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INTRODUCTION

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This book is aimed at the informed non-specialist who has to deal with questions of indoor air pollution. Although most of the contributors are British, the book is designed to be internationally relevant. It is hoped that it will be of value to occupational health physicians and nurses, industrial hygienists, personnel and safety officers, ventilation engineers, architects and building maintainers and operators.

The contributors to this book are all internationally recognised experts in their various fields. They have endeavoured to present, for each category of indoor air pollution an assessment of exposure levels and uptake into the body as well as a consideration of the health effects and the possibilities for the control of the pollutants. The references are restricted to the most important papers and reviews on each subject.

Indoor air quality problems depend in large part on climate and the economic requirements and abilities of developed and developing countries. Those living in the more affluent countries tend to forget that the bulk of the World's urban population have to live with much more heavily polluted outside air. Historically this distinction did not always exist. In the West, urbanisation led to horrific air pollution which was perhaps best exemplified by the infamous 'pea-souper' fogs for which London was notorious. These fogs occurred during the winter when sulphurous smoke, mainly from domestic coal fires, mixed with fog in conditions of thermal inversion. This choking fog often stayed for days at a time and at its worst caused thousands of acute deaths. Road traffic became impossible and businesses had to close until the fog lifted. Visibility was sometimes reduced to 2 to 3 metres. The situation in London changed radically with the introduction of the Clean Air Act which prohibited the use of soft coal in the 'smokeless' zones. Variations of the 'pea-soup' fog phenomenon, however, prevail in many parts of the world today.

With such severe external pollution, virtually no attention was paid to the quality of indoor air. People escaped into their homes to avoid the noxious exterior and thought or cared little about the presence of pollutants in their indoor environment. However, as the problems of outdoor air pollution have lessened in developed countries, more attention is now being given to the problems of indoor environments. Buildings in colder developed countries now usually have central heating, while in warmer developed countries there is air conditioning in homes, offices and public places. These systems may limit the intake of fresh air, particularly where air interchange rates with the outside have become lower due to the need to conserve energy both for economic and environmental reasons. Thus, the problems of indoor air pollution have become more pronounced.

In the urban areas of developing countries with warm climates few people can afford air conditioning and ventilation is largely natural via open windows, perhaps assisted by fans. In these situations the quality of internal air is largely dependent on the quality of the external environment. Developing countries usually have less stringent regulations or at least less rigidly enforced regulations controlling the pollution of outdoor air. In the developing countries, cities which experience cold winters very often have domestic heating by coal and the combustion products of coal are their major source of outdoor air pollution. In addition to coal combustion, other sources of outdoor pollution are industry and road traffic. The outdoor pollutants strongly influence the indoor environment, though there are also indoor sources. For example, the fuel used for cooking purposes and the smoke from cooking often contribute considerably to indoor air pollution.

Another factor influencing indoor air quality is the development of new materials and products which produce novel air pollutants or at least pollutants which were quantitatively unimportant a few decades ago. For example, modern building materials, insulation, bonding resins, fabrics, cleaning materials, personal care products, and pesticides now often expose us to high levels of a wide spectrum of chemicals, some of which have been demonstrated to be highly toxic in humans or even carcinogenic in experimental animals. In addition the air conditioning systems that we use in offices and public buildings can give rise to indoor air pollution. They may contain biological products such as moulds, fungi and bacteria and they may distribute dust, fibres and various pollutants.

We are now living in an era where indoor air pollution is seen to be increasingly important. Perhaps in many instances too much importance is attached to the potential risks to health from indoor air pollutants. All too often our perception of risk is determined not by what is real and measurable but by the extent of media presentation of the issue. Nevertheless, the issue is important, for indoor air quality can influence health. The chapters in this book show this clearly.

In the developing countries the greatest problems of indoor air quality come from the external air and their highest priorities should be the control of the sources of external pollution. In affluent countries, much more research is needed on the quantification of the risk from the known pollutants and on the means to ameliorate these risks. These requirements are, fortunately, becoming recognised by public and industrial health physicians, occupational hygienists, toxicologists, ventilation engineers and building designers.

It is immediately evident that there are several distinct types of problems. Most obvious and most dramatic is sudden death following exposure to a pollutant. Such events are, fortunately, rare, at least in the developed countries of the West and, when they occur, they attract considerable publicity as is witnessed by recent episodes of legionellosis. In Korea and parts of China, however, several thousand people die every winter following exposure to lethal levels of carbon monoxide. The traditional domestic heating system in this part of the world uses a form of underfloor duct through which the hot smoke and fumes from coal combustion pass. Cracks in the floor lead to leakage of the products of incomplete combustion such as carbon monoxide and NO_x. The problem is exacerbated by supplementary heating from often inefficient kerosene stoves and by insufficient ventilation. Even in Western Europe there are several hundred acute carbon monoxide deaths every winter.

The problem of legionellosis has been identified primarily in affluent countries and can be tackled by better design and maintenance of air cooling systems. The problems of North East Asia with carbon monoxide can only be resolved by the adoption of improved systems of domestic heating which are often beyond the financial resources of many people in this part of the world.

The other types of indoor air pollutants exposure to which can be potentially lethal are much less easy to determine since, in general, exposure often occurs many years or even decades before the onset of symptoms of the disease. One problem is that available scientific techniques do not allow one to say with certainty that various pollutants are a health hazard. We are all familiar with the concept of occupationally induced diseases. Epidemiology has identified as risk factors for workers exposure at high concentration and prolonged periods to heavy metals, asbestos, coal and other dust, various solvents, ionising radiation, etc, but it is only now becoming apparent that exposure to various pollutants in the home, the office, public buildings, transport and places of entertainment may also have long-term health consequences. Epidemiology has been of much less value in these situations since the risk ratios are very low, probably less than 2 in most cases, and the diseases which are reportedly associated with exposure are well known to be multifactorial in causation. This, of course, means that there will be a wide array of confounding factors to be taken into consideration. Because of the long time of onset of symptoms for diseases such as cancer of the lung it may be very difficult to obtain satisfactory quantitative evidence of exposure to the various risk factors. This is the situation prevailing with the purported association of exposure to environmental tobacco smoke (ETS) and lung cancer.

Of course, we need not rely on epidemiology in every case. Radon and its daughters represent for most people by far their most important source of exposure to ionising radiation. The level of suggested risk of lung cancer from exposure to radon and its daughters is not derived from epidemiological studies of the at-risk population but is based upon extrapolations from observed lung cancers occurring in people exposed to very high levels of radiation. It is difficult to make such extrapolations with any degree of accuracy since the body has mechanisms which can repair low levels of damage. Thus, estimates of risk to people living or working in areas with high levels of ground emanation of radon vary considerably. It is now widely accepted that 10 ± 5% of the lung cancer frequency in the temperate zones is induced by radon. To put this in perspective, adjustment for the somewhat lower average levels of radon in the UK gives an annual death rate of about the same as that due to road traffic accidents. Recently (*Nature*, 1990) the UK National Radiation Protection Board increased its estimate of lung cancers caused by radon by a factor of two. Since lung cancer in non-smokers is a rare disease, this level of risk from radon is sufficient to account for most of the cases of lung cancer occurring in non-smokers.

Some animal data are also available. Formaldehyde has been shown to cause nasal cancer in experiments on rats. Although formaldehyde exposure is common in some occupations there is no epidemiological evidence of any association with human cancer. Formaldehyde can, of course, cause irritation and sore eyes and nose, and chronic exposure has been known to cause sensitisation and allergy.

Most of the cancers which have been reported to be associated with exposure to indoor air pollutants are cancers of the lungs. The majority of our evidence about the association between exposure and cancer is epidemiological and often very controversial. In very few cases do we have any evidence on causation. Unfortunately the epidemiological literature contains numerous examples of publications showing associations between various types of exposure with serious outcomes which have subsequently been shown to be unsustainable. Recently Bailar (1985) discussed two papers which appeared in one issue of a journal. One of the papers showed that treatment with synthetic steroid hormones reduced the risks of cardiovascular disease in women and the other paper showed that such treatment increased such risks. The use of spermicidal creams has been reported to be associated with an increased risk of foetal deformities. The manufacturers of the cream withdrew it from the market and were sued by parents of deformed babies for many millions of dollars. Subsequently the USA Food and Drugs Administration exonerated the product and it returned to the market. There is a great dilemma facing the editors and referees of epidemiological papers. Over-willingness to publish unsupported papers may cause great panic when the media oversimplify the issues and cause people to fear the consumption of coffee, beer, mustard, spices and herbs or various food additives. On the other hand, failure to publish could allow continued exposure to dangerous agents.

Over the last decade, debate has raged over the risk of lung cancers in non-smokers exposed to other people's tobacco smoke. There is a wide range of epidemiological data available. This subject is dealt with in Chapter 12. At present it seems reasonable to accept the conclusions of the WHO International Agency for Research on Cancer (IARC, 1986) that 'the data are consistent with a low level of risk or with no risk'. It certainly seems most implausible that the relatively high level of risk (30% to 40% increase) reported in some epidemiological studies could be due to the low levels of exposure of non-smokers. Despite this basic implausibility on dosimetric grounds the US Surgeon General (1986), the National Research Council (1986) and the fourth report of the UK Independent Committee on Smoking and Health (1988) have all concluded that the risk of lung cancer from ETS is real. One might speculate that these committees might have been willing to moderate their scepticism in order to put pressure on smokers to indulge their habit less frequently.

A recent report that the keeping of pet birds (Holst *et al.*, 1988) is associated with a six- or seven-fold increased risk of lung cancer seems to have attracted relatively little interest although this level of risk is 20 times higher than that reported for exposure to environmental tobacco smoke which has attracted immense attention. The work of Holst merits thorough further independent investigation and, if confirmed, requires wide publicity.

Other studies have identified several indoor generated air pollutants which are considered serious risk factors for lung cancer. Asbestos is well known to be a very serious risk factor for mesothelioma, the cancer of the linings of the lungs. It can also increase the risk of lung cancer but, probably nowadays, there is rarely a sufficient level of exposure in the home or the office to cause any great risk – at least in the developed countries. Recently developed man-made mineral fibre substitutes for asbestos are not known with certainty to be without risk but probably seldom reach high enough concentrations to be dangerous.

There may be some risk factors for lung cancer in polluted outdoor air. In Britain, before the Clean Air Acts of the 1950s, London and other big cities experienced notorious 'pea-souper' fogs caused by combustion of coal for domestic heating and for industry. The British had higher rates of lung cancers than did most other countries for which reliable data were available. British who emigrated to New Zealand or South Africa had much higher rates of lung cancers than those born in these countries. We cannot, therefore exclude the possibility that outdoor air pollution may be a risk factor for lung cancer either through exposure to respirable carcinogenic material or perhaps subsequent to bronchitis or damage caused to the lungs by pollutants such as SO_2. There are parts of North East Asia where such 'pea-soup' fogs still occur and where chronic bronchitis is very common.

A final point worth mentioning here is the problem of allergies to indoor air pollutants. One of the most common and disabling forms of ill health due to exposure to indoor air pollutants are the allergic disorders such as asthma. These disorders have been referred to in Chapters 4, 10 and 11 as being induced by moulds, fungi, animal danders, house dust mites and their excretion, vegetable dust, etc. Chemical agents can also be causes of asthma.

Asthma is a disease which seems to be increasing in frequency worldwide. There have been in the last decade or so reports from countries as far apart as New Zealand and Finland that the incidence of childhood asthma has almost doubled. This effect has been reported in cold climates and hot climates, in affluent countries and developing countries and the causes are not at all clear.

In the UK the most important indoor allergen is the house dust mite (or its excreta) and it is commonly supposed to be the major domestic cause of asthma. It may be that changing conditions in homes and offices worldwide have contributed to the success of the house dust mite and thus have increased the incidence of asthma, but much research needs to be done in this field.

One of the important conclusions to be drawn from reading this book is that research and education are vitally and urgently needed into many aspects of indoor air quality.

One of the past problems has been that practitioners in one part of the overall science of indoor air quality have not been fully aware of the expertise and problems of practitioners in allied fields. It is hoped that this book will, at least, give the reader an awareness of the work and knowledge of experts in various disciplines. Without the development of this inter-relationship, progress in improvement of indoor air quality will not be as rapid as it might otherwise be.

Finally, it may be of interest to the reader that a new multidisciplinary international learned society has recently been formed[1] in order to bring together experts from all the various sciences and technologies involved in these problems.

Note

1 Indoor Air International, Postfach 2, CH-4467, Rothenfluh, Switzerland.

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THE PERCEPTION OF INDOOR AIR QUALITY

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Poor indoor air quality may, rarely, have clinically identifiable adverse consequences. Less rarely it may have sub-clinical health effects. All these may, or may not be, identified by the particular occupant as connected with the indoor environment to which he or she is exposed. However, there are many other factors which cause the sum of the sensations leading to the total perception of the indoor environment.

The factors which affect perception are shown in Figure 2.1.

Within the limits of this chapter, it is not possible to deal fully with all these factors. Attention is therefore concentrated on the two most important ones – thermal comfort and air quality – since these are generally the two most important factors in determining perception of the indoor environment.

The thermal environment

This is a very powerful factor in the occupant's perception of overall satisfaction with the environment. In the author's experience, most cases of dissatisfaction with the immediate environment have an element of thermal discomfort associated with them.

The following inter-related factors are the important ones in the total picture.

Air temperature
Mean radiant temperature (mrt)
Rate of air movement
Relative humidity
Insulation value of clothing worn
Metabolic rate of task being performed

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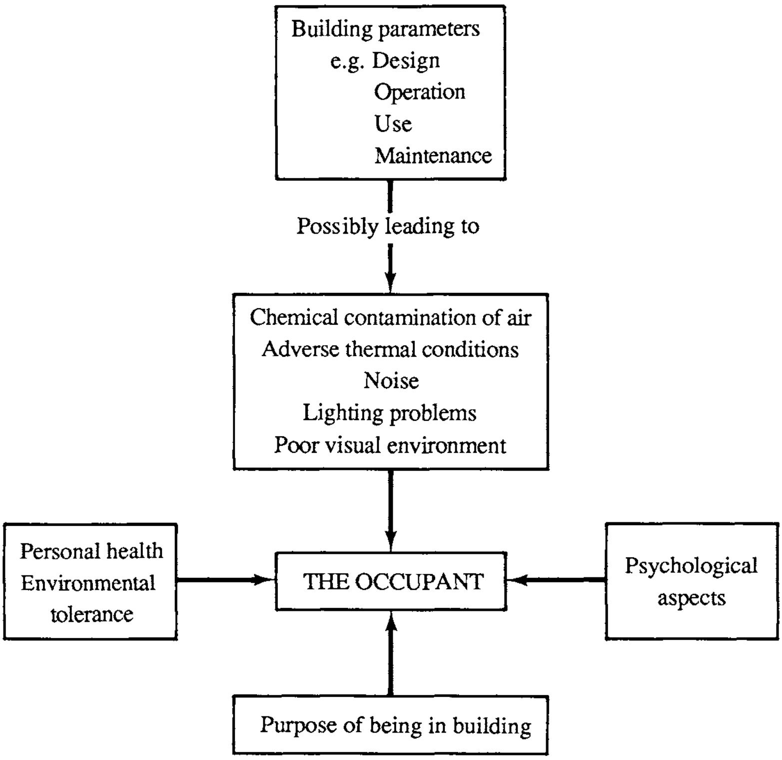

Fig. 2.1. Factors in the perception of air quality.

Fanger (1972) has produced an equation correlating these factors. This equation is complex since the heat transfer mechanisms are complicated. However, to ease the use of this thermal comfort equation, Fanger has reduced it to a series of graphs and tables, from which it is possible to predict the number of subjects who will be satisfied or, more importantly, dissatisfied with a particular set of thermal conditions. His results show that there are no, or only minor, differences in requirements for thermal neutrality between the sexes, or among persons of different ethnic origin or age. (Thermal neutrality is defined as the subject desiring to be neither hotter nor colder.) Two interesting points emerge. First, in a large population exposed to a particular set of conditions, it will be impossible to satisfy more than 96% of that population; generally a satisfaction rate of 90% is a suitable target figure. Second, whilst acclimatised persons working in tropical countries have become used to accepting heat-induced discomfort, their choice of conditions for thermal neutrality is the same as that for those persons from temperate climates.

There are over-riding limits for the first four individual factors given above.