GUIDELINES FOR HEALTHY HOUSING

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FOREWORD

Purpose

The purpose of these guidelines is to remind Member States, Ministries of Health and Architecture, policy-makers, environmental health officers, sanitarians, planners, architects and others concerned of housing hygiene in relation to "traditional" and "new" slum housing. The guidelines are aimed at encouraging administrations to formulate a sound housing policy that helps to solve basic health-related housing problems and to meet WHO's objective of healthful housing for all by the year 2000. The guidelines also will contribute to the United Nations Harmonization Programme (Economic and Social Council - Economic Commission for Europe) on housing.

The guidelines are aimed particularly at developing middle-income countries in Europe, defined by the World Bank as Belgium, Bulgaria, Czechoslovakia, Greece, Ireland, Italy, Poland, Portugal, Romania, Spain, Turkey and Yugoslavia. However, the principles of healthy housing have universal applicability as most countries of the developed world have areas of slum or otherwise insanitary housing.

It is hoped that the guidelines will be extensively used as a reference to basic health requirements for new housing and human settlements and as a guide for assessing the hygienic quality of existing housing. It also could be used in inter-professional and community education and training programmes.

Scope

The guidelines are divided into three sections. Section 1 deals with some general considerations applicable to basic housing hygiene. Section 2 outlines the fundamental technical and social requirements for maintaining housing hygiene including the health implications, suggested control measures and examples of standards. These requirements are categorized within a series of broad parameters setting out the minimum human requirements for housing in relation to health needs. The section should be of particular interest to architects, hygienists and technical personnel. Section 3 summarizes some of the operational and organizational priorities and constraints for achieving basic healthy housing goals. This section is aimed at the appropriate policy-makers within ministries, institutions and other housing agencies.

The guidelines focus mainly on requirements in the home and the microresidential environment rather than the wider macro-environment despite the obvious inter-relationship between them. Other WHO publications cover the broader environmental health aspects of human settlements. Similarly, the lack of detailed epidemiological information relating to conditions in developing countries and the wide disparities in geography, culture, social habits and political priorities means that these guidelines are inevitably very generalized. Detailed information on specific issues is available in the technical literature and textbooks. Member States are encouraged to draw up their own detailed guidelines by relating these healthy housing principles to their own national and local conditions and priorities.

WHO has been concerned with healthy housing from its formation in 1948. Much of this interest followed from work started by the health organization of the League of Nations. It is hoped that these guidelines will add to this knowledge and will stimulate renewed and sustained discussion of a subject, which is instrumental to the health and wellbeing of the world's population now and in the future.

R.P. Ranson

CONTENTS

1. GENERAL CONSIDERATIONS

1.1 Healthy housing - interpretation

Housing should provide a safe and healthy environment for its inhabitants. Many technical, social, planning and policy factors relating to housing may affect physical and mental health and social wellbeing. These factors can be expressed in terms of basic human requirements that can accordingly be incorporated into housing standards, policies and goals of attainment relevant to an individual country's needs, resources and priorities. No universal interpretation of healthy housing is possible, but typical requirements, as outlined in this volume, can form the necessary basis.

Unfortunately, most of the world's people do not live in shelters that meet even the basic requirements. Indeed, for increasing numbers, available shelter not only fails to protect against but exposes them to health risks that are for the most part preventable. Adoption of healthy housing principles will help governments, communities and families to safeguard against such risks.

1.2 Slum housing problems in the European Region

Most of the older European cities, towns and other human settlements have pockets of housing that have deteriorated into slums through lack of maintenance and rehabilitation. In addition, many of the developing countries within the European Region are undergoing fundamental demographic and social changes as a result of rural-urban drift and the accompanying increase in their urban populations is seriously affecting housing conditions in these countries. More and more people are moving from essentially rural societies based on agrarian pursuits to urban societies built upon industrial and commercial activities. This trend is most pronounced in developing Mediterranean countries where at least five different types of slum housing can be identified: traditional slums, industrial slums, shanty towns and self-build slums, modern slums and rural slums.

1.2.1 Traditional slums

In the inner city areas of older towns, overcrowding, industrialization, air pollution and poor environmental amenities have meant that the more affluent members of the population have moved out of the centre to more spacious housing at the urban periphery, leaving poorer, older and less mobile groups behind. Poor maintenance and lack of housing investment have created large areas of "traditional slums" in the older inner city areas. Martin & Oeter [1] described these areas as

> ... at best ... a threat to the health of the inhabitants due to overcrowding, defective physical structure of the building resulting in dampness, sanitary defects, increased home accidents and lack of suitable outdoor areas for children with a consequent increase in street accidents and in children being kept indoors. At worst, the influence of less desirable members of the population results in an increase in crime, juvenile delinquency and immobility.

1.2.2 Industrial slums

These are frequently to be seen in many inner city areas where the industrial population increased greatly in the late nineteenth and early twentieth centuries. In these cases, poor quality ribbon development and terraced back-to-back insanitary housing were erected with little thought to urban planning or long-term health effects. These houses rapidly deteriorated and, like the first group, were frequently occupied by the poorer members of the population, including immigrant workers often of different ethnic origins and with different social cultures and customs. Industrial slum areas are characterized by poor environmental conditions, overcrowding and industrial pollution.

1.2.3 Shanty-town and self-build slums

Shanty-town, self-build, squatter and mobile housing (such as caravans) can frequently be seen at the edge of cities where land is relatively cheap, sometimes adjacent to industrial areas or just outside the administrative control of the city authority. These make-shift dwellings are usually constructed of salvaged materials, such as wood and corrugated iron, completely lack indoor water supplies, drainage and sanitation (including provision for waste disposal), and have no proper access roads. Indoor space requirements and air quality are poor, and inadequate building materials fail to compensate for changes in temperature and other climatic factors during the year.

The scale of the shanty-town slum is difficult to comprehend. For instance, in Ankara, Turkey, 72% of the population lives in squatter shanty-town housing despite attempts by the Turkish Government to deal with the problem through municipal housing projects and planning controls. The problem is largely economic in two ways. First, the impoverished shanty-town occupants cannot afford to own or rent housing in the planned sections of the cities. Second, they need to be near the city centre for employment, where basic housing hygiene conditions are usually appalling and communicable diseases endemic.

1.2.4 The modern slum

The modern slum is perhaps the most tragic and certainly the most difficult type to deal with. These slums resulted from cheap, quickly built, high-density, system-package developments erected in the 1950s, 1960s and 1970s to "solve" the housing problem. Far from solving the housing problem, they often worsened it. They consist mostly of slab-block or high-rise buildings frequently overlooking each other and with little thought given to the planning, layout, internal design, maintenance and public health/social consequences within the context of urban planning and healthy housing principles. Planners and architects seemed either unaware or insensitive to the fact that people actually had to live in these buildings. Many of the designs are totally inappropriate to the climatic and socio-economic conditions. As a result, many of these apartments are damp, badly lighted, often completely lacking in through-ventilation, infested with vermin (which because of the design cannot be exterminated), very hot in the summer and very cold in the winter because of poor insulation and inappropriate heating methods, inadequately protected against noise, and are in a poor state of repair because of unsuitable building materials and design. These conditions are in addition to the adverse social and mental health consequences created by high-density, high-rise developments. They are often characterized by vandalism, excessive rent arrears and difficulty in renting simply because nobody wants to live in them. In many cities, they are being pulled down because this solution is cheaper than rectifying inherent defects in their design and construction.

1.2.5 Rural slum housing

Part of the reason for rural-urban drift is the belief (often mistaken) that housing conditions and employment opportunities are better in towns than in indigenous rural areas. Information on rural housing in many countries is often scarce, but rural areas of developing countries frequently lack piped water supplies or sanitation and are overcrowded. Water supplies are often inadequate, polluted or not reasonably accessible. Invariably, facilities for disposal of solid waste, surface water and waste water are unavailable. For instance, in a study of 10 rural towns in Bosnia and Herzegovina in Yugoslavia, almost half (48.7%) of the occupants had 6–10 m^2 of housing surface area and nearly 90% lived in overcrowded conditions. In addition, most houses had inadequate disposal of human and animal excreta and sometimes no form of toilet at all.[1] Offset against this, rural areas are usually quieter and less polluted by air pollution; they also have more open space and a healthier outside environment.

A definite cause-and-effect relationship exists between slum housing conditions and incidence of disease, particularly enteric diseases such as infantile diarrhoea and parasitic infections and respiratory diseases such as tuberculosis, pneumonia and other chest infections, and above-average numbers of home accidents. The combination of poor housing, poverty, malnutrition and ignorance in slum areas is largely responsible for increased infant mortality rates and high morbidity indices for the target population. These themes are common to all countries where housing hygiene is poor.

1.3 Housing and health

Throughout recorded history, people have been concerned with having adequate shelter against the elements and developing a safe and comfortable physical environment in which to live. The degree of success in achieving these goals is largely determined by prevailing socioeconomic conditions and the influence of environmental changes arising from, for instance, industrialization or technology. As a result, many parts of the developing world face a serious housing problem as expressed by homelessness, slums and other poor-quality housing, which contribute to hazards to health and wellbeing. For instance, disease, accidents and fires are more prevalent in slum areas, and psychological and social disturbances also are partly attributed to substandard housing.

Improvement of these conditions through slum clearance, rehousing or rehabilitation is generally thought to be justifiable on humanitarian grounds because they improve the physical, mental and social wellbeing of the community for the common good. Implicit to this concept is the belief in a linear dose-response relationship between housing conditions and state of health, which can be crudely expressed as:

BETTER HOUSING = BETTER HEALTH
POORER HOUSING = POORER HEALTH

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[1] Reported by F. Cericez at the WHO Workshop on Housing Hygiene in Mediterranean Countries, Split, 1983.

However, the empirical evaluation of housing improvement in bettering health has proved difficult because of the following reasons:

- Housing and health studies have usually failed to separate or take into account the multifactoral non-housing variables that affect health (e.g. poverty, ignorance, poor nutrition and lack of medical care). Even less clear is whether or not these various factors are equally important and how they should be evaluated in a research programme.

- The direction of a cause-and-effect relationship pertaining to housing and health variables also is often unclear. Thus, if a particular housing factor is shown to be associated with a disease, the question arises whether or not the disease has given rise to the factor or whether a third set of determinants is responsible.

- Indices for measuring health and the hygienic quality of housing are often too insensitive, inappropriate and/or lack universal acceptability. This is a particular problem when assessing the intangible or aesthetic effects of housing on social wellbeing, in determining comfort levels or measuring qualitative aspects such as quality of life.

- In many cases, <u>no</u> epidemiological studies into the effect of particular housing factors on health have been conducted. As a result the causal factors of potential housing-related illnesses are often unknown or insufficiently corroborated.

Despite these drawbacks, the first WHO Expert Committee on the Public Health Aspects of Housing [2] concluded the following:

> The lack of definite measurements does not denote the absence of a relationship between housing and health. By deductive measuring a strong relationship can be established. Since the residential environment consists of many elements of the overall environment, with each element capable of exerting individual detrimental effects upon health and wellbeing, it can be deduced that the effect of the residential environment upon health is the sum of the individual factors.

1.4 Collection of data

To reach a better understanding of the etiology of housing and health, we need to know as much as possible about the relationship between housing hygiene and its effects on health. Also, a less piece-meal approach towards data collection and epidemiology is needed. Better coordination of housing/health information between the various agencies and professions involved (e.g. architects, doctors, sanitarians, social workers and police) would prove invaluable to epidemiologists, health statisticians, planners and policy-makers in understanding the etiology of housing-related diseases.

One model for achieving this goal is described in the recommended protocol of the European study of public health aspects of the indoor environment of human habitations [2]. This protocol proposes epidemiological methods to identify and evaluate health hazards with the objective of ascertaining the relationship between various elements and components of human habitations and the health of the occupants. The study requires an interdisciplinary approach using various health scientists and others to design, plan, implement and monitor the research programme and to analyse results. This is in line with recommendations of a WHO Expert Committee on Housing and Health in 1974 proposing that multidisciplinary teams be set up to examine the etiology of housing and health [3].

1.5 Interaction of housing conditions and disease

In determining the inter-relationship between housing conditions and specific diseases, account should be taken of the interaction of three factors on which the hazard potential for causing toxic, traumatic or pathogenic effects on humans depends:

- the dose of the causative agent as measured by the intensity, frequency and/or duration separately or in combination with other agents and factors;

- the susceptibility of the host to the causative agent;

- the environment in which the interaction between host and agent may increase or decrease the toxicity, injury potential or pathogenicity of the potentially harmful chemical, physical and biological agent [2].

The major diseases possibly related to a poor housing environment can be crudely divided into communicable diseases and non-communicable diseases. They have a greater or lesser effect on physical health, mental health and social wellbeing.

Most housing and health studies have dealt specifically with the effects of housing on physical health and only a few with psychological or social illness. For instance, by 1962, of 14 selected European studies dealing with some aspect of physical health, 8 investigated solely the relationship between housing and tuberculosis, 5 analysed general morbidity rates, death rates, birth rates and infant mortality caused by respiratory diseases, and 1 studied the height of preschool children. By contrast, of 24 selected American studies, 10 dealt with physical diseases and studies of general morbidity while the remaining 14 studies dealt with social and psychological matters with a marked interest in a single topic. Of the 14 studies, 7 dealt solely with juvenile delinquency.

Most of the findings showed a marked positive association between housing and health: poor housing correlated with poor health, and better housing with better health. Some mixed, ambiguous or null findings and a very small number of actual negative findings were reported. Of 24 studies reviewed (14 European and 10 American) involving physical morbidity, 15 showed positive findings, 7 seemed ambiguous or showed no relationship between housing and health, and 2 arrived at negative results. Of 16 studies dealing with some aspect of social adjustment, 11 found a positive relationship to housing, 4 gave ambiguous or null results and 1 was negative [4].

The difficulties in establishing a relationship (if any) between housing and mental health or psychosocial disorders lie in the subjective nature of the symptoms and the indeterminate influence of other factors. As a result, clear cause-and-effect relationships based on facts are difficult to establish [3].

In many Eastern European countries, health and housing administrations are required to lay down specific environmental standards. This requirement has resulted in extensive research data dealing with the potential toxic effects of new chemicals used in housing and house furnishings, the efficiency of heating and ventilation systems, and insulation and housing design as they affect indoor microclimates. However, more information is needed about the potential carcinogenic or other adverse health effects due to use of certain construction materials, and the role of ergonomic housing design in comfort and wellbeing. Detailed epidemiological studies into the causes of home accidents also are needed. Similarly, little research has been carried out on the effects of indoor air quality on health, although considerable information is available on the chronic effects of outdoor air pollution on respiratory diseases such as bronchitis and lung cancer. Various research programmes into these problems are currently being undertaken by the WHO Regional Office for Europe in collaboration with research institutions. The information from these sources and from individual Member States can then be distributed and exchanged, particularly to avoid costly mistakes caused by poor planning and housing design in the future.

Member States are encouraged to establish their own coordinating centres from which information resources can be collated, if necessary, with WHO collaboration.

1.6 Parameters of health

Before an analysis can be made of healthy housing requirements, clarification is needed on the meaning of the term "health", which can be interpreted in various ways. WHO defines health as "not merely the absence of disease and infirmity, but a state of complete physical, mental and social wellbeing" [5].

Health has also been described as "an absolute condition of wellbeing" or alternatively "an optimum capacity of effective performance of value tasks" [6]. These different views of health have an important bearing on health models and subsequent health care services, standards and policies. In general terms, health is normally assessed by reference to deviant behavioural indicators, such as physical, mental or social pathologies. These indicators are often difficult to apply to wellbeing as many doctors fail to recognize them, treat them symptomatically, or are unwilling or unable to remedy the underlying cause.

Examination of current health models confirms the limitation of diagnostic and prognostic methods in dealing with physical, mental and social health needs. At present, developing countries are concerned mainly with biomedical conditions, while the developed countries are turning to biopsychosocial models of ill-health. The main reasons for this difference are changing patterns of disease and consumer expectations: developed countries have largely eradicated infectious, nutritional and other acute diseases through preventive and remedial action but are left with unabated degenerative, chronic and psychosocial diseases, which have a much more complex etiology.

In terms of housing, information about epidemiology and identification of causal factors rarely includes biomedical, psychosomatic and social pathologies. As a result, little is known about the contribution made by housing in causing stress-related diseases such as hypertension, migraine, depression, neurosis, alcoholism and social diseases manifested by pathologically derived antisocial behaviour (e.g. crime, violence, street mugging, vandalism, child abuse, and mental or sexual ailments). Without detailed cause-and-effect studies, remedial action cannot be precise, and symptomatic medical treatment is unlikely to be the only course of action available to sufferers of bad housing. However, this analysis takes no account of the intuitive or pragmatic considerations that often guide patients, doctors and others in coming to certain decisions about the causation of particular illnesses. Thus, in many cases, patients ascribe their state of ill-health partly or wholly to the state of their housing. For example, common colds and chest conditions are often blamed on damp and cold housing. However, intuitive considerations alone are often suspect as patients may be unaware of or unwilling to accept concomitant ill-health factors that are often present. Conversely, patients, doctors and health officials may be unaware of the etiology of a particular housing-related illness or be unable to help abate causal factors. Thus, unless healthy housing policies form part of a primary health care programme, housing and medical practitioners are unlikely on their own to be able to prevent housing-related illnesses. Clearly, people suffering from illnesses and disease need treatment while at the same time the insanitary housing and environmental conditions that caused them are removed. Unless this is done, re-exposure to the conditions will merely cause re-infection and recommencement of the treatment cycle.

1.7 General healthy housing needs[1]

We spend an estimated two thirds of our life within the home and its immediate surroundings. The health of each occupant is potentially at risk from an insanitary or otherwise unhealthy housing environment. However, the groups who spend most time in the home are children, mothers with young children, the elderly, disabled persons, the chronically sick and the unemployed. These groups can be expected to be disproportionately affected by poor housing conditions and also usually have special health and housing needs. Thus, housing suitable for general needs may not be suitable for these groups. In addition, considerable variation in healthy housing needs can be expected within these groups, a factor that would need to be taken into account in technical and policy requirements.

Nevertheless, common human health requirements can be identified in relation to housing. These are generally described in terms of the negative effects of the residential environment on health rather than in terms of the positive effects of "good" housing in maintaining and promoting good health.

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[1] An invaluable reference guide to the etiology of housing and health is contained in reference [7].

Thus, poor housing may affect <u>physical health</u> in at least three ways:

- it may facilitate the transmission of communicable diseases;
- it may interfere with physiological needs;
- its design or construction may cause injury to health.

The maintenance and promotion of mental health and social wellbeing are more difficult to define. However, as housing provides the scenario for family life, recreation, rest, sleep and social interaction, it follows that many aspects of poor housing, such as overcrowding, noise, air pollution, bad odours or dampness, give rise to considerable dissatisfaction and annoyance and perhaps contribute to poor health. Conversely, comfortable, pleasant surroundings aid satisfaction and facilitate the maintenance of friendly interpersonal relationships. Housing also forms part of the wide social setting whereby communities are formed and institutionalized. Community infrastructures are extremely important to individuals and the community alike, particularly in times of hardship or illness.

A healthful environment must therefore do more than merely limit the occurrence and spread of physical diseases and infections. It must permit individuals of all ages to conduct useful household activities without undue fatigue and without putting an excessive burden upon any organ of the body. The housing environment also should be comfortable, pleasant and provide a social setting for active and passive recreation, rest and exercise [2].

2. TECHNICAL AND SOCIAL REQUIREMENTS

The technical and social requirements of housing can be defined by a number of parameters likely to be relatively constant to basic healthy housing needs anywhere. For example, as long ago as 1939, the American Public Health Association devised a set of housing principles that were widely adopted for housing hygiene policies in a number of countries and are still largely applicable today [8]. However, the detailed control measures, standards and policies have changed and will vary in accordance with national, political and economic considerations. Wide differences in technical and social requirements also exist in rural areas compared with urban ones.

In terms of developing middle-income European countries, financial constraints largely determine what can be provided; inevitably the interest tends to be in minimal rather than optimal requirements and solutions. Control measures that require heavy capital investments have therefore been excluded from these guidelines.

In some cases, the technical and social requirements could be included in several different categories, and individual requirements should therefore be considered as part of an overall programme. For instance, the impact of physical factors upon social wellbeing means that technical and social factors often cannot be divorced. Similarly, the overlap between purely "health" considerations as opposed to "safety" provisions makes any distinction arbitrary. Nevertheless, providing that a holistic approach is taken, the basic framework should serve as a useful guide for architects, planners and others designing new settlements and dealing with the problems of existing housing.

2.1 Housing layout requirements

2.1.1 High-rise flats

In the post-war period, many countries built tall housing blocks as part of high-density developments, usually in response to an acute housing shortage or as part of a slum clearance programme. Shortage of land on which to build and the need to build housing within reasonable travelling distance of the workplace and city centres meant that residential densities were often very high although, in theory, reasonable indoor space norms could be achieved simply by building blocks of flats that much higher. However, high-rise flats are generally not socially suitable for family housing, and capital and maintenance costs of high flats are usually higher than of the normal type of two-storey housing.

In many cases, high-rise flats were system-built and erected using cheap and unsuitable building materials with little or no consideration given to healthy housing design, indoor air quality and indoor climate. As a result, living conditions are often extremely poor and a new generation of slums has been created.

(a) Health effects

A number of studies have examined the health effects of living in flats compared with houses or other types of development. For instance, an increase in illness has been found in flats: twice as many upper respiratory infections were found in children below the age of 10 who lived in flats as compared with house dwellers.

These findings were supported by research by Fanning [9] who studied two groups of families of members of the U.S. armed forces stationed in the Federal Republic of Germany, one group living in flats and the other in houses. The morbidity of families living in flats was 57% greater than of those living in houses. The greatest differences were seen in the incidence of respiratory infections in young women and children and of psychoneurotic disorders in women. The reasons for the differences in respiratory infections were felt to be due to the relatively small space available in a flat compared with that in a house and confinement of the family within the flat. This confinement and the resulting social isolation were thought to be the reasons for the increase in psychoneurosis in the women. Fanning suggests that further investigation is needed into the effects of flat life, particularly the individual causal factors that might account for the differences in morbidity patterns.

Factors in flats that might affect the physical health of occupants include poor indoor air quality and climate (which depend upon ventilation requirements, adequacy of heating methods and thermal insulation), inappropriate home safety design, insufficient indoor space provisions, and use of toxic or otherwise unsuitable building materials. The risk of children being killed or severely injured by falling from windows and balconies is much higher in homes above the first floor. Also, children's play activities are more restricted by multistorey living. The lack of access to fresh air and a garden by children and mothers alike means that they spend more time indoors, thereby increasing the risk of contracting respiratory infections and other communicable diseases.

Factors that might affect mental health of flat dwellers are much more diverse and difficult to define, particularly as they are usually inter-related with other factors not necessarily peculiar to flats or that might be applicable to one flat development but not another (e.g. location in relation to the town centre, transport, recreation facilities and hospitals).

Numerous research studies have shown that mental health indices of flat dwellers vary considerably with the type of development in terms of access (e.g. stair access, balcony access, deck access or tower block access), noise insulation values, number and ages of children, income level, marital status, proximity to friends and family relations, satisfaction with area and design of living accommodation. In fact, no generalizations can be made as some people like living in flats. Indeed, many single, working or childless couples prefer flats to traditional housing where additional maintenance responsibilities, gardening, etc., may be a source of worry. The advantages of high-rise flats is that they often provide good views, privacy and solitude from busy and noisy city areas below.

By contrast, numerous social studies of families living in flats have shown a disproportionate dissatisfaction with living on the upper floors (normally considered to be above the fourth floor level) and that this can in many cases adversely affect mental health. For instance, a major survey into the effects of flat living on families carried out by the United Kingdom Government between 1977 and 1978 highlighted the effects that mothers felt this had on their health and emotional state as well as identified the perceived causes of dissatisfaction [10]. The study showed that two fifths of mothers of families who had moved from higher storeys to lower floors of multistorey blocks said their health, particularly their emotional health, had improved. Those with children over 5 years of age felt they had benefited less - a reflection perhaps that some health problems connected with looking after toddlers are transitory and improve as the children get older. Mothers who moved down claimed that they were less irritable, slept better, and were less effected by nerves, depression, feelings of loneliness or a sense of being cut-off compared with when they lived on the higher storeys. In all cases, this change was more directly related to the age and number of children, size of income and type of access provided to the flats. A greater improvement in health was felt by low-income mothers with younger, larger numbers of children compared with other groups who also had previously lived on the upper storeys of flats, particularly tower blocks, which were the most unpopular form of housing in terms of mental illness. These health problems did not necessarily disappear when the people moved to lower storeys, but mothers and children <u>were</u> able to identify particular benefits that had eased worry and anxiety.

The United Kingdom study made a number of conclusions that have been shared by a number of other European countries:

1. Mother's dissatisfaction with their housing and mental illness increases the higher up they live, which in turn adversely affects their children's development.

2. Fear of being trapped in lifts prevents many school-age children from going out to play. This in turn can isolate them and reduce their ability to make friends. This applies particularly to children under 5 years who are probably more adversely affected by their mother's dissatisfaction with the housing than the older age groups.

3. The risk of a child being killed falling from his home is 57 times higher if he lives above the first floor level than if he lives on the ground or first floor.

4. Mothers with preschool children, particularly those with more than one child, are most dissatisfied with living off the ground and feel more cut off, isolated and depressed compared with mothers of school-age children.

5. There is no evidence of an increase in management problems arising from transfers of high-rise families with children to lower floors.

6. The allocation of dwellings on the lower floors of flats is more likely to be acceptable to families if lift access is available. There is some indication that maisonettes rather than flats are more satisfactory for family living, possibly because of increased opportunity to segregate the living area in the same way as a house (e.g. in putting children upstairs to bed). However, some countries have found that additional indoor space can help alleviate tension by providing more opportunity for privacy of individual family members.

In general, the psychosocial problems of living on the upper floors of high-rise buildings appear to be caused mainly by the lack of opportunity for contact between residents (this is true in all high-rise buildings but is exaggerated in tower blocks where the lift is usually the only common point of contact with neighbours). The social isolation felt by women in high-rise flats was described by Stewart [11] who had interviewed women who said they had not seen a neighbour for 3-4 weeks and reported going to the rubbish chute twice a day in the hope of meeting somebody.However, the need for such contact depends partly upon the individual, how much time is spent in the building and how much social contact is made outside. Thus, working people with plenty of contact with people during the day may welcome the sanctitude and solitude of an apartment socially isolated from other dwellings. On the other hand, housebound single people, such as the elderly, may become depressed by the loneliness and the lack of contact with others. Children undoubtedly need the stimulation of and opportunities for mixing with other children often denied to them in high-rise housing.

In addition, some evidence shows that children living in high-rise flats fail to acquire a sense of security, curiosity and later ability to explore and experiment, thus impairing normal personality development [12].

(b) Control measures

- Many countries have decided to restrict the building of new high-rise residential buildings. For instance, the Netherlands is attempting to limit residential buildings to six storeys and in the Republic of Ireland, the Building Corporation has decided to build no more dwellings higher than three storeys. However, in practice, much must depend on land resources, housing demand and degree of homelessness.

- In general terms, high-rise blocks of apartments are not normally suitable for housing families with young children and for housing single elderly persons who do not want or are unable to cope with the difficulties of high-rise living. This should be taken into account when planning new housing development and in allocating public housing. Preferably, young families should not be allocated flats at all but should be housed in traditional single- or two-storey housing with a garden, but where this is unavailable, allocation on the lower floors of multistorey blocks is preferable (i.e. below the sixth floor). In these cases, lift access should be provided.

- Housing managers should be aware of the management problems of re-housing people accustomed to living in single-storey housing into flats. This applies particularly to rural immigrants with close community ties who often have great difficulty adjusting to living in high-rise housing.

- To make the best use of resources, local housing services, education, recreation, health and social service departments and voluntary organizations should review together what facilities are in close proximity to multistorey family accommodation. In this way, gaps can be identified and consideration given to remedying deficiencies.

- Community facilities must be situated as near as possible to the flats. In some cases, community halls have been successfully provided by converting flats on intervening floors above ground level.

- Existing high-rise flats in central areas may be useful to accommodate some office workers and business executives who are single or married without children (assuming the wife also holds a job outside the home).

- In all cases, sufficient attention must be given to avoiding the difficulties created by high-density housing through good housing design and management. This can be done by ensuring that the following amenities are sufficient: play facilities for children; noise insulation of flats; facilities for drying clothes, space for parking cars, bicycles, etc.; facilities for hobbies; arrangements for refuse disposal; fire protection; and social arrangements to help people adjust to high-rise living - particularly the elderly and young families. Regular inspection and maintenance of lifts are especially important to keep them in good working order, and security arrangements must be adequate.

2.1.2 Low-rise, high-density housing

Low-rise, high-density housing is an alternative to high-rise, high-density developments. These schemes successfully overcome some of the problems associated with high-rise apartment buildings, such as the need for and reliance on lifts (which can break down), and they engender a greater sense of security. Mothers of young children show a marked improvement in mental health when moved to lower storey flats [10]. Low-rise, high-density development also is somewhat less expensive in terms of capital and management costs.

The disadvantages of these schemes are that they do nothing to alleviate the problems of density and space. In fact, pressure on space at ground level becomes even more intensive with low-rise building because a higher percentage of the site is covered with buildings. This means that open space, greenery, play space and recreational facilities are provided at a premium, causing poor environmental conditions. The situation becomes particularly difficult if provision has to be made for parking cars. Nevertheless, in overcrowded city areas where land for building is in short supply, low-rise, high-density housing often fulfils a useful role by accommodating small families and childless couples and, if properly allocated, could cater to the majority of housing needs of mixed community groups.

2.1.3 Traditional housing

Traditionally built single- or two-storey terraced, detached or semi-detached housing is the most common form of housing development in many developed and developing countries. However, high-rise or low-rise flats and apartments are gradually superseding traditional housing in urban areas where land is at a premium. Traditional housing is generally popular with residents because it allows a variety of design and construction materials, uses relatively simple building techniques, offers easy maintenance and cleaning, and brings independence from communally shared amenities. Compared with multistorey developments, traditional housing generally has less nuisance from transmitted noise, easier means of escape in case of fire, handier refuse disposal, and when a garden is provided, greater opportunities for recreation and play. The problems of alienation, loneliness and distorted sense of perspective of the outside environment also are thought to be less compared with those of multistorey flats.

In general terms, traditional housing is most suitable for families, provided that reasonable housing density requirements can be met. Obviously, terraced housing offers better opportunities for obtaining higher housing densities compared with detached or semi-detached dwellings, which are also costlier to build, maintain and heat. However, dwelling size, mix and type also depend upon other factors, including consumer demand, age distribution of population, desirability of neighbourhood, and location in relation to cities, towns and employment.

2.1.4 Mixed dwelling layout

Many authorities faced with acute housing shortages have successfully adopted mixed development schemes comprising two- or three-storey houses for very large families, four-storey maisonettes for families with two to four children and tall blocks for the remainder. The ratio of each development depends upon the overall density to be achieved and the need/demand for a particular type of housing. Nevertheless, reasonably high densities often can be achieved by using mixed developments without sacrificing basic healthy housing principles.

The main advantage of mixed development schemes is in encouraging a diversification of residents in terms of age groups, interests, and socioeconomic and cultural backgrounds, which in the long-term usually results in better community and social interaction. This point is particularly important to elderly or disabled people who are often based in nursing homes or hospitals and effectively cut off from the wider community.

2.1.5 Spacing

Providing adequate space between buildings is of central importance when planning the micro-environment. The principal features of badly spaced housing include intrusion of view and privacy, overshadowing (which reduces sunlight and daylight) and in some cases reduction of air circulation around buildings, which could reduce ventilation to rooms. Poor spacing standards are usually (but not always) associated with high residential densities and overcrowding.

(a) Health effects

The indirect health effects of badly spaced buildings concern those diseases and conditions associated with poor natural lighting, sunlight deficiency and gloominess due to the absence of view. In addition, fire has a higher chance to spread across narrow streets or to neighbouring buildings.

(b) Control measures

- Spacing standards are often applied as a legally enforceable planning control for new housing developments and also as a factor in assessing slum clearance options. Spacing standards should be applied with flexibility and consideration for other factors that might necessitate their relaxation. In some cases, selective demolition of buildings causing overshadowing will alleviate the situation.

- A spacing standard widely used in England and Wales recommends that a general width of 21.5 m should be provided between parallel rows of dwellings to safeguard privacy, sunlight and daylight [13]. This standard is appropriate mainly for housing with a private front garden (or space for cars). It stipulates a minimum distance of 6 m between the footpath and house, assuming that the verge is 2 m in width with a 6 m-wide carriageway. Earlier spacing standards prescribed a spacing of 1 m along new streets, where front entrances opened directly onto the footpath.

- Current Scottish Building Regulations set a minimum horizontal distance of 18 m between mutually visible habitable room windows of one dwelling and those of another and lesser minimum distances down to 2 m, where such windows are set at an angle to each other. The main intention of this requirement is to preserve privacy [14].

- In practice, spacing standards vary considerably with layout and concern for privacy. For instance, a spacing standard [15] applied for development control purposes by one planning authority requires that "if a living room is overlooked from an opposing dwelling or curtilage, the minimum eye to eye distance shall be 35 m". (This applies in the private zone side, normally the rear of the dwelling.)

2.1.6 Orientation of buildings

The orientation of houses and other buildings is an important factor in the planning and design of new housing developments. In hot countries, correct orientation helps ensure that buildings are not overheated by the sun and that at least one cool, shady room is available within the house. Conversely, in cooler regions, radiation can be used to warm dwellings by facing them towards the sun. Orientation planning also has to take account of other climatic factors such as wind direction and strength, which in cold regions can cause excessive infiltration of outside air. In these cases, windbreaks and technical measures should be employed while concurrently maximizing sunlight into living quarters through correct orientation. Marked differences will inevitably occur in orientation of buildings in warmer and cold climates, but orientation also depends upon site arrangement and the purposes for which rooms are used. In particular, natural lighting requirements of rooms often form an important factor in orientation.

The overall objectives of these design measures should be to ensure that buildings do not overshadow neighbouring property and that buildings in a proposed housing layout are so spaced as to satisfy not only the requirements of sunlight and daylight but also that they are not too near to each other as to intrude on privacy. Contrariwise, the close-knit character of an old town centre may justify closer spacing of new buildings than would normally be desirable. Nevertheless, this consideration should not prevent careful design for sunlight and daylight in the detailed arrangement of open ground, walls and windows.

The ideal orientation of housing allows all sides of the building to be exposed to the sun for some period of the day. Living rooms should receive maximum sunlight, but in hot climates, orientation would need to help keep these rooms from becoming excessively hot. In hot countries, housing is usually planned for coolness by designing rooms oblong in shape with the short axes running NS or NNE and SSW [16].

2.2 Space and density requirements

2.2.1 Housing densities

Different ways can be used to express residential housing densities as a measure of housing hygiene in a particular area. The objective of residential density norms is to prescribe limits for occupation of residential land compatible with good environmental conditions and planning criteria.

The gross density of an area is the product of the area and population of the neighbourhood, but housing densities are frequently expressed in terms of the net residential density or the number of habitable rooms per hectare. Another way of expressing density is by using persons per hectare, which has the advantage of giving direct numbers for planning environmental conditions, institutions and services, etc. A further distinction can be made between family housing and non-family housing and the need to define child densities in individual housing developments. Other indices of population and construction density and open space include the following: total residential floor area in relation to average height of buildings and the total area occupied by buildings and space surrounding buildings; ratio of vacant lots to total number of lots in neighbourhood units and the density of structures or arrangement interfering with light, solarization, ventilation and circulation; percentage of neighbourhood devoted to playgrounds, parks and other open areas for recreation and relaxation; and nearness of residential neighbourhoods to major parks, beaches and other major outdoor open spaces and green belts. High-rise, high-density developments theoretically provide more open space per person within a given area compared with low-rise developments with similar occupancy levels. A distinction therefore has to be made between these individual environmental physical planning requirements when considering housing hygiene and also between indoor space norms for the shelter itself.

(a) Health effects

High residential density within a given area can lead to unhygienic conditions and the spread of a number of communicable diseases as well as increased road traffic accidents (particularly where road traffic is not separated from pedestrian areas). However, reports on the relationship between population density and disease are ambiguous: some studies show a relationship between population density and health status, particularly overall mortality, lung cancer and cardiovascular diseases, while others do not.

However, noise levels are higher in areas with high residential densities, which can aggravate stress-related diseases. High densities of children in housing developments and parental dissatisfaction with housing are related. However, whether any correlation exists between high densities and emotional disorders or whether this is merely an artifact of other unrelated factors is not known.

(b) Control measures

- Residential density standards can be usefully incorporated into planning briefs for new housing development plans and comprehensive redevelopment or area improvement schemes. However, the problems in achieving optimum density standards cannot be overcome by planning controls alone. Problems of enforcing densities in overcrowded regions are inextricably linked with the available supply of suitable housing and the demand for accommodation. When demand outstrips supply, high residential densities inevitably result.

- A number of countries have included guidelines on desirable density norms into long-term development plans. For instance, the Greater London Development Plan recommends the following density standards for local authorities in the region:

  - In schemes with a housing mix with dwellings for families with children and in schemes designed for non-family households, the overall density should not normally exceed 250 habitable rooms to the hectare and should provide low-rise dwellings for that part of the accommodation to be occupied by families wherever possible.

  - Schemes that are mainly for family housing should, however, be at somewhat lower densities and should not normally be above 210 habitable rooms to the hectare.

  - To avoid the wasteful use of land for housing and infrastructure resources, the minimum density should be 175 habitable rooms to the hectare.

  - Higher densities that would not otherwise be permitted may be suitable for non-family housing up to a maximum of 350 habitable rooms to the hectare in locations with mixed developments of housing and commerce [17].

2.2.2 Floor area

The indoor space requirements for households depend upon the cultural, social and economic status of the population involved. There is thus little consensus concerning space requirements or the way in which space is appropriated within a dwelling unit despite the importance of indoor space in satisfying human requirements for health, safety, family life, privacy, rest, and domestic, recreational and social activities. Indicators of indoor space are normally expressed in terms of crowding indices or at low space levels in terms of overcrowding. Indoor space (i.e. the living area within the dwelling unit) is normally divided into dwelling space areas, such as living rooms, bedrooms and kitchens, and ancillary space, such as corridors, stairs and storage areas. The size, shape and number of rooms should be able to accommodate the activities normally carried out in these rooms, minimize the spread of infection, ease mental stress and accommodate the social needs of the household. For example, young children require less space than teenagers, teenagers of different sexes should ideally not have to share bedrooms, and the husband and wife normally prefer bedroom accommodation separate from other family members. Indoor space also may be used for non-residential purposes, such as outwork or small cottage industries; separate non-residential shelter may be needed to house domestic animals.

Indoor space levels are often extremely low in many developing countries in the European Region, particularly in urban centres as a result of rapid urbanization, rural-urban migration and uncontrolled population growth.

For example, in Turkey, which has one of the highest occupancy rates in the Mediterranean area, the annual increase of the urban population was 4% between 1975 and 1980. According to the 1980 census, the ratio of the urban population to the total population increased from 18.4 to 45% between 1950 and 1980 [18]. This is much higher than the growth level of industrial development and has created problems of unemployment, low-income levels, squatter settlements, overcrowding and above all poverty. The true relationship between overcrowding and poverty was illustrated by a survey of 60 houses in Ankara, where 72% of the population lives in squatter housing. The average low-income group house has 2.2 rooms and is 61 m^2 in size (ranging from 23 to 114 m^2) with an average occupancy of 4.48 persons (i.e. 14 m^2 total floor area per person). By contrast, the average upper income house has 3.9 rooms and is 109 m^2 in size (ranging from 38 to 212 m^2) with an average occupancy of 3.33 persons (i.e. 33 m^2 total floor area per person).

Table 1 gives further examples of occupancy densities in developing countries. In many of these countries, a family of perhaps four to six persons may live in one room.

(a) Health effects

Epidemiological studies have shown a positive association between crowding and respiratory diseases spread by transmission of infectious pathogens through air by droplet infection or aerosols. Crowding increases the risk of volatile infections (measles, rubella, rhinoviruses, influenza), droplet-transmitted (coughing, sneezing) infections, such as tuberculosis, pertussis, diphtheria, cerebrospinal meningitis, viral meningitis, and colonization by endogenous pathogens producing pneumonia and bronchopneumonia.

Research studies carried out at the Budapest National Institute of Hygiene in Hungary have shown an added correlation between increased frequency of respiratory infections, such as bronchitis, rhinopharyngitis and tonsillitis in children aged 1-3 years living in overcrowded housing, especially if subjected to environmental air pollution (P. Rudnai, personal communication, 1985). This has been explained by the adverse effect of air pollution on the defence mechanism of the organism and the increased possibility of pathogen transmission that overcrowding brings.

Enteric diseases also are often more frequent in overcrowded housing. This can be partly explained by the increased opportunity for cross-infection through person-to-person contact and by indirect contact with the poor sanitary conditions often associated with overcrowding.

However, it is not true to say that crowding elicits infectious diseases or that these diseases would not be spread in uncrowded conditions: the relationship is multilevel and complicated, but crowding increases vulnerability to possible infections by increasing frequency, duration and mode of contact between people and infectious agents. Thus, a sufficient dose of the pathogenic agent in respiratory illness (e.g. influenza, pneumonia and bronchitis) is readily spread, usually through air, in crowded and ill-ventilated rooms where people are coughing, sneezing or merely talking [20]. The sharing of beds by family members increases the transmission of airborne infections, and risks are exacerbated by the large variety of respiratory infections typically found in public places and the limited acquired immunity of the ambient population to respiratory diseases.

Studies by Stein in Edinburgh and Glasgow show a clear link between tuberculosis and the very severe degree of overcrowding in these two cities [21]. However, in addition to bad housing,

Table 1. Density of occupancy in selected developing countries [19]

Country	Average no. of persons/room			% of persons 1.5+ per room			% of persons 2.0+ per room			% of persons 3.0+ per room			Year
	R	U	T*	R	U	T	R	U	T	R	U	T	
Morrocco	2.6	2.1	2.1	84.7	69.8	78.8	77.3	61.4	71.0	47.4	34.4	42.3	1971
Turkey	NA	NA	2.2	NA	NA	66.9	NA	NA	52.3	NA	NA	28.1	1970
Yugoslavia	1.5	1.3	1.4	53.8	39.8	47.8	36.3	23.5	30.8	11.4	6.1	9.2	1971
Romania	1.4	1.3	1.4	45.8	38.5	43.1	30.5	23.3	27.8	11.0	6.7	9.4	1966
Bulgaria	1.1	1.3	1.2	31.8	47.0	38.4	18.8	28.6	23.1	5.7	8.9	7.1	1965
Czechoslovakia	1.1	1.0	1.1	22.4	21.6	21.9	14.6	7.5	10.4	3.0	1.2	1.9	1970

* R = rural; U = urban; T = total.
NA = no information available.

poverty, malnutrition and poor environment have long been linked with tuberculosis. In addition, there are difficulties in distinguishing the significance of income, nutrition, occupational hazards and social class from poor housing in the etiology of the disease [22]. In the developed countries, the spread of tuberculosis is now primarily linked with the presence of infectious cases. Although overcrowding is a subsidiary factor in the spread of the disease, it is no longer used as an index of housing deprivation. However, in developing countries with poor medical treatment facilities and poor sanitary conditions related to serious overcrowding, the association may still be prominent and relevant, and the number of cases of tuberculosis, especially among children, is still unacceptably high.

In general terms, children form the group most at risk from the effects of density and crowding on health. One study revealed retarded skeletal maturation in crowded children [23] and another reported a correlation between psychoneurotic disorders in later life and living in crowded dwellings in childhood [24]. Also, the housing conditions in a UK national child development study showed that children in crowded homes missed more school for medical reasons (mainly bronchitis), that boys from crowded homes were slightly shorter than non-crowded boys and that children from crowded homes had lower scores for both reading and math attainment at the age of 16 [25]. No reasons are suggested for these findings, but educational attainment probably depends partly on the home environment. For example, Wilner et al. [26] noted that one consequence of crowding was lack of sleep for family members. Thus, lack of sleep may cause a child to be regarded as backward and incompetent in school, and have an adverse effect on his education. Burn and scald injuries to children are higher in crowded houses, particularly those without separate cooking and lavatory accommodations for each family and without adequate indoor playing space [27].

Overcrowding also may promote disturbances in mental health by creating confusion, noise and lack of privacy, which may lead to low self-esteem, depression, feelings of annoyance and interpersonal conflicts. For instance, Brandon [28] has suggested that overcrowding, lack of privacy and lack of housing facilities may create a situation where violence may erupt when some triggering factor operates. However, adaptive mechanisms help to compensate for the adverse health impact of crowding on social organization and stress responses can be expected to depend on socioeconomic and cultural factors. Overcrowding also may increase promiscuity and incestuous relationships, which can add further tension and stress within the family.

(b) Control measures

In the developing countries, space norms and crowding indices are primarily an artifact of socioeconomic and cultural status. Short-term remedies for controlling overcrowding are complex, costly and often intrinsically insoluble. Policy makers are often confronted with the problem of dealing with the effects of overcrowding without being able to deal with the underlying causes, that is, in stemming uncontrolled population growth and urbanization. A long-term comprehensive planning strategy must therefore address these issues by improving rural conditions, employment opportunities and fiscal support measures aimed at discouraging further urbanization or setting up family planning schemes and other measures to encourage birth control and restrict family size. At a local level, the optimum design of indoor space at the planning stage will enable additional housing space to be provided comparatively cheaply at a later date when economic conditions improve or demands for space decrease. This policy is favoured in the USSR and other Eastern European countries and provides a better match between supply and demand for dwelling space. However, it does little to increase immediate space levels where demand exceeds supply despite rigorous management and legal control over space allocation.

In reality, good space planning is a sensible compromise between functional and performance requirements and minimum overall floor areas for the dwelling that are themselves dependent upon space availability. Space planning (which is based upon the size of the family and the activities the occupiers want to pursue within the home) assumes a detailed knowledge and understanding of people's housing needs and is much to be preferred to standardized numbers, sizes and layout of housing unit - providing of course that sanitary design norms can be maintained (e.g. by ensuring that lavatories do not interconnect with other rooms or that kitchens are kept separate from living room areas).

Overcrowding in urban areas is caused chiefly by a shortfall between the supply and demand for housing that people can afford to rent or buy (i.e. occupancy rate decreases in proportion with an increase in income levels). Thus, in the high-income groups, the family is smaller and the number of rooms increases, resulting in a lower occupancy rate, while in the low-income groups, the family is bigger and can afford fewer rooms, which subsequently have a much higher occupancy rate.

This situation does not necessarily improve as economic conditions get better, because in this situation land prices and rents are pushed up and the poor have to pay more for the same or (depending on demand) less living space. The economics of the market place thus determine occupancy rates and can be compensated by social intervention in the market to provide uncrowded housing space at a price that people can afford to rent or buy. In fact, space standards in the developing countries are likely to be a balance between a number of economic and planning factors, as reflected by housing investment resources, land availability and political/social/ cultural constraints. However, in some communities, "crowding" is not perceived as being detrimental to health or family enjoyment but is an established part of the way of life and social tradition. In these cases, removal or control of the negative effects of overcrowding would be preferred to family disintegration, compulsory removal or insensitive re-settlement policies. Examples of suitable action to control overcrowding are detailed below.

- The negative effects of crowding, such as transmission of certain communicable diseases and increased likelihood of home accidents, can be controlled by maintaining satisfactory indoor air quality and home safety measures.

- Large-scale provision of suitably designed low-cost housing that low-income groups can afford to rent or buy should be instituted. Such buildings should be built to absolute space standards with the facility to enlarge or add on further rooms as the need arises or as economic conditions improve. The long-term aim should be to optimize space standards to enable occupants to work, rest and play in reasonable conditions of comfort.

- Housing should be regarded as part of the whole environment. Where environmental air pollution is high, consideration should be given to requiring higher space standards.

- The renting of dwelling space in public and privately rented housing above permitted occupancy standards as prescribed by housing codes and implemented through a licensing scheme or tenancy agreement should be prohibited.

- Social intervention in the housing market may be necessary to prevent land prices and rents from exceeding the ability of low-income groups to pay for uncrowded housing space. This may be achieved by publicly subsidizing new house building, regulating land prices, controlling rent levels, providing housing benefit payments to low-income groups to assist with house purchase or rent, or providing interest-free loans or cheap building materials to prospective house builders.

- To reduce crowding in urban areas, new towns and urban satellites can be created, which an also provide employment opportunities.

- Areas of overcrowded slum housing can be re-developed.

No minimum standards have been developed for space requirements based on meeting human health needs, although a number of countries have developed their own based on pragmatic and economic considerations. The following are examples of space standards endorsed by international agencies or adopted by countries for legislative action.

- A WHO Expert Committee on the Public Health Aspects of Housing [2] proposed that one of the fundamentals of a healthful residential environment should be "a safe and structurally sound, adequately maintained, separate, self-contained dwelling unit for each household, if so desired, with each dwelling unit providing at least the following:

  (a) A sufficient number of rooms, usable floor area and volume of enclosed space to satisfy human requirements for health and for family life consistent with the prevailing cultural and social pattern of that region and so utilized that living or sleeping rooms are not overcrowded.

  (b) At least a minimum degree of desired privacy:

    (i) for individual persons within the household; and

    (ii) for the members of the household against undue disturbances by external factors.

  (c) Suitable separation of rooms as used for:

    (i) sleeping by adolescent and adult members of the opposite sex except husband and wife; and

    (ii) housing of domestic animals apart from the living room of the dwelling unit.

  These needs can be expressed in terms of space requirements (a) to perform household activities and/or (b) for occupancy standards.

- A United Nations report [29] on the use of space in dwellings proposed minimum floor space (in m^2) according to the size of family (Tables 2 and 3).
- The UN report also concluded that, based on the calculations that a double bed required 7.6 m^2 of space for movement on three sides and a wardrobe closet required 1.5 m^2 for itself plus another 1.5 m^2 for movement, the minimum area of a bedroom for two persons is 10.6 m^2.
- Another set of standards setting out minimum inhabitable surfaces for rooms in the European countries, prepared jointly by the International Union of Family Organizations (IUFO) and the International Federation for Housing and Town Planning [30], is given in Table 4.

Table 2. Minimum floor space by family size proposed by the United Nations [29]

Room	Index of capacity* (in m^2)								
	2/3	2/4	3/4	3/5	3/6	4/6	4/7	4/8	5/8
1. Living space									
Dining area	5	5	5	6	6	6	7	8	8
Living room	13	13	13	14	16	16	17	18	18
2. Kitchen	6	7	7	7	8	8	8	8	8
3. Bedroom (parents)	14	14	14	14	14	14	14	14	14
4. Bedroom 2	8	12	8	12	12	12	12	12	12
5. Bedroom 3	–	–	8	8	12	8	12	12	12
6. Bedroom 4	–	–	–	–	–	8	8	12	8
7. Bedroom 5	–	–	–	–	–	–	–	–	8
7. Bathroom with WC	4	4	4	–	–	–	–	4	4
7. Bathroom, no WC	–	–	–	4	4	4	4	–	–
7. Separate WC	–	–	–	1.2	1.2	1.2	1.2	1.2	1.2
7. Extra washbasin	–	–	–	1	1	1	1	2	2
8. Storage space	1.5	1.5	1.5	2	2	2	2.5	2.5	2.5
9. Additional bedroom (optional)	–	–	–	–	–	–	–	(8)	(8)
Total	51.5	56.5	60.6	69.2	76.2	80.2	86.7	93.7	97.7

* The first number refers to the number of bedrooms, the second to the number of occupants.

Table 3. Minimum floor space requirements for family of three to five proposed by the United Nations [29]

Room	m^2
Living plus dining room space	18.6
Kitchen	7.0
First bedroom	13.9
Second bedroom	12.0
Third bedroom	8.0
Total usable floor space	70.0*

*This can be compared with the average total floor area of 50 m^2 for aided self-help housing in Columbia.

Table 4. Minimum inhabitable surface per size of family [30]

Room	Index of capacity* (in m^2)								
	2/3	2/4	3/4	3/5	3/6	4/6	4/7	4/8	5/8
Day rooms									
Kitchen-dining	6	7	7	8	8	8	8	8	8
Dining room	5	5	5	6	6	6	7	8	8
Living room	13	13	13	14	16	16	17	18	18
Total area	24	25	25	27	30	30	32	34	34
Sleeping rooms									
Foe parents	14	14	14	14	14	14	14	14	14
For one child	8	12	8	12	12	12	12	12	12
For two children	–	–	8	8	12	8	12	12	12
For three children	–	–	–	–	–	8	8	12	8
For four children	–	–	–	–	–	–	–	–	8
Total area	22	26	30	34	38	42	46	50	54
Total	46	51	55	61	68	72	78	84	88

* The first figure refers to the number of bedrooms, the second to the total number of persons normally accommodated.

A survey by Lebegge [31] on room sizes in European countries found considerable variation in crowding standards. He concluded that a number of reasons accounted for these differences, including climate, way of life, ideas concerning internal arrangement and economic considerations. His data showed the minimum, maximum and average "inhabitable surface" in the European Region at the time as follows:

Inhabitable surface (in m^2)

	Surface*				
	Type 1	Type 2	Type 3	Type 4	Type 5
Minimum	20.7	35.9	49.5	60.6	42.9
Average	32.9	53.0	64.3	78.6	61.5
Maximum	48.2	82.3	97.9	104.7	96.8

*Key:

1. One floor residence (flat or bungalow with one bedroom) for an elderly couple.
2. Flat in a building without a lift (or in a two-storey house) for a family of four in an urban zone.
3. Flat in a building with a lift (or in a two-storey house) for a family of five in an urban zone.
4. Two-storey house or apartment for a family of seven.
5. House for a family of five in a rural zone.

- The American Public Health Service/Centres for Disease Control of the US Public Health Service recommended the following housing maintenance and occupancy ordinance [32].

1. Maximum occupancy of any dwelling unit shall not exceed the lesser of the following two requirements:

   (i) First occupant, at least 14.2 m^2 habitable floor area; second and subsequent occupants, at least 9.4 m^2.

   (ii) Permitted number shall be less than 2 times the number of habitable rooms within the dwelling unit.

2. Every dwelling of two or more rooms occupied for sleeping purposes by one occupant shall contain at least 6.6 m^2 of floor space for the first floor occupant and every room occupied for sleeping purposes by more than one occupant shall contain at least 4.73 m^2 of floor space for each occupant thereof.

Non-habitable floor space and storage space for personal effects of each permissible occupant also are defined in the ordinance.

- In the UK, recommended standards for floor space in public housing have been laid down and serve as a basis for granting loan sanction and approving housing subsidy (Table 5).

- In the Soviet Union, the "norm" for rationing living space is expressed in terms of specified floor space per person, rather than in numbers of persons per room. In the Russian Soviet Federation Socialist Republic, the sanitary norm for dwellings is the minimum permitted by civil codes is 9 m^2 per person irrespective of age and sex. The significance

Table 5. Recommended standards for floor space in new public housing in the UK [33]

	Number of people 6	5	4	3	2	1
	Minimum net floor area (in m^2)					
3-Storey house*	97.53	93.8	–	–	–	–
2-Storey terrace	92.00	84.5	74.13	–	–	–
2-Storey semi or end	92.00	81.7	71.5	–	–	–
Flat	86.4	79.0	69.7	–	–	–
Single-storey house	83.6	75.2	66.9	56.7	44.6	29.7
General storage						
Houses**	4.6	4.6	4.6	4.18	3.7	2.8
Flats and maisonettes	1.39	1.39	1.39	1.11	0.02	0.74
Inside	–	–	–	–	–	–
Outside	1.85	1.85	1.85	1.85	1.85	1.85

* Figures require modification with a built-in garage.
** Some of this may be on an upper floor but at least 2.3 m^2 should be at ground level.

of the norm is described in a Soviet housing textbook [34] as follows:

> The establishment of a living space norm does not mean that a person may not be assigned a larger or smaller living space than a stipulated norm, providing that a person occupies space within the limits of the norm, it may not be taken away from him without his consent. If he occupies space less than the standard norm and is required to vacate it, he is entitled to alternative accommodation, but it may also be less than the norm.

- The Uniform Building Code of the International Association of Building Officials recommends that at least one room in a dwelling unit has an area of 11.3 m^2. In addition, every room used for sleeping purposes must have an area of 8.5 m^2 and no kitchen must have an area of less than 4.7 m^2 [30].

- The WHO Regional Office for Europe recommends that 12 m^2 of habitable space per person be provided in housing.

2.2.3 Open space

Open space can provide some of the resources needed for active and passive recreation and also can contribute to a sense of wellbeing by providing aesthetically pleasing settings. Open space not only helps reduce residential densities but also facilitates the vital role played by green plants in oxygenation and controlling carbon dioxide. The report of a WHO Expert Committee on Environmental Health Aspects of Metropolitan Planning and Development [35] also drew attention to the other roles played by open green space in metropolitan planning:

(a) Protective: Green belts serve as living barriers between residential areas and industry: they protect against noise and fumes from motor traffic and they control expansion and divide urban areas from one another. Green belts are neither rigid barriers nor are they screens to hide ugliness: they act as a protection against the undesirable spread of noise, dust and fumes, and against wind and excessive cold or heat. They also are a microclimate regulator against the dangers of pollution.

(b) Recreational: Open space provides for a wide variety of recreational needs, such as activity for small children, who should be able to play near home, and for older children, who generally prefer more noisy games but whose playgrounds should be in the immediate neighbourhood. Open space also provides for sports and unorganized games for teenagers and young adults. Allotments also are valuable uses of open space in urban areas for growing food crops and flowers. Kitchen gardens are an important feature of many developing countries in the European Region.

(c) Other needs: Open space around schools, day nurseries, hospitals and health centres are necessary for calm and tranquility. Important ecological considerations also relate to the role of open space in the conservation of natural resources that are important not only at a microlevel but also at a macrolevel through farmland, parks, game preserves, and forests. They help to maintain the balance of nature and prevent reduced agricultural output of soil after deforestation, erosion and pollution.

In terms of the housing environment, open space makes the best use of fresh air, circulation and sunshine and, if properly controlled, can prevent encroachment into rural or agricultural outer regions. The protection of nature and open space usually requires positive action by the state through its land policy and planning laws. Such plans not only protect existing open space but can make open space available in urban areas as part of an overall re-development programme.

2.3 Social requirements

One of the primary objectives of balanced economic and social planning is to achieve high total production and a corresponding increase in the standard of living, while creating a condition in which the social values and culture of a society can be best expressed. The achievement of this dual objective, however, depends on the rational location of production, consumption and services in an efficient, healthful, comfortable and pleasing environment.

The report of a WHO Scientific Group on the Development of Environmental Health Criteria for Urban Planning acknowledges that certain sociophysical factors in the environment of predominantly residential areas are essential to promoting and enhancing the physical wellbeing of the residents [35]. This concerns the way individuals and communities form relationships either formally in clubs, associations, or civil, political and cultural groups or informally from day-to-day contact in shops, at work or when using transport. The role of these relationships for personal and social wellbeing and for reducing stress and anxiety cannot be overstated.

2.3.1 Normal family life, hobbies, recreation and social activities

The shelter as a social setting has to accommodate individual and different interests and activities involving any or all of the family, with or without visitors. It must be designed to provide reasonable individual and group privacy as well as facilities for family life as part of a community of friends and relations. The shelter should therefore provide for children's play, homework, sewing and reading, hobbies, entertaining friends and callers, and making love in reasonable conditions of privacy from other family members. The adequacy and design of indoor space are two crucial factors in achieving this objective.

2.3.2 Normal community and wide social life

The WHO Scientific Group on the Development of Environmental Health Criteria for Urban Planning [35] drew attention to the importance of sociophysical planning aspects of residential areas as stated by planning criteria as follows:

1. Urban planners should consider people not only as residents of large cities but also as members of communities, neighbourhoods and networks within those urban areas.

2. Such communities should be planned or maintained as residential units with recognizable spatial limits, so that people can identify themselves with their locality.

3. The residential clusters - neighbourhoods, districts, subcommunities - should have easy communal contact routes within and between them.

4. A range of facilities - schools, stores and buildings for recreational and assembly purposes - should be provided to encourage the development of interacting community units.

5. Through-traffic should, as far as possible, be kept from straining or severing community interactions and relationships.

6. Provision should be made for safe and easily identifiable access to units in a residential neighbourhood and for a balance between the opportunities for privacy and for community interaction of the individual and the family within the residential environment.

A number of social studies have supported these goals - people need roots, and the importance of the shelter as part of a wider social setting cannot be overstressed.

The many links with the district where members live, including friends, schools, familiar haunts, associations and memories of a lifetime, offer people a dimension in their lives whose value cannot be measured. This is particularly important to elderly people who often cannot adapt to moving to a completely different environment. Enforced moves to new, unfamiliar housing because of slum clearance, employment opportunities, etc., often has an adverse effect on social adaptation to new settings, particularly where people are moved from traditional housing to high-rise accommodation or new settlements.

2.3.3 Recuperation from sickness or ill-health

Community care facilities for people recovering from sickness or illness should be an integral part of any housing hygiene policy. Good housing with family or community support provides a suitable environment for convalescence (see section 2.10.4).

Efforts to preserve and enhance physical and mental well-being of accident-prone people, such as the sick, chronically ill and disabled, is a necessary accompaniment to the more immediate work of accident prevention. This means, for instance: avoidance of drugs that could affect balance or other faculties; attention to good vision, good muscle strength and agility; good footwear and foot care; proper nutrition; good general health care; building of self-confidence; maintaining family and social contacts; and freedom from financial worries [36].

Many of these requirements can be provided only by social policies designed to help those who, because of sickness and poor health, cannot help themselves. However, doctors and health officials can help by ensuring that patients suffering from illness that make them prone to home accidents are properly treated and by referring people, for example, to ear specialists, opticians and chiropodists where necessary. Glasses for people with poor vision, hearing aids for the hard of hearing, and walking sticks or other aids for partially immobile persons are examples of medical aids that might help prevent an accident by improving their ability to cope with their disability. Medical care facilities, such as burn and poison units, and other care services, should be readily available.

The home is not just a place to sleep and eat; it also is a refuge from the rigours of work, school or other activities, and a place to recover from sickness or ill-health. Therefore, peaceful, pleasant surroundings with sufficient indoor space and provision for privacy are important considerations in healthy housing and personal enjoyment.

2.3.4 Privacy

Privacy or "freedom from what is felt as unwanted intrusion by other people" can be expressed by different factors including visual, aural and social criteria. People's reaction to privacy depends as much on their own attitudes as on physical facts. The intrusion relates mainly to being seen, noise, social contact and communication [37]. The subjective reaction of people to each of these situations means that control measures and standards are extremely difficult to define, and little research has been conducted into the benefits and disbenefits of privacy or its effects on mental health and wellbeing. Clearly, cultural and adaptive aspects need to be considered. In some cultures, all family members share the same room (and sometimes bed) for sleeping whereas in other cultures, private sleeping quarters separated from the rest of the family are preferred. Similarly, in most cultures, people prefer privacy during personal toilet and washing activities while in others, this is not considered important or in some cases achievable. The need for privacy of the dwelling in relation to other dwellings and the wider community also varies significantly. Privacy must be considered in relation to a number of benefits, some of which may be incompatible with other housing hygiene requirements (e.g. large windows increase daylight - but reduce privacy by making interiors visible from outside; easy access in a housing development reduces privacy in gardens and front rooms; low-rise, high-density development multiplies the chances of intrusions of all kinds). Design measures can compensate only partly for imbalances between such opposing factors.

A report by the UK Department of Environment [37] noted that research is needed to analyse physical conditions and people's reactions to them to help establish privacy requirements. This would include such factors as distance and lighting to degrees of perception, the recognition of a person's physical attitude (standing, sitting) and his facial expression. It should relate the extent of view into rooms with the characteristics of the window, the position of the viewer and the angle of view. It also should study the effect of curtain meshes and the two-way loss of light and vision through the curtain, the movement of passers-by in terms of angle and duration of the intrusive views and the effectiveness of screening by vegetation.

Existing privacy standards are based mainly on spacing and visual standards, which may not always be relevant to sensible town planning. Reducing the spacing between buildings by imaginative screening and design measures is often possible without compromising on privacy requirements. Crude space standards should not be the sole basis for privacy standards. Where privacy requirements are applied, these should be incorporated into design briefs at the planning stage after having taken into account the various social and cultural needs.

2.3.5 Aesthetic satisfaction

A number of studies indicate that residents tend to judge the value of their home and housing environment largely by appearance and perceived visual impressions of various kinds. In terms of the housing surroundings, view is an important factor, but the aesthetic nature of view means that it is somewhat difficult to measure or define. However, the benefits of view can be assessed by examining the main components of the visual field and evaluating those factors that by common consent have a pleasing or unpleasing appearance. The total impression of view is affected by the magnitude of pleasant and unpleasant elements but also takes into account shape, size, lighting, movement, colour, patterns, texture, detail and variety of the outside environment. Even small changes to one of these factors can influence satisfaction of view. These same factors apply equally to the aesthetic satisfaction within the home. However, in the latter case, comfort provisions such as furnishings and consumer appliances also are important and relevant.

(a) Health effects

The importance of view for engendering a sense of wellbeing and satisfaction with the housing environment, as well as for being a therapeutic tool in aiding recovery from sickness, cannot be over-emphasized. By contrast, a gloomy outside environment tends to make people feel shut in or oppressed. Aesthetic satisfaction in the home also will benefit mental health and wellbeing although placing a "health" value on aesthetic considerations that are indeterminate and dependent upon social, cultural, economic and individual factors would be difficult.

(b) Control measures

Enormous difficulties are encountered in defining how to achieve aesthetic satisfaction in the surrounding of the home.

Much depends upon the topography, climate and presence of natural geographical features that can used to give a pleasant perspective from the home. Location of industrial and commercial activities in relation to the home also is important, as accompanying noise, pollution and unsightliness may adversely affect health and wellbeing. However, physical planning and design measures can be engineered to give a pleasant or unpleasant view and to control new industrial developments. These considerations should not be overlooked when designing new housing or when evaluating existing housing for re-development or improvement:

- Enclosed backyards should be avoided wherever possible. Gardens, where provided, should be open to view from the house. Any screen used to secure privacy or roofed yard space should be so placed as not to obstruct this view or cause undue enclosure. Huts, garages and outbuildings also should be so positioned as not to impede views from windows of principal living areas.

- Aesthetic satisfaction is increased considerably by design measures that maximize brightness of the external environment (e.g. avoidance of overshadowing from neighbouring buildings, good orientation to facilitate sunshine to outside areas and maximize daylight within rooms, and use of bright, visually appealing colours in buildings). Anything in fact that serves to make the micro-environment attractive. Similar factors apply to the indoor environment.

- Within the immediate environment, the view should extend not only beyond the line of opposite buildings in a narrow street but also provide some perspective immediately outside the building. Even a small gap between buildings (in view) through which open country is visible can be extremely valuable in creating an impression of openness. The prospect of providing distant horizons is usually limited by the topography and elevation of the site. Housing on flat sites shuts off 10° or so of altitude from the horizon in which views of distance tend to be concentrated, but views from upper storeys or on elevated sites can bring unpleasant views into the foreground as well as pleasant ones in the distance.

- Ideally, a distant view of the countryside or some other pleasant landscape and depth in the relatively short view will mitigate the unpleasant impression of building and road surfaces [37].

- The view inside the layout is strongly inter-related with sunlight and privacy, recreational space, access and parking, private garden area, maintenance arrangements for public amenities, soft surface play areas and landscaping [37]. Garden city designs that combine nature and buildings by setting the development in deep countryside and giving it an inner texture of greenness will often please residents. Vegetation (bushes, creepers and trees) also can be effectively planted to fill in solid angles in the field of view. The colour and movement of vegetation are both important to aesthetic satisfaction with housing surroundings.

2.3.6 Work activities carried out at home

In developing countries, one or more members of the family often use the home as a place of work. Small cottage industries are a normal part of the financial infrastructures of rural communities. In many cases, the women and children undertake this work to supplement family income, which is often insufficient to pay for food, clothing, heating/cooking fuel and other basic necessities. In Mediterranean shanty towns, home work has become institutionalized with small industries serving fringe activities for street vendors and servicing the shanty town itself. Therefore, opportunities must be made available to low-income groups to enable them to carry out work activities at home. The adaptation of traditional housing for some work activities may not always be possible. However, in many cases, a spare room can be easily converted into a suitable workroom. Huts or garages also are easily converted for a number of applications. However, the suitability of housing for carrying out work activities must depend upon the nature of the work, which might be a source of additional home accidents, including poisoning, asphyxiation or fire. Many industrial processes use chemicals and propellants that could adversely affect air quality. Other work activities (e.g. needlework) will require additional natural and artificial lighting to avoid eye strain. In terms of control measures, no hard-and-fast rules exist for home work activities, although in some cases special workshops can be provided in the settlements themselves. Of special importance is the monitoring of work activities in the home in order to advise on any necessary safety or health precautions or to regulate operations through other control procedures.

2.4 Shelter requirements

Shelter is a synonymous term for the individual home, flat, dwelling or rental unit: in fact, any residence or structure where people live. At a basic level, the shelter must protect against hostile elements in the immediate and wider environments, such as adverse climatic features, dangerous animals or external air pollutants. In addition, it must normally provide security against human intrusion. However, at a more sophisticated level, the shelter also is a social setting and a place of refuge and rest from the rigours of work, school or other activities. Its value therefore cannot be assessed just in narrow hygiene terms but must be seen as part of a much more overall function in satisfying social, aesthetic and intangible human needs.

2.4.1 External elements and natural hazards

Different climatic and geographical factors in the various subregions and areas of Europe mean that shelter requirements in relation to external elements and natural hazards differ widely from one area to another. Geographical considerations, such as ambient temperature, seasonal characteristics, sunlight, rainfall, snowfall and any susceptibility to natural hazards (e.g. earthquakes, volcanoes, cyclones, lightning, drought, flooding and landslip), are all important to housing design and planning.

Mediterranean countries have very long hot summers, but their winters can be cold with moderate rain and snowfall. The southern European Region also is characterized by high seismic activity and earthquakes, which are not problems in western and northern Europe. In these regions, colder winters and higher rainfall, snow, frost and wind are major factors affecting the built environment.

Information on climate is thus integral to any healthy housing policy; it enables planners to choose or evaluate a site that will not be unduly affected by adverse weather conditions or natural hazards. This information also is important when considering design factors for ameliorating unfavourable climatic conditions (e.g. by providing shelter from strong sunshine or wind) while at the same time taking advantage of beneficial climatic and geographical features. For example, outside ambient temperatures can be used when evaluating thermal requirements or a knowledge of rainfall patterns in assessing surface water drainage requirements.

In many cases, civil engineering and housing design measures now make possible the adaption of the housing environment to minimize the effects of adverse climatic conditions and natural hazards. Therefore, in assessing the consequences of external elements and natural hazards, an evaluation should be made of local conditions, including seismic and wind forces, meteorological and hydrological data, vectors and disease-transmitting life, and other climatic and natural conditions that affect the health and comfort of the occupants [38]. Housing situated in areas subject to regular flooding, earthquakes, volcanic disturbance, landslip or other geographical phenomena should be adequately protected where possible. Alternatively, settlements should be re-sited in a safer location.

2.4.1.1 Rainfall and penetrating dampness

Rainfall is significant to housing hygiene because it is the source of water supplies and is instrumental in determining the technical requirements for surface water drainage and anti-flooding measures (e.g. in calculating surface run-off from roofs, gutters, yards, roads and concreted areas). Information on annual mean driving rain indices also can indicate resistance of different housing designs to rain penetration. However, the main significance of rainfall is in causing housing dampness either directly through penetration of the shelter or indirectly by adding to condensation and water vapour levels inside the shelter (see section 2.9.1.6).

Structural dampness can be a serious source of building damage and cause for complaint. It is usually caused by poor design, poor building maintenance, use of unsuitable building materials, dampness rising from the ground or by penetration of rainfall through defects in the structure.

(a) Health effects

Although epidemiological studies are contradictory, damp housing is generally considered a contributory factor to rheumatism, arthritis or respiratory diseases such as pneumonia, bronchitis and upper respiratory infections. Clearly, however, dampness can sometimes affect mental health by causing stress to people worried about high heating bills (which are higher in damp houses) and destruction of clothes, furnishings, etc. Dampness also can affect social wellbeing by reducing the attractiveness of the home as a social venue, such as occurs when walls become damp or covered in unsightly mould. In other cases, dampness becomes a stigma that may give rise to feelings of shame, depression, alienation or a sense of injustice. In addition, some physiological effects may be brought about by changes in the thermal environment aggravated by dampness (see section 2.8.1). This can be critical in people with impaired thermoregulatory controls, such as children and the elderly.

(b) Control measures

- A damp-free environment should be regarded as a first priority by policy-makers. Housing codes and ordinances should be formulated to ensure that housing is constructed of suitable materials and of a design that protects against rainfall and penetrating dampness.

- Penetrating and rising dampness can be prevented by good housing design and construction techniques. In existing housing, penetrating dampness should be remedied by appropriate repair measures. Table 6 illustrates some possible causes of housing dampness and suitable remedial measures.

Table 6. Causes and remedies of penetrating dampness

Situation and form of dampness	Probable cause	Suitable remedy
Roofs		
Dampness localized	1. Cracked or defective roof coverings.	1. Repair or renewal.
	2. Faulty or absent flashings around vent pipes, chimney, etc.	2. Replace to approriate detail.
	3. Inadequate dampcourse.	3. Replace.
	4. Leaking or blocked gutters.	4. Repair, renew or unblock.
Dampness fairly extensive but mainly linear	1. Faulty valley gutters or faulty gutters behind parapet walls.	1. Remove and renew.
	2. Inadequate dampcourse to parapet walls.	2. Insert new one.
	3. Faulty skirtings to flat roofs.	3. Replace to appropriate detail.
	4. Underfelt to pitched roofs incorrectly finished at eaves.	4. Re-fix to be watertight.
	5. Eaves details allow rain or snow to enter.	5. Weather-proof eaves.

Table 6. (cont'd)

Dampness fairly widespread	1. Drying out of construction water. (May last several years uncertain conditions.	1. Provide suitable heating and ventilation.
	2. Unsuitable roof covering.	2. Renew with suitable alternative.
	3. Inadequate pitch or lap for type of weatherproof finish and degree of exposure.	3. Re-lay roof covering to proper pitch and lap.
Walls		
Dampness localized	1. Roof faults as above but where moisture is accessible to walls.	1. See above.
	2. Faulty wall jointing.	2. Re-point joints.
	3. Defective window sills or reveals.	3. Repair or replace.
	4. Cracked walls or rendering.	4. Repair or re-render.
	5. Cavity wall ties bridged by mortar.	5. Clean off mortar.
	6. Wall cavities obstructed.	6. Remove obstructions
	7. Water leaking from dripping overflow pipe, leaking gutters, downpipes or drains.	7. Remedy cause of water overflow. Repair or renew leaking gutters downpipes or drains.
	8. Leaking pipes or joints in ducting or chased into wall.	8. Repair.
	9. Hygroscopic salts in walls or rendering.	9. Treat walls or re-render.
Walls		
Dampness mainly in linear form	1. Rising dampness caused by absence of damp-proof course (DPC).	1. Provide suitable horizontal DPC.
	2. DPC deteriorated in old buildings, incorrectly placed too near ground, with	2. Renew PDC. Remove outside obstructions.

Table 6. (cont'd)

	outside obstructions or incorrectly positioned floor slabs, etc.	
	3. Horizontal DPC over lintels incorrectly detailed.	3. Replace to correct detail.
	4. Wall panel joints not waterproofed.	4. Waterproof them.
	5. Expansion joints not waterproof.	5. Waterproof them.
Dampness fairly widespread	1. Drying out of wet construction.	1. Provide suitable heating and ventil-ation.
	2. Presence of hygro-scopic salts.	2. Treat walls and re-render.
	3. Walling porous, inadequately thick or protective against rain in exposed con-ditions.	Remove and replace with impervious alternative.
	4. Cavity filled with insulation that is not waterproof.	4. Line-out walls with vertical damp-proof membrane.
Floors		
	1. Dampness fairly equal over solid ground floor caused by lack of adequate damp-proof membrane or slow dry ing out of construc-tion water	1. Provide damp-proof membrane to floors to correct detail or assist drying out process.
	2. Suspended ground floors with insula-tion on underside of joints may have con-densation in airspace if insulating material forms a vapour barrier.	2. Provide cross-ventilation to floor space.

- Built-up areas, particularly residential areas, should not be subject to flooding, even at infrequent intervals.

- Various measures can be taken to prevent flooding in low-lying areas. These include the following: civil engineering measures to raise the height of river banks and other water courses; providing surface water drainage systems, storm water relief sewers and flood barriers; adopting planning control measures to prohibit housing development in areas prone to flooding; and design measures, such as constructing housing on stilts or elevating them in some other way above flood levels.

- In highly exposed places, tall buildings should be adequately protected against the effects of lightning by lightning conductors and other preventive measures. Low-rise buildings usually do not require special precautions.

2.4.1.2 Strong winds

(a) Health effects

Excessive wind can lower thermal comfort, particularly if the building is draughty, in poor repair or poorly insulated. Strong winds also are frequently associated with driving rain, which can cause penetrating dampness. Housing situated in areas exposed to hurricanes and excessive wind gusts risk collapse and structural instability, which can be a major source of injury.

(b) Control measures

- The shelter should be sufficiently windtight to prevent excessive draught or infiltration.

- The degree of exposure of buildings to prevailing winds will depend largely upon their location and position in relation to topography and wind strength.

- The main structural elements of a building, such as walls, windows, roofs and outbuildings (e.g. huts and sheds), should be strong enough to resist typical wind speeds in a given situation.

- In assessing the wind loading on a building, account should be taken of the likely high wind speeds through and under access openings, which can create considerable pressure differences between the front and rear faces of the building. In these cases, suction loadings can damage glazing and cladding.

- Low-pitch roofs (15°) are particularly vulnerable to wind suction. This vulnerability decreases until the pitch reaches about 30°, but even in these cases, roof coverings can be dislodged near the ridge if not securely fastened.

- Wind speed usually increases with height above ground and also varies with ground roughness. These factors should be considered when planning new housing development.

- Wind-loading tables and maps should be consulted when designing buildings in areas prone to strong gust winds.

2.4.1.3 Snowfall

Roofs must be designed to withstand snowloads. The shelter also needs to be protected against the penetration of snow, which can lead to dampness. Planning factors also should consider that snowfall frequently cuts off remote settlements from the rest of the community.

Appropriate control measures include the following:

- The shelter must be sufficiently wind and weathertight to prevent the entry of snow.

- Roof design must have sufficient structural strength to withstand snowloads. Recent Swedish studies indicate that snowloads on pitched roofs may be appreciably higher than on flat roofs due to re-deposit of snow from windward slopes to leeward slopes of the former.

- Average and peak snowfalls should be taken into account when planning the location of human settlements, and arrangements need to be made for snow removal on access roads.

2.4.1.4 Frost damage

The depth to which the ground freezes depends upon the kind of soil, the kind of cover (i.e. vegetation or snow) and on the weather conditions. In Mediterranean countries, frost is extremely rare during the winter, but in colder climates frost can seriously damage fresh concrete or brickwork. In certain ground conditions, frost can cause "heave" to foundations, pavements and concrete slabs, resulting in subsidence and cracking. Frozen water pipes can burst on thawing and frozen drainage pipes can fracture. A given site will freeze much less readily if it is waterlogged than if well drained (e.g. very fine sand, silts or chalk soils). A cover of grass or a layer of snow will afford good insulation and reduce the rate at which the ground freezes. In cold climates, foundations and drainage and water supply pipes should be laid sufficiently deep underground to be protected from frost damage.

2.4.2 Direct sunlight and insolation

(a) Health effects

Sunlight is important to housing hygiene for many reasons. It provides significant physiological and psychological benefits to health and wellbeing. It is a source of warmth that may be pleasant in cold climates but unpleasant in very hot climates where it can cause thermal fatigue and sunstroke. It also directly influences natural daylighting conditions inside rooms as well as the character of exterior views. The sun's rays are important in sanitary compartments.

Sunlight also is significant to town planning; for example, recreation areas may need to be sunny while car parking areas need to be cool. Sunlight provisions have to be considered in relation to density requirements, orientation of buildings and spacing between apartment blocks. Finally, sunlight can degrade external paints, chemicals, sealants, other building materials and furnishings that may then emit unpleasant or toxic odours.

(b) Control measures

The main aim of planning authorities is to ensure enough sunlight and daylight on and between the faces of buildings for good interior and exterior conditions. The main aim of architects should be to ensure that sunlight and daylight can be had just where they are wanted (e.g. in gardens). These aims do not stand in isolation but form part of a set of inter-related aims that have to be balanced and accommodated. Also, sunlight and daylight should be safeguarded within a proposed layout for land that is likely to be developed or re-developed in the future and in any existing building or buildings affected by a development proposal.

In Mediterranean countries the main priority is to protect against excessive insolation. The following factors are particularly important in the planning of housing in hot climates:

- Buildings should be oriented so that doors and windows do not face the midday sun and do take advantage of prevailing summer winds. Good orientation also can assist warming in winter.

- Green belts, trees (especially large deciduous trees), shrubs, climbing plants and window boxes, etc., as well as water reservoirs (e.g. on flat roofs), will help reduce temperatures of walls and roofs, etc. Greenery on balconies and loggieas reduces air temperature by an estimated 5°C and radiant temperature by 20°C [2].

- Light-coloured paint on walls should be used to reflect as much solar radiation as possible.

- Buildings should be constructed of materials that do not absorb heat quickly.

- To reduce solar penetration, housing should be designed with living rooms that are long in relation to width. A width to length ratio of 1.4:1.6 is optimum. A ceiling height of 3.5 m is optimum for reducing radiant heating [2].

- Flat roofs should have a ventilated space between roof deck and ceiling.

- Devices for producing shade, such as venetian blinds, broad canopies, window shutters, screens, deflectors and awnings, can be useful to control sunlight penetration.

- Houses with verandas are particularly useful for preventing adjacent rooms from overheating. Gardens are invaluable in providing a cool place to rest and relax.

- Window areas should be about one tenth of floor area and capable of providing cross ventilation to all rooms. Reflective glass will reduce air temperature in insolated rooms by 3-4°C.

- Bright engineering metallized lavsan film on windows also effectively reduces solar penetration and brightness.

- The open area of windows should extend close to ceilings to allow hot air in the upper part of room to escape.

- Natural night ventilation is especially effective in reducing air temperature in housing during hot weather.

- Air conditioning is effective in maintaining a constant indoor air temperature but is expensive to install and run. A small circulating fan and an extract fan are useful for cooling room areas and assisting air movement.

2.4.3 Seismic activity

The Mediterranean region is affected by high seismic activity culminating in a number of earthquakes each year. The high density of urban areas (which often comprise old, historic towns) and the way in which building units are sometimes grouped contribute to loss of human life and property when earthquakes occur.

Appropriate control measures include the following:

- The assessment of preventive or remedial measures to strengthen or otherwise protect buildings against seismic activity assumes detailed knowledge about the risks and magnitude of earthquakes within each region. Control measures need to be implemented that provide optimum protection against seismic movement in new and existing buildings (particularly old buildings and town units built of stone and other traditional materials). The aim of all control measures, however, should be to ensure that buildings have sufficient seismic resistance and ductility based on probabilistically determined projections of vulnerability.

- Regional investigations should be carried out in areas affected by seismic activity based on the geotechnical structure of the region, and active and potential faults. This should be followed by a study of the earthquake phenomenon and ground motions so that intensity, frequency, amplitude and recurrence period can be assessed.

- Earthquakes are normally categorized into three levels of seismic activity: level 1 - for an expected earthquake effect-and-return period of 50-100 years (light and moderate earthquakes); level 2 - for an expected earthquake effect-and-return period of 200 years (strong earthquakes); and level 3 - for a maximum probable earthquake (catastrophic earthquakes). Such defined parameters represent the basis for determining the individual criteria as well as stability criteria [18].

- For level 1 earthquakes, the structure should be designed to reach the elastic range without any change to the basic structural system and minimum damage to non-structural elements, with no assumed intervention after the earthquake.

- For level 2 earthquakes, the structure should be designed to behave beyond the elastic range into the non-linear range. This means that structural elements are moderately damaged and non-structural elements considerably damaged. However, damage is assumed to be repairable and the structure usable again.

- For level 3 earthquakes, the building should be designed so that no structural collapse occurs although the structural elements may be severely deformed; heavy damage to and partial failure of the secondary infill elements is expected.

- In all cases, construction codes need to be drawn up detailing the design measure for each category. The redesign, repair and strengthening of buildings in seismic regions is detailed in a report by the United Nations Economic and Social Council [39].

- Typified, pre-fabricated or industrialized housing systems should not be grouped together so as to reduce seismic hazards.

2.4.4 Ambient air pollutants

The housing environment has a continuous but variable influx of air pollutants from the outdoor air to indoors. Important pollutants in this category are suspended particulates, sulfur oxides, nitrogen oxides, hydrocarbons, carbon oxides, photochemical oxidants and lead [40]. The shelter is able only partially to provide protection against external air pollutants that are best controlled at source whenever possible. However, the planning of housing away from industrial operations, busy roads and other pollution sources will reduce exposure within the shelter.

2.4.4.1 Sulfur oxides and suspended particulates

Sulfur oxides and suspended particulates (smoke) are common byproducts of fossil fuel combustion and are found together in the atmosphere with several other pollutants, particularly in urban areas. The temperature of the gases, the exhaust gas velocity and the height of the chimney are important factors in emission dispersal. Sulfur dioxide (SO_2) will form sulfuric acid in the presence of moisture or as a result of catalytic or photochemical action, falling to the ground as sulfuric acid deposition ("acid rain"). Indoor levels of SO_2 can be absorbed by many building materials (e.g. SO_2 can react with formaldehyde where it often acts as a scavenger on particle board) [41].

(a) Health effects

Sulfur oxides and suspended particulates become heavily diluted in the ambient air and pose little threat to health except in extreme cases of poor dispersal such as would occur in fog or temperature inversion. In these circumstances, mortality and morbidity curves and air pollution are closely related. A notorious example of this occurred in London in 1952 when fog, coupled with smoke and sulfur dioxide pollution, claimed 3500–4000 excess deaths, mostly in the very old or very young. Respiratory or cardiac conditions were the principal causes of death [42].

Bronchitis, pneumonia and other respiratory infections have been correlated with daily levels of smoke and SO_2, regardless of atmospheric conditions [43]. These pollutants also may increase pulmonary airway resistance [44] and have been associated with asthma and dyspnoea. However, other studies have failed to demonstrate the influence of air pollution on respiratory disease or to distinguish the exact causal pollutant agents [45]. For instance, the adverse health effects of sulfur dioxide cannot normally be distinguished from those of particulates in smoke, as both are generally found together. Also, climatic and geographical differences make direct comparisons between the adverse health effects of air pollution in different countries difficult to make.

Sulfur oxides also can contaminate water, soil and crops; this in turn can give rise to significant exposure via ingestion of contaminated food. Other effects of air pollution include the possible reduction in "wellbeing" in polluted areas due partly to reduction in the penetration of the sun's rays. The loss of ultraviolet radiation due to smoke and general air pollution in industrial towns can be 30% or more [46].

(b) Control measures

- Pollution control measures and legislation should be implemented to ensure the efficient burning of coal, oil and other fossil fuels and the dispersion of gases by tall chimneys. Old, inefficient fuel-burning plants should be gradually replaced by more efficient equipment.

- Smokeless zones and prohibition of coal burning in domestic fires have been largely responsible for reducing domestic pollution in many countries.

- A WHO task group on sulfur oxides and suspended particulate matter [46] concluded that for long-term exposure, annual mean concentrations of SO_2 of 100 ug/m^3 and of smoke of 100 ug/m^3 were the lowest concentrations at which adverse health effects in the general population might be expected.

2.4.4.2 Airborne lead

Sources of airborne lead include scrap metal yards, lead smelters, battery manufacturing plants and lead oxides from petrol-driven motor vehicles.

(a) Health effects

See section 2.5.3.3.

(b) Control measures

- Measures should be taken to keep the annual mean concentration of lead in air to less than 2 ug/m^3 in places where people are liable to be exposed continuously for long periods. These measures may include reduced emissions, re-location of industry or housing, or traffic management schemes.

- Allotments and vegetable gardens should be planned so that they are not adjacent to busy roads or near to lead facilities such as smelters or scrap yards.

- Streets, playgrounds and other areas frequented by children should be swept regularly to remove dust and road dirt that can contain lead.

2.4.5 Radioactive emissions

Sources of exposure to natural radiation include cosmic rays, terrestrial gamma rays and radioactive materials in the body. Sources of artificial radiation include fallout from weapons testing, certain occupational practices, radioactive consumer goods and radioactive waste [47]. However, the largest contribution to population exposure arises from the inhalation of the decay products of radon in indoor air. Radon usually exists at low concentrations in the open air but at more elevated concentrations within buildings - usually between two and ten times the concentration in the open air. In most instances, the dominant source of radon within buildings is the subjacent ground. However, building materials also contribute to radon concentrations in indoor air and in some circumstances may be the major source [48].

Building materials such as granite, alum shale stone, clay bricks, concrete containing uranium mine tailings, phosphate slag or aerated alum shale and gypsum board are potential sources of radon. Domestic water, natural gas, underlying soil and groundwater can release substantial amounts of radon to the indoor atmosphere in certain regions. Radon levels vary considerably between different regions, depending upon concentrations of uranium deposits in the soil and groundwater.

(a) Health effects

Radon is a chemically inert, dense radioactive gas with a half-life of 3.8 days; it is derived from uranium-238 deposits in the ground. This U-238 breaks down into other radioactive materials at a virtually constant rate, and one of these materials is radon gas. Radon gas can penetrate the materials in which it is found and pass into building materials and indoor air.

The potential consequence of irradiation is the induction of lung cancer and a resulting reduction in life expectancy. For instance, in one survey conducted in Schneeberg, UK, where large concentrations of radon gas were present, 75% of the deaths among miners were caused by lung cancer. For the average person, the lifetime risk of lung cancer from radon exposure is estimated to be 1% of the risk of lung cancer from all causes [49]. A report by the National Radiological Protection Board [48] concluded that "where the induction of cancer has been shown to be the consequence of exposure to ionizing radiation at high doses or dose rates, it is assumed that this effect will also occur at low doses or dose rates but with reduced frequency" and that exposure to products of radon-222 might be responsible for some of the lung cancer incidence in the general population.

Radon itself decays to produce two types of polonium, another radioactive substance. Polonium attaches itself to dust particles in a room, which are then inhaled by the occupants. Decaying polonium gives off alpha particles that, once in the lung cavity, are able to penetrate through the protective layers of tissue to damage living cells. Also, residual radon produced from building materials gives off gamma rays that, unlike polonium, deliver a dose to the entire body.

(b) Control measures

- The radon level is an important consideration when siting and designing new housing, particularly in areas where radon ground levels are high. Where high levels are suspected, radiological monitoring should be undertaken.

- In the developed countries, energy-conserving measures, such as draught-proofing and double glazing, are known to increase significantly the amount of radon within the building. Radon concentrations can be reduced significantly by increasing ventilation rates in buildings (both under the floor and within rooms).

- Building materials that do not contain deposits of radioactive materials should be used wherever possible.

- Where radon is diffusing into buildings through the ground, exposure can be reduced significantly by installing a vapour barrier between the ground and the living space above, or sealing floors and walls so as to prevent radon emissions.

- In the United Kingdom, the suggestion has been made that action should be taken to reduce annual doses of radon greater than 25 mSv and that doses between 5 and 25 mSv justify further investigation. New buildings should be designed within a dose limit of 5 mSv per year [50], which is in line with proposals of the International Commission on Radiological Protection.

2.4.6 Excessive noise and vibration

Noise (or unwanted sound) is identified by two physical characteristics: frequency (expressed in hertz) and loudness (usually expressed in decibels). The average adult of 25-30 years of age can hear sounds ranging from 20 to 20000 cycles per second, but this range decreases with age and is often accompanied by perceptible hearing losses within the limits of the range. Noise is transmitted inside buildings through air and by vibration through structural components. Outdoor sources of noise include aircraft, traffic (both rail and road), factories, road repairs, building site operations, street noise, animals, and children playing. Common causes of noise complaint indoors are amplified music systems, radio, television, loud conversation, children crying, door banging, maintenance operations, and noises from appliances (e.g. plumbing installations, lifts and refuse chutes). The increase in high-density, multiple-housing schemes, together with mechanization and urbanization, means that noise is a serious problem in most human settlements throughout the world.

(a) Health effects

Many ill-health effects are associated with exposure to noise. These include permanent and temporary loss of hearing at intensive or long-term noise levels > 110 dB(A), with sleep disruption and psychological/hormonal disturbances at lower levels. The reaction of people to unwanted sound is extremely variable and complex, depending on a number of social, economic and other factors, including state of health and age [51].

However, long-term exposure to certain sounds in the home can lead to functional disturbances of the central nervous system in some people. Such disturbances may manifest themselves in various ways, causing fatigue and reduced activity of the cortical processes, especially when rest and sleep are interrupted. For example, noise intrusion can interfere with falling asleep and can awaken people who are asleep. Studies indicate that the disturbance of sleep is worse when noise levels exceed about 35 dB(A) L_{eq}. The probability of subjects being awakened by a peak sound level of 40 dB(A) is 5%, increasing to 30% at 70 dB(A) [51]. Fatigue caused by long-term exposure to low-frequency, low-intensity sound is thought to result from many warning signals that evoke a stress reaction related to fear or uneasiness.

In other cases, the level of sound in the home may be so high that it plays an important part in the development of cardiovascular, nervous and psychological disorders. Other studies have shown that a high intensity of background noise in urban areas apparently affects the developing fetus and that exposure to high intensities of sound affects communication and learning, (including the acquisition of language), often leading to annoyance and aggressive behaviour. However, the interaction of noise with other environmental factors means that the adverse health effects of noise do not lend themselves to straightforward analysis. For instance, people accustomed to high levels of noise often have difficulties adjusting to a low-noise environment [52].

(b) Control measures

Because sound-reducing methods in existing housing are often expensive, impractical or too complex for normal usage, preventing excessive noise at source is a good public health practice. The best preventive action lies in intelligent planning precautions taken before new building development begins and adopting technical, educational and enforcement action to control noise in existing housing.

Outdoor noise

The following measures should be taken in planning, constructing and organizing human settlements to reduce noise in residential areas:

- Urban areas should be divided into zones that separate industry and transport from residential areas with buffer belts, parks, public gardens, etc..
- Industrial buildings and machinery should be insulated against noise at source.
- Highways should be so planned that through-traffic bypasses residential areas.
- Housing should be separated from main streets by wide green belts of thickly planted trees (strong-leafed varieties and conifers) and bushes so that house fronts are at least 15 m from the road.
- Urban main streets should be widened with protective belts of greenery to separate different zones.
- Vehicular traffic should be prohibited or reduced in residential streets, particularly at night.
- Public transport (ground and air) needs to be strictly controlled. This would include aircraft movements and location of airports. Railway cuttings and solid embankments can be provided in built-up areas and housing planned away from marshalling yards or railway lines.
- Paving and other hard surfaces should be avoided where possible to minimize ground reflection. Grass areas can be used to help reduce noise.
- As far as practicable, play areas for children should be planned away from but preferably within sight of the dwelling.

Indoor noise

The planning of the residential environment and the internal planning of housing should ensure that noise from outside and inside the building is separated from living and bedroom areas. Public health personnel, architects, planners, builders and others should be aware of the principles of noise reduction when designing or vetting new housing. In particular, multiple dwellings need careful planning; from the acoustical standpoint, the best arrangement is a series of detached buildings, whereas the least favourable arrangements are a single large building that is continuous with the outside of the building site with an inward facing central courtyard, or tall buildings overlooking narrow streets.

- Rooms with shared walls and shared floors should preferably be of similar use. This ensures that bedrooms are not exposed to noise from adjoining living rooms.
- The staircase, hall and kitchen should preferably adjoin each other on either side of shared walls, thus providing a noise buffer between living rooms.
- Bedrooms should not be planned next to balconies and preferably not underneath them - certainly not without soundproofing the floors.
- The water closet (WC) should not be located over living rooms and bedrooms, whether within the same flat or over other flats.
- Partitions between WC compartments and living rooms or bedrooms should have a sound-reducing factor against airborne sound of not less than 35 dB.
- WC cisterns should not be fixed on partitions next to bedrooms or living rooms and should be fitted with silencer pipes.
- Drain pipes should not be carried in ducts next to living rooms or bedrooms without a solid wall in between.
- Refuse chutes should not be placed next to living rooms or bedrooms, and hoppers should be fitted with effective sound deadening gaskets. Metal refuse chutes and containers should have sound-deadening linings.
- Main staircases in blocks of flats often reverberate noise. Some of the surfaces (e.g. soffits, stair treads and linings) should be finished with sound-absorbing materials.
- Lift motors should be mounted on resilient supports, and access doors from machine rooms to internal staircases should be well fitting and of solid construction.

- The banging of entrance and garage doors should be limited by suitable devices.

- The structure of the dwelling should be adequately insulated against noise from outdoors or from adjacent dwellings. This can usually be achieved by good design and layout and building materials that provide a high degree of sound insulation to walls, floors and ceilings.

- Cavity walls require great attention to detail if they are to improve sound insulation: cavities must be fairly large in area (> 10 m^2) and have a minimum 5-cm cavity width (preferably up to 30 cm). Wall ties will reduce sound insulation values. Indirect sound transmission can be reduced further by using heavy solid walls or boxed cavity construction with sound-absorbing materials in the cavity.

- Wall linings are more useful for sound insulation on lightweight walls than heavy walls. Linings should not be too stiff and must not be porous. They are usually fixed onto plastered walls by battens at least 400 mm apart.

- Sound entering buildings through open windows will be reduced by 4-10 dB, depending on the degree of open window and absorbent conditions within the room. Ordinary closed single windows reduce incoming noise by about 20 dB (25 dB if airtight). Heavy glass further reduces noise to about 30 dB. Well-designed double windows should have an air-space gap of 200-300 mm with sound absorbent linings to sides. Opening the windows or providing permanent ventilation to them substantially reduces sound insulation and has to be balanced against the need to secure good ventilation and indoor air quality.

- The main factors determining the sound insulation value of single doors is the mass of the door and the air leakage around its edges. Main entrance doors to common balconies should be designed to a high standard of sound insulation.

- A floating floor is an independent raft laid over a structural floor but separated from it by a suitable layer of resilient material such as plain wool quilt. Wood rafts are used for wood joist floors and usually a concrete screed for solid floors. Floating floors are an effective method to reduce noise transmission in existing and new multiple-housing schemes.

- Puggings is the loose-fill usually inserted between floor joists to add mass to the floor and to dampen sound vibrations. The minimum weight of puggings should be 15 kg/m^2, but for the higher values of insulation obtainable with joist floors, the weight should not be less than about 75 kg/m^2. Materials used for puggings include sand (about 1600 kg/m^3), ashes (about 800 kg/m^3) and slag wool (100-200 kg/m^3).

- Suspended ceilings are of benefit chiefly in raising the sound insulation of a concrete floor with a soft floor finish. The air space above the ceiling should not be less than 25-mm deep, and the ceiling membrane should be moderately heavy (not less than 25 kg/m^2) and airtight. Plastered expanded metal or ceiling boards are often used.

- Box structures within a room are sometimes used to isolate rooms from floors, ceilings and outer walls, and they provide a high degree of sound insulation (i.e. 60-70 dB). Their main use in housing is to insulate rooms immediately adjacent to extremely noisy rooms (e.g. lift rooms).

- Ventilation ducts can be very potent conductors of airborne noise within a building, often entering through main inlet or extract ventilation openings or being created within the duct system by the fan, motor or other mechanical equipment.

- Ventilation fans should be designed to be as large as possible and to run at the lowest possible speed. Noise also should be reduced along all strategic parts of the duct system. Special attention should be given to sound insulation of the duct walling, and ducting should be adequately lined with absorbent material between openings.

- Generally, sound absorption can best be achieved by increasing the mass of structural building elements, which is particularly effective at lower frequencies. However, porous absorbents, such as mineral wool, felts, acoustic tiles and soft furnishings, are effective for absorbing noise at higher frequencies. Resonant panels are effective only for noise in the range of 50-200 Hz and are therefore not applicable to most general noise problems. Sound insulation of stud partitions can be improved by staggering studs, infilling with mineral felt or sand, and properly sealing the stud cavity with plasterboard.

- Fans, compressors, lift motors, power-driven saws, steam hammers, drills and motor exhausts are examples of industrial machinery and equipment that should be so designed, maintained and situated that they do not cause noise nuisance in residential areas.

- Where possible, quieter processes should be substituted for more noisy operations, such as welding for riveting.

- Legislation to prevent noise nuisance from factories, machinery, building operations or housing is often effectively used in many countries. Such legislation may be applied at the planning stage for new buildings and noise abatement legislation for existing noise resources. Courts should be empowered to ban noisy operations and to impose penalties on offenders.

- Tenancy agreements should stipulate the conditions for the playing of radios, musical instruments, etc., and noise from these sources should be prohibited during night-time hours.

- Building regulations and ordinances should stipulate noise insulation values for new industrial and residential construction. These should be enforced by building or architect departments of the local health administration.

- The general public, building operatives, factory managers and others need to be fully informed about preventive measures to reduce noise emissions as part of a hygienic housing educational programme.

- The WHO Task Group on Environmental Health Criteria for Noise [51] recommended that for good speech intelligibility indoors, background levels of less than 45 dB(A) L_{eq} are required and 35 dB(A) L_{eq} in bedrooms. The group further recommended that outdoor noise levels of less than 55 dB(A) L_{eq} be maintained during the day and 45 dB(A) L_{eq} at night.

- A WHO Working Group on Noise Control in Buildings [53] made recommendations on maximum permissible sound levels, appropriate airborne sound insulation and impact sound levels, and reverberation time in dwellings. These standards should be consulted when designing new housing.

2.4.7 Disease vectors, pests and vermin

(a) General health effects

Many insects and mammals are important to housing hygiene and public health because of their ability to transmit disease, cause nuisance or otherwise adversely affect health. Many of these animals have a parasitic relationship with humans and/or have a life cycle where pathogens spend part of their time in an intermediate invertebrate host, and so spread disease by this route. Other biological vectors indirectly cause disease by transferring pathogens onto food or into water by contact with their wings, feet or body. Others carry pathogens in their alimentary tract and cause disease by urinating or defaecating onto food or into water.

(b) General control measures

In terms of shelter requirements, sanitary design, housing maintenance and good housekeeping must be adequate to discourage insect and other animal disease vectors: for example, by thorough, regular vacuum cleaning to remove food debris and dirt, regular inspection of void spaces such as lofts and cupboards, rotation of food stocks, keeping food in sealed containers, good design and maintenance of the structure to eliminate gaps or holes, and prompt, efficient disposal of all waste and rubbish. Three general factors must always be considered in controlling pests and vermin: elimination of breeding places, destruction of the insect or its larvae, and preventing the vector from reaching humans. However, as no hard-and-fast rules apply, much depends upon environmental conditions, disease patterns and a detailed understanding of the habits and life cycles of animal and disease vectors with particular reference to their adaptation to humans and the housing micro-environment.

2.4.7.1 House flies

(a) Health effects

The house fly and many of its relatives are common agents for transmitting numerous infectious diseases. The mouth parts, numerous body spines and the sticky pads on the feet can carry many pathogens that cause human disease, including typhoid fever, cholera, bacillary and amoebic dysentery, tetanus and anthrax. Disease is spread by flies feeding on excrement, sputum, open sores or putrefying matter that is then transferred to food, milk, mucous membranes or uncontaminated wounds.

Many studies have shown a causal relationship between flies and enteric disease. One American study [54] demonstrated that effective fly control in areas with a high fly population reduced the prevalence of Shigella infections and other diarrhoeal diseases. Similar results were observed by a WHO team studying diarrhoeal diseases in Venezuela. Another American study [55] showed that construction of sanitary privies reduced the access of flies to the faecal material, hence breaking the chain of transmission for enteric disease.

(b) Control measures

- The transmission of disease by house flies can be controlled by preventing access of flies to human faeces by constructing sanitary conveniences and providing sanitary drainage arrangements for liquid and solid waste.

- Adequate measures also need to be taken to keep flies out of dwellings and in particular from contaminating food. This can be partly achieved by screening doors and windows to larders and other food storage cupboards with fine wire mesh, and ensuring that food is not left uncovered in food preparation areas. Dirt, grease and other food debris should be removed daily.

- Environmental health measures, such as the sanitary disposal of household refuse, waste food and manure, also should be implemented.

- Insecticides, such as dichlorvos, slow-release resin strips or pyrethrins, distributed either by hand-operated spray guns or aerosol sprays are effective for house fly control, although as with all insecticides great care must be taken in their application in food rooms.

2.4.7.2 Mosquitoes

(a) Health effects

Several species of mosquitoes are known transmitters of encephalitis, malaria, filariasis, dengue fever and yellow fever. In infected areas, these diseases are spread by mosquitoes biting infected persons and then transmitting the disease to non-infected persons through biting. As with other biting insects, mosquitos also affect comfort and efficiency through severe annoyance, itching, loss of sleep and nervousness. Some people also are allergic to insect bites.

(b) Control measures

- Mosquito control is best accomplished at the aquatic stage of the life cycle. Breeding sites are removed in several ways: emptying standing water in tanks, cisterns, tins and other containers; clearing blocked gutters, gullies, drains and ditches; draining ponds and swampy areas; and making adequate provision for surface water drainage.

- Biological control also can be employed by introducing natural predators into ponds and lakes.

- Larvicidal agents also are effective in some cases to control mosquitos.

- Adult mosquitoes within buildings are killed quickly by pyrethrins synergized or boosted with piperanyl butoxide.

- Protection while sleeping in infested areas can be achieved by mosquito nets or doors and windows mosquito-proofed with fine-gauged mesh of bronze wire or of plastic such as nylon.

- Detailed measures for controlling mosquitoes are set out in numerous WHO documents and publications, which should be consulted before carrying out mosquito control programmes.

2.3.7.3 Cockroaches

Cockroaches harbour in cracks, crevices, and heating and ventilation ducts of dwellings. They are particularly fond of warmth, dampness and darkness and are thus commonplace in insanitary or poorly designed housing. They commonly infest kitchens and areas where waste food is found.

(a) Health effects

Cockroaches impart an unsavory odour and taste to food they infect. They carry organisms causing enteric diseases such as diarrhoea, dysentery, typhoid and food poisoning. They also have been associated with the spread of numerous other diseases. As with other crawling insects, cockroaches spread pathogens mainly by dirt and infected food particles adhering to their bodies. Moreover, they also contaminate foodstuffs with their excreta and egg cases.

(b) Control measures

- Gaps in skirtings, pipe ducts and dados, etc., should be closed off. Voids to brickwalls around disused fireplaces or kitchen ranges need to be properly sealed off and crevices around heating pipes sealed.

- Proper hygienic facilities for food storage and disposal of waste food should be provided.

- Heating and ventilation ducts should be so designed that they do not provide harbourage for cockroaches. Access points would be provided for disinfestation.

- Cockroaches are resistant to many insecticides, but dieldrin-based lacquers are often effective if applied at base of walls where roaches must pass in search of food. Cockroach traps also are available, and cockroaches can be trapped in vessels containing beer, syrup or sweetened liquids.

2.4.7.4 Bedbugs

Bedbugs can infest hygienic and insanitary housing but prefer warm conditions and feed only in darkness. Nevertheless, bedbugs thrive in dirty conditions at an optimum temperature of 25°C. Bedbugs feed readily on the blood of poultry, mice, rats and other animals, but humans are the preferred host. Adults, eggs and nymphs can be found in cracks and crevices on or around beds, together with the empty cast-off shells. A heavy infestation is characterized by an almond-like odour.

(a) Health effects

Bedbugs are not known to carry any communicable diseases and are mainly troublesome because of their nuisance value. Some people are very sensitive and/or allergic to bedbug bites.

(b) Control measures

- Normal hygiene measures, such as vacuuming of beds and mattresses will help control bedbug infestations. Cracks and crevices in walls and floors should be filled in.

- The eggs of bedbugs are unlikely to hatch at a temperature below 13°C, and their survival through the winter in unheated houses is unlikely. Conversely, a temperature of 45°C kills the eggs and adults in 1 hour.

- Fenitrothion or lindane should be sprayed on all surfaces where bedbugs are likely to be hiding. Bedding is preferably steam-treated.

2.4.7.5 Fleas

The human flea can breed in dust in cracks of floors and wherever organic material has accumulated (e.g. hair, wool or flakes of skin). Fleas are able to lie dormant in the cocoon stage in empty houses and become activated by the vibrations of a person entering the house. Fleas also are carried by many domestic and wild animals, including dogs, cats, foxes and rats.

(a) Health effects

The rat flea conveys the bacillus of bubonic plague from rat to humans. It also transmits *R. mooseri*, the rickettsia responsible for murine typhus. Rat fleas can remain infected with *Pasteurella pestis* for up to 43 days. Cat and dog fleas also feed on humans and cause considerable irritation through biting.

(b) Control measures

- Rat fleas are best discouraged by normal rodent control measures to exterminate rat populations.
- Cat and dog fleas can be killed by periodic dousing of infested animals with a suitable insecticidal powder.
- Human fleas can be partly controlled through normal domestic cleaning activities, particularly vacuuming of floors, dusty crevices and other infected areas. Personal hygiene arrangements also are important.
- Infested houses should be sprayed with an insecticide such as lindane and infested bedding treated with pyrethrin or pressurized steam.

2.4.7.6 House mites

House mites and house-dust mites are common, endemic sources of allergens inside houses. Mites are extremely small in size (barely visible with the naked eye) and are easily distinguished from insects by having eight legs (rather than six) in the adult stage. The most common species of mite found in houses is the house-dust mite (*Dermatophagoides pteronyssinus*). This mite is nearly always found in bedding and mattress dust or in pillows, cushions (especially feather-filled), rugs and upholstered chairs, where it feeds on dead human skin cells. House mites and house-dust mites require a high relative humidity (RH) to survive and will die in very dry, very hot or very cold conditions. House-mite populations peak in late summer when the RH is high. At a minimum RH of less than 45%, mites die from desiccation. Optimum development of mites varies with the species: D. pteronyssinus, for example, prefers a RH of 80% at 25°C. Other mites found in housing include pests of stored food products. For example, Glycyphagus domesticus is a common pest of damp larders or walls where it feeds on mould spores. Other sources of mites in houses include infested bedding material for pets and other animals (e.g. hay and straw), floor covering in cages and bird-nesting materials.

(a) Health effects

Many of these arachnids are parasitic and can produce a mild to severe dermatitis in some people. In addition, some mites are the causal agents of mange and scabies in humans and other animals.

Airborne mite faeces are the main source of allergens, but small airborne pieces of mites (<5 um diameter) could be inhaled into the lungs and cause an allergic response. The symptoms of dust-mist allergy are similar to those of other airborne allergies (see section 2.7.1.8), including irritation of the nose and throat, rhinitis and in some people causes breathlessness and asthma several hours after exposure.

(b) Control measures

- House mites and house-dust mite populations are best controlled by reducing the RH to below 45%. This is best achieved by controlling water vapour emissions from household activities and providing good ventilation to rooms. Housing dampness should be remedied.

- Strong sunshine also kills house mites. Rooms, carpets, bedding and mattresses should be regularly aired in strong sunshine. Furnishings should be vacuumed regularly to remove dust and house mites. Bird-nesting material should be removed from roof spaces.

- Steam treatment of mattresses and bedding will kill house mites, but insecticides are largely ineffective.

- In some cases, articles or furnishings giving rise to allergies should be replaced, but this may not always be practicable. In some cases, re-housing of sensitized persons may be necessary.

2.4.7.7 Other insect pests

Other insect pests include beetles, weevils and ants, (often found infesting food stored in damp, dirty and unhygienic food stores) earwigs, wasps, silverfish, house moths and woodworms. The former group are mainly of importance because of their nuisance value and can be treated by normal housing hygiene measures and suitable insecticides. However, wood-boring insects can cause considerable damage to structural timbers, such as rafters and joists, and should be treated with suitable biocides. Pre-treated timber should be used in areas particularly vulnerable to woodborers. Alternatively, hardwood timbers, which are not as attractive as softwood to woodworm attack, should be used.

2.4.7.8 Rats and mice

Rats, mice and other rodents play an important part in the spread of many diseases, either directly by contaminating human food with their urine or faeces, or indirectly by fleas and mites. They are commonplace where housing hygiene is poor. In addition, numerous indirect effects on health need to be considered. These include aesthetic reactions to the presence of rodents, rodent damage to sewerage systems, and losses of stored and growing crops, which exacerbate problems of malnutrition and susceptibility to disease in local human populations. Rats also may cause fires by gnawing through the insulating material around electrical wiring.

(a) Health effects

The most serious rodent-borne disease is bubonic plague. It is spread by infected fleas of many rodents, the most significant of which is the rat. Like bubonic plague, tularaemia is a natural disease of rodents and lagomorphs (rabbits and hares) that also may be transmitted to humans by blood-sucking arthropods (e.g. mites, ticks), fleas and mosquitoes, contact with or ingestion of water, inhalation of dust contaminated by rodent faeces, or by contact with infected live mammals, their carcasses or insufficiently cooked meat.

Other diseases spread by rats and mice include rat-bite fever, leptospirosis, salmonellosis, trichinosis and murine typhus fever. Rickettsial pox is transmitted from the house mouse to humans by the bite of the house mite. Rat bite fever is a public health problem associated with heavy urbanization, occurring primarily in lower economic areas with substandard housing, crowding and poor sanitation.

(b) Control measures

- Good hygienic measures can eliminate harbourage for rats and mice. This includes hygienically storing and disposing of house refuse, removing any accumulations of rubbish and destroying nesting material when disinfecting buildings.

- Rats and mice are attracted to houses with a plentiful food supply. Proper hygiene measures in the kitchen and other rooms of the house to ensure that food is not left uncovered and removal of waste debris together with routine cleaning measures will discourage rodent infestation.

- All reasonably practicable steps should be taken to ensure that houses and other buildings are so designed and repaired to make them rat-proof. Particular attention should be given to the spaces behind skirting boards, suspended ceilings, hollow partitions, ducts and conduits, holes in conduits and the drainage system.

- The whole building site should be covered with a concrete layer to prevent rats and mice from burrowing into houses.

- All bridges to buildings, such as cables, tree branches or objects leaning against walls, should be avoided.

- The eaves of roofs should be rat-proofed with expanded metal or wire mesh and wire balloons used at openings of all ventilation pipes.

- Access to roofs by vertical pipes close to walls can be prevented by 20-gauge metal pipeguards fitted tightly to pipes by an adjustable metal collar projecting out about 250 mm. Horizontal pipes and cables between buildings should be similarly protected.

- Junctions between wood floors and brick walls should be treated with fine wire mesh, and air bricks, ventilators, doors, windows, etc. also need to be similarly proofed.

- Where necessary, buildings should not be erected with windows opening less than 1 m from the ground, and every opening should be protected by a heavy overhanging sill. Brickwork should be painted with high-gloss paint, 150 mm deep up to 1 m from the ground to discourage climbing by rats.

- All possible points of entry below 1 m from the ground should be closed to prevent rats jumping up to openings.

Gnawing at the bottom of doors can be prevented by fitting a 300-mm high, 20-gauge metal kick plate on the outside.

- All disused drain runs should be filled with compacted concrete. Drains in use should be fitted with intercepting traps where necessary to discourage rats from entering domestic drainage runs from main sewers.

- Drains, inspection chambers, fresh air inlet grids and sanitary fitments should always be kept in good repair.

- Food storage facilities should be adequately proofed against the entry of rats and mice.

- Edible refuse and empty food containers should always be placed in bins with tightly fitting lids while awaiting collection.

- Rats and mice can be removed by poisoning (including gassing) and trapping. Poisons can either be single dose (acute) or multiple dose (chronic) and can be incorporated into bait or used as contact poisons in the form of dust. Care must be taken that these rodenticides are not indiscriminately used and are properly stored in the home so they are not a source of danger to children and domestic animals.

- Rats in sewers should be controlled by regular baiting and/or trapping.

- Specifications for pesticides used in rodent control are published by WHO [56].

2.4.7.9 Other animal pests

Other common animal disease vectors associated with insanitary housing include pigeons and other birds, which often infest lofts and dilapidated outbuildings and carry many parasitic insects and diseases, such as salmonellosis, from droppings. Therefore, roof coverings and eaves should be properly sealed and water storage tanks properly covered to keep out birds. Other animals that carry zoonotic diseases include foxes and other scavenging animals, which may find harbourage in poor housing. These animals are often infected with tuberculosis and carry a number of parasitic diseases in their faecal droppings. Where necessary, these animals should be controlled by shooting, poisoning or gassing.

2.4.8 Intrusion by humans or dangerous animals

2.4.8.1 Human intrusion

(a) Health effects

In areas where burglaries and personal assaults are commonplace, this form of human intrusion can be a major health and personal safety hazards. This is a particular problem to people who live on their own, such as the elderly who often live in continual fear of being attacked or mugged by intruders in or near to their homes and who often sustain serious injuries in such attacks. The problem is exacerbated where security against intrusion into the home is inadequate, which often leads to feelings of insecurity and stress.

(b) Control measures

- Housing developments should be designed so as to avoid hiding places for intruders by careful planning of open walkways and approach roads that are well lit at night.

- Additional policing and security patrols may be necessary in housing developments with a consistent record of burglaries or personal assaults.

- Simple security devices, such as mortice deadlocks, drawbolts, door chains, door spy glasses and window bolts, should be fitted to all entrance doors and accessible windows as appropriate. In some cases, more elaborate security devices, such as burglar alarms, close circuit TV and intercom-operated door entrance systems, may be appropriate to discourage human intrusion.

- Ground floor front rooms should have adequately sized windows at eye level for effective surveillance. Bay windows and walk-in bays are better than windows flush with the frontage or high-level bays.

- Front doors should be recessed slightly so as not to impede the line of sight from windows. Front-facing doors are better than sideways-facing ones, providing they can be seen from front doors opposite.

- No high obstructions, such as walls, hedges, garages, meter compartments, pram sheds or dustbin kennels, should obstruct the view of the street from windows.

- Back gardens should not abut onto alleyways, paths or roads to maximize security for small children, prevent intruders from entering and to increase privacy. Layouts where the front of one row of houses faces the back of the next row are to be avoided [57].

2.4.8.2 Animal intrusion

(a) Health effects

Intrusion into housing by dangerous animals is a serious problem in many parts of the world. For example, bites by snakes and stings by insects that enter houses looking for food or shelter cause pain and discomfort to occupants, sometimes culminating in death. The psychological effects of this possibility on occupants can be considerable.

(b) Control measures

- Housing should be adequately secured against intrusion by dangerous or poisonous animals. Cracks, crevices, gaps in roofs and other entry points or harbourages should be eliminated. In some cases, traps and poisonous baits can be used, but these may themselves create a health hazard unless proper safety precautions are taken.

2.5 Design and constructional requirements

The detailed design and constructional requirements of housing hygiene encompass all of the technical factors relating to the shelter and the physical infrastructures serving it. For example, the adequacy of building construction plays an important part, particularly in relation to stability, strength and durability of the structure but also in maintaining sanitary internal conditions and thermal comfort, reducing noise transmission, affording protection and means of escape in case of fire, and providing shelter against the external elements and security against intrusion.

These issues are described elsewhere in the guidelines as specific requirements. However, some common requirements relate to the performance of primary building components, such as foundations, walls, floors and roofs, and the toxicity of materials, which are briefly described in this section. Other matters specific to design and performance also are included in this category.

Methods of building construction, type of design and choice of materials will depend largely upon the desired requirements of the building, supplies of suitable building materials, manufacturing plant and availability of trained building construction workers, site conditions, climate, finance and consumer interests. Therefore, to conform with these requirements, each country must draw up detailed specifications relevant to its particular requirements and local conditions.

2.5.1 Facilitation of household tasks

This healthy housing requirement is an all-embracing parameter incorporating a number of features dealt with elsewhere in these guidelines. In the main it concerns environmental and housing facilities that meet general and individual physical and mental health requirements as well as comfort and aesthetic considerations. For example, sufficient but not excessive indoor space (including readily accessible storage space) will optimize the performance of household tasks. Floor, wall and other surfaces that are easy to keep clean will reduce time and physical effort spent on this task, and a good indoor thermal climate and indoor air quality will similarly optimize comfort while carrying out household tasks. Household appliances, such as vacuum cleaners, washing machines and spin driers, considerably reduce physical and presumably mental fatigue. Good natural lighting to rooms with pleasant decorative finishes and comfortable furnishings aids aesthetic and psychological satisfaction.

2.5.2 Choice of building components for easy maintenance and repair

General requirements

Good healthy housing design and construction are necessary to enable cleaning and sanitary operations to be effectively carried out. In particular, floors, walls, ceilings, work surfaces and appliances should be constructed of smooth, impervious materials capable of being kept clean, all parts of housing should be accessible for cleaning, dust-traps in ducts or conduits should especially be avoided, and suitable hygienic facilities should be provided for storing domestic goods, personal belongings, etc.

The building structure should be sufficiently strong, in good repair and not likely to collapse. In particular, building materials, foundations and overall design should not facilitate subsidence, slipping or other movement, particularly in areas prone to soil movement or seismic activity. Remedial action should be taken to ensure that walls are not badly bulged or leaning dangerously (e.g. by shoring or underpinning walls).

- Loose roof tiles, slates or other coverings should be properly secured. Loose chimney pots should be taken down and re-bedded into chimneys.

- Structural timbers, such as floor joists, wallplates, floorboards, lintols or roofing timbers, that are rotted or damaged because of fungal or insect attack should be replaced with new timbers impregnated with preservative.

- Ceilings that are loose, badly bulged or otherwise insecure should be replaced. Broken glass in windows can cause lacerations and should be replaced.

<u>Specific requirements</u>

<u>Foundations</u>

- Foundation design must take account of possible ground movement, the nature of the subsoil and the nature of the supporting structure so as to avoid differential building settling. Therefore, the nature of the subsoil both at the level of the foundations and for some depth below is important to ascertain.

- Topsoil, which is composed of loose soil, plant life and decaying vegetation, is a very soft and unsatisfactory foundation for buildings.

- Fine-grained soil include <u>clay</u> soils, which have high plasticity; it dries slowly and shrinks appreciably on drying. Under pressure of the load of foundations, clay soils compress as water is squeezed out and buildings may continue to settle for some years after completion.

- Foundations should be laid at a suitable distance below ground level to prevent the clay from shrinking on drying and expanding on wetting. In the United Kingdom, foundations are normally laid 1 m below the surface and up to depths of 4 m or more below large trees. As a general guide, buildings on shallow foundations should not be closer to single trees than the height of the tree at maturity, and one-and-a-half times the height at maturity of groups of trees to reduce the risk of damage to buildings by shrinkage and swelling of clay soils. Special precautions need to be taken when rebuilding on clay soils after clearance of trees and shrubs from the site.

- Rock is normally a good substrate for building foundations, although the load-bearing capacity will depend on the type of rock. Unlike soils, rock does not compact under the weight of buildings.

- Ground that has been filled or made up with tipped soil, waste or refuse is unsuitable for building because of the difficulty in predicting the amount of compaction under load and the likelihood of uneven settlement. However, building on made-up ground is sometimes possible by using raft or deep-pile foundations. The construction of terraced housing on made-up ground, however, should be avoided because of the likelihood of differential settlement and cracking. Such sites also may be unsuitable for housing because of the possibility of toxic materials and chemicals from the ground being brought to the surface during excavation activities. Soils from made-up ground should be routinely tested for heavy metals and toxicity.

- Water-soluble sulfates, particularly in clay soils, can combine with the hardened cement in the concrete of foundations and cause expansion cracking and disintegration of concrete. In these situations, sulfate-resistant cements should be used. Dense, impermeable concrete is less susceptible to sulfate attack than poorly compacted forms.

- Frost heave is a particular problem where the water table is near the surface. The water freezes and may expand when frozen, causing heave below foundations and causing them to move and possibly fracture. Frost heave is unlikely to occur in heated buildings.

- Building foundations should be designed to transmit the load of the building to the ground so that, at most, only a limited settling of the building occurs. It is especially important that foundation settlement is uniform and that movement is limited so as to avoid damage to service pipes and drains connected to the building.

- The width and depth of a concrete strip foundation depend on the bearing capacity of the subsoil and the imposed loads. The greater the bearing capacity of the subsoil, the less the width of the foundation for the same load. The minimum width of a strip foundation is 450 mm, which gives a reasonable bearing area for most two-storey houses on the subsoils and provides space in the trench to lay any foundation brickwork. The minimum depth of concrete for a strip foundation is generally 150 mm, and the concrete should be at least as thick as the projection of the strip on each side of the wall. However, the thickness of the concrete should be not less than the projection of the strip on each side of the wall so that if a failure of the concrete by shear occurs, the 45 degree angle of shear would not reduce the bearing of the base of the subsoil. The minimum practical depth of a strip foundation is usually 450 mm of concrete.

- Raft foundations consist of a raft of reinforced concrete under the whole of the building so designed to transmit the load of the building to the subsoil. They are used for buildings on very loose or soft ground, such as very soft clay, or where soil is very compressible and in which strip foundations would not provide a stable base.

- Pile foundations are used where the subsoil has poor or uncertain load-bearing capacity or where appreciable ground movement is likely, as with firm shrinkable clay.

- The foundations to walls on sloping sites can either be stepped or at one level depending on the degree of slope. Where foundations are stepped, the steps should be uniform in height and equal to the thickness of the foundation concrete and in no case less than 300 mm.

- Where the subsoil has poor bearing capacity for some depth below the surface (e.g. where ground has been made-up), a foundation of piers on pad foundations is often economical. The isolated concrete pad foundations are spread in the base of excavations, on which piers or columns of brick or concrete are raised to ground level to support reinforced concrete ground beams off which the walls are raised. The spread of the pad foundation is determined by the loads on it and the bearing capacity of the subsoil. The thickness of the concrete is either at least equal to the projection of the pad each side of the pier or the pad foundation can be reinforced.

Walls

The wall is either a load-bearing or non-load-bearing solid structure of bricks, stone, concrete, timber, metal or some other material enclosing and protecting a building or forming compartments and rooms internally. The functional requirements of a wall are to provide stability, strength, durability and fire resistance, to exclude rain and have adequate thermal properties and resistance to sound transmission. Internally, wall finishes need to be cleaned easily and sufficiently durable for household activities. No material or type of wall fulfils all these requirements with maximum efficiency, but choice of materials should take into account climatic factors, such as ambient temperature and rainfall, living patterns (e.g. degree of heating, occupancy) and density/design (e.g. noise insulation).

Other design factors to be considered are as follows:

- Strength: A wall should be designed to support safely its own weight, and to take window loads and the loads imposed by floors and roofs. Strength depends on the material characteristics of the wall and the wall thickness.

- Stability: A wall should be able to resist foundation movement, irregular loads, wind forces and expansion/ contraction due to temperature and moisture changes. This will be determined largely by thickness and stiffness of walls and height of building although buttresses or irregular profile walls can be used to give greater stability. Suitable lintols should be built over windows, doors and other openings.

- Durability: Walls should be so constructed and designed to last the anticipated life of the building and require little if any maintenance and repair (excluding normal weathering). Again, the characteristics of the building materials and their suitability to the climate are the main factors determining durability.

- Fire resistance: All walls should be able to provide adequate resistance to collapse, flame penetration and heat transmission during a fire, depending upon the period of resistance required. This in turn depends upon the size, occupancy and height of the building as well as the means of escape. In general terms, walls to traditional one- or two-storey buildings require less fire resistance than other types of development.

- Protection against rain: The ability of walls to exclude rain depends largely upon the exposure of the wall to prevailing winds in terms of orientation, wind speed and rainfall. Other important factors include the proximity of the building to the coast and to other buildings, height of building and its degree of elevation. A number of measures can be taken to exclude rain from penetrating a building: for example, cavity wall construction (where the inner wall is separated from the outer wet skin), increasing thickness, selecting impermeable building materials (however, these may have poor thermal insulation properties), and by cladding wall surfaces with an outer skin of rendering, slates or tiles. In all cases, damp-proof openings to windows and doors as well as damp-proof courses and flashings to any parapets are needed.

- Protection against humidity: A wall should be able to absorb humidity produced from within the shelter and protect against interstitial condensation. This is particularly important in rooms such as bathrooms and kitchens where washing and cooking produce considerable moisture. It also is important in rooms such as living rooms and bedrooms where reduced ventilation rates coupled with intermittent heating and hard wall plasters with poor moisture-absorbent properties often cause severe condensation and mould growth.

- Thermal insulation: Walls should be able to accommodate changes in thermal conditions originating from outside and inside the building in order to maintain reasonable and economical conditions of thermal comfort inside; that is, they should be able to provide adequate insulation against excessive loss or gain of heat, have adequate thermal storage capacity and be so designed that internal wall faces are at a reasonable temperature. A balance between the need to heat or cool wall surfaces quickly in cold or hot conditions is essential. However, at the same time thermal storage capacity must be sufficient to prevent thermal discomfort when temperature conditions drop.

- Noise transmission: Walls should be so designed that they do not transmit excessive noise and have sufficient sound insulation properties against impact sound.

A number of different materials can be used for walls, of which the most common are the following:

- Clay bricks provide good stability, durability and very good resistance against fire; they also have good thermal and sound insulation properties. Bricks are cheap to manufacture, providing that suitable supplies of clay are locally available. However, the varying nature of the clay and the methods of manufacture, firing, etc., mean that the colour, texture, density and strength vary considerably. Therefore, bricks should be used for the purpose to which they are most suitable and they should be so bonded to maximize structural strength.

- Concrete blocks are extensively used for both load-bearing and nonload-bearing walls. Lightweight aggregate concrete blocks have good insulating properties, are cheap and quick to erect, and are often used for the inner skin of cavity walls. The main disadvantage of concrete blocks is that they suffer from moisture movement, which may cause cracking of plaster inside or rendering outside.

- Clay blocks are made from special brick clays and are comparatively lightweight, do not suffer moisture movement and have good resistance to damage by fire but are used mainly for internal nonload-bearing partitions as they have poor thermal insulation properties.

- Concrete is an extremely strong durable building material with good protection against fire and is very resistant to the effects of weathering. However, it has a very drab appearance and is normally used only in non-traditional buildings over three storeys in height.

- Asbestos cement sheet is extremely durable and has good thermal insulation and fire-resistant qualities. However, itis relatively brittle and lacks structural strength. Although formerly used extensively in prefabricated housing construction, its use is decreasing because of the health dangers associated with release of asbestos fibres.

- Corrugated iron is not normally suitable for wall and roof construction because it has poor thermal insulation properties: it makes rooms excessively hot in warm climates and extremely cold in cold climates. It also needs to be regularly painted to prevent rusting and corrosion.

- Timber for wood-framed walls is a relatively rapid and cheap construction material, provided that a plentiful supply of timber and skilled labour is available. A timber-framed wall has sufficient strength and stability to support the floors and roofs of small buildings and houses. Timber has good thermal insulation properties and is reasonably fire resistant if it is adequately covered with suitable non-inflammable wall and roof coverings. However, wood-boarded buildings require more maintenance. Provision also has to be made for timber movement and protection from insect attack, decay and the effects of weathering. Suitable insulation needs to be provided either between the wall studs or over the inside face of the wall, and measures taken to prevent moisture from the warm air side permeating the insulation material.

Floors

The functional requirements of a floor are stability, strength, moisture resistance, durability, fire resistance, thermal properties, resistance to sound transmission and adequate sound absorption.

- For stability, vertical support for the floor structure should be adequate, and the floor should have adequate stiffness against deflection when under load. A deflection of about 1/300 of the span is generally regarded as a maximum in the design of timber floors.

- For strength, a floor should be capable of adequately supporting people, furniture and household equipment, and be capable of supporting the dead load of the floor structure, partitions and other fixtures as well as anticipated imposed loads. Solid ground and basement floors are usually built off the ground with concrete (sometimes reinforced) and supported by a layer of compacted hardcore below.

- For durability, ground floors on a solid base or solidly supported suspended floors should last for the life of a properly constructed building.

- Moisture penetration through the floor is another hygiene consideration. The ground floor of a heated building tends to encourage moisture from the ground below to rise, making the floors damp, cold and uncomfortable under foot. This can aggravate respiratory illnesses of occupants. Dampness may cause wood rot and damage to timber floors and finishes, but the degree of moisture penetration depends upon the nature of the subsoil, water-table level, whether the site is level or sloping, and the adequacy of the floor itself including any damp-proof membrane to keep moisture out. For instance, on a gravel or course-grained sand base where the water table is usually well below the surface, little water penetration takes place, whereas on a clay base with the water table close to the surface, the penetration of moisture from the ground will be appreciable. A slab of site concrete over the soil reinforced with a waterproof membrane will stop water penetration in all cases. However, earth floors are not satisfactory for housing hygiene because the continual penetration of water from the ground makes the floor damp and cold. Ground level, wooden, suspended floors can be adequately ventilated with air bricks to prevent dry rot and dampness in timbers.

- Fire-resistance requirements depend mainly upon the height of building. In high buildings, concrete floors, which have a higher resistance to fire, may have to be used.

- Thermal properties of floors must minimize transfer of heat from the building and prevent feet from feeling cold. The use of warm materials, such as timber, will meet these criteria, but ventilated, raised-timber ground floors need to be insulated against excessive transfer of heat.

- Resistance to sound transmission and provision of sound absorption are particularly important to upper floors. Concrete floors are better than low-mass timber floors for reducing transmission of airborne sound. Impact sound can be deadened by carpeting or other floor covering.

- Floor finishes also need to be smooth, impervious to liquids, chemicals and grease, easy to keep clean and non-slip. Various finishes are suitable for floors, concrete and timber being the most common and appropriate especially if covered with suitable linoleum, rugs or carpets.

Roofs

The functional requirements of a roof are stability, strength, exclusion of rain and wind, durability, fire resistance and good thermal properties.

- A roof should be able to support the dead load of the roof structure, covering, snow loads, and pressure or suction caused by the wind. The stability of a flat roof depends on adequate support from walls or beams and the size of timber joists or concrete relative to spans and assumed levels. The stability of a pitched roof depends on the depth of the triangular framing at mid-span. The strength of both flat and pitched roofs depends on the materials used and the method of design and construction.

- A roof covering should be capable of excluding wind and rain from the building and keeping it sufficiently cool in hot weather and warm in cold weather. The degree of slope of the roof depends upon the size and type of roof covering.

- Bitumen roofing felt for covering flat roofs is cheap and easy to apply. Glass-fibre-based felts are resistant to expansion and contraction, non-absorbent and rot-proof. The cheaper fibre-based felts are not suitable and in very hot or very cold climates easily tear, allowing water to penetrate. In all cases, adequate lap (50 mm at sides and 75 mm at ends) between each layer and sufficient fall (at least 18 mm) is important to encourage run-off of rainwater.

- A properly laid asphalt roof covering does not absorb water and does not have to be laid at a fall as any rainwater on it will eventually evaporate. Asphalt is comparatively cheap and durable, having a useful life of about 20 years.

- Sheet metal coverings such as copper, lead, zinc and aluminium are excellent roof coverings giving good protection against wind and rain; they also have good durability and are light in weight. Lead and copper have a useful life of up to 100 years, but zinc has only 20 to 40 years. All of them are more expensive than bitumen felt or mastic coverings and more difficult to apply.

- The durability of the roof is the main factor affecting water penetration that could rot timbers and cause decay to other structural elements

- A roof and its coverings should have adequate resistance to damage by fire and flame spread to enable inhabitants to escape safely.

- In cold climates, roofing materials and structures need to provide adequate insulation against transfer of heat by providing insulation material in the roof space. In hot climates, the need is to ensure that the roof does not become excessively hot by using suitable covering materials and ventilating the roof space. In all cases, a vapour barrier needs to be provided to ensure that moisture does not penetrate the insulation either through the roof covering or from humid air from inside the buildings. A ventilated roof space area between the roof covering and the upper ceilings is needed in all climates so that conditions of thermal comfort can be attained.

- A roof and its coverings also must exclude animal intruders, such as birds and rodents, that may damage structural elements of the roof. In vulnerable areas, roofing timbers should be treated against insect attack.

- Clay or concrete roofing tiles are extensively used for covering pitched roofs. Good quality tiles weather well, have good durability and are resistant to damage by rain, heat and industrial air pollutants. However, they are heavy in weight and need to be adequately supported and fixed to prevent movement and possible uplifting.

- Stone slates are hard and dense, do not readily absorb water, are not affected by frost damage and have a long useful life. The better quality slates do not absorb water and are practically indestructible. It is important that they are fixed adequately to roofing battens with copper nails as galvanized or iron nails rust in time, causing slates to slip.

2.5.3 Choice of building materials, furnishings and consumer goods

A number of toxic chemicals and materials are used in buildings, furnishings and consumer goods. Some of these products contribute to indoor air pollution (e.g. asbestos and urea-formaldehyde products). Others are toxic through ingestion (e.g. lead). Cleaning agents and certain toxic varnishes also may contain organic constituents that evaporate into the indoor air; hobbies or industrial pro cesses within the home are additional pollutant sources (e.g. solvents, adhesives, paints, paint removers, soldering fluxes and welding materials) [40].

Other sources of potentially toxic materials include polymers, which have been widely used in housing for covering floors and walls, insulating pipes against heat and sound, waterproofing and sealing wall panels and partitions, and manufacturing prefabricated housing units. Plastics that have been used in buildings include polyethylene, polystyrene, polyvinyl alcohol, polyvinyl acetate, polyurethane, melamine, formaldehyde resins, polysiloxines, and the epoxy and coumarone resins.

These polymers liberate volatile substances above 60°C, which may be harmful especially if burnt or heated. Polymers also may provide a substrate for the development of microflora, for example, in water pipes. Other polymers can promote allergies in certain susceptible persons. For these reasons, the use of polymers should be controlled strictly and balanced against the known hygienic benefits.

As regards consumer products generally used in building materials and products, a WHO Working Group on indoor air was unable to estimate the health risk because of the large numbers of constituents involved and the sometimes undetermined uses to which they are put [40]. Where there is any doubt, the WHO Working Group thought that the most appropriate control measures or toxic consumer goods were prohibition of toxic chemicals in certain applications, product substitution, or appropriate product labelling and other educational approaches.

2.5.3.1 Asbestos

Three types of asbestos fibre have been used in the home and environment: chrysotile (white), amosite (brown) and to a lesser extent crocidolite (blue). These fibres have been used widely in building materials, such as asbestos cement products, insulation boards, water pipes, lagging to boilers and pipes, sprayed decorative/fire protective coatings to ceilings, and as a constituent of roofing materials. Asbestos also is used to make textiles, brake linings and consumer goods such as oven gloves, ironing board pads, and seals and gaskets to ovens, boilers and flues.

The main properties giving asbestos its commercial value as a building material are incombustibility, strength and effectiveness as a reinforcing or binding agent when combined with other materials such as cement or plastic. The different fibre types also are resistant in different degrees to high temperatures, electrical current and alkalies, and at absorbing sound.

Asbestos fibres tend to split into finer fibres when subjected to suitable treatment. Fibres tend to break not only into shorter fibres but also, because of their crystalline structure, to split lengthwise into finer fibres (or fibrils) invisible to the naked eye (two million can sit on a pinhead). These fibres can penetrate the lung.

The main risk of exposure to asbestos fibres in the home arises through do-it-yourself or maintenance operations; damage to asbestos panels and other products through abrasion; mechanical vibration or deliberate disruption of asbestos surfaces, and indiscriminate removal. For instance, sanding, drilling, cutting or breaking asbestos panels releases substantial amounts of asbestos fibres (e.g. sanding asbestos insulation board will release 6-20 fibres/ml, and power-sawing asbestos cement sheets produces 10-20 fibres/ml in air [58]). Concentrations are highest at the point of initial impact and vicinity of immediate exposure. The softer, more friable forms of asbestos products with a high asbestos content (e.g. boiler lagging or sprayed coatings) are more likely to release large numbers of asbestos fibres to indoor air, compared with compact, hard formulation products with a low asbestos content such as asbestos cement sheeting.

(a) Health effects

Release of asbestos fibres to indoor air poses a potential health risk as reflected in epidemiological, technical and experimental findings linked to asbestos exposure (i.e. direct occupational exposure, para-occupational exposure and true environmental exposure). Asbestos fibres especially >5 um in length and <1 m in diameter and having a length to diameter ratio >10 are biologically the most active and have been shown to cause asbestosis, bronchogenic carcinoma and mesothelioma. All types of asbestos fibre (crocidolite, amosite and chrysotile) have been implicated in causing disease, but crocidolite (blue) has been shown to be the most dangerous form and is more likely to appear in the lung area, whereas chrysotile is found largely in the pleura. This has been linked with fibre dimensions rather than chemical type. At present, asbestos-related disease has been associated mainly with occupational exposure. It has not been possible to come to a reliable quantitative assessment of the risk of malignancies for the general public as present evidence does not point to a threshold level of dust exposure below which tumours will never occur [59].

All asbestos-related diseases have a long latency period to onset of symptoms - often 10, 20 or in the case of mesothelioma 15-40 years after first exposure. They are nearly always fatal (often resulting in a long, painful death), and despite improvements in medical technology, none of the diseases are curable.

(b) Control measures

- A WHO Working Group on indoor air pollutants concluded that the emission of asbestos from building materials has sufficiently serious short-term and long-term consequences to warrant taking action to limit the problem by whatever measures feasible, in both new and existing buildings [61].

- The Working Group also concluded that the use of asbestos materials that can release fibres to the indoor atmosphere should be avoided in new construction. Existing buildings should be surveyed for such materials, and measures taken to eliminate or prevent them from releasing further fibres.

- Whenever possible, suitable non-asbestos alternatives should be used in new housing and public buildings. The choice of substitutes will depend on the specific performance required of the material (e.g. fire resistance) and the over-riding need to ensure that alternatives do not themselves create a health hazard.

- The mere presence of asbestos-containing materials in the home does not necessarily constitute a hazard, and removing undamaged material may create more hazard from dust and fibre release than would leaving it in place. The course of action for dealing with asbestos in existing buildings will therefore depend upon a number of factors:

(i) Condition of asbestos (i.e. whether damaged or not).

(ii) Friability of material: Fibres released from asbestos contained within hard materials such as concrete or plastics are negligible compared to soft asbestos boards containing little else apart from asbestos fibres and adhesive.

(iii) Treatment of surface: For example, painted or papered asbestos provides some protection from fibre release.

(iv) Position: Asbestos is more hazardous inside a dwelling compared with outside (externally, fibres quickly disperse and are heavily diluted). Air currents passing over asbestos surfaces (e.g. heating duct linings) increase the chances of asbestos fibres being released to the living accommodation.

(v) Accessibility: The more accessible the materials, the greater the risk of damage, particularly during maintenance operations or by accidental and non-accidental damage to asbestos products.

(vi) Content: The concentration of asbestos fibres in the material.

The relative importance of each of these factors may need to be weighted on a points-scale basis for determining whether to remove, seal or leave the asbestos undisturbed. This procedure would enable some removal priority to be established as part of an overall asbestos policy. Local health administrations should keep a register of the location of asbestos in their districts and keep details of persons exposed.

- In certain cases, it may be possible to seal in asbestos by painting or spraying with paint, bitumen or other suitable sealant.

- Health education programmes need to be drawn up to inform housing residents, members of the public and maintenance workers of the dangers of asbestos in the home and environment and the preventive measures available to control exposure.

2.5.3.2 Non-asbestos mineral fibres

The numerous non-asbestos mineral fibres have various uses and characteristics. The most common mineral fibres are "man-made" (MMMF), glassy fibres made from molten slag, rock or glass. Manufacturers characterize MMMF products by their nominal diameter. In occupational health, fibres are arbitrarily defined as elongated particles with a length-to-diameter ratio of 3 to 1. For example, a particle of 3.5-um diameter must be at least 10.5 um long to qualify as a fibre [60].

Slagwool and rockwool fibres are used mainly to make insulation wools, which are then compressed into blankets, boards, sheets or used as loose wool for loft and building insulation and as a reinforcing material in cements and mortars. Other mineral fibres include special purpose glass fibres with very small diameters and ceramic fibres used in high-temperature conditions.

(a) Health effects

MMMF can cause skin irritation but have not otherwise been demonstrated convincingly as hazardous to health (i.e. through inhalation). A conference on the biological effects of man-made mineral fibres, convened jointly by WHO and IARC, concluded that "there is no clear epidemiological evidence of increased cancer death or other diseases associated with MMMF exposure" [60]. However, animal studies show that inhalation of long, thin MMMF fibres can cause cancer (e.g. fibres with a diameter <0.25 um and a length of 20 um showed the maximum carcinogenic potential). Increasing the fibre length increases the proportion of fibres deposited in the lung. At present, MMMF represents a much safer alternative to asbestos in thermal insulation and fireproofing applications.

(b) Control measures

- There is little need to control the uses and applications of MMMF in the home and environment. Indeed, MMMF should be encouraged as an acceptable alternative to asbestos. However, it would be prudent to reduce exposure to the lowest possible point permitted by available technology [62], and direct handling of these materials should be avoided by use of protective clothing and some form of respiratory face mask during installation or maintenance operations.

- Whenever possible, long, thin MMMF within the respirable range should be specified for applications within the home.

2.5.3.3 Lead

Lead has been widely used in housing for water pipes, fittings and soldered joints. Lead oxides also have been used as a paint additive - particularly in lead primers. In normal circumstances, the most important sources of exposure are lead from food as a result of weathering of lead-rich ores and minerals in the soil, contamination of canned food by lead solder used in making cans, contamination of tap water used in cooking by lead in the plumbing system, and contamination of soil, crops and food by lead in air and dust [63]. Adventitious sources include eye cosmetics, medicinal products and lead-glazed food utensils.

(a) Health effects

The intake of lead in food, air and water is a major public health concern, particularly because of the pervasive toxic nature of lead exposure of the general population. In terms of acute lead poisoning, old lead paintwork has been identified as the most serious source. For example, Sachs [64] reported that 80% of patients seen because of evidence of lead absorption had a history of eating paint or plaster and another 10% revealed lead in the abdomen. A small paint flake 2-3 mm in diameter may contain over 1000 ug of lead, or over ten times the daily intake from all other sources [65]. A child who habitually ingests this amount can suffer severe lead poisoning in 3-4 months. In the United Kingdom, as in many other countries, old lead paintwork in the home is the single most common cause of severe lead poisoning and accounts for about one third of all known cases and about a quarter of all poisoning deaths from non-medicinal substances other than carbon monoxide [63].

Lead is an important neurotoxin, and young children are more susceptible to lead poisoning than adults because (a) a child's lower body weight means that it cannot tolerate the same dosage as an adult, (b) the effects of low-lead intoxication disproportionally reduce a child's concentration, intelligence and educational attainment, (c) children absorb more lead into their bodies (particularly bones as part of their normal physical development, and (d) children are more exposed to lead than adults because of their tendency to lick or chew old lead paintwork or eat or lick dirt or dust containing lead.

The symptoms of early lead intoxication include apathy, loss of appetite, anaemia and abdominal pain. In some cases, this leads to convulsions, ataxia, persistent vomiting and coma, which denote the onset of encephalopathy sometimes culminating in death. However, these cases of lead poisoning should be distinguished from subclinical effects characterized by behavioural disorders, learning difficulties, hyperactivity and other disorders that have been claimed to be associated with elevated blood-lead levels in young children.

(b) Control measures

- Each country should investigate the sources and distribution of lead in its housing stock with a view to formulating a policy that incorporates technical, legal and educational objectives aimed at minimizing lead intake from all sources. Such a programme could incorporate a routine blood-lead or preferably tooth-lead screening programme for preschool children and other high-risk groups and routine monitoring of lead in paint, soil, air, water and food.

- Childhood lead poisoning can be minimized by ensuring that lead-free paint is specified for all interior wood surfaces in new housing projects (especially in children's bedrooms, toys, nursery furniture and outdoor playground equipment).

- A number of control measures should be taken in existing housing to minimize the effect of high-leaded paint on walls, woodwork or other sources: loose or flaking lead paint to walls, woodwork or other sources should be carefully scraped off or removed with paint stripper, heat guns or wet sanders. (Dry power sanders should NOT be used as they release very large amounts of lead dust into the room.) Window sills, balustrades, cot furniture and door architraves need special attention as these are likely places where a child might chew. In all cases, old paintwork should be repainted with a lead-free paint and kept in good condition.

- Replacement of lead piping and lead-lined water tanks should be considered in areas where chemical attack from water is a problem (<pH 7). Water authorities should take all possible steps to reduce levels of lead in tap water by adjusting acidity of water and by using non-lead alternatives for water supply pipes and fittings. When lead pipes are replaced by copper, care should be taken that lead-soldered joints or brass fittings containing lead are not used.

- Lead-glazed earthenware intended for storing or cooking food should undergo strict quality control.

2.6 Sanitation requirements

The importance of sanitation as a healthy housing requirement has long been recognized by WHO. As long ago as 1949, a WHO Expert Committee defined environmental sanitation as "the control of those factors in man's physical environment, which exercise or may exercise a deleterious effect on his physical development, health and survival". In particular, it refers to "the control of housing to ensure that it is of a character likely to: (i) provide as few opportunities as possible for the direct transmission of disease ... and (ii) encourage healthful habits in the occupants". Provision of basic sanitation in human settlements has remained a primary objective of WHO and other United Nations programmes for developing countries, but over half the people in the Third World still do not have safe water to drink and three quarters have no sanitation [14].

In practical terms, housing sanitation is generally regarded as a clean supply of water, either piped into the dwelling or readily accessible to it for drinking, preparation of food, domestic washing activities and personal hygiene; a sanitary means for disposing of solid and liquid household wastes; and controlling insect, parasitic and other animal vectors of disease. The principal objective of sanitation is thus to minimize the spread of food and waterborne enteric infections as well as other diseases. However, this objective can be achieved only if improvements in sanitation are accompanied by good hygienic practices and health education programmes.

2.6.1 Water supply

The provision of potable and non-potable water supplies for drinking and washing purposes, respectively, is a basic housing hygiene measure still denied to millions of people around the world, particularly in rural areas of developing countries. Surveys by WHO indicate that an estimated 1800 million people are without clean water and 2400 million are without satisfactory sanitation out of the total world population of approximately 3200 million [66]. In addressing this problem, the United Nations Conference at Mar del Plata, Argentina, decreed 1981 to 1990 as the International Drinking-Water Supply and Sanitation Decade. The Decade's objective is to provide the entire global population with safe water supplies and hygienic waste disposal systems.

In the European Region, water supply provision varies considerably, but as expected, the developing countries and in particular rural areas are most deprived. For instance, a WHO rapid assessment exercise in 1981 showed that in one group of countries (Albania, Bulgaria, Czechoslovakia, Greece, Hungary, Ireland, Italy, Poland, Romania, San Marino, Spain and Yugoslavia), 90-97% of the urban population was connected to a good quality water supply but only 40% was connected to a sewerage system, whereas in the rural areas most of the population was served only by private wells and only 15% was connected to a sewer [67]. European countries with an industrially based economy also have deficiencies, with an estimated 40-95% served by a community water supply system and 0-30% connected to a sewerage system. However, in urban areas 95-99% was connected to a satisfactory water supply system and 70-75% to a sewerage system [67].

(a) Health effects

Historically, the location and eventual growth of human settlements have always been related to some extent to the availability of adequate water supplies from rivers, wells, springs and other sources. Without water, the human body dehydrates and physiological processes become severely impaired, leading in a few days to death. Humans also need water for growing food crops, preparing food and cleaning and washing. Water is thus important for long-term economic growth, prosperity and community development. Health problems can occur when the demand for water outstrips supply because of natural consequences, such as drought or adverse hydrological conditions, or unmatched population growth or excessive water demands related to industrialization or increased water consumption.

More commonly, human or animal excreta and toxic industrial effluent pollute water, making it unfit to drink or be used for other domestic operations. Contamination can occur either at source or during carriage from source to consumer. Some of the diseases caused by waterborne pathogens, viruses, parasites, chemicals and heavy metals are listed in Table 7. Of these waterborne diseases, especially diarrhoea is considered the major cause of morbidity and mortality in young infants and children, who are particularly susceptible to the effects of enteric diseases: a minimum of 1000 children under the age of 5 die every hour in developing countries from diarrhoeal diseases, amounting to 8 million children a year. In the countries of the developing world, 30-50% of all deaths of children under 5 is attributable to diarrhoeal diseases [68].

In addition, polio can be transmitted through chlorinated surface water, filtered water or untreated well water. The hepatitis virus also survives normal chlorination, and coagulation and sedimentation methods of treatment must be used to eliminate these viruses from water supplies. All these diseases

Table 7. Typical diseases associated with water supplies

Bacteria		
	Vibrio cholerae	Cholera
	S. typhi	Typhoid fever
	Shigella	Bacillary dysentery
	S. paratyphi	Paratyphoid fever
	Salmonella spp	Gastroenteritis
	Salmonella spp	Salmonellosis
	Legionella pneumophila	Legionellosis
Viruses		
		Enterovirus infections, including poliomyelitis and Coxsackie virus
		Echovirus and rhinovirus infections
	Hepatitis A	Epidemic hepatitis
Parasites		
	Roundworm	Ascariasis
	Nematodes	Oxyuriasis
	Whipworm	Trichuriasis
	Hookworm	Ancylostomiasis
	Guinea worm	Dracontiasis
	Flukes	Fascioliasis
	Flukes	Fasciolopsiasis
	Lung fluke	Paragonimiasis
	Flukes	Schistosomiasis
Chemicals		
	Iodine deficiency	Goitre
	Fluoride deficiency	Caries
	Excess fluoride	Fluorosis
	Excess inorganic salts	Diarrhoea
	Excess inorganic salts	Gastric upsets
	Sulfates	Nephrolythiasis
	Cadmium	Hypertension
	Sodium	Methaemoglobinaemia
	Nitrates and nitrites	Cyanosis
Heavy metals		
	Lead	Lead poisoning
	Arsenic	Black foot disease
	Arsenic	Skin and lung cancer
	Cadmium	Nephropathia
	Cadmium	Itai-Itai disease
	Mercury	Minimata disease
	Mercury	Nephropathia

are caused by pathogens from untreated sewage that contaminates water supplies. Epidemiological studies have shown that the rate of Shigella dysentery in children up to 10 years of age living in housing without an inside water supply was about twice that of a corresponding group whose homes had a pressurized inside water supply [68]. Other American studies have shown that the prevalence rate for shigellosis, the incidence of Ascaris infections and the morbidity from diarrhoeal diseases were inversely related to the availability of water [69,70]; that is, the further away the premises are from the water source, the greater the number of diarrhoeal diseases [71]. Other diseases, such as schistosomiasis, may be related to the absence of a piped water supply to houses, necessitating the collection of water for domestic use from a natural source and thereby exposing people to the disease.

Another infectious agent causing periodic outbreaks of disease is Legionella pneumophila, the cause of Legionnaire's disease. This bacteria has been isolated from water in air-conditioned cooling towers and evaporative condensers, hot and cold water taps and showers, and from creeks, ponds and the soil from their banks. Legionella spread through water-contaminated air has become a major problem in some hospitals and major public buildings.

Chemical contamination of water supplies for drinking and cooking also can adversely affect health. For example, excessive amounts of nitrates and nitrites from agricultural fertilizers can seriously contaminate water sources in some areas and may be responsible for causing methaemoglobinaemia in infants. Also, certain forms of cancer (e.g. bladder or gastric cancer) may be associated with very high levels of nitrate/nitrite in water through in vivo formation of nitrosamines and secondary or tertiary amines. The bacteria and optimum pH levels needed for the nitrosamine formation are available in the living organism. However, the link between nitrosamines and cancer has not been confirmed epidemiologically and it could be associated with food as well as with water.

Contamination of water from lead used in water supply pipes and fittings also can significantly contribute to blood-lead levels in children and adults, particularly in areas where plumbo-solvency is a problem. Other chemical contaminants of water include copper, iron and zinc from water pipes and fittings, but their adverse health effects under normal circumstances have not been proven. Nevertheless, large concentrations of copper and zinc can act as an emetic, and evidence from some Scandinavian countries suggest that copper in water is one cause of infantile diarrhoea, which has been fatal in these countries when water containing copper at levels of over 6000 ug is used to prepare an infant's bottle feed [72].

Other heavy metals that can adversely effect health include cadmium, mercury and arsenic. A more insidious concern is the presence in water of many organic compounds, often in very small concentrations and frequently unidentifiable with present techniques. Little is known about the health effects of these chemicals. For instance, at a WHO conference in 1975, toxicological data were available only for 45% of the 289 compounds occurring in water.

(b) Control measures

Wholesome supplies of drinking water and sanitary disposal of liquid waste products are of paramount importance to public health and housing hygiene, particularly in controlling enteric disease. A safe water supply is estimated to reduce the cases of all diarrhoeal diseases by 50%, with a similar reduction in bacillary dysentery, amoebic dysentery and gastroenteritis, while reductions in cases of typhoid could be expected to be as high as 80% and cholera 90% [66]. In rural areas of developing countries, no single measure can do more to improve health and wellbeing than an ample supply of safe water, providing that adequate facilities are made for the sanitary removal of waste water and excreta disposal.

- In general terms, potable water supplies should be wholesome, which means that its physical appearance, taste and odour are acceptable to the consumer and that it does not contain anything deleterious to the health of the consumer. Developing countries should carry out a countrywide survey of human settlements to ascertain which populations have reasonable access to clean water supplies and to identify those not served. Following the survey, short-term and long-term water supply plans should be drawn up to take account of the degree of scarcity of drinking water; number and location of settlements where enteric disease is endemic; total population of settlements to be served; per capita cost of each project and available capital; and the practical considerations of terrain and feasibility of providing disposal/treatment facilities for waste water.

- In new developments, water supply, water distribution, waste water disposal, drainage and sewerage should form an integral part of a master development plan.

- An institutional framework should be established for setting up an organization with the necessary manpower resources for planning, installing, operating and maintaining water supply and sanitation systems. Administrative, technical and managerial staff should be trained where necessary to enable personnel to plan, design, construct, operate and maintain the various water supply installations. Where possible, a single ministry, department or agency should be made responsible for water supply and waste water/sewage disposal administration.

- All reasonable steps should be taken to ensure that water supplies are quantitatively and qualitatively adequate at source. In particular, wells, streams, springs, reservoirs and other water supplies should not be polluted by human or animal excreta, toxic waste or other chemical contaminants such as nitrates and fertilizers.

- Where possible, water supplies should meet the standards specified in the International Standards for Drinking Water recommended by WHO [73] and EEC directives in countries belonging to the European Common Market. Water supplies need to be sampled and tested regularly to ensure compliance with these standards.

- Piped water supplies also need to be protected adequately against cross contamination from harmful bacteria or chemicals in the ground. In urban areas, water supplies are normally chlorinated or otherwise treated at source, but this is rarely undertaken in rural areas. Poor water quality often results unless supplies are adequately protected from excreta or chemical contamination.

- Water supplies in urban areas should be continuous, adequate, safe and supplied under sufficient pressure: interruption of service, intermittent supply or continued low pressure in the distribution system leads to the introduction of pollutants, such as sewage, into the water system. Also, a high water table can cause back pressure in water pipes if the water pressure is low. Vacuuming can occur in peak hours due to increased demand over supplies (particularly in furthermost areas). This can be a major source of entry for soil pollutants, causing outbreaks of enteric disease. When this occurs, pipes should be flushed with a high chlorine concentrate. The minimum water pressure for piped supplies is 1 kg/cm for each 10-m run.

- Potable and non-potable water supplies should be separated to avoid the possibility of cross connection between the two systems, which could constitute a serious hazard to health.

- In principle, adequate supplies of safe water should be provided for the domestic use of every inhabitant. Preferably, this should be by a piped supply of chlorinated water into the home but this may not be possible in some rural areas or in temporary shanty-town or slum housing. In these cases, deep-bore wells should be used, preferably pumped by electric pump and totally enclosed by a concrete surround. Deep springs also can be used for water supplies, providing that they are protected from surface and faecal pollution. If water supplies have any risk of being polluted, double jar disinfection with a mixture of sand, chlorine and sodium phosphate should be used.

- As an alternative to piped supplies, standpipes or public hydrants should be provided as near as possible to dwellings. Hygienic facilities should be provided for drainage of water from standpipes, including a surround. However, these measures should be regarded as short-term options for permanent settlements.

- Water storage tanks either inside or outside the home should always be kept covered to discourage algae growth following exposure to sunlight, and to prevent the entry of mosquitoes, rats, mice, squirrels and birds that could contaminate supplies. Storage tanks also need to be regularly cleaned to remove grit, dirt and other debris. They also need to be kept out of reach of children.

- The selection and design of materials used for water services need to be carefully considered to ensure that they do not provide a source of bacterial or chemical contamination to supplies. In areas where plumbo-solvency is a problem, <u>lead</u> should not be used in service supplies or tanks.

- In view of the importance of safe water supplies, individual countries should formulate legislation to control the design and construction requirements of all new and existing water installations and services from source to supply. The disposal of sewage and other wastes also should be regulated to make it an offence to knowingly pollute water supplies intended for human consumption.

- Local codes, ordinances and regulations should prescribe, in detail, construction materials and sanitary design of all water services, fittings and appliances. Provision should be made for enforcing the legislation at district level. Also, the development and application of surveillance procedures for monitoring raw water quality and the quality of drinking water throughout the distribution system are of the utmost importance.

2.6.2 Disposal of waste and surface water

The construction of new water supply systems increases the need for collection and sanitary disposal of domestic waste water, yet such systems are either non-existent or grossly inadequate in many communities throughout the world. The main reason is that community water supply has enjoyed a higher priority than the collection, treatment and disposal of waste water, which is often delayed until after water supplies have been provided. This delay occurs despite the fact that community water supplies, a water-carriage waste disposal system and sanitary disposal of excreta are all basic inter-related requirements for controlling enteric and other diseases. Thus, the provision of piped water supplies to an area commonly causes a deterioration in existing health conditions until adequate waste disposal facilities have been installed [74].

However, non-industrial countries are hampered by limited financial resources, skilled labour and lack of a manufacturing base for materials and plant; more priority and money thus need to be given to drainage and sewage disposal schemes when installing community water supplies if waterborne diseases are to be controlled effectively.

(a) Health effects

Inadequate drainage arrangements for waste and surface water may result in pools and puddles of muddy and marshy areas that provide breeding places for mosquitoes, flies and other insect disease vectors. Similarly, water run-off from standpipes, latrines and food preparation areas can provide a major source of biological contamination, particularly when mixed with animal excreta and solid waste.

Inadequate surface water drainage also can cause periodic flooding of roads, wells and housing, creating further hazards to health and safety.

(b) Control measures

- Waste-water collection/carriage systems should be installed at the same time as new piped water supply systems wherever practicable. However, each waste water treatment problem is unique and the solution must be adapted to local resources, including water availability, labour and materials, rather than blindly adopting waste water treatment processes appropriate to developed countries.

- Piped water carriage systems connected to a main sewer is the preferred method for removing foul water and sewage. However, it is important that the design and construction of drainage systems conform with sanitary principles and that drainage effluent does not leak out into surrounding ground, contaminating water supplies or otherwise causing a public health hazard. In particular, improperly made joints and sewer connections are responsible for many leakage problems associated with a piped disposal system. Uneven settling of pipes resulting from poor installation or soil movement is the main cause of pipe fracture and leakage to the surrounding ground.

- Rainwater can be disposed of by individual soak-aways situated a minimum distance of 4 m from a building. It is important that water can permeate from soak-aways into the surrounding subsoil, which is not possible where the surface material is impervious to water. In these cases, a soak-away should be carried down into permeable soil below.

- To prevent waterlogging, soak-aways should not be carried below the highest natural level of the water table.

- Rainwater and surface water also can be drained directly to a stream or other water course without treatment. Open rainwater drainage channels frequently become blocked with rubbish, leaves and other debris, creating a public health hazard. Closed pipes with access points and for maintenance and appropriately protected from traffic, etc., are preferred.

- Access to drains and sewers should be provided by inspection chambers so that every length of drain is accessible for maintenance (>90 m between access points). This is particularly important at all changes of drain direction and gradient (except where change is not too great for cleaning), at all drain junctions where cleaning is not otherwise possible and at the head of each length of drain. (A rodding eye may suffice for a shallow branch drain.) Inspection chambers need to be watertight and large enough to enable them to be cleaned from the surface. Suitable materials include brickwork, cast iron and precast concrete.

- The flow in a waste-water collection system is normally at atmospheric pressure, with the direction of flow being from a higher to a lower elevation. To enable self-cleansing and flushing, a waste-water plumbing system should make use of the smallest pipes that will conduct waste water away rapidly without clogging or siphonage of traps. Plumbing should be easily accessible for ease of maintenance and should be designed with no possibility of back pressure that might lead to contamination of the water supply system.

- The plumbing system should normally be vented to prevent siphonage and loss of water seals. Venting also provides circulation of air in the drainage system, ensuring gravity flow and minimal odours. Alternatively, unvented, single-stack systems constructed to proper sanitary design should be used.

- Venting stacks should not generally be of less than 32-mm diameter, should extend vertically through the roof and so discharge that foul air does not cause nuisance.

- Traps should be used on all plumbing fixtures to provide a liquid seal preventing passage of air without materially affecting the flow of waste through it.

- To prevent back siphonage of waste water from a plumbing fixture or vessel into water supply pipes due to negative pressure (particularly in plumbing fixtures or tanks with inlets below the level of the top rim), potable and contaminated waters should be separated by an air gap.

- Cleaning access points must be readily accessible at each major change of direction of plumbing pipes.

- Materials for the plumbing systems should be selected for strength, durability and ability to resist the corrosive action of wastes discharged into them. Cast iron pipes with lead-caulked joints have long been the standard material for main indoor plumbing, galvanized steel being commonly used for vent pipes. Plastic is replacing metal for small-bore plumbing and is most suitable in developing countries because of ease of construction and cheapness.

- Underground drains and sewers should be of sufficient size to accommodate the number of properties serving them, including any future demands arising from new development. Separate sewers for foul and surface waste water are often advantageous. Although initially more expensive than a combined sewerage system, this system reduces scale and cost of sewage treatment in the long term.

- House drainage pipes should be a minimum 100-150 mm in diameter with a smooth, even internal bore, and be constructed of strong, durable materials impervious and resistant to chemical or acid attack. Suitable materials for underground drainage pipes include cast iron, vitrified clay, concrete, asbestos-cement or sometimes pitch-fibre or unplasticized polyvinyl chloride. Choice of materials depends mainly upon loading, thermal movement and ground conditions - particularly ground movement. Where separate sewerage systems are used, it is important that adequate controls prevent cross connections.

- House drains should be laid straight and at a sufficient gradient of not less than 2% to enable a self-cleaning velocity to be maintained.

- Most drainage can be joined by either rigid or flexible joints. In general terms, flexible joints are preferred where ground movement or thermal expansion of pipes may occur. In these cases, pipes need to be adequately supported by readily compacted granular material. Pipes with rigid joints need to be encased in concrete to ensure water tightness, prevent root penetration and maintain structural strength. The depth of cover over a drain or sewer beneath a paved surface should be not less than 450 mm and beneath an unpaved surface not less than 600 mm.

- Gullies with a minimum water seal of 50 mm should be provided to drains carrying waste water and surface water. Intercepting traps are sometimes used to disconnect the passage of air from a sewer or cesspool into a drain. However, these often block up and need frequent inspection and maintenance.

- All parts of the house drainage/sewerage systems should have a free passage of air through each part of the system. Permanent openings are required at the lowest and highest points with due regard to preventing odour nuisance.

- All old drain pipes should be removed or properly sealed off to prevent them being used as rat runs.

- Adequate drainage needs to be provided for rainwater run-off to courts, yards or paved areas.

- A number of technical, legal and educational measures need to be taken to ensure that all parts of the drainage system do not get damaged, become blocked up, cause nuisance or create conditions prejudicial to health. The drainage and plumbing system must be regularly inspected and maintained.

- Building codes and ordinances should specify design and construction requirements for all new drainage. Owners should be legally required to submit plans and proposals for all new drainage works or alterations of the existing system to the local health administration for approval. Agencies need to be established for inspecting and testing drainage works as necessary and enforcing codes and ordinances.

- Wherever practicable, owners of new and existing buildings should be encouraged or legally made to connect with a sanitary sewerage system when provided. Financial assistance may need to be given in some cases to pay for connection costs.

- Owners of existing buildings should be legally required to make satisfactory provision for drainage and to repair, alter or unblock insanitary appliances, fittings or pipework. This should include filling up, removing or otherwise treating a disused cesspool, drain or sewer.

- Drainage legislation also should make the putting of any matter into a sewer or drain that is likely to impede the flow or affect the treatment and disposal of contents an offence. This would include controlling disposal of chemical waste, steam, petroleum products and foreign objects.

2.6.3 Toilet facilities

(a) Health effects

Numerous epidemiological studies have shown that insanitary toilet facilities encourage the spread of enteric diseases. These diseases are usually transmitted through the faecal-oral route by contaminated hands or disease vectors such as flies and crawling insects. Open-air defaecation or bucket privies are still commonplace in many underdeveloped and developing countries, and satisfactory toilet facilities are still deficient, particularly in villages and shanty towns. Communal or shared toilet accommodation is often extremely insanitary and provides a route for cross-infection of enteric diseases.

Research in Nottingham, England, over a 10-year period showed that typhoid fever had an incidence of 1 in 137 for persons residing in dwellings served by a privy compared with a case incidence of 1 in 558 for persons residing in dwellings with indoor flush toilets [75]. An American study showed that the incidence of diarrhoeal disease was about twice as high in dwellings with privies for excreta disposal compared with persons living in houses with inside flush toilets [76].

A national health survey in 1935 and 1936 in the USA showed an excessive incidence of typhoid and paratyphoid fevers, diarrhoea, enteritis and colitis among persons living in housing without private inside flush toilets as compared with families having them [77].

Studies of diarrhoeal disease in Guatemala during the 1950s showed that Shigella infection was approximately three times greater among families living in areas where inside toilets were available in less than one half of the dwellings than among those families living in areas where more than one half of the houses had such facilities [78].

(b) Control measures

- Every dwelling unit should be provided with its own separate inside sanitary accommodation. However, this may not be possible in housing shared by more than one family or in some multiple housing schemes where sanitary accommodation has to be shared. In these cases, special care has to be taken that sanitary arrangements are adequate and regularly cleaned to reduce the risk of spreading infection.

- To prevent odour nuisance, sanitary accommodation should preferably be so sited that it does not open directly into a habitable room or kitchen (i.e. there should be an intervening ventilated lobby between rooms and sanitary apartments). Where possible, a compartment containing a WC, urinal or slop sink should be situated on an external wall.

- Outside toilet accommodation is rarely convenient to users, especially at night. However, where provided, it should be within reasonable distance of the dwelling unit and easily accessible to all members of the household. Alternatively, in some cases, it may be practicable to provide covered access to it.

- Every sanitary compartment should be constructed with smooth, impervious surfaces to floors and walls that enables easy cleaning. In particular, floors should be coved at their junction with walls to enable effective cleaning operations.

- Sanitary compartments should be suitably lighted and ventilated by means of a window opening directly to the outside. Where mechanical ventilation has to be used, the apartment should have an exhaust system. Both natural and artificial ventilation systems should provide at least three air changes per hour.

- Adequate sound insulation should be provided between WCs and adjoining rooms. Silencer tubes should preferably be fitted to water supply pipes.

- WCs rely entirely on the wash-down action of the flow and are the preferred method for the sanitary disposal of domestic sewage. The closet receptacle should have a smooth and readily cleansed non-absorbent surface, so constructed and fitted as to discharge through an effective trap to a drainage pipe or sewer. Both the wash-down closet and siphonic closet are self-cleansing and are suitable fixtures for normal use, providing that the flushing apparatus can effectively cleanse the toilet bowl. Enamelled fireclay and glazed earthenware (porcelain) are strong, durable materials suitable for heavier types of fitting such as toilet closets.

- Siphonic units are more expensive than wash-down types but are neat, generally quieter and more hygienic because the flushing action does not create such an aerosol. However, they are more liable to blockage within the siphon.

- Toilets with timber inserts of the rim are useful where hard, rough usage is anticipated but are not as hygienic as those fitted with drop-down seats and covers.

- Where blockage might be a problem, toilet pans with an integral clearing eye should be provided. Toilets should be so arranged that pipes from them go direct to a soil-vent pipe, or in the case of ground floors, to the drain.

- Eastern closets are a typical feature in many developing European countries. They are particularly popular in communities where cultural traditions discourage bodily contact with a toilet seat as in traditional WC fittings. This overcomes the risk of cross-infection by this route. However, eastern closets frequently become badly soiled and insanitary, particularly in the bowl area. It is therefore important that satisfactory flushing equipment for cleansing the closet bowl is provided and regular arrangements made for routine cleaning and maintenance. This is best achieved by a flushing cistern permanently connected to a piped water supply. Where this is not possible, manual pour-flush cleaning can be used.

- To prevent nuisance from odours, eastern closets must be properly disconnected from the sewerage system by a trapped interceptor, particularly when connected to a cesspool, pit latrine or septic tank.

- The earth closet uses the well-known power of dry earth to neutralize faecal matter deposited in a storage receptacle. The earth chosen should be clean, dry, fertile top-soil sifted through a 6-mm mesh (sand and ashes are not suitable). This is deposited in a stout galvanized receptacle of not more than 55-litre capacity held in position by a suitable guide and fitted closely into a suitable enclosure.

- Earth closets are not, strictly speaking, sanitary fixtures but are still commonly used in many rural areas lacking piped water supplies or a water-carriage sewerage system. Earth closets are not recommended for collecting and storing excreta as the need to regularly empty and dispose of contents in a sanitary manner often creates public health problems.

- Earth closets should be so situated that they do not pollute any spring, stream, well or other source of water which is used for drinking or domestic purposes. In particular, the storage receptacle should be of non-absorbent material and be watertight.

- Chemical closets use a deodorizing, liquefying or sterilizing liquid that neutralizes faecal waste. The closets are usually constructed of fibre glass and range from an enclosed bucket to semi-permanent, re-circulating units. As with earth closets, adequate collection and disposal arrangements need to be made with this system.

- Slop sinks are hopper-shaped sinks with a flushing outlet similar to a toilet pan. They are used for receiving and discharging excreta and are particularly common in communal systems. They should be provided with siphonic flushing cisterns or flushing valves in the same way as WCs are properly connected to the drainage system.

2.6.4 Excreta disposal

Sanitary facilities for excreta disposal are still inadequate in many developing countries. This has always been a problem in villages and rural areas, which are rarely connected to main sewerage schemes and where dry systems for excreta disposal are commonplace. For instance, a survey of community water supply and sewage disposal conditions conducted by WHO in 1971 and 1972 in 91 developing countries showed that in urban areas, only 28% of the population was served by a public sewerage system, while 29% (114 million people at 1970 figures) was not served by any sanitary system whatsoever. In rural areas, 92% of the population (or 962 million people at 1970 figures) was without sanitary facilities at all. In the European Region alone, less than 10% of the rural population in developing countries has adequate facilities for excreta disposal at the present time [1].

(a) Health effects

A significant number of epidemiological studies have been conducted on the significance of correct drainage and excreta disposal in preventing enteric and other diseases. In the main, these are related to cross-contamination of water supplies through leaking drainage pipes or direct contamination of water sources by untreated sewage. Water pollution from disposal of domestic sewage, liquid wastes and industrial effluents also can have an indirect impact on air and soil pollution. This can directly contaminate food crops. Overflow from latrines, cesspools or septic tanks can contaminate well water or underground water courses as well as create insanitary surface conditions that expose people directly to helminthic and protozoal parasites and other pathogenic organisms, and encourage fly infestations.

These pathogens are a major source of enteric disease (particularly in children) in developing countries.

Table 8 summarizes the principal viral, bacterial and protozoan pathogens found in human excreta. In carriers, 1 gram of faeces can contain about 10^{10} bacteria, of which 10^{8} are coliform; moreover, 10^{8} salmonella organisms have been found. These bacterial and viral diseases may be spread to humans by polluted water supplies, contaminated food, house flies, crawling insects and other disease vectors.

Human faeces also may contain eggs of cestodes (tapeworms), such as _Taenia saginata_ and _Taenia solium_, or of nematodes, such as _Trichinella spiralis_, from human hosts who have eaten infected meat. Up to 90% of the rural population in Mediterranean countries sheds worms in excreta, the most common being round-

Table 8. Viral bacterial and protozoan pathogens found in excreta [79]

Group/Organism	Disease*	Reservoir
Viruses		
Polio virus	Poliomyelitis	Humans
Echovirus	Various	Humans
Cocksackie virus	Various	Humans
Hepatitis A virus	Infectious hepatitis	Humans
Rotavirus	Gastroenteritis in children	
Bacteria		
Salmonella typhi	Typhoid fever	Humans
S.paratyphi	Paratyphoid fever	Humans
Other salmonellae	Food poisoning	Humans and other animals
Shigella spp	Bacillary dysentery	Humans
Vibrio cholerae	Cholera	Humans
Other vibrios	Diarrhoea	Humans
Pathogenic E. coli	Gastroenteritis	Humans
Yersinia spp	Yersinosis	Humans and other animals
Campylobacter spp	Diarrhoea in children	Humans and other animals
Protozoa		
Entamoeba histolytica	Amoebic dysentery and liver abscess	Humans
Giardia lampblia	Diarrhoea and malabsorption	Humans
Balantidium coli	Mild diarrhoea	Humans and other animals

* All diseases listed have a symptomless human carrier.

worms, hookworms and ringworm. These parasitic diseases may be perpetuated by human excreta on land used for grazing by cattle, pigs and other intermediary hosts, indiscriminate excretion or insanitary sewage disposal methods. Concerning pathways for human contact, edible animal tissues or products might be contaminated through primary and secondary impact, possible bio-accumulation processes and transfer from soil to animal tissues.

In addition, inadequate disposal of sewage effluents or sludges onto land can seriously raise the levels of metals normally present in sewage, such as copper, lead, zinc, cadmium, chromium or mercury. Finally, the inadequate drainage of standing water from a neighbourhood also carries the risk of widespread epidemics of filariasis in some tropical cities by providing breeding sites for mosquitoes that spread the disease. Insanitary domestic drainage and sewage disposal arrangements also may cause considerable nuisance from odours and attract flies as well as possibly interfere with the local ecology of watercourses used as open sewers.

(b) Control measures

- In urban settlements, a piped water-carriage system is preferred for effluent, which can then be treated at a suitable sewage treatment plant serving the whole area. The aim of all waste water and sewage treatment plant design is the removal of pollutants from the waste water to the extent necessary to achieve the desired quality in the plant effluent.

- Communities lacking sanitary excreta and waste water disposal facilities have to rely on ditches, streams, open conduits or direct disposal to the ground. Where water supplies are inadequate, dry systems for excreta disposal may be used. As has been pointed out, these unhygienic methods are an obvious source of nuisance and threat to health: their removal should therefore be a main priority of a housing hygiene policy. In the interim period, arrangements need to be made for the proper collection and disposal of excreta to suitable disposal points.

- Large-scale sewage treatment schemes are fundamentally appropriate only in large urban settlements, providing that sufficient water is available for carrying the excreta to the plant. The quality of treatment effluent must meet international standards for sewage effluent before discharge to land, watercourses or the sea.

- In rural or remote areas, septic tank installations enable waste to be treated biologically and ensure that polluting factors are removed from the liquid or otherwise rendered harmless before discharge over the site or into an adjacent stream. It comprises settling tanks where anaerobic bacteria break down the solids into liquid form and contact or filter beds where aerobic bacteria remove the solids left in suspension before final disposal of the liquid waste. Sludge settling in the bottom of septic tanks has to be removed occasionally by a tanker or spread over the site and dried before being used as compost. This plant is particularly suitable for small groups of buildings not accessible to a main drainage system, but which have room to dispose of the treated effluent.

- The principal criteria for septic tank installations and other disposal schemes is that they must be automatic, require a minimum of attention and be free from nuisance, either of sight or odour.

- Purified sewage effluents may be disposed of by surface or subsoil irrigation or sometimes by discharge into a stream. The siting of the tank and the outfall should be carefully considered so that it does not cause nuisance or pollute water supplies.

- The type of soil on-site must permit septic tanks to dispose effluent evenly and harmlessly when other outlets such as streams are unavailable. For example, a septic tank installation would be unsuitable in heavy clay soil (unless the required standard of purification could be obtained without the need for land filtration and it could be fed direct to a stream) or if the water-table is likely to be within 1.5 m of ground level for periods of several weeks.

- A settlement tank or septic tank should be of suitable depth, of adequate size and capacity for its use and be covered or fenced in. In addition, it should be properly ventilated and constructed with access for inspection, emptying and cleansing.

- Septic tanks should be situated away from trees and protected from falling leaves with wire mesh or other means.

- Cesspools are the cheapest and therefore the commonest means of hygienic storage of sewage outside a sewered area, providing that they are designed and located in accordance with sanitary principles.

- Cesspool tanks should be constructed and designed to be impervious to surface water and rainwater (i.e. they should be watertight and should not have any outlet for overflow or discharge other than the outlet provided for emptying or cleansing). This is of particular importance if cesspools are situated near watercourses or other water supplies.

- Cesspools should have sufficient capacity. Ideally, they should not be less than 18 m^3 and be so situated that they can be emptied easily and hygienically (usually three or four times a year). In developing areas, the drainage system to the cesspool should be so positioned that it is capable of being easily connected to a new sewerage system at a later date.

- Cesspools should be adequately ventilated and fitted with a suitable manhole cover to permit inspection, emptying and cleansing, and be of a suitable depth for complete emptying.

- Cesspools should be used only for storing excreta and foul water; surface drainage should be discharged into soak-aways.

- Pit latrines are more common in developing countries where, because of cheapness, they are the only economically appropriate method for excreta disposal. Several different designs in use rely on either a single- or double-leeching pit that may or may not be watertight.

- The location of pit latrines and their watertightness should depend upon the positioning of underground water supplies and available resources for emptying of pits. Double pits permit excreta to decompose into a harmless and organically rich fertilizer. Provision has to be made for a water seal to be installed between the latrine pit and the fittings.

- Numerous international standards for drainage and sewerage construction materials exist, including several relevant to EEC countries. However, several WHO publications detail the various drainage and sewage disposal options for developing countries, including Community waste water collection and disposal by Okum & Ponghis [80]. The design and construction of septic tank installations are fully described by Wagner & Lanoix in the WHO publication Excreta disposal for rural areas and small communities [81].