). The tables were not supposed to be used without consulting the accompanying text in that report. However, four additional working groups have since reviewed and updated the tables, making them a distinct entity and annex of their respective report.

During its meeting at Charleston, SC, USA, in November 1989, the seventh WHO working group on IAQ reviewed the assessments made by previous working groups. Their revised assessments of the levels of knowledge are presented in three tables: indoor population exposure factors in Table 1, exposure-response relationships in Table 2, and consensus of public health concern in Table 3.

Table 1 Current levels of knowledge concerning indoor population exposure factors

Pollutant	People with low exposure	People with high exposure	Sources	Distribution	Instrumentation	Indoor and personal monitoring (including biological)
ETS	most	some	+	+)	+	+)
RSP	most	some	+)	+)	+)	+)
NO_2	most	few	+	+	+	+
CO	most	few	+	+	+	+
Radon and daughters	most	few*	+	+	+	+
Formaldehyde	most	few	+	+	+	+
SO_2	most	few	+	+	+	+
CO_2	most	few	+	+	+	+
O_3	most	few	+	+	+	+
Asbestos	most	few	+	+	+)	+
Mineral fibres	most	few	+)	+)	+	+)
VOC	most	some	+	+	+	+
Other organics	most	few	0	0	+	+)
Aero-allergens	some	most	+	+)	0	0
Infectious agents	most	few	+	+)	+)	0

* = varies from area to area
\+ = adequate
+) = less than adequate
0 = inadequate

Table 2 Current levels of knowledge concerning exposure-response relationships

Pollutant	People at low exposure	People at high exposure	People exposed	Adverse effects at levels of concern	Exposure response relationship	Means of control
NO_2	most	few	+	airway effects systemic	+ 0	technical regulatory educational
CO	most	few	+	systemic	+	technical regulatory educational
SO_2	most	few	+	airway effects	+	technical regulatory educational
CO_2	most	few	+	systemic	+	technical
O_3	most	few	+	mucosal irrit. airway effects odour	+ + +	technical (indoors) regulatory
Radon and daughters	most	few*	+	cancer	+	technical regulatory educational
ETS	most	some	+	odour irritation airway effects carcinogenic systemic	+ + + + +	technical regulatory educational social
RSP	most	some	+	mucosal irrit. airway effects systemic	+ + +	technical regulatory educational
Asbestos	most	few	0	carcinogenic respiratory disorders	+ +)	technical regulatory educational
Mineral fibres	most	few	0	irritation airway effects carcinogenic	+ + +)	technical regulatory educational
VOC	most	some	+	odour sensory irrit. mucosal irrit. systemic airway effects cancer	+) +) +) +)[a] +) +[a]	technical regulatory educational social
Formaldehyde	most	few	+	odour mucosal irrit. airway effects cancer systemic	+ + + +[a] +[a]	technical regulatory educational
Other organics	most	few	0	odours mucosal irrit. airway effects cancer systemic	+ + + +[a] +[a]	technical regulatory
Aero-allergens	some	most	+)	airway effects mucosal effects	+) +)	technical educational medical[b]
Infectious agents	most	few	0	respiratory other organs systemic	+) 0 0	technical medical[b] educational regulatory

* = varies with region
[a] = for some it is inadequate
[b] = medical measures are preventive
\+ = adequate
+) = less than adequate
0 = inadequate

Table 3 Consensus of concern regarding selected indoor air pollutants at 1990 levels of knowledge

Selected pollutant[a]	Typical range of concentration (10-90%)[b] mg/m³	Concentration of limited or no concern[b] mg/m³	Concentration of concern[b] mg/m³	Remarks (average exp. period) Concentration mg/m³	
RSP (incl. tobacco)	0.01-0.15	<0.1	>0.15	0.15 (Japanese Standard)	(24h)
$NO_2$2	0.02-0.4	<0.15	>0.40	AQG[e]0.4	(1h)
CO	1-11	<2% COHb	>3% COHb	AQG 10	(8h)
Radon and daughters	3-75 Bq/m³EER	<10 >30 carcinogen	carcinogen	Swedish standard: new house 70 Bq/m³ AQG 100 Bq/m³	EER(1y)
SO_2	0.01-0.08	<0.25	>0.35	AQG 0.35	(1h)
CO_2	300-2000	<2000	>7000	1800 is widely used	(1h)
O_3	0.01-0.1	<0.1	>0.12	AQG 0.15 -0.2	(1h)
Asbestos	100-10000F*/m³	carcinogen	carcinogen		(24h)
Mineral fibres	100-10000F*/m³	-[c]	-[c]	Skin irritat.	(24h)
Organics					
Formaldehyde	0.02-0.06	<0.06	>0.12	AQG <0.1	(30min)
Benzene	0.002-0.02	carcinogen	carcinogen		
Dichloro-methane	0.005-<0.01	-[c]	-[c]	AQG 3.0	(24h)
Trichloro-ethylene	0.001-0.02	-[c]	-[c]	AQG 1.0	(24h)
Tetrachloro-ethylene	0.002-0.02	-[c]	-[c]	AQG 5.0	(24h)
p-Dichloro-benzene	0.001-0.02	-[c]	-[c]	TLV[d] 450	(8h)
Toluene	0.03-0.15	-[c]	-[c]	AQG 7.5	(24h)
m,p-Xylene	0.01-0.04	-[c]	-[c]	TLV 435	(8h)
n-Nonane	0.002-0.02	-[c]	-[c]	TLV 1050	(8h)
n-Decane	0.003-0.05	-[c]	-[c]		
Limonene	0.002-0.07	-[c]	-[c]	TLV 560	(8h)

* Fibre count with optimal microscope.
[a] All gases were considered on their own without other contaminants.
[b] Short-term exposure averages.
[c] No meaningful number can be given because of insufficient knowledge.
[d] TLV (threshold limit values) established by the American Conference of Governmental Industrial Hygienists (1987/1988). These values are for occupational exposures and might be considered the extreme upper limit for non-industrial populations for very short-term exposures.
[e] AQG values are from *Air Quality Guidelines for Europe.*

Appendix 3

Conclusions and Recommendations of the WHO IAQ Working Groups

Each of the working groups ended their deliberations with a set of specific conclusions and recommendations, directed to WHO, national authorities or the scientific community concerned. Some of the recommendations have been followed up and eventually implemented, while others are still awaiting action.

This appendix presents the conclusions and recommendations of three most recent working groups (sixth-eighth) for easy reference and review.

Sixth WHO Working Group on IAQ: Biological Contaminants

Conclusions

1. A substantial portion of disease and absenteeism from work or school is associated with infections and allergic episodes caused by exposure to indoor air. Since this morbidity is often due to biological contaminants generated in buildings or to the crowding of occupants, it can be reduced significantly.
2. The increase in costs associated with improving the inadequate maintenance of ventilation systems results in greater comparative benefits in

terms of better health for the occupants and reduced absenteeism.

3. Biological aerosols in buildings, including homes, are caused predominantly by persistent moisture and inadequate ventilation in spaces and building elements: proper design and construction are essential to prevent these conditions.
4. The levels of biological contaminants in indoor air vary enormously in time and space, so data bases on the distribution of the levels of contaminants in conjunction with occupants' response must be large enough to provide useful information for risk management.
5. Methods for collecting environmental samples of biological contaminants have generally not been standardized. Sampling methods for pollen, specific bacteria and viruses are close to standardization, but sampling methods for fungi, mycotoxins and other biological materials are not.
6. Laboratory procedures for the analysis of some fungi, mycotoxins, viruses, bacteria and other biologically derived materials of potential interest in indoor environments have not yet been standardized.
7. The use of biocides in the cleaning and maintenance of heating, ventilating and cooling systems or surfaces in buildings presents risks, both directly and through the promotion of resistant microbes.

Recommendations

1. Buildings and their heating, ventilating and cooling systems should not produce biological contaminants that are then introduced into the ventilation air. If the use of biocides is unavoidable, they should be prevented from entering space that can be occupied.
2. Standards and building codes should ensure the effective maintenance of ventilation systems by specifying adequate access and regular inspection and maintenance schedules.
3. In a building in which the occupants cannot effectively control the quality of ventilation air themselves, an individual who is responsible for this task should be made known to them.
4. To reduce allergic diseases in the community, total exposure to allergens should be minimized by controlling allergens and their sources in buildings.
5. For the risk assessment of allergic diseases, exposure-response curves should be established by measuring antigens in the air and specific IgE antibodies in the population.
6. Statistically designed population studies should be carried out using commonly accepted methods to obtain the concentration distributions of biological contaminants in specific geographic locations.
7. Sampling and analysis methods for aero-allergens and biological irritants should be standardized, and the effects of time, temperature and moisture should be determined.
8. The production of biological aerosols in buildings should be prevented by introducing appropriate prescriptions for design and construction practices into building codes.
9. The maintenance personnel of public and office buildings should be given adequate training in the routine inspection and maintenance of the buildings' systems.
10. Biological irritants and infectious agents cause nonspecific aggravation of respiratory and skin diseases, and they should be minimized by controlling their levels and sources in buildings.

Seventh WHO Working Group on IAQ: Combustion Products

Conclusions

1. *Indoor sources*

Indoors, unvented kerosene space heaters are the major source of SO_2, and an important source of NO_2, CO, RSP, and acids in the vapour and particulate phase. Unvented gas space heaters are the major source of sustained (>1 hour) high levels of NO_2, and an important source of CO. Gas cooking ranges and unvented domestic hot water heaters produce high peak concentrations of NO_2. Wood burning stoves and fireplaces contribute RSP and a wide range of organic compounds. ETS is the major source of RSP and an important source of a wide range of both vapour and particulate phase air contaminants, including VOC.

2. *Health effects*

Combustion products from indoor sources contribute significantly to the total human exposure to NO_2, CO and CO_2, and to increased acute and chronic disease. CO concentrations can reach values as high as in busy streets, and venting failures may lead to lethal concentrations. NO_2 concentrations may exceed health-based air quality guidelines for short periods of time. ETS ingredients have irritant and genotoxic properties and, with extensive exposure, there is evidence of an increased lung cancer risk in non-smokers. ETS and NO_2 are associated with a significant attributable risk for bronchial responsiveness and acute respiratory disease.

3. *Engineering controls*
In cold and temperate climates, where the fact of making the envelope of buildings more airtight has resulted in increased concentrations of air pollutants, the principal indoor combustion appliances are those related to space heaters. Generally they have flues that discharge all combustion products outdoors, but faulty design or installation, blockage or adverse weather conditions can lead to leakage indoors. Current building codes and standards governing design and installation of vented appliances are not adequate for controlling their leakage.

4. *Vehicles*
Occupants of vehicles can be exposed to elevated concentrations of combustion products if the vehicle has a faulty exhaust system or because of the exhaust gases from other vehicles entering through the cabin air intake.

Recommendations

1. Emission rates and concentrations of certain combustion products, such as particle-bound organic compounds and acids, should be determined, also through the development of appropriate instrumentation, to assist in the evaluation of distributions of population exposure.
2. Means for water vapour control indoors should be publicized and applied.
3. Existing and future new air quality guidelines should be used to guide decisions on source control in indoor vented and unvented combustion.
4. The general public should be informed about the dangers of fireplace spillage and downdrafting, especially at the end of the burn, and be provided with instructions on ways and means to avoid this hazard.
5. Buildings should be designed and operated so as to reduce the intake of vehicular combustion products form garages and streets, and from neighbouring buildings' exhaust vents.
6. The use of modes of transportation and traffic strategies which minimize emissions should be promoted to reduce exposures in vehicles.
7. Studies should be conducted to determine the carcinogenic potential of particle-bound formaldehyde.
8. Whenever the envelope of a building is made more airtight, careful consideration should be given to the active and controlled ventilation required.
9. Educational strategies should be used to communicate the risks associated with exposure to combustion products, as well as the options each person has to avoid such exposures.
10. The frequency and severity of leakage of combustion products from vented appliances should be documented with the objective of minimizing such occurrences through better equipment design, installation, maintenance and operation.
11. The use of unvented space heating and water heating appliances should be phased out as rapidly as possible.
12. Properly designed local exhaust with adequate provision of make-up air should be used to reduce peak exposures to NO_x associated with gas cooking.
13. Tobacco smoking should not be allowed in public buildings, public transportation and related buildings and areas, or office buildings, and it should be minimized in the residential environment through education campaigns and other appropriate means.

Eighth Working Group on IAQ: Inorganic Fibres and Other Particulate Matter

Conclusions

1. Airborne contamination with asbestos is widespread and as a consequence asbestos fibres can be found in most human lungs.
2. The carcinogenic potential of mineral fibres increases with fibre length, and with their increasing durability.
3. All commonly used forms of asbestos have produced excess incidence of asbestosis, lung cancer and mesothelioma.
4. Elevated rates of lung cancer have been reported in rock- or slag-wool production workers. Current airborne MMMF concentrations in indoor environments are considered to represent an insignificant risk.
5. There have been special situations where envir-

onmental exposure to erionite and crocidolite have caused increased rates of mesothelioma.

6. The possibility of lung fibrosis is of concern only to people who repeatedly disturb fibrous materials, thus creating high local concentrations of airborne fibres. These people may also be at increased risk for lung cancer and mesothelioma.
7. Exposed, loose or friable thermal and acoustic insulation materials are the major sources of indoor exposure to mineral fibres.
8. The main causes of mineral-fibre release are installation, removal and damage of mineral fibre-containing materials, and demolition of buildings.
9. The great majority of buildings have airborne asbestos concentrations which do not represent a significant excess risk.
10. Exposure to MMMF can cause skin and eye irritation.
11. Average indoor levels of MMMF range up to 300 F/m^3 in buildings containing these materials. Average indoor levels of respirable asbestos range from 100 to 1000 F/m^3 (fibre length >5 μm) in buildings containing asbestos products. When loose, friable asbestos and MMMF materials are abraded, much higher levels are generated.

Recommendations

1. Standard methods for measuring indoor inorganic fibres should be established so that they can be determined and reported in terms of fibre length and diameter, with speciation of fibre type. Indoor samples should be collected over a one-week period.
2. Prior to their use in building products, mineral fibres should be systematically investigated with respect to the exposure and health effects likely to result.
3. All construction and operating documents, including those listing an inventory of inorganic fibre-containing materials in the building should be kept by the building manager, and referred to in the event of maintenance and repair.
4. The use of carcinogenic mineral fibres (such as asbestos and erionite) in construction should be avoided wherever reasonably possible.
5. Exposure to airborne mineral fibres should be kept as low as possible. Particular attention should be given to the management of loose, soft, friable and accessible mineral fibre-containing products.
6. Mineral fibres should be coated or covered with other materials to prevent fibre release and to minimize exposure of the public by inhalation and skin contact. In the event of contamination, mineral-fibre dust should be removed from the affected area before normal activity is resumed.
7. Precautions should be taken to reduce airborne-fibre exposure of people who disturb mineral fibre-containing materials during maintenance and repair.

Erratum

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