INDOOR AIR QUALITY AND VENTILATION

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MEDICAL ASPECTS OF INDOOR AIR QUALITY

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ABSTRACT

The borderline between discomfort and ill-health is indistinct. The physiological and psychological responses to irritation - whether physical or mental - are easy to confuse with those indicative of ill-health. Pure indoor air of acceptable temperature and humidity is a laudable, but elusive, goal. In striving to achieve it sensible priorities, which vary according to climate and other circumstances, need to be established. Potential health problems from inadequate indoor air quality are reviewed in the light of these considerations.

INTRODUCTION

Fifty years ago two ladies sitting in the same compartment of a railway train were arguing fiercely about whether the window should be open or closed. The one said that if it was left closed she would die of claustrophobia and suffocation, while the other claimed that if it was left open she would die of pneumonia. They both stoutly rejected the mediating guard's suggestion that if it was left half-open they would both have a 50% chance of surviving the journey. Finally, irked beyond the call of duty, he ruled that the window should be left wide open for the first half of the journey and tight shut for the second half. This, he suggested, should ensure that neither of the cantankerous women would live long enough to cause any problems for the guard on the return journey!

This simple tale illustrates that people may vary widely in what they consider acceptable as far as air quality is concerned. It also, perhaps, illustrates the point that the physical qualities of air - its temperature, humidity and the presence or absence of draughts - may override most other considerations.

I suspect that if people living in different countries and climates were asked to define the advantages and disadvantages of windows, they would give a wide range of answers. Most might say they provide daylight, but art museum curators might worry that light destroys masterpieces. In London for most of the year, windows provide a welcome source of so-called 'fresh' air. But in many of the big cities of the world, windows are seen as the portals of entry for traffic and industrial fumes - and in great stretches of the United States openable windows, apart from providing light, tend to be seen by ventilation engineers simply as hindrances to the control of indoor temperature and humidity. Thus in terms of the control of temperature and humidity and the exclusion of polluted outside air, the status of windows is quite different in different countries. However, there is another function of windows which is far more widely shared irrespective of climate. There is a common human need to be able from time to time to gaze into the distance. Being able to do so somehow liberates the mind from the immediate burdens of every day living and gives a perspective to the small, irritating, fidgety tasks which confront most people from time to time.

I make absolutely no apology for introducing this paper on the Medical Aspects of Indoor Air Quality in this way because I most strongly decry technical approaches to considerations on indoor environments which assume that the acceptability of indoor air can be defined for all humans simply in terms of physical and chemical criteria.

In this regard there is another important point to make. There is such a thing as sensory boredom. In other words it can be boring to live at exactly the same temperature and humidity hour after hour. It is for this reason that people confined to efficiently air conditioned offices for much of their working days long "to get out in the air" - even if outside it is boiling hot or freezing cold, and even if they can stay outside only for a few minutes. It could be claimed that the sauna is the perfect antidote to sensory boredom.

DISCOMFORT AS DISTINCT FROM ADVERSE EFFECTS ON HEALTH

Most people spend most of their time not consciously thinking about whether they are comfortable or not. They adjust to ambient air temperatures and humidity by donning or shedding garments. Also, they make physiological adjustments to conserve body heat or to lose more of it by sweating. It is mainly just when people enter rooms that they notice that they are too hot, too cold, stuffy or smelly. Thereafter, they get used to their immediate environment and forget about it. However, these automatic adjustments may not occur if people are fundamentally not happy with their work or are bored or not fulfilled by it. Under these circumstances they look around for something to blame, and the quality of the air around them is an easy target. Positive pleasure from entering a cosy room on a cold day or from going out into the "fresh" air from a heated building is also evanescent. Pleasure can soon change to discomfort. "Cosy" becomes "stuffy", "fresh" becomes "freezing".

A sensation of discomfort in a normal person may be regarded as an "early warning system". The sensation warns an individual that he might be risking his/her health if he/she doesn't at least temporarily move to somewhere hotter or less stuffy. On the other hand, complaints of discomfort may themselves be no more than a symptom that a person is unhappy, bored or unfulfilled by what he/she is doing. Unhappiness arguably constitutes ill-health but the illness is not primarily due to the quality of the indoor air.

ADVERSE EFFECTS OF POOR INDOOR AIR QUALITY ON HEALTH

Some of the short term health effects of exposure to indoor air pollutants are listed in Table 1:

Table 1 Examples of immediate, short term, and long term health effects of polluted indoor air.

EFFECT	AGENTS RESPONSIBLE
Immediate	
Headache	- Reduced O_2 - High CO_2 - High temperature - High humidity
Itchy eyes, irritated throat, blocked nose	- Aldehydes such as acrolein, acetaldehyde, formaldehyde. - Oxides of nitrogen - Sulphur dioxide - Dust particles
Atopic symptoms	- Allergenic pollens, fungal spores, bird feathers, animal dander, etc
Nausea	- Volatile organic chemicals liberated by building materials, fabrics. - Pipe, cigar, cigarette smoke (i.e. environmental tobacco smoke). - Garlic - Body odours and perfumes. - Food and cooking smells
Mental confusion, death	- Carbon monoxide
Short term	
Upper respiratory infections and influenza	- Viruses emitted by people
Legionnaire's disease	- Badly designed/maintained air conditioning plant.
Long term	
Chronic bronchitis/ emphysema Chronic asthma Cancer	- Irritants - Particles - Allergens - Radon - Asbestos

It is perhaps noticeable that, despite the attention paid to environmental tobacco smoke in the media, it gets little mention in Table 1. This is partly because it is only one of many sources of irritants none of which are unique for tobacco smoke. Open fires, cooking ovens and kerosene heaters can be much more potent sources of oxides of nitrogen and sulphur and of aldehydes than tobacco. Also, nausea can be triggered by different things in different people. Body odour, garlic, perfumes and cooking fumes can be just as nauseating for some people as tobacco smoke - particularly pipe smoke - is for others. Tobacco smoke is not itself allergenic. However, in some atopic individuals, it can enhance atopic symptoms. Mental confusion and death from carbon monoxide poisoning is never attributable to carbon monoxide generated from tobacco. These serious manifestations are invariably due to inadequate ventilation whereby fumes from heating systems or from vehicular exhausts find their way into indoor air environments. In countries such as Korea, carbon monoxide poisoning from unventilated domestic heating is common and many deaths due to this occur each year.

The contribution of environmental tobacco smoke to lung cancer risk is either non-existent or negligibly small. Epidemiological studies which purport to demonstrate such an association are all flawed in one way or another.

It is ironic that whereas environmental tobacco smoke, which can undoubtedly be irritating and nauseating for some people, has attracted a great deal of attention in relation to possible lung cancer risk, radon which is a much more serious hazard but not irritating has until recently received little attention. Thus if a house is built in a geological area in which radon is emitted from rocks, and if this radon can seep into the basement of the house and can then circulate around the house, as happens in many ranch-type houses in the USA, then the residents of such a house may be exposed to highly dangerous levels of irradiation from radon and radon daughters. Furthermore all this can happen without the residents being aware that anything is amiss. Exposure is silent and insidious being unaccompanied by any symptoms of irritation or allergy. In the United Kingdom it has been suggested that as many as 2,500 lung cancer deaths per year may be due primarily to exposure to radon (Clark & Southwood, 1989). Comparable estimates for the United States range up to to 40,000 lung cancer deaths per year.

NOTES ON SELECTED INDOOR AIR POLLUTANTS

(i) Cooking and heating fumes

Whether or not cooking and heating fumes pose a health problem depends very much on climate as well as on the amount of indoor space and ventilation. The colder the climate, the smaller the space, the poorer the ventilation, the worse the potential health problems. When cooking is carried out in the open air or when the windows of indoor kitchens can be left open, the potential for health effects attributable to cooking and heating fumes are minimal. The same is true when cooking is by electricity. The spectrum of pollutants of main interest varies with the type of fuel and with the efficiency of its combustion. The spectrum includes carbon monoxide [CO], carbon dioxide [CO_2], oxides of nitrogen, particularly nitrogen dioxide [NO_2], sulphur dioxide [SO_2], aldehydes, particles, and pyrolysis products such as polycyclic aromatic hydrocarbons [PAH].

(ii) Carbon monoxide [CO]

Carbon monoxide [CO2] is a product of incomplete combustion of all carbonaceous fuels. It is odourless and non-irritant but nevertheless potentially acutely toxic because of its affinity for haemoglobin which leads to a reduction in the oxygen-carrying capacity of the blood. In turn this may lead to dizziness, blurred vision and rapid breathing.

In the short-term and on an intermittent basis, most people can inhale enough CO to reduce the oxygen carrying capacity of the blood by 10% or more without ill effect. However, people with reduced circulatory reserve [eg because of existing heart disease] may, in theory at least, be temporarily compromised by heavy exposure to CO such that their exercise tolerance is reduced and they develop anginal pain after less exercise than they are normally capable of. The hard evidence that this happens under realistic conditions of indoor air pollution is, however, lacking. In any case, once exposure to CO ceases, it is fairly rapidly lost from the body and the blood returns to normal. Under conditions of prolonged exposure to CO an equilibrium is reached wherein a proportion of the haemoglobin is continuously useless for the purposes of carrying oxygen. In response to this the body increases its production of red blood cells and haemoglobin in much the same way as it does when people climb from sea level to altitudes where the oxygen pressure is reduced. Research aimed at finding an association between chronic exposure to CO and increased risk of atherosclerosis or coronary heart disease has given only negative or equivocal results. Also, concern that exposure to CO at the levels present in indoor air might be a cause of reduced birthweight or of birth defects has proved to be unfounded.

It has to be recognised, of course, that in conditions of very bad ventilation, the use of some types of indoor heating and cooking appliances can lead to such high levels of CO in a room that death occurs. Also, lethal concentrations of CO can be built up by running a car engine in a garage with the doors closed.

(iii) Oxides of nitrogen, particularly nitrogen dioxide [NO_2]

Oxides of nitrogen, and particularly NO_2, are irritant to the eyes and nose and can damage lung tissue. The damage, which is due to the oxidant properties of the gas, occurs primarily in the vicinity of the terminal and respiratory bronchioles and consists of metaplastic changes in the airway epithelium at these sites, increased susceptibility to respiratory infections, and impairment of lung function because of the destruction of alveolar walls. Repeated heavy exposure to nitrogen dioxide as occurs in some occupations [eg shot-firing in mines], can result in centrilobular emphysema with destruction of elastic fibres and loss of elastic lung recoil. Particularly at risk are individuals suffering from the genetically determined disorder known as X1-antitrypsin deficiency.

There is considerable evidence that exposure to oxides of nitrogen derived from gas cookers, oil-fired heaters and wood fires, under ordinary home circumstances, can be sufficient to produce adverse effects on health. Thus, Melia et al [1979] found that boys living in Scottish homes with gas cooking have an 18% higher prevalence of respiratory illnesses than boys living in comparable homes with electric cooking. This difference was highly statistically significant [$p<0.01$] after correction for age, sex, social class, and number of cigarettes smoked within the dwelling. Other studies have shown that exposure to NO_2-containing emissions from gas stoves adversely affect lung function in children [Speizer et al, 1980; Samet et al, 1987].

(iv) Formaldehyde and other aldehydes

Formaldehyde and other aldehydes are among the products of incomplete combustion. Thus they are present in fumes from coal, wood and oil-fired heaters, bonfires and tobacco smoke. However polyurethane house insulation and other building materials are also important sources of formaldehyde. Aldehydes are extremely irritant to the mucous membranes of the upper respiratory tract and are lachrymatory. Formaldehyde is a mutagen and prolonged exposure to high concentrations has been shown to cause nasal cancers in laboratory animals [Griesemer et al 1982]. Acetaldehyde has also been found to be carcinogenic in laboratory animals.

In rodents nasal cancers arise out of a background of pre-existing irritation and necrosis of the nasal epithelium. There is no evidence that tumours arise in the absence of pre-existing severe tissue damage of these kinds. The hope therefore is that humans exposed to levels of formaldehyde lower than those that produce nasal cancers in rodents and lower than those associated with any evidence of chronic damage to nasal epithelium in man are wholly without cancer risk for man. So far the results of numerous epidemiological studies that have been carried out on people exposed to formaldehyde at work [eg pathologists, embalmers] suggest that this hope is fulfilled. This being so there would appear to be no serous health effects from exposure to the relatively low ambient levels of formaldehyde encountered in indoor air environments. The same is hopefully true for acetaldehyde and other aldehydes although in this case there are no epidemiological data to back up the hope.

(v) Sulphur dioxide

The burning of soft coal and of sulphurous oils were at one time the main surces of sulphur dioxide in both outdoor and indoor air. Before the burning of such fuels came under careful control, sulphur dioxide was a major cause of chronic bronchitis and emphysema and directly killed many people each year in Britain. Even at that time however the concentrations of sulphur dioxide in indoor air were generally only 20% of those in outdoor air, unless chimneys were blocked and the smoke from fires remained indoors [Perhac, 1985]. Nowadays sulphur dioxide in indoor air is not a source of major concern in developed countries. However, it still may be so in parts of the world where dwellings are not adequately ventilated and where sulphur-containing fuels are used without appropriate control. Also, of course, there are no grounds for complacency in relation to the use of sulphur-containing fuels by power stations. These continue to contribute to environmental pollution in the form of acid rain.

(vi) Respirable particles

The concentration of particles including fibres in indoor air environments is extremely variable both with regard to size and chemical composition. Large particles tend to be deposited in the nose, nasopharynx and larynx whereas smaller particles may be taken into the lungs.

The extent to which particles enter the lungs from ambient air depends inter alia on their size. In the case of a spherical particle, its aerodynamic properties can be expressed in terms of its diameter. However the aerodynamic properties of fibres and irregularly shaped particles are more complicated. A long thin fibre aligned at 90° to the airstream behaves like a sphere with a diameter equal to the length of the fibre and is deposited high up in the respiratory tract. However a fibre aligned longitudinally with the airstream in which it is suspended behaves like a spherical particle of the same diameter and density as the fibre and tends to be co-deposited with such particles. For this reason long thin fibres can penetrate deeply into the lungs and reach sites where only small spherical particles normally reach.

Whether or not particles [including fibres] taken into the lungs are harmful to health, or not, depends firstly on the number of particles inhaled, secondly on where particles are deposited, thirdly on whether the inhaled particles are toxicologically active or inert, and soluble or insoluble in body fluids, and fourthly on whether they are inhaled alone or along with other particles or gases which are toxicologically active.

Provided that the particles are not too big, not too numerous, not toxicologically active, and are deposited on airway epihelium as distinct from alveolar epithelium, they are relatively easily and efficiently removed from the lungs, either via what is called the ciliary escalator or by phagocytosis by lung macrophages. The airways are lined by cells which have tiny hairs [cilia] which 'wave' particles upwards towards and through the larynx. Once through the larynx they are swallowed and cease to be of any toxicological importance. Removal of inhaled particles is a silent continuous process. If irritant gases are inhaled or the air is so heavily contaminated with particles that the rate of disposition exceeds the rate of elimination, there may also be increased production of mucus by glands within the airway walls, and to a lesser extent by mucus-producing cells in the surface epithelium lining airways. In this case the particles travel upwards on the mucus-escalator along with variable amounts of mucus. If mucus production is heavy then its expulsion from the lungs may be aided by intermittent coughing.

Smaller particles which are gobbled up by lung macrophages may leave the lung within the macrophages as they take a free ride on the upward escalator. Alternatively the macrophages may find their way into lymphatics and carry their burden of engulfed particles away from the lungs to lymph nodes and ultimately the bloodstream. Macrophages are equipped with enzymes capable of destroying many of the chemicals of which particles consist. Macrophages that have picked up inert particles tend to get lodged in local lymph nodes where their presence does little or no harm.

By these various means the healthy lung can rid itself of large numbers of inhaled particles each day. However in certain circumstances things go wrong. For instance, the waving movements of cilia can be paralysed temporarily by poisonous gases. In practice this is probably not as serious a problem as was once thought. More serious is the fact that chronic exposure to irritants can destroy cilia and lead to the replacement of ciliated cells by flat, so-called, squamous cells. When this happens the capacity of the lung for cleaning itself is embarrassed and chest disease is much more likely to ensue.

Problems also arise if macrophages accumulate in the lungs because of excessive exposure to particles or because they are poisoned by the particles which they have engulfed or by gases taken into the lungs along with the particles. Such macrophages eventually die and release the proteolytic enzymes which they normally use to destroy engulfed particles. These released enzymes destroy lung tissue and thereby cause the condition known as emphysema. The lungs of genetically-normal individuals are able to neutralize proteolytic enzymes released from macrophages in this way. However, a minority of the population [ie those suffering from X1-antitrypsin deficiency] is genetically less able to neutralize proteolytic enzymes and these people are especially prone to develop emphysema as a consequence of inhaling particles into their lungs.

(vii) Asbestos

It is now widely accepted that the main reason why asbestos fibres are dangerous to health is the fact that they can behave aerodynamically like much smaller particles. As a consequence they end up in peripheral parts of the respiratory tree where there is no effective way of getting rid of them. A long thin asbestos fibre is much too large to be engulfed by a single macrophage. Although relatively chemically inert, the prolonged residence of asbestos fibres starts a lung reaction which can lead to fibrosis [asbestosis] or to two different forms of cancer: cancer of the lung itself and cancer of the pleura [mesothelioma]. There is some evidence that asbestotic fibrosis predisposes to lung cancer, but it is by no means certain that asbestos-related lung cancer is necessarily preceded by pulmonary fibrosis. The extent to which the variable chemical composition of asbestos fibres is implicated in their fibrogenicity and carcinogenicity continues to be a topic for debate. However, the importance of their physical shape is not disputed. For this reason there is a fear that other insoluble or poorly soluble fibres of the same long, thin dimensions, such as glass fibres, might prove similarly fibrogenic and carcinogenic.

Second only to radon, the contamination of indoor air by asbestos fibres is probably the serious problem as far as lung cancer risk is concerned.

Fortunately the seriousness of this risk is now widely appreciated and in developed countries, at least, the casual use of asbestos in building materials and paints for fireproofing and for heat insulation has virtually ceased. However, many older houses, offices, and other buildings still retain asbestos in their construction particularly in the lagging around water pipes. Little danger attaches to this unless the lagging is disturbed, disintegrates or is carelessly removed.

It is most unlikely that anyone would be sufficiently exposed to asbestos fibres in indoor air environments to be at risk of developing asbestosis. However, cases of mesothelioma have been seen in persons no more than lightly exposed to the inhalation of asbestos fibres so that a risk of this form of cancer and also of lung cancer from asbestos fibres in indoor air cannot be dismissed.

(viii) Polycyclic aromatic hydrocarbons [PAH]

Some compounds of this class are present in particles generated during the pyrolysis of almost any organic material. Thus, PAH are present in bonfire smoke, smoke particles in cooking fumes, fumes from kerosene heaters, and in tobacco smoke. Several PAH have been shown to be carcinogenic and their inhalation may well increase the risk of lung cancer in man. In the past the higher risk of lung cancer in cities where people were exposed to air that was heavily polluted with smoke particles, PAH have been blamed for the higher cancer risk. The levels of PAH in indoor air, except under conditions of very heavy pollution by smoke particles [ie cooking, smoking, heating fumes, or tobacco smoke], are unlikely to constitute more than a negligibly small risk of lung cancer.

(ix) Volatile organic chemicals [VOC]

Samet et al [1987] list numerous compounds that fall into this category and the sources from which they are derived. The latter list includes building materials, paints, varnishes, numerous domestic and personal care products and tobacco smoke. The concentrations of most VOC is very low most of the time and under ordinary conditions it is difficult to conceive that they could pose any real threat to health. Of course, there can be exceptional circumstances (eg glue sniffing], where serious health effects arise, but such instances are outside the scope of this talk.

(x) Ozone

Oxygen can be converted to ozone by any source of ultra violet light or electrical discharge. Copying machines as found in most offices and an increasing number of homes are a significant source of ozone. In terms of concentration required to produce toxic effects, ozone is more than 10 times as toxic as nitrogen dioxide. Exposure to a low concentration [eg 0.7ppm] for a period of 2 hours is enough to cause significant impairment of gaseous exchange in the lungs - probably because of oedema of alveolar walls [Young et al 1964]. The symptoms of excessive exposure to ozone are irritation of the respiratory tract, headache, tightness of the chest and wheezing [Challen et al 1958].

(xi) Bacteria, fungal spores, allergens, etc

By contrast with most of the chemicals considered above adverse effects on health from bacteria, fungal spores, and allergens may be frequent and sometimes serious.

The truth of the matter is that at the present time we do not really know how much illness is caused by the presence of these agents in indoor air pollution. Prior to the advent of air-conditioning systems, it was well known that people living in dirty, damp conditions were more prone to a variety of respiratory infections and rheumatic disorders than people living in dry, warm conditions. Also, it was clear that atopic individuals are at greater risk of developing hay fever, allergic rhinitis and asthma because of their exposure to the excreta of house dust mites which live on the flakes of skin shed continuously by humans.

The introduction of circulating ducted air systems has magnified old problems and introduced new ones [Robertson, 1988]. If, because of bad design, improper use and/or inadequate inspection and maintenance, moisture, fungi, bacteria, protozoa, rodents or birds etc are allowed to collect and multiply in air ducting and filter pads etc, then dangerous dusts and living bacteria may be widely circulated in high concentrations to the occupants of buildings. Some of the serious consequences of this are listed in Table 3. Humidifier fever is a typical example. This form of hypersensitivity pneumonitis is caused by antigenic proteins in cells of the amoeba, Acanthamoeba, which can thrive in the warm stagnant water of badly maintained humidifier reservoirs.

An increasing problem in recent years has been that not only persons working within buildings but even persons walking the streets outside them can be at risk from the bacterium which causes the potentially fatal lung disease Legionnaires' disease [ie Legionella pneumophila]. This disease is caused by breathing deeply into the lung very small water droplets containing the bacterium. Such infected droplets can arise from water cooling towers associated with air-conditioning plants, from the spray arising from hot water taps and from bathroom showers.

Table 2 lists the main physico chemical indoor air pollutants of medical concern in homes and offices:

Table 2 Indoor Air Pollutants of Medical Concern in Homes and Offices

SOURCE	POLLUTANTS
The earth	
Earth underlying home	- Radon
Cooking and heating	
Gas stoves	- CO, NO_2
Wood stoves and fireplaces	- CO, Respirable particles, PAH, Aldehydes
Gas-fuelled space heaters	- CO, NO_2, Aldehydes
Kerosene-fuelled space heaters	- CO, NO_2 SO_2, Aldehydes
Building materials and furnishings	
Building materials	- Formaldehyde, Radon, Asbestos
Furnishings and household products	- Formaldehyde, VOC
Other	
Air conditioning systems	- Fungal spores, bacteria, respirable particles, CO, NO_2
Copying machines	- VOC, Ozone
Tobacco smoke	- Respirable particles, CO, NO_2, Nicotine, Aldehydes, VOC
Moist materials surfaces, pet birds	- Fungal spores, bacteria, allergens
Building inhabitants including dogs and cats	- House dust, mite excreta, dandruff [danders]

KEY
CO = Carbon monoxide
NO_2 = Nitrogen dioxide
PAH = Polycyclic aromatic hydrocarbons
SO_2 = Sulphur dioxide
VOC = Volatile organic chemicals

(xii) The keeping of pet birds

Recently Holst [1988] reported that people who keep pet birds in the home have a 6.7 times higher risk of developing lung cancer than those who do not, after taking smoking into account. The only plausible explanation of this finding, which needs to be confirmed, is that the increased risk stems from the liberation into the atmosphere from the birds' cages of excess allergens and dust particles which cause pathological fibrotic changes which, in turn, predispose to the development of cancer.

Table 3 distinguishes between diseases caused by bacteria, fungi and allergens that are traditional in nature, and those that have been newly introduced or magnified by badly designed and/or badly maintained air conditioning systems.

Table 3 Examples of diseases caused by bacteria, fungi and allergens etc

1.	Traditional diseases		
	Coughs and colds and other infectious diseases		
	Tuberculosis		
	Allergic symptoms	-	House mite
	- hay fever	-	Fungal spores
	- rhinitis	-	Various other dusts containing allergenic proteins etc cotton dust, bird feather dust
	- asthma		
2.	Diseases that have been newly introduced or magnified by badly designed and/or badly maintained air conditioning systems		
	Humidifier fever	-	Acanthamoeba
		-	Thermoactinomyces
		-	Micropolyspora species
	Legionnaires'	-	Legionella pneumophila
	Lung cancer	-	Radon

DISCUSSION

In countries and situations where people live in houses where windows are always open the main determinant of indoor air quality may be the quality of the external air. Furthermore several of the problems attracting attention in developed countries with temperate or humid climates relate to air conditioning systems that do not exist in undeveloped countries, or to building materials that are not used. Under most conditions the spread of infectious diseases from person to person is the commonest hazard. In certain geographical locations and under particular circumstances the build-up of dangerous levels of carbon monoxide or high ambient levels of radon can be the most serious hazards. Priorities for action about indoor air quality, therefore, vary widely according to circumstances and to the degree of sophistication of life.

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