THE INDOOR AIR QUALITY PROGRAMME OF THE WHO REGIONAL OFFICE FOR EUROPE

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The indoor air-quality (IAQ) programme of WHO/EURO was initiated in the mid-seventies when realizing that over 70% of the general population spends its time indoors, such as in homes, office buildings, schools, hospitals, transportation means, etc. The first meeting of experts on health aspects related to IAQ was convened in 1979, probably being the first international meeting on IAQ with participation from Eastern and Western Europe and North America. Seven more meetings followed between 1982 and 1990, discussing the "sick building" syndrome, IAQ research, formaldehyde and radon, organic pollutants, biological contaminants, combustion products, and mineral fibres. A ninth meeting on sources, control and mitigation is planned for 1991.

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 it 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 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 into 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. This was probably the first international meeting on IAQ, with the participation of scientists from various European countries - both East and West, and North America (see Annex 1). The experts recognized that two major developments have made urgently necessary an assessment of the health aspects of IAQ. The first, rapid increases in the price of energy for heating buildings and the need to reduce energy use had led to measures to reduce the rate of natural and forced ventilation in buildings. To the extent that these efforts were successful, IAQ was bound to deteriorate further. In fact, designers and engineers faced with a maximum rate of air change requirement would tend to aim for even less than such a maximum, further aggravating the problem.

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, and hobby and home craft materials, all of which can discharge a large number of harmful contaminants in appreciable quantities and high concentration 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, inclcuding conclusions and recommendations, was published the same year (1). The results of that meeting have raised immediate interest in some countries. The first to respond, and soon, was Health and Welfare Canada - the Canadian national health authorities, which had consequently developed a national programme of research on the different aspects of IAQ. Health and Welfare Canada was also the first national health authority in the world to publish in April 1987 a set of national guidelines on IAQ entitled Exposure Guidelines for Residential Indoor Air Quality.

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. As more data had become available since the first meeting in 1979, this meeting reexamined the IAQ issues and went into more details. 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 about 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 about population exposure. The Group also reviewed the adverse health effects that have been reported in conjunction with indoor air pollutants and the current level of knowledge about 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 were the adequacy of knowledge about the exposure-response relationships and about 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 Annex 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 (2).

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 20-24 August 1984, with the purpose to review, recent work in IAQ and to examine new developments in research methodology. A full report, including conclusions and recommendations, was published in 1985 (3).

The Group began with a review of the field as it emerged from the international conference. Substantial progress was being made in the field of IAQ and especially in the description of its effects on the occupants of buildings. The interest in and the level of activity related to the formaldehyde issue have seen a moderate decline, with an increase of interest in radon, in the issue of "sick buildings", and in volatile organic compounds in the indoor environment. There was also an increased level of interest in, but little corresponding progress in the determination or estimation of the overall impact on public health of different indoor air pollutants.

The Group discussed the development of strategies and policies aimed at effectively reducing exposure to indoor air pollutants. It was concluded that in the indoor environment the reduction of exposure was the responsibility of the occupants, the owners or operators, architects and engineers, suppliers of materials and products and, ultimately, different forms of local and national government. Because of this divided responsibility, the design and implementation of effective control strategies offer special challenges that deserve attention.

The Group reviewed the needs that existed in the development of laboratory research. The characterization of emission rates of materials has a high priority, especially in the area of volatile organic compounds and radon. Inorganic contaminants require relatively less urgent development in the laboratory. The development and validation of biological monitoring methods deserve high priority, as do the development and use of interlaboratory comparisons, which are an important element in any design for quality assurance and quality control of measurements made in the field.

Much of the discussion for the remainder of the meeting was devoted to the current status of research methodology in the field and in the study of associated health effects. The nature of the problem makes it desirable to establish "population laboratories" consisting of a large number of buildings with their inhabitants, which should be representative of a much larger region, or of a whole country, in terms of building stock characteristics and the demographic characteristics of the population. Buildings and inhabitants in such a laboratory should be well enough described to allow the selection of subsets with very specific combinations of characteristics, which would permit the effective study of one or a very few risk factors, while minimizing interference by other factors. It was also agreed that field studies, whenever undertaken, should consider as many indoor air pollutants simultaneously as possible, and that health outcomes should be studies and recorded at the same time.

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 larger than was originally thought. In fact, quite large populations suffer from the complaints associated with the "sick building" syndrome. It was agreed that the application of industrial hygiene measurements or of more sophisticated analytical techniques did not usually increase understanding of the causes of the syndrome. A staged sequence of observation and analysis of a problem in a particular building is a more effective approach, starting with a competent evaluation of the architectural and engineering plans, inspection of the site and evaluation of the maintenance and operating procedures. If this does not suggest a solution, a simple but standardized questionnaire and simple measurements should be applied and the results evaluated before much more complex and sophisticated measurements are even considered.

The first "sick buildings" were recognized prior to 1960, and since then there have been increasing numbers of case reports in several countries. The symptoms reported, primarily in the Scandinavian countries and the United States, are of a broad spectrum but have many features in common, such as: eye, nose and throat irritation; sensation of dry mucous membranes and skin; erythema; mental fatigue; headaches; high frequency of airway infections and cough; hoarseness, wheezing, itching and unspecific hypersensitivity; and nausea and dizziness. The number of case reports describing similar symptoms is now so large that it is reasonable to assume that we are dealing with a true environmental health problem.

One category of so-called temporarily "sick buildings" comprises either newly constructed or newly remodelled buildings, where the symptoms decrease in time and mostly disappear after approximately half a year. It is possible that the decline in symptoms is due to evaporation of the volatile compounds in building materials, paints, etc. In the second category of permanently "sick buildings", the symptoms persist for years and are sometimes resistant even to extensive remedial action. Normally no obvious cause is evident in this category, even after extensive investigations of the composition of the air and performance of the ventilation system, and of the building structure itself. However, it appears that such buildings have certain features in common:

1. They almost always have a forced ventilation system, usually serving the whole building, or large sections of it, and relying on partial recirculation of the air. Some buildings have an inappropriately located air intake, while others use heat exchangers that transfer pollutants from the return air into the air supply.
2. The indoor surfaces are to a large extent covered with textiles, including wall-to-wall carpets, and other features of the interior design favour a large interior surface-to-volume ratio.
3. They are energy-efficient, are kept relatively warm, and have a homogeneous thermal environment.
4. They are characterized by airtight building envelopes (windows often cannot be opened).

Indoor air contains a complex pattern of sensory stimuli, but although patterns of pollution vary, patterns of response are almost identical. No single irritant, therefore, is likely to be responsible. Usually, the sensation of dry mucous membranes is not noticeable in the "sick building" syndrome. The onset is gradual and the duration long, compared with the psychogenic illness characterized by hyperventilation, headache, nausea and dizziness, by symptoms related to specific illness, by a sudden onset preceded by a triggering event such as a strange odour and by a duration of days or weeks, although repeated relapses may occur. The symptoms can be differentiated from ubiquitous syndromes found in control buildings; they are the more acute symptoms of discomfort, annoyance and irritation such as eye and throat irritation, odour, sneezing and stuffy or runny nose. Acute diseases such as colds, productive cough, asthma and fever are also widespread. Psychogenic symptoms may also be present in some cases, and this will require much more investigation.

Thermal factors often play a role, in which case it is recommended that an analysis of the thermal environment is carried out to ensure that temperatures and temperature gradients are not excessive, and that clothing, air humidity and air velocity are appropriate. The homogeneous thermal indoor environment and the homogeneous air quality produced by recirulation may increase the probability of locally generated pollutants spreading throughout the building and exposing all the occupants to them for a long period of time.

As regards airborne irritant pollutants, one should ensure that formaldehyde is not present in adverse concentrations. It should be noted that other irritants may cause symptoms almost identical to those produced by formaldehyde. Such irritants may originate from building and surface materials, furnishings, and human use of household or hobby products. At present very little is known about interactions among low-level irritants. It is possible that, in the case of some compounds at subthreshold concentrations, a summation or potentiation takes place, causing sensory reactions to the mixutre of pollutants. It is also possible that chemical reactions take place, converting less irritating compounds to more irritating ones. It is usually not possible to find suitable controls to establish the background prevalence of complaints in a comparable population.

The Group also discussed methodic approaches to be chosen for investigating the problem. It examined the extent of the problem, what population groups would be at risk, how should health outcomes be measured, how to conduct practical investigations and how to design studies, and finally, proposed some remedial measures (3).

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 wellknown issues, and a lot of questions have been raised at different governmental levels. The case of formaldehyde from home insulation in Canada is wellknown, 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, roots 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. Much of the natural background radiation to which the general population is exposed comes from the decay of radium-226 which produces radon gas and other products. Because radium is a trace element in most rock and soil, radon can be produced indoors by a wide variety of substances, from building materials such as concrete or brick to the soil under building foundations. Tap water taken from wells or underground springs may be an additional source. Tests indicate that indoor concentrations of radon and its decay products are often higher than those outdoors. The effects of exposure to radon and its decay products consist predominantly of an increased risk of lung cancer, especially for smokers.

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. Perhaps best known as an embalming fluid, formaldehyde is a common ingredient in foam insulation, furniture, carpets, curtains and other household items. Its commonest use is a component of resins used as bonding agents in plywood and chipboard. Formaldehyde is also a by-product of combustion, e.g., natural gas used in cooking and home heating. Formaldehyde can have effects on health ranging from acute nausea, eye irritation and respiratory impairment to more serious long-term effects. Formaldehyde levels have been measured at several energy-efficient research houses. Studies have shown that concentrations exceeded 0.14 mg/m^3 in a number of new residential buildings and mobile homes with fewer than 0.3 air changes per hour. Formaldehyde makes its presence known by acute and continuous odour and irritation, causing predominantly discomfort although a cancer risk in humans cannot be ruled out.

In the case of radon, levels are mostly determined by the site characteristics and secondarily by the 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 (4). It was also included as a shorter version in a volume on air quality guidelines (see last chapter).

ORGANIC POLLUTANTS

The fifth working group was organized in connection with, and immediately following, the fourth International Conference on Indoor Air Quality and Climate in Berlin (West), held 17-21 August 1987. The Group considered the state of knowledge of organic pollutants in indoor air, and assessed what is known about the adverse effects on health that could result from current levels of exposure. Organic indoor air pollution was a difficult, little known and little understood subject. The meeting examined the chemical characterization of indoor organic pollutants and their distribution, estimated the population exposure, characterized health effects, discussed sensory effects, and analyzed systemic toxic effects, genotoxicity and carcinogenecity. As a class of contaminants, organic compounds in indoor air are extremely diverse; in the last decade hundreds of such chemicals have been identified. Although most occur in extremely low concentrations, there is appropriate concern about the effect on human health. Some of the compounds are genotoxic and many exhibit toxic, irritant and/or odorant properties.

Committees on indoor pollutants have always mentioned volatile organic compounds (VOC) as an important category of indoor air pollutants. Most of these reviews listed sources of such pollutants and their possible effects on health, but refrained from a detailed assessment of the total effect on public health. The reluctance to make this type of assessment is understandable because of the very large number of chemical species reported, the lack of systematic studies of concentrations, and the distribution of these concentrations over the very large number of indoor areas in which people are exposed. In addition, knowledge of the adverse effects on health associated with such a large number of compounds to which people are exposed is also very limited.

To address the very legitimate questions produced by the increased concern, it was necessary to assemble the combined knowledge and insight of environmental chemists about the species of chemicals encountered, their concentrations and the distribution of such concentrations. Also, the knowledge and insight of toxicologists, experimental psychologists and environmental and occupational epidemiologists needed to be applied, together with those of the chemists, to construct an overall assessment of the public health impact. Since the public health impact consists of the products of the exposure distribution, the exposure-effect relationship and the number of people exposed, its assessment required the simultaneous and coordinated participation of all the relevant disciplines. It was necessary to consolidate the available data about concentration distributions from several larger studies in which the VOC in a number of residential spaces had been measured systematically. Although these studies had been carried out in different countries with somewhat different objectves and protocols, there was quite good agreement between the results. The environmental chemists were thus able to produce systematic and consolidated exposure data for consideration by the whole Group. At the same time, the toxicologists, physicians and environmental and occupational epidemiologists reviewed the health effects data for the organic compounds that had been measured in the larger scale surveys, and presented their findings to the Group. Psychologists, expert in sensory effects, similarly reviewed the existing knowledge about sensory effects of the same compounds and presented these findings to the Group. This simultaneous and coordinated review produced much clearer insights into the total impact, and at the same time led to the identification of areas where important and necessary information was most lacking.

The Group reviewed the findings from a number of systematic studies of personal exposures and of studies of residential indoor environments and integrated and consolidated the results, giving for each compound of significance the distribution of concentrations that had been reported. It was found that the concentrations and the species of VOC were very similar in the studies considered. In each case, these conceantrations were higher than the corresponding outdoor concentrations, indicating sifnificant sources and emissions of these compounds in the indoor environment.

The Group also considered the state of knowledge about the health effects associated with each of these compounds, and in each case evaluated these effects both at high concentrations and at the concentrations reported in indoor environments. These effects cover a wide variety of responses ranging from unwanted sensory effects such as odours and sensory irritation, through toxic effects that modify or interfere with the normal functions of organs or injure tissues, to genotoxic effects. These effects have different time characteristics, ranging from acute perception of odour with subsequent adaptation, through irritant action that grows more severe with prolonged exposure, to the delayed expression of the effects of genotoxicity with accumulation of exposure. Similarly, sensory effects have a concentration threshold below which the response does not occur, and this is also true for most of the toxicity that affects tissues and organ systems, but it is generally accepted that genotoxic effects have no such threshold. There are some compounds that are thought to have important effects for which there is inadequate knowledge of population exposure, and there is a set of compounds that has been measured for which one cannot indicate public health impact at present.

Some of the chemicals, such as benzene, have been shown to be carcinogenic in humans while others, such as trichloroethylene, carbon tetrachloride and chloroform, have been demonstrated to be carcinogenic in rodents and are suspected human carcinogens. At the concentrations found in indoor environments, their contribution to causation of cancer in the population is judged negligible to minimal. The Group identified a number of organic contaminants where exposure distributions are inadequately known but which cause potentially more concern. Such contaminations are exemplified by the complex mixture of ETS, soot from unvented combustion, and those associated with some forms of cooking. Similarly, biocides used in and about the home need to be evaluated with respect to the hazard associated with current usage.

Only limited exposure studies have been conducted for organic compounds in ETS, including nitrosamines, aromatic amines, acrolein and aldehydes; these are important and deserve further evaluation. Only limited studies have been conducted for polynuclear aromatic hydrocarbons and for benzo[a]pyrene specifically; they are from various combustion sources, out- and indoors (with an indoor/outdoor ratio sometimes close to 1.0). Other possibly important genotoxic compounds need source strength determinations, as well as exposure assessments, including other non-chlorinated alkenes and epoxy resins, and constituents of polyurethane resins. For the large majority of the compounds involved, the concentrations reported in the indoor environment are several orders of magnitude lower than the concentrations at which adverse health effects have been reported. Many organic compounds found in indoor air have been reported to have toxic effects, but most of these reports concern industrial occupational exposures at concentrations considerably higher than those reported in nonindustrial indoor environments. The Group considered many of the most ubiquitous organic compounds reported in indoor air, and concluded that the reported concentrations in indoor air surveyed were several orders of magnitude below the level at which systemic effects have been reported for each compound. The same was found to be true for irritation characterized by tissue damage. For sensory effects, this separation is much smaller and for some compounds it is absent.

Organic compounds in indoor air can roduce sensory effects such as perceptions of odour and irritation, which can severely affect human health and wellbeing. Some organic compounds have been shown to modify behaviour through their effect on the central nervous system at concentrations found in some industrial environments. In nonindustrial environments, however, concentrations are several orders of magnitude lower. Although considerable progress was noted in the evaluation of sensory effects of organic compounds in indoor air, this evaluation remains a difficult and complex problem. The effects are mostly acute, often transitory and usually reversible, but the total number of people involved can be quite large. As a result, the total public health importance and the effect of reduced wellbeing on quality of life and productivity is likely to be significant but as yet difficult to quantify.

The Group discussed methods that allow the simultaneous incorporation of exposure distribution data, carcinogenic unit risk estimates or other exposure-effect relationships, background incidence of the illness under consideration, and any workplace or indoor standards and guidedlines into an overall impact on the health of the population of current exposures to a specific organic compound. Such standardized approaches are necessary to develop priorities for research and for mitigating exposure.

In the final assessment of the health impact of a compound on a population base, it is necessary to consider the distributed exposure in connection with the adverse effects on health for that exposure. To this end, an approach has been developed to link the exposure distribution to the effect on health in a convenient way. One must bear in mind, however, that there are many uncertainties and sources of variance in the estimations, one of which is the distribution of exposures and another is the distribution of sensitivities among the population. For the Group's assessment, the assumption was made that the distribution of sensitivities is independent of the distribution of exposures at the prevailing levels.

The report of this meeting served as a basis for the deliberation in the

United States in 1986 of a national committee assigned the task of preparing an IAQ research programme for the US EPA. The Group's conclusions and recommendations are given in Annex 3.

BIOLOGICAL CONTAMINANTS

The sixth working group met in 1988 in Finland to consider the state of knowledge on suspended viable particles, aero-allergens and other biologically derived suspended material, to examine the nature and magnitude of their adverse effects on human health and wellbeing, and to evaluate the role of buildings, building systems and contents in producing and disseminating such pollutants. By doing so, the experts dealt again with a little known and little understood IAQ issue, and have broken new grounds with the discussion results (6), and their respective conclusions and recommendations (see Annex 3).

Viable particles suspended in air, and other biologically derived particles indoors, form a distinct class of contaminants. When they are present in indoor air, even in small quantities, they can have a powerful effect on occupants. This effect can be through infection of the occupant by a suspended infectious agent, in which case the organism multiplies in the new host and can produce illness. There can also be allergic or irritant effects characterized by reactions ranging from uncomfortable to disabling.

Some infectious diseases such as tuberculosis, legionnaires' disease or measles have been demonstrated to spread through airborne transmission of the infectaious agent; airborne transmission may play a contributory role in others. In many allergic conditions building occupants can develop a hypersensitivity to secretions or to fragments or other products derived from animals and plants. Viruses do not multiply in buildings, but may spread from human and a few animal sources. Buildings can contribute to the airborne spread of viral disease, either through overcrowding or by the spread of airborne viruses through the ventilation system. Lack of an adequate supply of outdoor air will also increase the likelihood of airborne transmission of infectious disease, through an increase in the concentration of suspended viruses and bacteria in droplet nuclei. Exposure to airborne biological contaminants contributes to morbidity in the population. There is a wide variety of biological agents and biologically derived materials in the indoor environment, and these are associated with a range of illnesses. In presenting these agents and their associated illnesses, it was important to rate their frequency and severity as well as the contribution to total incidence attributable to indoor exposure.

There are many diseases that have been associated with problems of IAQ. The following conditions may sometimes be associated with or caused by biologically derived aerosols, as well as having causes unrelated to the building environment: rhinitis, sinusitis, otitis, conjunctivitis, pneumonia, asthma, alveolitis, humidifier fever, bronchopulmonary aspergillosis, contact dermatitis, atopic eczema, contact urticaria, mycotoxicosis, allergy, and pseudo-allergic reactions. These conditions have been defined in the report on the basis of the medical literature.

Much attention has been devoted to pathogenic organisms that multiply in buildings and building systems, such as Legionella pneumophila which causes Legionnaires' disease (legionellosis) and non-pneumonic Legionnaires' disease (Pontiac fever). Factors in buildings such as crowding and recirculated ventialtion air can also promote the spread of airborne pathogens emitted by occupants suffering from tuberculosis, measles, varicella and other diseases. Assessment of the effect of biologically derived aerosols has to be made for the medical management of individual patients, or for populations in the case of an outbreak in an exposed population. The connection between exposure and outcome is often not easy to make. Since the overall process usually begins with a presenting clinical outcome either in an individual or in a population, the first discussion has concerned itself primarily with outcome assessment.

When examining the hazard associated with environmental exposure, a number of issues were reviewed, including infectious and allergic mechanisms, inhalation of mycotoxins and irritants desrived from bio-aerosols indoors. Environmental measurement and sampling were carefully reviewed. The discussion of sources and control of microbiological contaminants included reference to ventilation, moisture, temperature, building microbiology, biologically derived particles from animals, pollen and fungi, bacteria and viruses brought indoors, strategies for control, building design and construction materials, ventilation and filtration systems, humidity control and air conditioning, cleaning, maintenance and repair, behavioural factors, and social, economic and regulatory considerations. Ventilation system components such as cooling towers, air chillers and humidifiers and dehumidifiers can support the growth of fungi, bacteria and other microorganisms. These can also grow on the structural parts of a building if the relative humidity inside the building reaches 70% or more, while dust mites can multiply in furnishings. Such microorganisms or products excreted by them or by arthropods and larger animals can be introduced into the indoor air, causing a variety of allergic and irritant reactions in the occupants.

Excessive concentrations of water vapour and accompanying condensation, water leaks, failures of equipment drains or lack of cleaning and maintenance can all contribute to the introduction of viable or biologically derived contaminants into building ventilation air. A sizeable proportion of the population is, or is capable of being, sensitized over a lifetime to these forms of biological air contaminants. Other allergenic and toxic contaminants are animal dander, fragments of mites and other arthropods, and aerosols formed from animal faeces and urine. The combined effect of all the biological air contaminants in indoor air is thought to account for a substantial proportion of absenteeism in schools and workplaces and of the days where activity is restricted. In the general population, five to ten days of restricted activity per head per year is a normal average. By reducing biological air contaminants indoors, acute infections and allergic episodes could be significantly reduced. It was pointed out that, in any building, the cost of losses in productivity due to absenteeism and restricted activity far exceeds the total cost of operating and maintaining the heating, cooling and ventilation systems. Because of the usual division of responsibility and authority in organizations occupying buildings, the relationship between these costs is not often considered.

COMBUSTION PRODUCTS

The seventh working group was convened in Charleston, SC, USA, in 1989, to consider the state of knowledge of combustion products in indoor air, their distributions in the population, and to assess what is known about the adverse health effects which might be caused by the population exposures.

The Group considered the progress made in recent years in characterizing the distributions of the exposures to combustion products as these had been recorded in recent years. The findings in this area from a number of different systematic studies were reviewed and the findings were integrated into a general assessment of exposures in the industrialized world. The presence of unvented combustion sources in the residential environment was found to dominate the indoor concentrations and exposures to the combustion products they contributed. In indoor environments, in which tobacco is smoked, RSP is determined primarily by the level of smoking rather than by either other indoor sources, or by the contribution from RSP from the outdoor environment. Similarly, when unvented appliances are used for space heating, their contribution to indoor NO_2 concentrations dominates that of all other sources, including that from the infiltration of outdoor NO_2. Unvented space heaters are also major sources of water vapour which can bring about multiplication of fungi, bacteria and insects. (These biological agents can produce a variety of aerosols and odours with biological activity which in turn produces adverse health impacts in occupants, a subject dealt with the previous chapter.)

The Group considered the state of knowledge about 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 great likelihood that the total human exposure to combustion products will be dominated by indoor exposures. The Group's conclusions and recommendations are given in Annex 3.

INORGANIC FIBRES AND OTHER PARTICULATE MATTER

The eighth working group, which was organized the previous week in Kingston, ON, in conjunction with the present International Conference on Indoor Air Quality and Climate in Toronto, Canada, concentrated on particulate matter from asbestos, man-made mineral fibres, rockwool and the like.

The conclusions and recommendations will be published very soon in a Summary Report, while the full report will have first to be prepared and, eventually, published by WHO/EURO next year.*

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 still important 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 and mitigation of 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 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 princicples 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 unergo 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 (8).

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3. WHO/EURO (1985) Indoor air quality research. WHO Regional Office for Europe, Copenhagen. EURO Reports and Studies 103.

* As the paper was prepared before INDOOR AIR '90 took place, it was not possible to provide in this paper details on the outcome of the meeting's deliberations.

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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 efforts and faithful support.

Annex 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 background (i.e., academia, government, industry). So far, a total of 75 experts participated 131 times in the first seven working groups.

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 i presented in Table 3.

* WHO publications may be obtained directly from WHO Headquarters in Geneva, Switzerland, or from national sales agents. A sample order form and addresses are provided on the last two pages.

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	Health aspects related to IAQ	Bilthoven, The 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) Final report in preparation
8	IAQ: inorganic fibres and other particulate matter	Kingston, ON Canada	24-27 Jul 1990	In preparation

* See also list of references on the previous two pages.

Table 2: Countries and organizations providing participants to WHO IAQ working groups (1979–89)

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

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

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

Total participation in first seven meetings 131

Total number of experts involved 75

Expert participation in*:

All 8 meetings	7 meetings	4-5 meetings
JAJ Stolwijk (USA)** MJ Suess (WHO)**	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		
11 experts from: Belgium Netherlands United Kingdom Canada Norway United States Denmark Sweden		

* 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 several activities on the same subject is being undertaken. Also, this has helped the easy and smooth absorption into the work of 54 additional experts, whose specialty was required for the discussion of a certain topic at one of the meetings.

** Respectively, permanent Rapporteur of the IAQ working groups, and convener and Scientific Secretary on behalf of WHO/EURO.

Annex 2

ASSESSMENT OF LEVELS OF KNOWLEDGE ABOUT IAQ

At the second working group in 1981, the experts attempted for the first time to consolidate levels of knowledge about IAQ in the form of three tables (1). The tables were not supposed to be used without consulting the accompanied text in that report. However, four additional working groups have since reviewed and updated the tables, making them a selfstanding 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: about indoor population exposure factors in Table 1, about exposure-response relationships in Table 2, and consensus of public health concern in Table 3.

Table 1. Current Levels of Knowledge about indoor population exposure factors

Pollutant	People with low exposure	People with high exposure	Sources	Distri-bution	Instru-mentation	Indoor & 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 fibers	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 about 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	+	air way effects	+	technical
				systemic	0	regulatory
						educational
CO	most	few	+	systemic	+	technical
						regulatory
						educational
SO_2	most	few	+	air way effects	+	technical
						regulatory
						educational
CO_2	most	few	+	systemic	+	technical
O_3	most	few		mucosal irrit.	+	technical
				air way effects	+	(indoors)
				odour	+	regulatory
Radon and daughters	most	few*)	+	cancer	+	technical
						regulatory
						educational
ETS	most	some	+	odour	+	technical
				irritation	+	regulatory
				airway effects	+	educational
				carcinogenic	+	social
				systemic	+	
RSP	most	some	+	mucosal irrit.	+	technical
				airway effects	+	regulatory
				systemic	+	educational
Asbestos	most	few	0	carcinogenic	+	technical
				respiratory disorders	+)	regulatory
						educational
Mineral fibers	most	few	0	irritation	+	technical
				airway effects	+	regulatory
				carcinogenic	+)	educational
VOC	most	some	+	odour	+)	technical
				sensory irrit.	+)	regulatory
				mucosal irrit.	+)	educational
				systemic	+)[a]	social
				airway effects	+)	
				cancer	+[a]	

(continued)

Table 2 (continued)

Pollutant	People at low exposure	People at high exposure	People exposed	Adverse effects at levels of concern	Exposure response relationship	Means of control
Formal-	**most**	few	+	odour	+	technical
dehyde				mucosal irrit.	+	regulatory
				airway effects	+	educational
				cancer	+[a]	
				systemic	+[a]	
Other	**most**	few	0	odours	+	technical
Organics				mucosal irrit.	+	regulatory
				airway effects	+	
				cancer	+[a]	
				systemic	+[a]	
Aero-	**some**	most	+)	airway effects	+)	**technical**
allergens				mucosal effects	+)	**education**
						medical[b]
Infectious	**most**	few	0	respiratory	+)	**technical**
Agents				other organs	0	**medical**[b]
				systemic	0	**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 about selected indoor air pollutants at 1990 levels of knowledge.

Selected pollutant[a]	Typical range of concentr. (10%-90%)[b] mg/m³	Concentration of limited or no concern[b] mg/m³	Concentr. 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 (24h) (Japanese Standard)
$NO_2$2	0.02-0.4	<0.15	>0.40	AQG[e] 0.4 (1h)
CO	1 - 11	<2% COHb <10 >30	>3% COHb	AQG 10 (8h)
Radon and daughters	3-75 Bq/m³ EER	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 (1h) is widely used
O_3	0.01-0.1	<0.1 >0.12		AQG 0.15 -0.2 (1h)
Asbestos	100-10000F*/m³	carcinogen	carcinogen	(24h)
Mineral fibers	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 optical 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 occupationakl 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

To reflect on the change in expert judgement (on the basis of the research done during the seven years 1982-89) and the new knowhow developed, a copy of the first set of the tables (2) is presented here too, for comparison purposes only. It is worthwhile noting that five key experts were present both in the second and seventh meetings.

Table 1. Current levels of knowledge about population exposure

Pollutant	People with low exposure	People with high exposure	Sources	Distri-bution	Instrumen-tation	Indoor/ personal monitoring
Tobacco smoke (passive smoking)	most	some	+	±	±*	±
NO_2	some	some	±	0	+	±
CO	most	few	±	0	+	±
Radon and daughters	most	few	±	0	+	0
Formaldehyde	most	few	±	±	+	±
SO_2	few	few	±	±	+	0
CO_2	most	few	+	±	+	+
O_3	few	few	±	+	+	±
Asbestos	few	few	0	0	±	0
Mineral fibres	few	few	0	0	±	0
Organics	most	some	±	0	±	0
Allergens	most	some	0	0	±	+

* For respirable particulates.

+ = adequate
± = marginal
0 = inadequate

Table 2. Current levels of knowledge about exposure-response relationships

Pollutant	People with low exposure	People with high exposure	Population exposed	Adverse effects at levels of concern	Exposure-response relationship	Means of control
Tobacco smoke (passive smoking)	most	some	±	irritation	±	regulatory
				odour	±	technical
				airway respiratory	±	social
				carcinogen	0	educational
				systemic	0	
NO_2	some	some	0	airway respiratory	0	technical
				odour	±	regulatory
				systemic	0	educational
CO	most	few	0	systemic	+	technical regulatory
Radon and daughters	most	few	0	carcinogen	±	technical regulatory
Formaldehyde	most	few	0	irritation	±	technical
				odour	±	regulatory
				airway respiratory	±	
				carcinogen	0	
				systemic	0	
SO_2	few	few	±	airway respiratory	0	technical regulatory
CO_2	most	few	0	systemic	±	technical
O_3	few	few	±	irritation	+	technical (indoors)
				airway respiratory	±	
				odour	+	
				systemic	0	
Asbestos	few	few	0	respiratory disease	±	technical
				carcinogen	±	regulatory
Mineral fibres	few	few	0	airway respiratory	±	
				irritation	±	
Organics	most	some	0	odour	0	technical
				irritation	0	regulatory
				systemic	0	educational
				airway respiratory	0	
				carcinogen	0	
Allergens	most	some	0	airway respiratory	±	social
				odour	±	regulatory
				irritation	±	medical[a]

[a] The medical measures are *preventive*

+ = adequate
± = marginal
0 = inadequate

Table 3. Consensus of concern about indoor air pollutants at 1982 levels of knowledge

Pollutant[a]	Concentrations[b] reported	Concentration[b] of limited or no concern	Concentration[b] of concern	Remarks
Tobacco smoke (passive smoking)	0.1 - 1 respiratory particulate	≈0	—[c]	Japanese standard 0.15 mg/m³
NO_2	0.05- 1	< 0.19	> 0.32	according to WHO EHC 4 (47), 99.9%
CO	1 - 100	< 11 (2% COHb)	> 30 (3% COHb)	continuous exposure
Radon and daughters[d]	4 -8 000 Bq/m³	≈0	> 70 Bq/m³	Swedish standard for new houses
Formaldehyde	0.06- 1.3	< 0.06	> 0.12	long- and short-term
SO_2	0.02- 1	< 0.5	> 1.35	SO_2, alone, short-term
CO_2	600 -9000	<4 500	>12 000	Japanese standard 1 800 mg/m³
O_3	0.04- 0.4	< 0.12	> 0.15	WHO EHC 7 (48)
Asbestos	$<10^8$ fibre/m³	≈0	$>10^5$ fibre/m³	for long-term exposures
Mineral fibres	—	—	—	
Organics	—	—	—	

[a] All gases were considered on their own, without other contaminants.

[b] Concentrations are given in mg/m³ unless otherwise indicated.

[c] Because of the complex nature of these pollutants, meaningful concentrations cannot be given.

[d] 1 Bq/m³ = 0.027 nCi/m³

[e] Account was taken only of short-term effects of SO_2 on its own, without particulates or sulfates or NO_2, which may be present simultaneously and are then likely to be the limiting factor. For long-term exposures, outdoor air quality standards or guidelines will provide a better margin of safety.

Annex 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 Annex presents the conclusions and recommendations of three most recent working groups (fifth–seventh) for easy reference and review.

Fifth WHO working group on IAQ: organic pollutants

CONCLUSIONS

1. The distribution of indoor concentrations of CO, NO_2 and VOC is much better known than those of very volatile, semi-volatile and particle-bound organic compounds, and reactive substances from all these groups. There is a need to collect data on the distribution of the latter groups.

2. Organic compounds may cause odours, mucosal and sensory irritation and airway effects at levels encountered indoors. Any acute toxic effects to various organs usually occur only at concentrations higher than normally encountered indoors.

3. Evaluating the effect on health of single compounds may not always be adequate, because indoor pollutants usually occur in mixtures and many sources emit mixtures of pollutants. However, with the present state of knowledge, only a compound-by-compound approach can be applied to risk estimates in most instances.

4. Exposure to organic compounds, particularly semi-volatile and particle-bound compounds found in the indoor esnvironment, occurs by various routes (inhalation, ingestion and skin absorption). The assessment of total dose and the relative contribution of indoor air exposure requires further study.

5. The detection limits of analytical instruments used at present do not coincide with the detection limits of human sensory systems. Therefore, many strong odorants may not yet have been chemically identified.

6. An indoor concentration limit value based on the detection or recognition of an odour or a sensory irritant by 50% of people (ED_{50}) will not protect the most sensitive part of the population. Also, such a limit does not protect against systemic or genotoxic effects of substances that are not odorants or irritants.

7. Methods are available to assess the total effect in terms of chronic disease of indoor organic air pollutants. These incorporate all available information on exposure distribution, health effects measured in other settings, and the background incidence of the disease in question.

8. The available information on the potency as odorants or sensory irritants of organic air pollutants commonly encountered indoors is inadequate.

RECOMMENDATIONS

1. To facilitate the use of data on exposure to organic compounds, the distribution of the respective concentrations should be reported as the 10th, 50th and 90th (and, if possible, the 95th and 98th) percentiles.

2. Because of the great variety of organic compounds in the indoor air and the difficulties in implementing indoor air quality standards, various approaches to source control should be studied and developed. Where appropriate, forms of social control (such as with ETS) should be developed through education, mass media campaigns and, if necessary, legal action.

3. Methods for estimating exposure distributions over time (peak exposures versus long-term averages) and over space (exposures in many different spaces) from relatively few measurements need to be developed and validated.

4. Total personal exposure estimates for the organic compounds known to cause adverse health effects within populations should be assessed. This is especially true for exposures due to emissions from complex sources and emissions from multiple sources.

5. Methods for assessing biological burden and activity, including exhaled breath analysis and assays of secretions, should be further developed for organic compounds and their metabolites.

6. In planning studies concerned with health effects, exposure characterization and mitigation of organic compounds, attention should be focused on those compounds whose estimated contribution to the disease in question is more than 2% of the total background incidence.

7. Unwanted odorous compounds should not be present in concentrations exceeding the ED_{50} detection threshold. Similarly, sensory irritants should not be present in excess of their ED_{10} detection threshold.

8. Increased emphasis should be given to research in humans on the sensory

effects of organic compounds in low concentrations. This is especially true for detection and recognition data, which should be collected in a way that allows the full dose-response curve to be determined, including the ED_{10} and the ED_{50} values.

9. The source strength, as well as the rate of change of emissions of organic compounds from building materials and consumer products, should be determined and evaluated in relation to actual human exposure and the associated health effects.

10. As the available information on indoor concentrations of pesticides and herbicides does not permit an adequate evaluation of the associated acute and chronic health effects and in view of the toxicity of these compounds, further data should be urgently generated.

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 down-drafting, 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 from 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.