

# THE PHYSIOLOGICAL BASIS OF HEALTH STANDARDS FOR DWELLINGS

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## PREFACE

*As a society advances, the rise in its cultural level and standard of living is accompanied by an immense increase in the demands made upon the home, in which most of a person's life is spent.*

*The modern home should not only provide protection from unfavourable atmospheric conditions, but also prevent the spread of contagious diseases and ensure physical and mental comfort, rest or creative activity, and the maintenance of human health in the wider sense. To this end, the most recent achievements in the science of building should be employed, and the design of the dwelling should be based on physiological data.*

*Sanitary science as a whole, and that part applicable to housing in particular, must define optimum hygienic conditions for the home such that the health of the population is maintained and their work output enhanced.*

*The formulation of standards for sanitary living conditions is a difficult and responsible task. Experiments on animals and observations on human beings must be used to discover the limits within which particular environmental factors are harmful to mankind or adversely affect physiological comfort.*

*Physiological data are available on many of these factors; but many others, such as the microclimate of the home in various latitudes, noise and psychological factors affecting health in the home, and problems related to the action of radiation, have not yet been sufficiently studied, because of their seemingly slight effect. However, the prolonged action of these factors, frequently extending over the whole human lifespan, means that they can have a very important effect on environmental health, and therefore merit investigation.*

*Research carried out on conditions in the home in countries such as the USSR, Great Britain, and France makes it possible to define a number of fundamental physiological requirements and standards applicable to housing construction; these in turn provide a guide for the drawing up of local "standards" which, as new scientific data accumulate, and as economy*

*and industry advance, will be further improved both in the developed and in the developing countries. Emphasis has been placed on this point in the first report of the WHO Expert Committee on the Public Health Aspects of Housing which discussed these problems in 1961.<sup>1</sup>*

*Such research should have three main aims:*

- (a) definition of the optimum physiological conditions in dwellings;*
- (b) adaptation of various features to various climatic zones; and*
- (c) co-ordination of housing planning and community planning.*

*These three aspects are dealt with in this paper. Despite the brief treatment, necessitated by the limited space available, it is hoped that the paper will stimulate interest in and discussion of this important topic.*

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<sup>1</sup> *Wld Hlth Org. techn. Rep. Ser.*, 1961, 225.

## CHAPTER 1

# THERMAL COMFORT AND THE MICROCLIMATE OF THE HOME

### GENERAL CONSIDERATIONS

In the design and construction of homes, one of the most important tasks is the provision of means for creating the best possible microclimate within the building. The microclimate of a dwelling is determined by the temperature of its walls and furnishings and by the temperature, moisture, movement, and exchange of the air within it. The values of these factors must be selected so as to give maximum protection against the exterior climate and to promote and maintain the health and well-being of the occupants.

The voluminous literature dealing with physiology and public health has established a firm foundation for the understanding of thermoregulation and for the study of the reactions of the human body to climatic and other environmental factors.

Conditions that lead to discomfort and disturb the body's heat-regulating mechanism and equilibrium may lead to a number of pathological conditions such as colds, pharyngitis, and neuralgia through cooling or overheating of the body.

It must be remembered that, despite the considerable ability of the human body to adjust to the environment, its powers of thermal regulation can compensate for only a relatively small range of climatic conditions. The so-called "zone of indifferent metabolism", which may be defined as the temperature range over which human energy expenditure is minimal, extends from 15 °C to 22 °C (Rubner, 1907), or to 25 °C (Maršak, 1931; Slonim, 1952), and even within this narrow range of 7-10 °C the body always reacts very sensitively to comparatively small changes in atmospheric conditions.

The establishment of health standards for the microclimate can no longer be decided by popular feeling. It is now essential to standardize all the factors that determine the microclimate of the dwelling. This task becomes all the more important because of the extensive application of mass-production methods to home construction, the use of improved

methods of heating, ventilation and air conditioning, and the use of automatic methods for regulating temperature and humidity.

The first need, therefore, is to determine the optimum microclimatic conditions for the home. There is no doubt that there are conditions that are preferred, and these are usually described as conditions of comfort, which Pavlov (1951a) has defined as those ensuring "optimum equilibrium" with the environment. Ecological observations have demonstrated the existence of an optimum temperature range within which an energy balance is most readily attained (Kalabuhov, 1956). For man, therefore, the zone of preferred temperatures is determined not merely by his subjective feelings but also by physiological factors. Consequently, the zone of thermal comfort is conceived of as a set of atmospheric conditions under which the least demands are made upon the human thermoregulatory system (a state of physiological rest); at the same time, all the physiological functions proceed at a level most favourable to rest and to the recovery of strength after previous exertions. Such a definition of the zone of comfort is further justified by the fact that the modern dwelling is designed chiefly with a view to affording rest.

From the health point of view, the usually accepted approach to domestic heating, which aims at the maintenance of thermal equilibrium, is not really sound. For example, if the environmental temperature exceeds the body temperature, thermal equilibrium may be attained through increased heat loss due to evaporation, but this will not produce thermal comfort.

The high biological adaptability of the human body to the environment ensures that it is unnecessary to establish any narrow standard of thermal comfort for all persons under all conditions. However, for a given population living under conditions involving the same degree of activity or rest, such standards may be established and may be described in terms of normal values designed to suit the "average" healthy individual.

Such standards will vary with climate and season, will differ for men and women, and will differ still more for the elderly, for children, and for those whose thermoregulatory ability is impaired. Therefore, to establish standards of thermal comfort in dwellings, account must be taken of the limits of physiological adaptation of different population groups.

#### THERMOREGULATION: PHYSIOLOGICAL CRITERIA OF THERMAL COMFORT

It is known that all vital processes are associated with the production and liberation of heat. All species of birds and mammals, including man, have evolved a temperature-regulating mechanism that provides an adjustment whereby the body temperature is maintained at a constant



level quite independently of climatic conditions, whether tropical or polar; this adjustment is an extremely important factor, ensuring that the internal processes are, to a large extent, independent of variations in the temperature of the environment.

However, the temperature of an animal or man does not depend exclusively upon the constant production of body heat, which continues as long as life is maintained. An extremely important role in the maintenance of body temperature at a more or less constant level is played by regulation of heat loss. This loss, like all other body functions, is to a large extent automatically regulated and is under the control of the cerebral hemispheres.

The body temperature of a healthy person varies within very narrow limits. The rectal temperature is usually  $37^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ , and in the armpit it is  $36.6^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ . The temperature of the skin and subcutaneous tissue in the limbs is not only lower than the body temperature but also appears to vary over quite wide limits ( $28^{\circ}\text{C} \pm 15^{\circ}\text{C}$ ) without any after-effects being noticed by a healthy person.

This observation was made as long ago as 1886 by Pavlov (1951b), who introduced the modern concepts referred to in English as the "core" and the "outer shell" and in German as *Kern* and *Leiter*.

From this point of view, the body of a warm-blooded animal may be considered as consisting of a strictly homoiothermic core and a more or less poikilothermic outer shell. This does not, of course, refer to morphologic structures. The core not only remains at a temperature which is constant within more or less narrow limits, but it also responds to external temperature changes by a change in the opposite direction. Thus, if the body is cooled, heat production is increased and the rectal temperature rises; if the body becomes too warm, heat production is reduced and the temperature falls (only, of course, during the period of compensation). If the heating or cooling is continued or increased beyond the capacity of the compensatory mechanisms, the temperature of the core may fall or rise.

For the outer shell, the reactions are of a different type. When the environmental temperature falls, the temperature of the shell also decreases, with the result that the rate of heat loss is slowed; if the environmental temperature rises, there is a corresponding increase in the heat loss.

A change in the temperature of the outer shell has a further important consequence. As a result of the drop in the temperature of the skin and the muscles of the limbs or of the skin and the subcutaneous tissue of the trunk, there is a reduction in the flow of blood through these tissues. However, their thermal conductivity depends, to a large extent, on the amount of blood they contain and on the rate at which it flows through

them. The greater the amount of blood or lymph in the tissues, the higher is their thermal conductivity and the lower is the insulating power. On the other hand, the less blood there is in the tissues, the greater is their degree of thermal insulation; the lowest heat conductivity is shown by the fatty tissues of the body and the greatest by the blood. Therefore, when the temperature of the superficial tissues (the outer shell) falls, there is a corresponding reduction in the direct transfer of heat through them to the external environment.

When the blood vessels are dilated to their maximum extent, heat is transferred from the surface at the rate of  $5.55 \text{ cal/m}^2/\text{h}$ ; when they are constricted to the minimum extent, the rate of heat transfer is only  $3 \text{ cal/m}^2/\text{h}$ —i.e., it is reduced by 40 %. This means that although the mean skin temperature may vary over a range of  $33^\circ\text{C} \pm 3^\circ\text{C}$  in the state of muscular rest, the heat insulation provided will, because of the change in the blood flow through the tissue, remain approximately the same, as will the heat conducted away from the internal organs through the superficial tissues.

This mechanism is fairly effective for comparatively small variations in external temperature, but it is far from adequate in severe cold. This is well demonstrated by the fact that at an air temperature of  $-40^\circ\text{C}$  heat loss to the surroundings changes by no more than 5 %, the mean cutaneous temperature falling from  $33^\circ\text{C}$  to  $30^\circ\text{C}$ .

It should be noted that, in the region of the trunk, the cutaneous reaction more closely resembles that of the core; that is, the temperature is maintained at a higher and a more constant level. The same is true of the skin of the forehead. The skin of the face, hands, feet, and loins is typical of the outer shell and undergoes far greater temperature variations than does that of the trunk region.

Heat loss is essentially a physical process; the human body, like other bodies, loses heat to the environment through convection, conduction, radiation, and evaporation (Table 1). As shown in Table 2, the loss of body heat by radiation is related only slightly to the velocity of the surrounding air. On the other hand, heat loss through convection increases with the velocity of air movement. There is a considerable loss of water from the human body by evaporation. The latent heat of evaporation of water is high: to convert 1 g of water into 1 g of water vapour at body temperature requires the expenditure of 584 cal (about 0.6 kcal).

All modes of heat loss are subject to purely physical laws, and the human body is incapable of bringing about any alterations in this respect. It can, however, regulate the conditions of its heat exchange by changes in position, changes in the temperature of its outer parts, perspiration, variation in the production of heat, and so on. Change in position presents a very clear example of adaptive thermoregulatory response.

Because the rate of heat loss is proportional to the surface area, a person in cold surroundings may reduce the surface exposed to heat exchange by drawing up his limbs on to his trunk and tucking his head into his shoulders. On the other hand, if he is hot, he can adopt an extended position, thus increasing the heat-exchange surface.

TABLE 1. MODES OF HEAT LOSS IN A NORMALLY CLOTHED ADULT, AT REST UNDER CONDITIONS OF THERMAL COMFORT

Author	Percentage of heat transfer *		
	Convection and conduction	Radiation	Evaporation
Bazett (1949) . . . . .		76.0	24.0
Crowden (1951) . . . . .	33.0	45.0	22.0
Du Bois (1937) . . . . .	14.2	59.7	20.7
Letavet & Malyševa (1954) .	15.0	56.0	29.0
Rubner (1927) . . . . .	32.4	45.9	21.7
Vitte (1956) . . . . .	33.0	44.0	23.0

\* Total heat loss taken as 100%.

TABLE 2. HEAT LOSS BY CONVECTION AND RADIATION AT VARIOUS AIR VELOCITIES \*

Air velocity (m/sec)	Percentage of heat loss by		Thermal insulation of the air (clo*)
	Radiation	Convection	
0.09	52	48	0.85
0.25	39	61	0.64
0.36	35	65	0.57
0.49	31	69	0.25
0.81	26	74	0.43
1.21	23	77	0.37
2.25	18	82	0.29
4.00	14	86	0.23

\* Data from Burton & Edholm (1955). Based on an air temperature of 25 °C.

\*\* The clo is an arbitrary unit of thermal insulation used with reference to clothing. One clo represents approximately the insulation provided by a 0.5-cm thickness of wool.

In addition, the bodies of warm-blooded animals, including man, react to atmospheric changes by alteration of the surface temperature. The effectiveness of this mode of thermoregulation may be illustrated by some examples, bearing in mind that the heat loss, as a whole, is proportional to the difference between the temperature of the body and that of

the environment. For example, if the room temperature is  $21^{\circ}\text{C}$  and the temperature of the hands is  $29^{\circ}\text{C}$ , the heat loss will be proportional to  $8^{\circ}\text{C}$ . If the air temperature falls to  $13^{\circ}\text{C}$ , the temperature of the hands may fall to  $19^{\circ}\text{C}$  as a result of the constriction of blood vessels and the reduction of blood-flow through the peripheral tissues. Had the skin temperature remained constant, the temperature difference would have increased to  $16^{\circ}\text{C}$  ( $29^{\circ}\text{C} - 13^{\circ}\text{C}$ ) and the heat loss would therefore have doubled. In fact, the difference in temperature between the skin and the surroundings is now only  $6^{\circ}\text{C}$  ( $19^{\circ}\text{C} - 13^{\circ}\text{C}$ ) and the heat loss is therefore less than before.

At a high air temperature the blood vessels are dilated and the skin temperature may rise to some extent and thus increase the heat loss. However, this mechanism is not particularly effective; apart from a few exceptional cases, the skin temperature cannot appreciably raise the temperature of the blood passing through the peripheral vessels. In such cases, the powerful mechanism of sweat secretion comes into operation.

For conditions of comfort, however, active sweat secretion may be ruled out as a thermoregulatory mechanism. In setting up standards, therefore, the only heat losses with which one is concerned are those due to heating the expired air and saturating it with water vapour and those due to insensible perspiration, both of which may be considered constant. Insensible perspiration normally amounts to  $40\text{ g/h}$ , corresponding to a heat loss of about  $20\text{ kcal/h}$ . This represents 20 % of the total of  $100\text{ kcal/h}$  produced by the body.

The activity of the sweat glands is greatly increased when the skin temperature exceeds  $35^{\circ}\text{C}$ ; the body becomes covered with a layer of large droplets of sweat, which, as secretion increases, form a continuous moist surface covering large areas of the body. The loss of heat is then greatly increased on account of the rapid evaporation of this moisture. The rate at which sweat evaporates may be very high; quite frequently, individuals in hot workshops or in the desert may secrete as much as one litre of sweat per hour.

If all this moisture were to be evaporated directly from the body surface, a heat loss of as much as  $600\text{ kcal/h}$  could occur. Very frequently, however, the effectiveness of this mode of heat loss is limited by environmental conditions. If the rate of evaporation into the atmosphere is insufficient to deal with the amount of sweat that is secreted, the sweat will merely run off the body without benefitting it. The rate at which sweat evaporates into the air is governed by the relative humidity of the air. The difference between the moisture content (or vapour pressure) of the air at a given temperature and the saturation pressure of water vapour at the skin (body) temperature is called the "physiological saturation deficit".

The powerful mechanism of sweat secretion effectively prevents overheating, but the body's ability to counteract cold by means of vasomotor reactions is extremely limited. Under these circumstances, physical thermoregulation becomes particularly important; cold is counteracted by increased heat production from increased muscular activity. Even in the absence of specific physical activity, the production of heat is increased by involuntary muscular tremor in cold surroundings; in very intense attacks of shivering it may be increased by a factor of two or three, and over a fairly short period by a factor of four or five.

With small degrees of cooling, before an appreciable degree of shivering or tremor occurs, heat production may be increased by 30-100 %. Electrophysiological investigations have shown that, although there may be no visible contraction of separate muscle fibres, the electromyogram will show increased electrical activity, indicating an increase in the muscle tone (i.e., the "cold muscle tone"), which is one of the most important thermoregulatory reactions. When the body is overheated, the tone of the muscles, particularly the extensors, is markedly reduced and, in extreme cases, the reduction may disturb the maintenance of an upright posture. Impairment of muscle tone will naturally interfere with movements involved in work, and an additional voluntary effort will be required to overcome this hindrance.

The rate of heat production in man depends primarily on muscular activity, but at rest and under the conditions used for determination of basal metabolism, this rate is determined mainly by the body surface. The metabolic rate is also influenced by age and sex: it is higher in children than in adults; after maturity has been attained, it is somewhat reduced and remains at the same level until advanced age.

Under conditions of extreme cold, the body reacts chiefly by increasing the production of heat, and the response to overheating is increased secretion of sweat. When the temperature variations are moderate, the main mechanisms of heat regulation are vascular reactions and changes in the insulating properties of the superficial tissues.

It is now possible to consider what physiological criteria are most important for the establishment of standards for thermal comfort in the home. From what has already been said concerning dwellings and the requirements for thermal comfort, it is clear that, in setting up standards for the microclimate, no demand should be made upon such responses as shivering, variation in heat production, increase of sweat secretion, or changes in body temperature. These thermoregulatory responses are intended for the maintenance of body temperature at a constant level in the face of considerable deviations from the normal atmospheric conditions. Prolonged demand on these compensatory reactions will inevitably reduce the work output of the body or lead to some functional exhaustion,

and consequently they cannot be included among the criteria for the thermal comfort of the home.

Winslow & Herrington (1949) have expressed the general view in saying that at moderate environmental temperatures the chief factor determining the feeling of thermal comfort is the skin temperature. The distribution of the skin temperature is determined by the environmental temperature (Du Bois & Hardy, 1937; Du Bois, 1951; Postnikov, 1957; Goromoso, 1963; Slonim, 1962).

Since the temperature of the skin varies considerably in different parts of the body, any calculation of heat loss must be made on the basis of a mean value that takes these variations into account. However, measurements indicate that although the changes in the skin temperature of the forehead and the neck are in the same direction as those in the oral temperature, the changes in the skin temperature of the limbs are in the opposite direction. For this reason, Aschoff (1955) believes that the mean skin temperature is an insufficiently accurate index of the thermal state of the individual.

Bazett (1949) pointed out that the narrow, approximately cylindrical shape of the limbs renders them particularly suitable for fine regulation of body temperature. Although the distal parts (fingers, wrists, forearms, shins) have a relatively small volume, their large surfaces are of great importance in connexion with heat loss. Thus, the surface of the foot constitutes 7 % of the total body surface. At a high air temperature, the heat loss from the foot is approximately 13 % of the total loss (under basal metabolic conditions) but at low air temperatures, when a considerable increase in the heat loss from the foot would be expected, it is in fact less, being not more than 5-6 %.

Thus, physiological data indicate that limb temperature is the body's most sensitive index of changes in the thermal conditions of the environment; it should, therefore, be used as the primary criterion for evaluating the conditions of the microclimate. However, the thermal indices of various other parts of the skin should also be taken into consideration.

Winslow & Herrington (1949) observed that, at a normal environmental temperature, thermal comfort was experienced when skin temperatures were at the following levels: forehead, 33-34 °C, hand, 31 °C, and foot, 27 °C. Discomfort occurred at temperatures below 31 °C for the forehead, 31 °C for the trunk, 30 °C for the hand, and 25 °C for the foot.

All these results indicate that the establishment of thermal comfort depends, to a large extent, not only on the temperatures of different parts of the skin, but also on the way these temperatures are related in a healthy individual at a particular season. Any disturbance of these relationships

may indicate not only that environmental conditions have given rise to discomfort, but also that there has been a disturbance of the thermoregulatory processes.

These thermoregulatory processes provide the fundamental physiological criteria on which standardization of the indoor microclimate may be based. However, the study of these processes should not be confined purely to temperature indices. To establish criteria for satisfactory industrial and living conditions, use should be made not only of thermometric data, but also of those on cardiovascular reactions, muscle tone, sweat secretion processes, and gas-exchange. At the same time, attention should be given to the sensations of heat that characterize the interaction of Pavlov's first and second signalling systems during changes of atmospheric conditions. It is necessary to take into account the different "settings" of the human thermoregulatory system in different climatic zones and in different seasons. It must also be borne in mind that studies related to the prolonged action of low-intensity atmospheric factors on the human body may, in many cases, require electrophysiological observation of reactions of the central nervous system, and, especially, of higher nervous activity.

#### DIFFERENCES IN THE PHYSIOLOGICAL EFFECTS OF HEAT EXCHANGE BY CONVECTION AND BY RADIATION

Man can discern and react to even small changes in the temperature of the walls and surrounding objects; a source of heat may be detected if it emits as little as  $0.00015 \text{ cal/cm}^2/\text{min}$  (Galanin, 1952). There is a sensation of coldness even when the heat loss is only  $0.03\text{-}0.045 \text{ cal/sec}$ ; this feeling becomes pronounced at a heat loss of the order of  $0.1\text{-}0.2 \text{ cal/sec}$  (Slonim, 1952). These facts explain the unpleasant sensation experienced in a room whose walls are appreciably cooler than the air in the room. Nielsen & Pedersen (1952) have shown that heat loss by radiation increases rapidly when the temperature of the surroundings is decreased. For the same air temperature, at wall temperatures of  $17.7^\circ\text{C}$ ,  $14.3^\circ\text{C}$ , and  $12.9^\circ\text{C}$ , the losses by radiation were, respectively, 56.5, 66.5, and 71 kcal/h. Even a slight increase in the loss of heat by radiation (e.g., from  $2.7$  to  $3.3 \text{ cal/cm}^2/\text{h}$ ) causes a sensation of cold in man and a drop of  $1.6\text{-}2^\circ\text{C}$  in the skin temperature (Galanin, 1952). When the wall temperature rose from  $22^\circ\text{C}$  to  $23^\circ\text{C}$  while the air temperature remained at  $22^\circ\text{C}$ , the subjects under test described the room as "hot" or "unpleasant (too hot)"; a wall temperature of  $22^\circ\text{C}$  gave rise to a thermal sensation described as "pleasantly warm" (Letavet & Malyševa, 1941).

The area of the source of radiant heat is naturally of great importance; the larger the area, the greater is the sensation of heat.

The high sensitivity of the body to radiant heat is explained by the fact that, although human skin (irrespective of its colour) has a very high absorption coefficient in the infra-red region of the spectrum, nevertheless, a proportion of radiant heat passes through it (Galanin, 1952; Malyševa, 1963). If the surroundings are at a low temperature heat is lost, not only from the skin surface, but also directly from the deeper tissues, principally the muscles and blood vessels. At a low level of heat exchange, little radiant heat penetrates the skin and it has no appreciable physiological action, but the greater the proportion of heat exchange by radiation, the greater is the physiological effect. When heat exchange by radiation is very high, skin temperature is no longer the principal index of thermal comfort, because a proportion of the radiant heat penetrates the skin; in this situation, there is no longer a correlation between the skin temperature and the thermal condition of the individual.

It is important to remember that, when the body is cooled by radiation, the compensating increase in the metabolic rate develops much later than in the case of cooling by convection, with the result that, for a certain time, the body is no longer in thermal equilibrium (Slonim, 1952, 1961). In observations on human subjects under conditions of approximately equal cooling at a rate of 6-7 cal/sec, the heat loss, primarily from radiation, caused a reduction of 3 °C in the temperature of the skin of the trunk, where it is usually comparatively stable. (With convection cooling at the same rate, there was no change in the skin temperature throughout an observation period of 1½ hours.) Despite this marked fall in skin temperature and a clear subjective sensation of cold, there was no increase in the metabolic rate throughout the period of observation.

It is very important to recognize that, in dwellings, any considerable increase in the heating or cooling of the body, whether by radiation or convection, causes changes in the relative amounts of heat lost (through whatever physiological mechanisms may be involved) and has an unfavourable effect upon the general condition of the individual. This consideration is particularly important in health research and in the establishment of standards for the microclimate within dwellings during both cold and warm seasons; it has also to be taken into account in selecting and assessing various types of dwellings and in the construction of partitions or systems of heating and ventilation in various climates.

#### DIURNAL AND SEASONAL VARIATIONS OF THERMAL COMFORT

Healthy conditions and thermal comfort may be ensured in different climates and during all seasons of the year if houses are constructed



scientifically. The influence of the local climate on the body must be taken into account, as should the processes of acclimatization. Also important are certain facts concerning rhythmic (e.g., diurnal and seasonal) variations in physiological functions (Slonim, 1954; Kandrор, 1955; Kuno, 1961). Seasonal changes in the thermoregulatory reactions of the body lead to changes in the conditions necessary for thermal comfort. For example, investigations made in the USSR at the Institute of General and Public Health, Academy of Medical Sciences, have shown that, in winter, the range of acceptable temperatures in the home is 21-22 °C in cold climates and 17-18 °C in warm climates; in summer the temperature range is 23-25 °C (Goromosov, 1951, 1963). It is, of course, important to note differences in the "setting" of the thermoregulatory apparatus in different climatic zones, not only in relation to the establishment of a standard microclimate for dwellings, but also in interpreting the wide range of figures given for thermoregulatory responses in man at different seasons and in different climatic zones. For example, no comparison can be made between data on the topography of the skin temperatures in relation to various atmospheric conditions unless it is known in what climate and in what season they were collected.

Ultimately, the optimum levels of the complex conditions prevailing in the dwelling must be determined by seasonal fluctuations in the thermoregulatory function.

During sleep there is an important inhibition of thermoregulation, causing a reduction of the temperature differences between the deep and the superficial tissues that are characteristic of the waking state. This inhibition can be deepened only when external thermal disturbances are weak. Even with only slight overheating, sleep is uneasy, whereas, if the skin is adequately insulated, a moderate reduction in the temperature of the inspired air facilitates the deep inhibition of thermoregulation that is associated with sound sleep. It is particularly important that these conditions be satisfied in order that normal, healthful sleep may be enjoyed by children and the elderly.

Consequently, if measures designed to prevent disturbance of human thermoregulation and to protect dwellings from overheating (such as artificial cooling or air-conditioning) are to be specified for the duration of the hottest summer months, they must be made to apply to a particular period of the day. The actual time will, of course, vary and will depend on the climate of a given region. Similarly, it is quite justifiable to investigate the usefulness of heating dwellings at various periods of the day or night in order to prevent the temperature during the sleeping hours from falling below the minimum levels required for the maintenance of thermal comfort that have been established for the particular climate concerned.

The rhythmic changes in physiological functions, and modifications due to acclimatization, are important considerations in the determination of standards for the microclimate within a dwelling.

#### THE THERMAL EFFECT OF ILLUMINATION ON THE MICROCLIMATE

A number of physiological investigations have shown that illumination exerts a considerable stimulant effect on the higher levels of the central nervous system. It is important to note that the rate of heat production (metabolic rate) in man increases under strong illumination (Slonim, 1952). It has been shown that, in buildings where the heat loss by radiation was considerable and where skin temperature fell appreciably (without any increase in air circulation), an increase in illumination from 40 to 90 lux influenced the thermal state of the body. By stimulating the central nervous system, increased illumination leads to greater heat production and to a rise in the skin temperature. The results obtained from observations on human subjects have been confirmed by work on animals (Slonim, 1952). Thus, for example, if a bright light is turned on, or if the subject moves from shadow into sunlight while direct thermal stimuli are excluded, the physiological effect produced is similar to that produced by warmth. This effect, which is important for an understanding of the subjective sensation of heat (or reduced sensation of cold) in sunlight, must also be taken into account when microclimates in dwellings are considered.

#### THERMAL COMFORT IN THE HOME IN RELATION TO CLOTHING

Yaglou & Masser (1941) have carried out studies in an experimental chamber on the importance of clothing in connexion with standardization of the microclimate.

The observations were made at an air and wall temperature of 22.2 °C, at a relative humidity of 30 %, and with air moving at 0.1 m/sec. It was found that the mean skin temperature was 1 °C lower in women than in men. Men described their subjective sensations as comfortable, while women reported feeling cold. When the air and wall temperature was raised by 1.8 °C, the women felt comfortable, but the men were too warm. The difference between the temperatures found comfortable by men and by women was 1.5 °C. This difference was not attributed to physiological causes because, in conditions of comfort, the mean cutaneous temperature in women and men was precisely the same (33.3 °C); it was, rather, ascribed to differences in dress. When women wore the same

type of clothing as men, they too experienced thermal comfort under the same conditions as the men.

Subjects wearing the linen, wool, or worsted clothing normally worn in a temperate climate felt comfortable at an air temperature approximately 12 °C lower than the mean skin temperature.

The hygroscopic properties of clothing play an important part in determining the thermal state of an individual. Linen and cotton materials lose practically all occluded air when moist and therefore suffer a great loss in their heat-insulating properties. On the other hand, wool contains about 60 % of air even when moist and therefore retains its insulating properties.

Observation made in the Antarctic have illustrated the effect of clothing upon thermal comfort (Palmai et al., 1962). For example, it was found that conditions of individual thermal comfort could be attained by the wearing of suitable clothing despite considerable temperature variations within the dwelling (from 13 °C to 19 °C). From the point of view of health, however, compensation for unfavourable microclimatic conditions by means of clothing is inadmissible. Standards for the microclimate of the home must be related to the clothing normally worn indoors. Nevertheless, the effectiveness of clothing in compensating for individual preferences when the microclimate is close to the optimum means that it is not necessary to set up very narrow standards for the microclimate of dwellings.

#### CRITERIA FOR THE OPTIMUM MICROCLIMATE IN THE HOME

Conditions favourable to health and appropriate thermal comfort in a dwelling are ultimately determined by numerous factors, particularly heat radiation and the temperature, motion, and humidity of the air. However, it is also important to take into account the considerable influence of general climatic conditions, the planning and arrangement of inhabited areas, the design and construction of dwellings, and certain other factors that influence the internal microclimate. The influence of various external conditions and of the microclimate on human thermal comfort must be considered, both separately and together, and seasonal variations in these factors must be taken into account.

##### *Microclimate of dwellings during the cold season*

*Air temperature.* The figures given by various authors for the indoor temperatures found to be comfortable during winter, when artificial heating is required, are in rather close agreement, as shown below.

<i>Author</i>	<i>Year</i>	<i>Air temperature (°C)</i>
Erisman	1887	18-20
Flügge	1925	17-19
Hlopin	1930	17-18
Bürgers	1932	19-20
Liese	1933	17-18
Bedford	1954	15.5-20

In the USSR, recommended healthful indoor temperatures in winter vary in the different climatic zones as follows: 21-22 °C in the northern regions; 18-20 °C in the temperate regions; and 17-18 °C in southern regions (Goromosov, 1951).<sup>1</sup> It is of interest that Bedford (1954) recommends lower temperatures in England, principally because of the woollen underclothing worn there and the use of open fires for heating.

The official temperature standards for dwellings in winter are roughly the same in various countries: Switzerland, 18-20 °C; Germany (Federal Republic), 18-20 °C; USA, 19.6-21.8 °C; USSR, 18-21 °C; England, 15.5-20 °C.

In recent years there has been a tendency to recommend higher indoor temperatures. Thus, the Committee on the Hygiene of Housing of the American Public Health Association recommended a temperature of 24 °C for normal houses having minimal air movement. Winslow & Herrington (1949) consider that, for the normal clothing worn indoors in the USA, the optimum temperature would be 24-25.5 °C during moderate activity, and 26.5 °C during complete rest. An inquiry made by the London Accommodation Bureau showed that the preferred indoor temperature was 17.7-22.2 °C.

The differences in these recommendations are evidently to be attributed not so much to different methods of determination as to differences in the living habits and climatic conditions in the countries concerned.

Prolonged conditioning of the human body to various meteorological conditions leads to certain changes in thermoregulation and thus to differences in the temperatures preferred by inhabitants of different climatic regions. Some experimental studies of this phenomenon are considered below.

To establish the differences in the temperature ranges accepted as comfortable in winter, microclimatic and physiological studies were conducted in 20 towns in the USSR (in the north, in the south, and in intermediate latitudes); about 5000 adults living in 2122 homes were

<sup>1</sup> Although a temperature range is recommended for each region, the standard should, in each case, be set at the upper limit of the range, since the thermoregulatory apparatus of children, the elderly, and those suffering from cardiovascular disease is relatively unstable and such persons usually require a higher indoor temperature during the colder periods of the year.

included in these investigations.<sup>1</sup> At the same time, physiological investigations were made in an experimental air-conditioned chamber (Goromosov, 1951-54, 1963).

The results for the temperate region showed the range of comfortable temperatures for adults to be 18-20 °C. In the other climatic regions there were considerable differences: 21-22 °C in the cold regions and 17-18 °C in the warm ones.

The question arises as to the extent to which a preference for a higher indoor temperature in winter in cold regions corresponds to body requirements, and whether it has any physiological basis. To explain the differences in the temperatures preferred in the various climates, consideration must be given to the possibility that the differing general climatic conditions may modify the degree of response of the human subjects.

In cold regions, where the climate is particularly severe and where winter temperatures reach — 45 °C and below, the body may become considerably overcooled, even when little time is spent in the open air. The maintenance of thermal equilibrium imposes a considerable strain on the thermoregulatory mechanisms, and it is evident that a higher indoor temperature is required to restore the body quickly to its normal thermal state. In warm climates, on the other hand, the demand for warmth indoors is very much smaller in the winter.

Attention should also be paid to the considerable importance, under certain climatic conditions, of the "setting" of the thermoregulatory mechanisms of the body and of its adaptation to local conditions during acclimatization. This adaptation has been confirmed by investigations into the health aspects of housing, and a number of physiological changes have been observed in inhabitants of the northern regions during acclimatization (Kandror, 1952). This author showed that people who have dwelt for a long time in the north find high indoor temperatures more comfortable than do those who have not. It was also found that, at high temperatures, certain processes of physical thermoregulation are more active than at low temperatures. For example, at higher indoor temperatures, the skin temperature returns to normal more rapidly after a standard cooling, and certain muscular, vascular, and other physiological reactions take place, bringing about favourable changes in the flow of impulses from the interoceptors, a general sensation of warmth, disappearance of the feeling of fatigue, and rapid re-establishment of thermal comfort.

Consequently, the preference of northern populations for a high indoor temperature is a consistent adaptive response of the body that

<sup>1</sup> The studies were all made at the same time, in winter and with analogous external temperatures, in dwellings in which the vertical temperature drop did not exceed 2-3 °C and remained within specified limits. (See discussion of temperature gradients in the next section.)

is suited to the conditions prevailing in a harsh climate. Thus, the preference for higher indoor temperatures in winter in the cold regions is quite rational from the standpoint of health and has a physiological basis.

The studies described above are presented as examples of investigations designed to establish the factors determining healthful microclimates in different climates. They may serve as the basis for similar investigations elsewhere and for recommending microclimatic standards for different climatic zones.

*Temperature gradients.* In providing for thermal comfort within a dwelling, one must consider not only the optimum mean air temperature but also the horizontal and vertical differences in air temperature.

At the present time, most authors agree that the horizontal differences should not exceed 1-2 °C and that the difference between floor temperature and the temperature at a height of 1.5 m from the floor should not exceed 3 °C. Under these conditions, a normally clothed person is not aware of any unevenness in the temperature.

According to Hlopin (1923) no temperature differences greater than 2.5 °C should be allowed. The American Public Health Association Committee on the Hygiene of Housing (1938) recommends that the difference between the air temperature at 15 cm from the floor and that at 45 cm from the floor should not exceed 1.5 °C; the same difference is permissible between the air temperature at 45 cm and that at 180 cm from the floor. Crowden (1952) and Bedford (1954) consider that the difference should not exceed 2.8 °C. Vetoškin (1955) recommends an average difference of 3 °C between the floor temperature and the air temperature at a height of 1.5 m.

Under all conditions, it must be remembered that the vertical temperature difference depends, to a large extent, upon the nature of the heating system. From the results of work in the Netherlands, Van Zwillen (1958) proposes the following permissible temperature intervals for various heating systems: radiant panels in the ceiling, 0.5-1.5 °C; radiators beneath the windows, 1.3-2 °C; stove heating, 2.3-3.5 °C.

When it is remembered that the standard for the air temperature indoors usually refers to a height of 1.5 m from the floor, it can be seen that an increase in the vertical temperature gradient may cause the feet to become cold and may induce reflex temperature changes in the upper respiratory tract (Maršak, 1957). Coldness of the feet in children and elderly persons with impaired thermoregulatory mechanisms is particularly undesirable. With modern building techniques, it is now entirely feasible to ensure a minimum vertical temperature interval indoors. In

this connexion, consideration must be given both to heating and to thermal insulation of the floor, outer walls, entrances, etc.

*Temperature of the interior walls.* Health requirements are satisfied if the temperature of the interior wall surfaces is not much lower than the air temperatures recommended above. Observations lead to the conclusion that the difference should not exceed 3 °C at the optimum indoor air temperature (Galanin, 1952; Vernon, 1932; Houghten & McDermot, 1933; Yaglou, 1938). According to Galanin (1952), under these conditions and at an air temperature of 20 °C, the extent of the so-called "negative radiation"<sup>1</sup> near the walls will be less than 0.075 cal/cm<sup>2</sup>/min, so that no sensation of cold is experienced.

*Temperature of the heating devices.* The degree of comfort provided by the conditions of the microclimate depends, to a great extent, on the type of heating system and on the temperature of the radiators, panels, or other heating devices. From the technical point of view, it is best to have the smallest possible hot surface at the highest possible temperature, but a limit to the practicality of this rule is set by the effect on individuals. This limit depends upon the heating system used—i.e., whether heat is distributed by convection, radiation, or both.

The maximum temperature of radiators is limited, first of all, by the extent to which dust on them is heated and the organic portion volatilized. It is known that this effect results in the liberation of gaseous products that have unpleasant odours and irritate the mucous membranes. From this point of view, the optimum surface temperature of a radiator should be 70 °C and the maximum 80 °C.

In heating by radiation with a low-temperature device, the maximum temperature is set by the type and arrangement of the panels (whether on the wall, beneath the window, or on the ceiling or floor), by their size, by the height of the room, etc. The very high sensitivity of the body to small changes in environmental heat radiation, and the discomfort experienced when the temperature of the surroundings is raised, must be taken into account. Numerous observations have shown that from the point of view of health, the optimum temperatures of heated surfaces are as follows: wall panels at a height of 2 m, 33-38 °C; panels beneath windows, 40-45 °C; ceiling panels, 25-30 °C (depending upon the height of the ceiling); and floor panels, 22-28 °C.

*Air humidity.* It is known that the combination of high humidity with either warm or cold air adversely influences a person's thermal

<sup>1</sup> "Negative radiation" is the cooling of the body by radiation when the temperature of the surroundings is below body temperature.

condition as well as his sense of well-being. A high relative humidity, particularly at an elevated temperature, may adversely affect the thermal condition by reducing evaporation of sweat and thus slowing the loss of heat. On the other hand, extremely dry air increases evaporation from the mucous membranes of the respiratory passages and gives rise to unpleasant sensations. Furthermore, dry air impairs the filtering action of the mucous membrane of the upper respiratory passages on microflora and dust.

The fact that moist air feels cooler than dry air at the same temperature can be explained by an increase in heat loss from the body due to (a) the higher heat conductivity of moist air (Ignatov, 1929; Pomorcev, 1934); (b) the increased heat capacity of moist air (Vetoškin, 1955); or (c) the increased absorption by moisture of radiant heat from the body (Levickij, 1933).

Burton & Edholm (1957) have shown that an important part is played by changes in the humidity of the clothing, which when moist offers reduced thermal insulation, leading to a considerable loss of heat.

When the temperature of the air is high, its moisture content is the principal factor influencing body heat. For example, at 22 % relative humidity, profuse sweating does not occur until a temperature of 30 °C is reached, but at 60 % relative humidity sweating begins at 20-25 °C (Maršak, 1931).

These circumstances restrict the permissible range of relative humidity indoors. It is generally believed that the relative humidity should not fall below 30 % or exceed 60 %, particularly since, under conditions of comfort, the indoor humidity very seldom lies outside these limits. (In coastal regions, it may be higher, particularly after sunset, when the air temperature falls.)

Liese (1933) showed that a relative humidity below 30 % at an air temperature of 18.3-20.5 °C caused no feeling of discomfort. Only when the humidity fell below 12 % was any unpleasant feeling of dryness of the air experienced. Winslow & Herrington (1949) and Bedford (1954) also consider that permissible humidity variations at temperatures of 18-20 °C lie between 20 % and 80 %.

Kaufmann, Thauer & Zöllner (1955) hold that, within the range of comfortable temperatures, variations in humidity have little effect, and that quite wide variations produce only comparatively small changes in the heat loss.

It is known that evaporation of sweat depends not on the relative humidity of the air but on the difference between the saturation pressure of the water vapour at the surface of the skin and the partial pressure of water vapour in the atmosphere—i.e., the physiological saturation deficit.



It would thus appear that the permissible limits of humidity at moderate temperatures may be set somewhat more widely than was previously supposed. However, from the standpoint of health, the humidity should not exceed 60 % or be lower than 30 %.

*Air movement.* The part played by air movement in heat transmission, and the unfavourable influence of completely still air out-of-doors, have been demonstrated experimentally. When the air is quite still, there is no vascular response to thermal stimuli. Stillness of the air exerts an unfavourable influence on general metabolism and on the thermal state of the body (Maršak, 1931), often causing a sensation of "oppression" (Hill, 1953-1954), of heat discomfort, or of excessive fatigue; sometimes there is an adverse effect on the respiratory organs (Crowden, 1952), or there may be a feeling of general discomfort (Goromosov, 1951; Šafir et al., 1957).

It is known that air movement facilitates the loss of heat by evaporation and has a cooling effect on the body. From the standpoint of health an important consideration is that the cooling action experienced by a person when out-of-doors is due to constant circulation of the air, even when no movement is detectable with the instruments normally used.

At the end of the nineteenth century Brown-Séquard (1893) put forward the view that, when people remain indoors, the air becomes contaminated by "anthropotoxins". However, by the beginning of the present century, it was known that the unpleasant sensations experienced by people remaining for a long time in a badly ventilated place are due chiefly to changes in the physical properties of the enclosed air that hinder heat loss, and to a deterioration in the composition of the atmosphere.

Recently, an effort to understand the stagnation of air has been made by the consideration of its ionic composition. It has been noted, for example, that when a large number of people are present in a poorly ventilated building, the number of light ions in the atmosphere is reduced, while the number of heavy ions increases (Minh, 1958). This phenomenon can be explained by the settling of ions on the dust particles and micro-organisms dispersed in the atmosphere. Since electrically charged dust particles are retained in the upper respiratory tract to a far greater extent than are uncharged ones, it would appear that the accumulation of heavy ions in the atmosphere of a poorly ventilated place is unfavourable from the health standpoint. The introduction of fresh air from outside a building greatly improves the ionic condition of the air inside.

The optimum indoor movement of air must also be considered. It has been shown that, even at air velocities of only 0.03-0.05 m/sec, a change in temperature is perceptible to an unclothed person. Most authors

recommend that, under conditions of comfortable temperature and humidity, indoor velocities should fall within the ranges shown below.

<i>Author</i>	<i>Year</i>	<i>Airvelocity (m/sec)</i>
Hocjanov	1949	0.1-0.15
Winslow & Herrington	1949	0.1
Bedford	1954	0.1-0.15
Hill	1952	0.07-0.1
Goromosov	1963	0.05-0.1

A too rapid indoor movement of air is felt as a draught.

Provision of a constant supply of fresh air that is moving at the optimum velocity is, from the point of view of health, one of the most important factors that must be considered in the design of buildings.

#### *Radiant heating and health standards*

In recent years, systems of radiant heating have become increasingly common in homes. At the same time, there has been an increasing interest, in many countries, in the structural and health problems associated with this form of heating. Some of the more notable studies are those of Missenard (1959) in France, of Kollmar & Liese (1955) in Germany, and of Livčak (1956), Ponomareva (1954), and Goromosov (1957) in the USSR.

The general conclusion to be reached from these investigations is that, under conditions of radiant heating, the human body loses considerably less heat by radiation to the environment than in the case of convective heating, and the body is thus protected against the deleterious effects of negative radiation. Since less heat is lost by radiation, there is a considerable reduction in total heat loss. Consequently, as shown in Table 3, comfortable thermal conditions can exist with radiant heating at a lower air temperature, so that, with normal clothing, the tone of the muscular system is high, and there is a feeling of freshness and vigour (Goromosov, 1957, 1963).

The basis of this phenomenon, as has been explained previously, is that there are fundamental differences between the physiological effects of heat exchange by convection and by radiation. Convective heat acts mainly on the skin via the receptor apparatus and causes changes in the amounts of heat lost. Radiant heat not only acts on the body surface but also penetrates it and influences the deeper-lying tissues (Galanin, 1956; Malyševa, 1963). This characteristic of radiant energy explains its marked biochemical effect—i.e., the activation of enzymatic processes within the

cells—as well as its influence on the central nervous system, the activity of the internal organs, and gas exchange.

TABLE 3. PHYSIOLOGICAL REACTIONS TO ENVIRONMENTAL CONDITIONS WITH DIFFERENT SYSTEMS OF INDOOR HEATING \*

Indices		Heating system			
		Radiant **		Convective	
Environ- mental conditions	Indoor air temperature (°C)	16	17	18	20
	Mean radiation temperature of the enclosure (°C)	20.4	20.7	20.9	19.1
	Rate of air movement (m/sec)	0.10	0.10	0.10	0.1
	Relative humidity (%)		45-50		
Physio- logical reactions	Mean skin temperature (°C)	29.6	32.0	32.4	32.7
	Skin humidity (in arbitrary units)	3.2	3.4	3.5	3.0
	Infrared emission from the skin to the enclosure (kcal/cm <sup>2</sup> /hour)	2.1	1.9	1.8	2.4
	Vascular reaction of skin to cooling (time for return to initial temperature, in seconds)	180	150	165	185
	Pulse rate (beats per minute)	60-64	60-68	68-70	60-70
	Respiration rate (breaths per minute)	16	16	16	16
	Subjective sensation	Cold	Comfortable	Comfortable	Comfortable

\* Data from Bürgers (1932). Mean data from 40 observations on 8 subjects.

\*\* Observations were made with a panel 3.6 m<sup>2</sup> in area at a height of 2.4 m and at a temperature of 35 °C.

When the body is heated by radiation, the changes that occur in the normal relationships between the different modes of heat loss are of great importance from the standpoint of health. With convective heating, the level of gas exchange is higher than with radiant heating (Ponomareva, 1954). In consequence, under conditions of radiant heating, 10-15 % less energy is required for the performance of a given task than with convective heating.

The high heat capacity of the large areas of the floors, ceilings and walls of rooms heated by radiation guarantees rapid establishment of the required air temperatures, even after prolonged ventilation.

From the point of view of health, too much importance cannot be given to the permissible limit to the intensity of the infrared radiation emitted by heating panels (i.e., their temperature). It is necessary to maintain conditions that will permit optimum heat exchange between the individual and the environment. At present it is possible to formulate, on the basis of experimental data, appropriate recommendations in this respect, although further work is needed on the influence of such factors as the spectral distribution of the radiation, the nature of the radiating surfaces, the parts of the body that receive the radiation, and the duration of low-intensity radiation (Bazett, 1949; Turner, 1955).

Standards recommended by various authors for radiant-heating panels are as follows: floor systems, 22-28 °C; ceiling systems, 25-35 °C; wall panels, 33-38 °C; and panels beneath windows, 40-45 °C (Galanin, 1952; Vernon, 1932; Kellmar & Liese, 1955; Chrenko, 1955, 1957; Goromosov & Ciper, 1957; Ponomareva, 1954; Tihomirov, 1951).

In recent years, it has been recommended that the temperature of ceiling panels should depend upon the height of the room and the size of the panels. Chrenko (1952), on the basis of his own observations, recommended that ceiling panels measuring 7.6-16 m<sup>2</sup> in area should, if at a height of 3 m, have a temperature of 29-32 °C; at a height of 2.7 m, 28-30 °C; and at a height of 2.5 m, 26-28 °C.

The necessity for adjusting the temperature of a heating panel in relation to its area was demonstrated by Turner (1955), who compared thresholds of sensation in response to the irradiation of areas of the skin ranging from 15 cm<sup>2</sup> to 200 cm<sup>2</sup>. It was found that, the greater the skin area that was irradiated, the greater was the change in temperature felt by the subjects.

The temperature of a panel covering the entire ceiling in a room 3 m high should not exceed 30 °C. Nieven (1950) recommends a panel temperature not higher than 32 °C; Bedford (1946) recommended that the temperature of the water in the pipes should not exceed 32-37 °C, and maintains that under these conditions the panel temperature would not exceed 28-32 °C. For panels in the floor, Chrenko (1957) recommends that the surface temperature of the panels be 24 °C or less (at a room air temperature of 21 °C). The results obtained by many authors indicate that these temperatures will provide the best feeling of warmth.

Further investigation and more detailed analysis of the problem of optimum air temperatures in spaces heated by radiation are required, for various climates and in relation to comfort levels. This problem is of

particular interest because some authors (Bedford, 1946; Chrenko, 1953) consider that for optimum indoor conditions the temperature of the inhaled air should be about 10 °C.

A reduction in the temperature and humidity of the inhaled air increases the temperature difference between the air and the surface of the mucous membrane of the upper respiratory passages, and lowers the water vapour pressure of the air; consequently, there is an increased cooling effect within the nose during inhalation, which may create a feeling of freshness (Munro & Chrenko, 1959).

Because radiant heating—and cooling—of dwellings are today coming into increasing use, a study of the biological action of low-intensity long-wave infrared radiation is necessary so that standards can be established for dwellings employing this kind of heating. Theoretical study of the delicate biological changes that occur in the body when it is subjected to radiant heating will permit further improvements to be made in the establishment of health standards.

#### *Optimum microclimate in dwellings during the hot season in warm regions*

The previous section discussed problems related to the establishment of optimum conditions in connexion with different heating systems during the cold season. It is no less important to establish optimum conditions during the hot season. In cold and temperate regions this problem is generally solved more or less satisfactorily by control of ventilation, but in warmer regions such measures are insufficient.

In southern cities in relatively temperate regions, indoor temperatures during the summer may be as high as those in tropical or subtropical countries. This is due, in part, to faulty city planning and housing design, which result in the gross overheating of buildings.

In some warmer regions, the diurnal variation in indoor conditions is such that in the evening the temperature remains high for a long time after the outside temperature has fallen. In this situation, maximum discomfort is experienced during the hours of maximum insolation, when the indoor temperature is 8-10 °C above the comfort level.

In regions with a hot, dry climate, the outdoor temperature may rise to 46 °C or even 50 °C in the shade, and the relative humidity may be 15-20 %, while in regions with a hot, humid climate the temperature may be 40-45 °C or more at 80 % relative humidity. Under these conditions, dwellings become even more overheated. Prolonged residence in such overheated buildings adversely affects a person's general condition because of the extreme demands made upon his thermoregulatory mechanisms. Under the influence of high temperature and a high level of radiation, the heat production and blood pressure fall, the respiration

rate and blood circulation rate increase, there is an increased secretion of sweat, a marked change in the general metabolism, alterations in the water and salt metabolism, and so on.

Even though the thermoregulatory mechanism is highly efficient, it is unable to cope with the demands made upon it by these conditions. When the body has difficulty in disposing of excess heat, the blood vessels of the skin dilate, but those of the internal organs show a compensatory constriction. This results in a relative reduction in the blood supply to the viscera, with an increase in the temperature of the blood bathing the diencephalon, which may lead to heat stroke (Douglas, 1953).

Despite the fact that the changes in physiological reactions occurring under these conditions concern chiefly the protective and adaptive responses directed toward establishing an equilibrium with the environment, it cannot be assumed that prolonged and excessive use of these cortically regulated reactions will always ensure optimum vital conditions for the organism. Overheating of dwellings may lead to several undesirable physiological changes and frequently to pathological effects. Statistics show that old people and children between 1 and 12 years of age are extremely sensitive to heat, particularly when they are unaccustomed to it. Measures to prevent overheating of dwellings in hot climates during the summer are therefore urgently needed. Among those who have studied this problem in recent years are Vetoškin (1955), Goromosov et al. (1954, 1957), Douglas (1953), Drysdale (1951), and Aronin (1953).

Most investigators have reached the general conclusion that the radical approach to the problem of overheating of dwellings is cooling and conditioning of the air. Modern air-conditioning systems are quite capable of coping with this task. However, it has been shown that more favourable indoor conditions may also be attained in the warmer regions by simpler measures for the prevention of overheating. The optimum microclimatic conditions in hot weather have received much less attention than have optimum conditions during the cold season. The problem is all the more urgent because of the ever-increasing rate of housing construction in the developing countries, many of which have hot climates. In such countries the provision of favourable indoor conditions is of considerable public health importance.

Between 1951 and 1963 the author carried out studies in the USSR with the object of establishing optimum health standards for the microclimates of homes in regions with hot climates (Goromosov, 1951, 1963). These studies were conducted in 13 towns in Kazakhstan, Turkmenistan, and Uzbekistan in Central Asia, all of which have hot, dry climates, and in Georgia, on the Trans-Caucasian shore of the Black Sea, where the climate is hot and moist. The outdoor temperatures ranged from 35°C to 38 °C. The microclimates of 2834 apartments were examined, and the state of

health and physiological responses of 6000 adults were studied. This population was questioned concerning the thermal conditions within the home, and experimental physiological investigations were made simultaneously in air-conditioned rooms in which responses to artificial cooling could be observed. The findings are summarized in Table 4.

TABLE 4. PHYSIOLOGICAL RESPONSES IN HUMAN SUBJECTS  
IN A COOLED ROOM AT VARIOUS TEMPERATURES \*

Physiological reactions	Temperature of the dwelling (°C)				
	Back-ground **	24-25	26-28	30-31	33-34
Mean skin temperature (°C)	33.0	33.3	33.6	34.7	35.6
Skin humidity (in arbitrary units)	1.7	1.8	5.2	18.2	20.8
Infrared radiation from skin (kcal/cm <sup>2</sup> /hour)	4.1	3.6	4.0	0.9	0.8
Vascular reaction of skin to cooling (time for return to initial temperature, in seconds)	200.0	200.0	260.0	290.0	290.0
Pulse rate (beats per minute)	64	64-66	68	72	74
Respiration rate (breaths per minute)	16	18	18	20	22
Subjective sensation	Comfortable	Comfortable	Warm	Hot	Hot and oppressive

\* Relative humidity, 40%; air movement, 0.10-0.15 m/sec; outdoor temperature, 35 °C (mean data from 106 observations on 27 subjects).

\*\* The initial level of physiological responses was established under optimum summer environmental conditions: in the early morning, in a dwelling with open windows, with the subject at rest.

For air-conditioned homes in hot climates where the outdoor air temperature is 35 °C, the recommended indoor temperature is 23-25 °C, the relative humidity 50-55 %, and the air velocity 0.15-0.2 m/sec. If such a degree of cooling cannot be attained, a temperature of 26-26.5 °C is permissible with an air velocity of 0.25 m/sec. An increase of the indoor temperature to 27-28 °C is not acceptable, even when the air movement is 0.25 m/sec.

These findings suggest that, when the outdoor air temperature is 35 °C or higher, the difference between outdoor and indoor temperatures in dwellings should not be more than 10 °C. Adolf (1952) and Aronin (1953), among others, consider that, at this level of outdoor air temperature, the

difference should be between 8.5 °C and 9 °C. It is sometimes recommended that in buildings such as cinemas and theatres, which are visited only for brief periods, the temperature difference under these circumstances should be as little as 6-7 °C, so as to avoid "temperature shock". However, a number of recent investigations have caused considerable alteration in these views.

For example, the American Society of Heating, Refrigerating and Air-Conditioning Engineers now considers, on the basis of experimental studies extending over several years, that the thermoregulatory mechanism of the body is able to adapt readily to quite large temperature differences on entering or leaving an air-conditioned building and that this adaptation is not harmful to a person in good health. The marked chilliness experienced by a person entering a cool building from a hot street is caused by the evaporation of sweat from the skin and clothing. It takes several minutes for this moisture to evaporate and for the skin temperature to fall to its normal level.

From work carried out in the Sahara it was concluded that for normal comfort, even in areas with a hot, dry climate, air-conditioning should maintain an air temperature of 26.5 °C at a humidity of 70 % or 28 °C at a humidity of 50 % (Demarre, Fournol & Dournon, 1958).

For the climatic conditions in France, the following values for the microclimate are recommended for air-conditioning in summer: air temperature 24 °C at a relative humidity of 60 % (or 26 °C at a relative humidity of 30 %) and an air movement of 0.1 m/sec.

In England, Webb (1959), on the basis of many years of observations on the sensations of heat experienced in the tropics, proposed the so-called "comfort index" for indoor air. This he gave as about 77-80 °F (25-27° C).

In the USA, according to the handbook of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, the optimum summer conditions for dwellings are: air temperature, 24 °C; relative humidity, 50-60 %; and air movement, 0.2 m/sec.

Studies in the USSR have shown that, when the outdoor air temperature is 35 °C, the air temperature in homes should, for comfort, be 23-24 °C at a relative humidity of 50 % and an air velocity of 0.15 m/sec in regions with a hot, dry climate; for regions with a hot and moist climate, the indoor air temperature should be 24-25 °C at a relative humidity of 50-55 % and at air velocity of 0.2-0.25 m/sec.

In regions with a hot, moist climate, it is important that provision be made for the reduction of relative humidity to the values given above; this is one of the problems to which further attention must be given.

When devices for the artificial cooling of homes are not available, an attempt must be made to improve indoor conditions in summer by a suitable combination of design, constructional, and protective measures.



Since overheating of dwellings is due mainly to the entry of solar radiation by way of windows, the most effective single protective measure is shielding from such radiation. However, no single constructional measure can be fully effective against indoor overheating during the summer, and only by the combined use of many different techniques of construction can the problem be successfully solved (Selejhovskij, 1948; Vetoškin, 1955; Goromosov, Ciper et al., 1954; Vasil'ev, 1957; Douglas, 1953; Aronin, 1953; Drysdale, 1951; Atkinson, 1950).

In the planning of dwellings in regions with hot climates, the following six factors have been found to be of particular importance:

- (1) In extensive building in habitable areas, provision of adequate protection against heat in the buildings;
- (2) Planting of trees and shrubs, using irrigation if necessary, around built-up areas, as well as the growth of greenery on balconies, in window boxes, etc.;
- (3) Orientation of buildings so that doors and windows face away from the midday sun, and design of individual apartments on the principle of open construction, so as to permit cross-ventilation;
- (4) The use of devices for producing shade, such as venetian blinds, broad canopies, screens, deflectors, and awnings;
- (5) The use of light-coloured paint on walls, so as to reflect as much solar radiation as possible; and
- (6) Provision of a rational system of ventilation, particularly at night.

The combined use of these techniques may lower room temperature by 5-7 °C or more, a decrease that would play a significant part in the moderation of the indoor microclimate.

Interesting technical means for achieving these ends have been proposed by French investigators who have studied their effectiveness in the construction of housing in the Sahara (Demarre, Fournol & Dournon, 1958).

#### METHODS FOR EVALUATING THE COMBINED EFFECT OF METEOROLOGICAL FACTORS ON THE HUMAN BODY

From the beginning of the present century attempts have been made to find means by which to determine the over-all influence of meteorological factors on the thermal state of the human body. These attempts have resulted in the construction of special devices that are analogues of

the body and in the development of various temperature scales such as effective temperature, equivalent effective temperature, operative temperature, and resultant temperature. Attempts have also been made to define various coefficients and indices for a description of the physiological condition of the body, especially under extreme meteorological conditions. It is therefore important to review this problem, even if only in general outline, and to decide to what extent these measurements may be useful in the study of indoor microclimates in relation to health.

The "human analogues" that have been constructed have made possible the making of instruments for determination of the rate of cooling of the human body and of the temperature of its surface and its internal layers (the surrounding air being maintained at a temperature close to that of the body). Such instruments include the eupatheoscope, developed in England by Dufton (1932), and the thermo-integrator (a special model called the "copper man", developed in the USA in 1935). Although attempts to construct a physical device that can completely simulate all human responses to changes in meteorological conditions have been unsuccessful, such attempts have made possible a more complete and detailed description of the effectiveness of various combinations of meteorological factors than was possible previously. It is now realized (Yaglou & Winslow, 1949; Sahbazjan, 1940) that these devices may be useful in assessing the importance of the meteorological factors that they measure. However, in all accurate scientific work in this area, each of the fundamental meteorological factors (temperature, humidity, air movement, and heat radiation) must be measured separately by an instrument designed specifically for that purpose only. Furthermore, such measurements must be made independently of any method used to evaluate the combined effect of meteorological factors.

What has been said above may be applied to the so-called temperature scales. The modern American scale of effective temperatures originated in 1922-1924 (Houghten & Yaglou), underwent considerable change at the suggestion of the authors, and was further modified in 1933 by the Special Commission of the Harvard Medical School. On this scale, the effective temperature is defined as an arbitrary combined index of the degree of heat or cold perceived by a person as the result of the combined action of temperature, humidity, and rate of air movement. Such a scale cannot, by itself, represent an index of comfort, as was previously believed. Actually, if consideration is given only to the subjective evaluations that were used to draw up the scale, effective temperatures indicate only combinations of meteorological factors that will be perceived by man as more or less equivalent, in the sense that they influence his thermal sensation in the same way. However, such conditions can by no means always be perceived as optimum or even comfortable.

The scale applies only to the thermal sensations of people seated at rest or carrying out light work in a room heated by convection, where the difference between the air and wall temperatures does not exceed 1-2 °C. Moreover, the range of comfort established for the USA on the scale cannot be applied to the inhabitants of different climatic zones, a restriction that limits its usefulness.

This system of effective temperatures has been widely and critically discussed and has recently been modified for application to the problems of air-conditioning. However, despite all the modifications the scale has undergone, it still has the important limitation that extensive extrapolation is necessary—first, because it is not based on objective physiological data, and second, because it does not take into account radiation and other factors.

To meet the second of these objections, Bedford (1946) introduced corrections that made allowance for the radiation factor. However, as Yaglou (1949) has shown, the use of these corrected scales at high air velocities may lead to serious errors.

More than 30 years ago, Dufton et al. (1932) proposed the use of the concept of “equivalent temperature” (ET), which took into account the combined action of temperature, air movement, and radiation. The effect of humidity was not taken into account. The “equivalence” of different meteorological conditions was established in terms of heat loss as measured by the eupatheoscope, which Dufton himself constructed. However, observations on human subjects showed that there were essential differences between the temperature changes on the skin of a clothed person and the indications of the eupatheoscope.

Missenard (1959) proposed an analytical expression or formula for the estimation of the net influence of the principal factors that affect human perception of heat (including radiant heat), referring to this quantity as the “resultant temperature” (RT). Missenard defined the resultant temperature as one that evokes the same sensation of warmth as is experienced in a room when the air is stationary and completely saturated with water vapour, and when the mean temperature of the internal wall surface is equal to the air temperature.

The scale of operative temperatures proposed by Winslow, Herrington & Gaage (1941) not only takes into account the temperature of the atmosphere, the rate of air movement, and radiation, but also includes indices of skin temperature. In order to find the operative temperature, it is first necessary to determine both the mean radiation temperature (by means of a specially designed globe thermometer) and the mean skin temperature of the subject. The operative temperature cannot, therefore, be defined in terms of the usual meteorological data.

Other such indices and formulae have been proposed. Plummer, Ionides & Siple (1945) advanced the so-called coefficient of thermal acceptability. These authors admitted that their formula was imperfect and would have to be reviewed as further data became available. Robinson, Turell & Gerking (1945) proposed the so-called index of physiological effect for evaluating the action of high temperatures.

Belding & Hatch (1955) have proposed several indices, including one that expresses the degree of thermal stress. However, most of these indices were intended for outdoor conditions and had no application to dwellings.

Unlike temperature scales, the various formulae for indices and coefficients include factors that describe some physiological reactions to the external conditions. However, there is no reason to believe that any index yet formulated reflects all the varied reactions of the human body to the different levels of temperature, humidity, radiation, or air movement that are possible within a room or in an open space, or takes into account unconditioned and conditioned reflexes, the phenomena of acclimatization, seasonal changes, etc.

Bazett (1949b) has considered the hypothesis of a single thermoregulatory mechanism. This author, who is a noted specialist in the study of human heat exchange, pointed out how extremely arbitrary is the use of various empirical formulae, and stated that "We cannot expect any formula to give more than a rough comparison even when applied to a 'steady state'".<sup>1</sup> Bedford (1954), in discussing the calculation of thermal stress and heat exchange in man, emphasizes that, in evaluating external factors, particularly in clothed persons, no "calculation of the heat balance" can give accurate results.

In conclusion, it must be admitted that none of the proposed "human analogues" or methods of calculating temperature scales or indices provides a complete picture of the combined action of meteorological conditions on the thermal state and the over-all feeling of the human subject. To investigate successfully the influence of the indoor microclimate on human health, careful study must be made of changes in meteorological conditions and of the physiological responses of the body to such changes. Only through an analysis of data obtained by these means will it be possible to evaluate conditions in relation to health and hence to develop proposals for standard environmental conditions.

A combination of methods must be used, including study of the indoor microclimate, physiological investigation, and statistical study of the thermal conditions under which populations actually live.

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<sup>1</sup> The question under discussion was the calculation of the mean body temperature from results of cutaneous and rectal temperatures under different meteorological conditions.

The various temperature scales and indices may be successfully applied only to the evaluation of environmental conditions as a whole and to scientific comparison of different heating or cooling systems. Further extensive investigations in this field are required.

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## CHAPTER 2

# THE INDOOR ATMOSPHERE AND AIR CIRCULATION

### OPTIMUM CHARACTERISTICS OF THE INDOOR ATMOSPHERE

The atmosphere of the home should have no adverse or unpleasant influence upon its inhabitants and should facilitate rest and restore the ability to work.

In an inhabited room, the air becomes progressively contaminated by carbon dioxide, resulting from metabolic processes, and by bacteria in suspension in the exhaled air. In addition, amines are given off from the surface of the skin. The use of coal gas and other fuels may result in further contamination with both carbon dioxide and sulfur dioxide.

As a result of the emanation of body heat, the indoor temperature tends to rise, and there is an increase in the relative humidity due to moisture evaporated from the skin and exhaled from the lungs.

Deterioration in the physicochemical properties of the indoor atmosphere adversely affects the comfort of the occupants. It is known that a feeling of oppression is experienced in insufficiently ventilated rooms. It is for this reason that provision for an adequate rate of air renewal in all rooms is one of the important problems of domestic architecture. It is most important that both living and subsidiary quarters, as well as the construction and location of heating devices, be planned rationally. In the modern scientific view, the problem of achieving a standard renewal of air in homes can be solved satisfactorily only by taking careful account of the combined action on man of all environmental factors, and not merely by studying the chemical composition and temperature of the air.

### SOURCES OF CONTAMINATION AND STANDARDS FOR ATMOSPHERIC PURITY

#### *Carbon dioxide*

Carbon dioxide is one of the constituents of the earth's atmosphere, where it is present to the extent of 0.03 % by volume. In urban areas,

the mean atmospheric concentration of carbon dioxide is higher than in the country and may reach 0.07 % as a result of its liberation from domestic fires, power stations, and other industrial plants. It is also liberated in the exhaust gases of motor vehicles (Rjazanov, 1961). In dwellings, the principal source of carbon dioxide is the air exhaled by the inhabitants; it is also produced by the burning of gaseous, liquid, or solid fuels for domestic purposes.

Until recently, two criteria were used in the study of the effect of carbon dioxide on health. First, physiological studies had shown that, at concentrations greater than 0.5 %, carbon dioxide raises the respiration rate above the level required for gas exchange, imposing an additional load on the respiratory system. Second, in 1881 Pettenkofer & Flügge had proposed that 0.07-0.1 % be regarded as the permissible atmospheric concentration of carbon dioxide. Although the latter figure had no physiological basis, it proved of considerable practical value as an indirect index of the contamination of air in the home. Until very recently, it was used to calculate the required rate of air renewal in a given room, and it has served as a criterion for assessing the quality of air in rooms and the efficiency of ventilating systems.

Recent work carried out by a group headed by Rjazanov showed that the inhalation of 0.1 % carbon dioxide for a short time causes marked changes in respiration, circulation, and cerebral electrical activity (Eliseeva, 1964). No previous study had been made of the effects of such low concentrations of carbon dioxide on the human body.

Using six healthy volunteers aged between 19 and 45 years, Eliseeva (1961) studied the effect of carbon dioxide concentrations of 0.05 % and 0.1 % on respiration, the cardiovascular system, and cerebral electrical activity. A second (control) group breathed air containing 0.03 % carbon dioxide (the normal concentration).

It was found that a carbon dioxide concentration of 0.1 % had a marked effect on respiration, the amplitude (depth) of the respiratory movements being reduced. The respiration rate itself and the ratio of the volumes of inhaled and exhaled air underwent no noticeable changes. Using the method of rheovasography to study the effect of carbon dioxide on the peripheral circulation, it was found that a concentration of 0.1 % markedly influenced the circulatory condition and increased peripheral blood flow. Finally, study of the cerebral electrical activity during inhalation of air containing 0.1 % carbon dioxide showed that, at this concentration, the gas may influence the functional state of the cerebral cortex and may increase the amplitude of the brain waves.

The work of Eliseeva appears to indicate that the presence of a concentration of 0.1 % carbon dioxide in the air has a directly harmful effect. He has concluded that the indoor concentration of carbon dioxide should

not be allowed to exceed 0.1 %, and that the average concentration should be less than 0.05 %.

Since a man engaged in light work exhales about 22.6 litres of carbon dioxide per hour, and since the normal concentration of the gas in the atmosphere is 0.03 % (0.3 litres/m<sup>3</sup>), the volume of fresh air required per person to ensure a carbon dioxide concentration not exceeding 0.05 % would be  $22.6/(0.5 - 0.3) = 113$  m<sup>3</sup> per hour. For a maximum concentration of 0.1 % (1.0 litre/m<sup>3</sup>), the required volume of fresh air would be only  $22.6/(1.0 - 0.3) = 32$  m<sup>3</sup> per hour.

Assuming that a man requires an "air cube" of 25-30 m<sup>3</sup>, the maintenance of a hygienic atmosphere requires more than three changes of air per hour if the carbon dioxide concentration is not to exceed 0.05 %. If a carbon dioxide concentration of 0.1 % is deemed acceptable, slightly more than one change of air per hour is necessary.

#### *Airborne bacteria*

In addition to CO<sub>2</sub>, the exhaled air also contains micro-organisms in suspension. These are principally saprophytic bacteria, and include sporogenous bacilli, various moulds, and a small number of pathogenic bacteria, such as the pathogenic cocci and the diphtheria bacillus (Rečmenskij, 1961). The particles of this "bacterial dust" usually do not exceed 1-100  $\mu$  in size. Many pathogenic micro-organisms (e.g., streptococci, staphylococci, and diphtheria and tuberculosis bacilli) may remain viable and virulent for months in room dust, in contaminated clothing, and in bedclothes, and may be the cause of aerial droplet infection. Rečmenskij has noted that, after a patient with a streptococcal infection is removed from a room, viable streptococci may persist in the dust of the room for four to five days.

There is no general agreement as to be best index of the bacteriological purity of air. One view is that the condition of the air should be assessed in terms of the total number of micro-organisms per cubic metre, and the total number of *Streptococcus viridans* and *Str. haemolyticus*; another is that it should be assessed only in terms of *Str. viridans*. Studies by Turžeckij & Olen'eva (1957) have shown that, because *Str. viridans* is cultured more readily than *Str. haemolyticus*, it is a better indicator of the microbial content of the air. It has been shown that, during loud conversation, *Str. viridans* is ejected from the mouth in quantities hundreds of times greater than is the case with *Str. haemolyticus*.

However, no comparative data were obtained from these experiments on the quantity of *Str. viridans* in pure and in contaminated air, so that these indices cannot yet be used for assessment of the hygienic quality of air.



*Organic substances*

Organic compounds that appear to be derived from physiological metabolic processes are also found as contaminants in indoor air. Most of these compounds are amines (methylamine, dimethylamine, and trimethylamine), but the air may also contain small amounts of formaldehyde and acetone (Krotkov, 1962).

In recent years, attempts have been made to establish indirect indices of the degree of contamination of the air by organic substances—the so-called “oxidizability of the air”.<sup>1</sup> Observations have shown that, in the air of a well ventilated room, the “oxidizability” does not exceed 4 mg/m<sup>3</sup>. However, this index is entirely arbitrary, because the nature and properties of the organic substances involved are not determined.

*Carbon monoxide*

Among the various contaminants of indoor air derived from the use of heating and cooking devices and other domestic processes, the highly toxic carbon monoxide is among the most important. Carbon monoxide is a product of incomplete combustion and, in rooms heated by stoves burning gas or solid fuel, it may accumulate in quantities exceeding the permissible amount (Martynjuk, 1957; Lampert, 1963; Troickaja, 1958). This is significant from the point of view of health because carbon monoxide acts primarily on tissue respiration, and in particular on the respiration of the brain cells, where it causes changes in the higher nervous activity and disturbs the cortical regulation of tissue metabolism (Rjazanov, 1961). Experimental investigations have shown that the prolonged action of concentrations of carbon monoxide as low as 2 mg/m<sup>3</sup> may give rise to marked changes in the relationships of the chronaxia of antagonist muscles and may impair prophyrin metabolism (Šul'ga, 1961).

From the standards formulated above concerning the atmosphere of dwellings, and in view of the toxicity of even low concentrations of carbon monoxide, the presence of this gas in inhabited rooms must be regarded as inadmissible. In the USSR, the maximum permissible concentration of carbon monoxide in atmospheric air is 1 mg/m<sup>3</sup> (mean daily concentration).

*Sulfur dioxide*

The combustion of domestic fuels may cause contamination of the indoor atmosphere with sulfur dioxide, the concentration of which may

<sup>1</sup> The principle of the method is that the air to be tested is passed through a solution of potassium dichromate in concentrated sulfuric acid. The amount of active oxygen consumed in the oxidation of the organic substances contained in the air sample may then be determined from the change in the titre of this solution.

exceed the maximum permissible levels ( $0.15 \text{ mg/m}^3$  for the mean daily concentration;  $0.5 \text{ mg/m}^3$  for the maximum concentration). In concentrations exceeding the permissible limits, the gas acts upon the respiratory reflexes. Studies have shown that in concentrations of  $0.6 \text{ mg/m}^3$  sulfur dioxide acts upon the functioning of the cerebral cortex (Dubrovskaja, 1957). According to Buštueva et al. (1960), these concentrations also influence the formation of the "electrocortical conditioned reflex".

### *Odour*

The appearance of unpleasant body odours and odours caused by domestic activities may be considered as an index of the hygienic condition of the air. Physiological reactions to odours may include nausea, headache, and depression of respiration. Because of the extensive functional connexion between the olfactory system and various parts of the cerebral cortex, olfactory stimuli may influence the emotional state and induce autonomic reactions, such as changes in skin temperature, blood pressure, and activity of the internal organs.

Many authors take the presence or absence of odour as one of the fundamental criteria for evaluating the necessity for renewal of air and assessing the effectiveness of ventilation (Crowden, 1952; Bedford, 1954; Becher, 1961).

### STANDARDS FOR AIR RENEWAL

The problem of the establishment of optimum standards for air renewal in a room is closely related to the standard "air cube" per person.

Many investigations have shown that, with an "air cube" of  $25\text{--}30 \text{ m}^3$  per person, and one change of air per hour, the condition of the air does not differ greatly from the conditions specified in various sanitary standards (Goromosov & Ciper, 1952; Sakovskaja, 1963).

After volunteers had spent six hours in a room containing  $15 \text{ m}^3$  of air per person, the concentration of carbon dioxide rose to  $0.2 \%$ , the temperature from  $19^\circ\text{C}$  to  $22^\circ\text{C}$ , and the relative humidity to almost  $70 \%$ . Physiological observations showed a  $13\text{--}14 \%$  increase in pulmonary ventilation and a disturbance in conditioned reflexes.

When the air cube was reduced to  $8 \text{ m}^3$  the carbon dioxide content of the air rose to at least  $0.35 \%$ , the air temperature to  $23^\circ\text{C}$ , and the relative humidity to  $75 \%$ . In association with the deterioration of the microclimate, the subjects experienced impairment of pulmonary ventilation and of higher nervous activity.

Recent comparative studies of physiological processes occurring in the central nervous system and in the optic tracts of subjects supplied with

amounts of air varying from 6 m<sup>3</sup> to 25 m<sup>3</sup> per hour confirmed that the most favourable physiological indices were obtained with a supply of not less than 25 m<sup>3</sup> of fresh air per hour per person (Sergeev et al., 1963).

The results indicate that a volume of less than 25-30 m<sup>3</sup> of air per person is insufficient and confirm the necessity of a system for renewing the air in a room; the smaller the volume of the room, the more frequent the air renewal must be. Under all conditions, when the volume of air per person corresponds to an "air cube" of 25-30 m<sup>3</sup>, the air must be renewed at least once per hour.

The standard building regulations for dwellings in the USSR provide for continuous day and night ventilation, calculated as follows: at an outdoor air temperature of - 5°C, the rate of air extraction must not fall below 20 m<sup>3</sup> per hour per person; at the prescribed indoor winter temperature of 17-22 °C this rate must not fall below 25-30 m<sup>3</sup> per hour per person. The rate must not be less than 60 m<sup>3</sup> per hour in the kitchen or 25 m<sup>3</sup> per hour in the bathroom and toilet. It is also recommended that the rate of air extraction from kitchens should be increased to 150-300 m<sup>3</sup> per hour when gas cookers are in use.

TABLE 5. MINIMUM STANDARD VENTILATION RATES \*

Type of room	Cubic capacity (m <sup>3</sup> /man)	Minimum supply fresh air (m <sup>3</sup> /hour/man)	Frequency of air replacement (changes/hour)
Living rooms and bedrooms	8.5	20.5	2.5
	11.5	17.0	1.5
	14.0	12.0	0.75
Kitchens	—	56.5	—

\* After Crowden (1952). These standards have been adopted in the United Kingdom.

Becher (1961) in Denmark calculated similar values on the basis of his own investigations. He recommended a round-the-clock air-extraction rate of 32 m<sup>3</sup> per hour for kitchen ventilation and 29 m<sup>3</sup> per hour for that of the combined bathroom and toilet. In France, the Centre scientifique et technique du bâtiment (1962) has recommended that the volume of air extracted from inhabited rooms should be at least 30-45 m<sup>3</sup> per hour.

The minimum standards for the ventilation of dwellings accepted in the United Kingdom (Crowden, 1952) are presented in Table 5. Crowden emphasizes that the amount of fresh air needed per person is related to

the volume of the room, and that the figures represent the minimum amounts of air per hour that would prevent the build-up of body odour.

Bedford (1954) stresses that most of the standards for ventilation proposed in recent years have been based on calculations of the amount of air required to eliminate odours that are unpleasant or difficult to tolerate. Investigations conducted in the USA indicate that a flow of  $16.8 \text{ m}^3$  of fresh air per hour is necessary for this purpose.

However, such a change of air, which does not take into account the wide range of factors that determine the properties of indoor air, evidently cannot ensure the establishment of favourable conditions within the dwelling.

#### PREVENTION OF CONTAMINATION OF AIR IN THE HOME

##### *Planning of apartments*

The quality of the air in an apartment is influenced by architectural features as well as by the air-renewal system. For example, in rooms having windows in only one wall, the air may be renewed about 0.7 times per hour. However, in rooms having windows in opposite walls, the air-renewal rate may be 1.0-1.5 times per hour. Indeed, if the windows on both sides are opened for 15-20 minutes, so as to create a through draught, the rate of air renewal may rise to two to three changes per minute.

It is recommended that apartments be planned so as to permit through ventilation in all climatic zones except those of extreme cold.

On the other hand, the location of the kitchen may have an important influence on the quality of the air in the living quarters. Studies of apartments laid out in various ways show that the purity of the indoor atmosphere can be increased by the isolation of the kitchen from the living quarters. A direct connexion between the kitchen and the living-rooms is undesirable, even when an efficient extraction system is used.

##### *Domestic appliances*

Although electrical appliances are now used on a large scale in the home, cooking and heating by gas are still common. To avoid the adverse effects associated with the use of gas, the rational construction of gas-burning appliances is essential.

The gas stove most widely used for cooking is still of the so-called "open-burner" type, from which the products of combustion are given off directly into the air. In addition to the products of complete combustion

(which, as noted above, include carbon dioxide and sulfur dioxide), products of partial combustion (such as carbon monoxide) may also be emitted. Such appliances are, therefore, clearly unsatisfactory from the health standpoint.

In recent years, gas burners that ensure more efficient combustion have been designed, whose effluent gases include only a small amount of carbon monoxide. For example, according to the standard for gas stoves in the USSR, the amount of carbon monoxide emitted may not exceed 0.03-0.04 % by weight (calculated on the basis of the dry gases).

One burner of advanced design provides flameless combustion; owing to the high temperature created at the heating surface, combustion is complete, and no carbon monoxide is formed. The most radical solution to the problem is the construction of stoves from which the combustion products are completely removed to the outside by means of a flue, an arrangement that completely avoids all contamination of the air with combustion products; this cannot be achieved with "open" combustion of the gas, even in the most effective burners.

Heating devices may also, if poorly made or incorrectly placed, be sources of air contamination, particularly by combustion products such as carbon monoxide and sulfur dioxide. Also to be considered is the possibility of volatilization or chemical decomposition of dust at the surfaces of radiators that have been overheated (to temperatures above 80 °C). Another possible source of air contamination is an improperly designed or installed central-heating furnace inside an inhabited building. In the USSR, regulations demand that groups of dwellings be supplied with heat by externally situated furnaces.

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## ILLUMINATION AND INSOLATION

### BIOLOGICAL EFFECTS OF RADIANT ENERGY AND THEIR IMPORTANCE TO HEALTH

Observations have shown that prolonged deprivation of sunlight leads to disorders in the physiological equilibrium of the human body and to the development of pathological symptoms that have been referred to as "light starvation". For this reason, it is necessary to ensure the free access of sunlight into human dwellings. This can be achieved by measures such as the rational planning and building of towns, favourable orientation of windows, and the use of window glass that transmits ultraviolet rays. The provision of adequate natural and artificial illumination within houses and public buildings, in which man spends most of his life, is an important public health task, particularly in regions with cold climates.

The provision of adequate and comfortable illumination in living premises is difficult, and must be based on extensive research in many directions. The concept of comfortable lighting should be considered from the biological standpoint; that is, indoor illumination should approach the qualities of natural outdoor light as closely as possible, both quantitatively and qualitatively. The establishment of standards for both natural and artificial light within dwellings must be considered together. As the natural light that enters dwellings does not always comply quantitatively or qualitatively with all health requirements, it must be supplemented by artificial sources, employing methods similar to those used to correct other environmental factors. For example, if there is a lack of long ultraviolet rays, the illumination system should include artificial sources of long-wave ultraviolet radiation of measured quantity and composition. In other words, a sort of artificial sunlight should be provided within the premises so as to offset existing deficiencies.

The use of the biological properties of sunlight will, of course, depend largely upon the orientation of the windows. The main consideration in the siting of windows should be the establishment of optimum duration,

extent, and area of insolation. Measures should also be taken to prevent overheating due to the thermal effect of insolation—e.g., the use of air-conditioning. The unfavourable effects of hot weather upon the indoor microclimate of the home can also, to a certain degree, be mitigated by suitable orientation of buildings.

It must be mentioned that “geometric standardization” (the light coefficient) and “technological light standardization” (the daylight factor) which are at present used, cannot provide adequate characterization of natural light from the standpoint of health, especially with respect to its quality. The orientation of the building and other important factors are not taken into account with these methods. The *calculated* daylight factor differs from the true factor not only because of the possible influence of the orientation of the building, but also the calculated factor does not take into account the light reflected from the walls and ceilings, although such reflected light constitutes 70-80 % of total indoor illumination.

Although it is well-known that the penetration of direct sunlight into living quarters has a favourable psychophysiological effect, designers frequently fail to pay sufficient attention to it in attempting to provide optimum indoor illumination. The belief still prevails that infrared radiation has only a thermal effect, and that the visible part of the spectrum produces merely a visual sensation. In fact, however, infrared radiation—particularly the near infrared—has a pronounced effect, and the important biological activity of the radiation within the visible spectrum has been demonstrated in a number of reports.

It has been well established that impulses originating from the eyes stimulate the autonomic nervous system (Jores, Markelov & Vojtkevič, 1944; Gaske, 1949) and cause increased secretion by the pituitary and parathyroid glands. This increases the general tone of the body and stimulates various functions. Radiation in the visible spectrum stimulates oxidative processes and gas exchange and increases the rate of growth and development in animals (Jores, 1934, 1935; Benoit, 1935; Hasama, 1937; Hollwich, 1955; Kazbekova, 1941).

The work of Ščerbakova (1937) is of particular interest in this context. This investigator showed that, if monkeys were kept in cages illuminated at night and darkened during the day-time, their daily periodicity of function could be reversed; that is, the functional state normally typical of day-time could be observed at night, and that normally found at night could be observed during the day. It was even found possible to replace the normal biphasic daily rhythm by a tetraphasic rhythm by application of artificial light and darkness at appropriate intervals. This study demonstrated the powerful psychophysiological effects of the visible part of the spectrum, which must be taken

into account when establishing standards for comfortable conditions of illumination.

The data that are currently available on the intensity of visible light that would be optimum from a general biological point of view are insufficient to establish suitable standards. However, it may be assumed that the level of illumination sufficient to produce a general biological effect will be higher than that required to permit the normal functioning of the visual organ. The studies by Koškin (1946, 1963) and Markelov (1945) contained some data concerning the level of natural indoor illumination that is sufficient to produce a general biological effect. Stimulation of physiological functions could be observed at illumination levels of 500 lux and more. However, both authors were primarily interested in other problems, and gave only approximate figures for the level of illumination sufficient to produce a general biological effect.

The establishment of standards for comfortable illumination in dwellings requires further study.

#### PHYSIOLOGICAL IMPORTANCE OF DIFFERENT KINDS OF RADIANT ENERGY

Under natural conditions, man is exposed to all components of solar radiation, including infrared, visible, and ultraviolet rays. It has been established that the combined biological effect of this radiation is not simply additive, but may be altered by antagonism or synergism between various parts of the spectrum (Lotz, 1951; Helmke, 1955; Efimov & Kazimirova, 1936; Koškin, 1946; Frank, 1950).

The mechanism by which biological reactions are initiated by exposure to radiant energy is complex and has been insufficiently studied, although in recent years it has been the subject of numerous experimental studies in which particular attention has been given to the role of the higher parts of the central nervous system. It is undeniable that radiant energy exerts a direct effect on the organism, but its biological action must be explained primarily on the basis of neuroreflectory and neurohumoral mechanisms.

The biological actions of each region of the spectrum, and the role that each plays in the production of the total effect of sunlight, are extremely complex. It is clear, however, that the physical differences in the various regions of the spectrum lead to qualitative differences in their biological actions.



*Ultraviolet radiation*

Recent studies have revealed the exceptional biological activity of ultraviolet radiation. Ultraviolet rays influence the nervous system, producing in small doses a stimulating, and in large doses an inhibitory effect; they also activate the endocrine glands and the enzyme systems.

Ultraviolet radiation provides a natural means of supplying the body with vitamin D, which participates in the development of numerous functions and structures. It activates oxidative and other metabolic processes and is involved in the formation of biologically active substances such as histamine and other compounds that stimulate body defences. Ultraviolet radiation also accelerates the healing of wounds and increases the phagocytic activity of leucocytes and the resistance to infections (Abrosimov, 1955; Dancig, Belikova & Mac, 1958).

Prolonged deprivation of solar ultraviolet radiation leads to decreased formation of vitamin D, which regulates phosphorus and calcium metabolism. This leads to disorders in bone-formation and increased vascular permeability, and enhances the development of caries, exudative reactions, etc. (Galanin, 1952; Parfenov, 1963). Insufficient ultraviolet radiation may lead to rickets in children and to osteomalacia in adults. Thus, the provision of adequate ultraviolet radiation in the natural and artificial lighting of living premises is an important health requirement:

Studies devoted to methods of compensating for environmental deficiency in ultraviolet radiation carried out in the USSR (Dancig & Zabalueva, 1953; Dancig, 1963; Koškin, 1962) showed that, in children, ultraviolet radiation not only prevents the development of rickets but also diminishes the number of colds and enhances growth and development.

Ultraviolet radiation also has a bactericidal effect that is of great epidemiological importance. Numerous observations have shown that even partial disinfection of air by means of ultraviolet radiation reduces the incidence of influenza, tonsillitis, and other infectious diseases. Ultraviolet radiation having wave-lengths between 254 and 258 mμ has the greatest bactericidal effect. Such rays are absent from the solar radiation that reaches the earth, but there is no doubt that normal solar radiation has a bactericidal effect. The loss of ultraviolet radiation from sunlight due to smoke and general air pollution in industrial towns is known to reach 30 % or even more (Belikova, 1957).

When sunlight passes through ordinary window glass, wavelengths shorter than 320 mμ, which are biologically the most effective, are absorbed more than longer ones. In consequence, the biological as well as the hygienic effects of sunlight are diminished. Recent studies have shown that, when the windows are closed, not more than 30-40 % of

the ultraviolet radiation that falls on the outer surface of the glass actually penetrates it and enters the building. It is possible, however, to use special types of glass that transmit a higher proportion of ultraviolet rays and, even if ordinary glass is used, the entry of shorter-wavelength ultraviolet radiation can be secured by leaving the windows open in warm weather. Numerous experiments have shown that even the solar ultraviolet rays of longer wavelength, which are able to penetrate window-glass, have a bactericidal effect, particularly when exposure lasts for at least three hours (Belikova, 1957). This author reported that exposure of *Staphylococcus albus* cultures to ultraviolet rays passing through window-panes for 2-3 hours completely arrested or considerably diminished the growth of colonies. In another series of tests, virulent *Staph. albus* cultures were exposed for various periods to ultraviolet rays passing through glass windows and were then injected intradermally into rabbits. It appeared that, after exposure of the cultures for at least 1 ½ hours, only a very weak necrotic reaction, or none at all, developed in the skin of the animals. Cultures exposed to ultraviolet radiation for 1-3 hours did not cause illness or death in mice, whereas all mice infected with cultures not previously exposed to radiation died toward the end of the second post-injection day. These investigations established, from the physiological-hygienic standpoint, the minimum period of insolation for living premises required for biological effectiveness. They also showed the great importance for health of window-panes that transmit long-wave ultraviolet rays, particularly in cold regions where severe climatic conditions force the population to spend most of its time indoors, even in summer.

It is common knowledge that exposure of premises to artificial ultraviolet light plays an important part in the prevention of infections transmitted by airborne droplets (Koškin, 1962; Kudrjavcev, 1960; Smorodincev, 1943; Lidwell & Williams, 1960; Buchbinder, 1942). This fact further underlines the importance of constructing buildings in such a way that living quarters receive adequate amounts of solar ultraviolet radiation.

### *The visible spectrum*

The eye is able to perceive extremely small quantities of energy, of the order of a few photons. At a wavelength of 505 mμ, a stimulus of the order of 8 photons is sufficient to excite a visual response (Vavilov, 1936); at a wavelength of 510 mμ, 5-7 photons are sufficient (Hecht et al., 1942). The normal process of vision induced by an adequate stimulus — i.e., by radiant energy at wavelengths of 300-800 mμ — is an extremely

complex phenomenon based on photobiological processes within the retina, in the fibres of the optic nerve, and in the central nervous system.

The ability of the visual apparatus to modify its sensitivity and to analyse the stimuli received within a wide range of brightness (visual adaptation) is very important for the maintenance of the link between the eye and the conditions of illumination that prevail in the environment; in addition to changes in the sensitivity of the retina, this process involves changes in the functional state of the central nervous system (loss of excitability).

*Dependence of visual function on conditions of illumination.* In studying the relationship between light and human activities, particular attention must be paid to the degree of illumination (brightness), as this has an important influence on visual comfort. Perception of light by human beings is known to be based on photochemical, retinomotor, and electrical processes that occur in the eye. These processes determine the character of the nervous impulses transmitted from the receptor to the cerebral cortex.

The retinal cones begin to react when the brightness reaches 30 stilb (sb)<sup>1</sup> and the function of the retinal rods ceases at a brightness of  $10^5$  sb. Hence it follows that objects with a brightness between 30 and  $10^5$  sb are perceived by both rods and cones. As the rods cannot perceive colour, there is a tendency for objects to appear grey at dusk.

*Contrast sensitivity* increases when the brightness of the field of vision reaches  $65 \times 10^5$  sb, which corresponds to an illumination of 2600 lux, assuming a reflection coefficient of  $\rho = 0.785$ . In this case, illumination of the order of 3000 lux still lies within the optimum range.

*The differential sensitivity* of the eye reaches its maximum at high intensities of illumination, exceeding the brightness given by 200 lux normally incident upon a white surface. Even intensities as high as 2500-3000 lux still fall within the optimum range.

*Visual acuity* is a function of the intensity of illumination. The brighter the light falling upon a white background, the better can dark objects be discerned against it. Maximum visual acuity is produced at an illumination exceeding 200 lux.

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<sup>1</sup> 1 stilb (sb) is equivalent to 1 candela/cm<sup>2</sup>.

*Stability of the clear image* is determined by the time required for clear perception of a test object in relation to the total time of observation under conditions close to the threshold — i.e., it is the ability to discern details fixed by the eyes within a certain time. It has been established that the stability of the clear image increases with the intensity of illumination. Studies by Semenovskaja (1931) and others have shown that the optimum value lies between 200 and 300 lux.

*The speed of visual perception* is of great importance for the function of the eyes and related organs. Samsonova (1939a, 1939b) and others have shown that there is a logarithmic relationship between the speed of visual perception and the intensity of illumination. Only at very high intensities of illumination (of the order of 6000 lux) is it permissible to speak of an intensity beyond which the speed of visual perception against a grey background increases only slowly.

*Dependence of visual function on the type of illumination.* The visual function depends not only on the intensity of illumination but also upon its quality. Light quality includes factors such as suppression of reflections, even brightness over the surface of an object and its surroundings (walls, ceilings, etc.), contrast (in brightness and in colour) between the details of an object and its background, and the direction, degree of diffuseness, and spectral composition of the light. Too sharp a difference between the brightness of an object and that of its surroundings decreases the visibility and with it the capacity of the visual function. The eye always tries to see a given object as clearly as possible, and to this purpose brings into action all means at its disposal: fixation, pupillary reflex, accommodation, and convergence. If conditions are such that clear perception is impossible, all this effort will be ineffective and the eye will become tired; this is often followed by painful sensations in the eyeball and by headache.

The following maximum brightness ratios have been recommended in the USA: 3 : 1 between the object in question (such as the pages of a book) and the adjacent background; 10 : 1 between the object and a more distant background, such as a wall; and 40 : 1 between the object and any other element within the normal field of vision. The recommended reflection coefficients are at least 0.85 for the ceiling, 0.6 for the walls, and 0.05 for the furniture.

*Visual fatigue.* It has been shown both experimentally and theoretically (Lazarev, 1947) that prolonged action of a visual stimulus is followed

by an exponential decrease in the sensitivity of the eye to visual stimuli (adaptation to light). This decrease in sensitivity takes place mainly within the first minutes or even seconds of exposure to the light and depends not only on the brightness of the light producing the stimulus but also on the size of the retinal image. As far as the wavelength of the stimulating light is concerned, Kravkov (1950) established that, out of three colours of equal brightness (red, green, and blue-violet), green produces the lowest and blue-violet the highest degree of fatigue.

In addition to subjective symptoms of fatigue in the eye, such as pain in the eyeballs and lack of definition of perceived images, eye-strain may also be characterized by objective signs. Thus, it has been established that a tired eye tends to blink more than a rested one (Meškov & Brjulova, 1941). Similarly, after-images take longer to disappear in a tired eye than in a rested one. The act of blinking darkens the retina for a short moment and improves the blood circulation in the ophthalmic vessels. The eye is thus given a brief rest, and the more tired an eye is, the more frequently it will blink. It has been suggested that the degree of visual fatigue should be estimated by the number of times per minute the eye blinks.

The frequency of blinking also depends on many other factors, such as the brightness of the surface looked at and the moisture of the cornea.

Luckiesh & Moss (1940) recommended the use of the frequency of blinking as a basis for the assessment of the lighting conditions. Their findings are summarized in Table 6.

TABLE 6. FREQUENCY OF EYE-BLINKING AS A FUNCTION OF ILLUMINATION

Frequency of blinking	Illumination (lux)		
	10	100	1000
Number of eye-blinks during the first and last 5-minute reading periods . . . . .	35-60	35-46	36-39
Increase in frequency of eye-blinking during the last 5-minute period (%) . . . . .	71.5	31.4	8.3

#### *Infrared radiation*

All living organisms continuously exchange radiant heat with their environment, most of the energy they emit being within the infrared

part of the spectrum (approximately between 0.76 and 340  $\mu$  in wavelength). The biological effect of infrared radiation varies according to its wavelength and the duration of exposure. Short-wave and long-wave infrared rays differ in their capacity to pass through living tissues, and in consequence they have different thermal effects (Malyševa, 1963).

It has been established that infrared radiation of wavelengths between 0.7 and 1.4  $\mu$  can penetrate human tissues. Infrared with a wavelength exceeding 1.5  $\mu$  does not penetrate deeply into the tissues and is largely absorbed by the skin, producing a rise in temperature (Galanin, 1952).

The action of infrared radiation upon living organisms has been extensively studied. However, most authors have confined their researches to a relatively narrow range of wavelengths (those near 1.1  $\mu$  and those between 3.0 and 4.5  $\mu$ ). These investigations were mainly connected with problems of industrial hygiene and were based on experiments involving short-lasting and localized exposures to infrared rays. The biological effect of prolonged exposure to low-intensity infrared radiation at wavelengths of 8-10  $\mu$  (i.e., the type of infrared radiation to which persons are most frequently exposed in their homes) has been inadequately studied.

Through nervous or humoral pathways, exposure to infrared radiation may influence the rate of intracellular metabolism (Razenzkov, 1939), the general intensity of metabolism, and immunological reactivity. It has also been found that infrared rays may stimulate or inhibit the central nervous system, depending on their intensity (Zajdšnur, 1960).

Local changes produced in the skin by exposure to infrared radiation also depend on the physical characteristics of the radiation and can vary from barely perceptible changes in pigmentation to burns.

Planners of towns and of housing generally regard infrared radiation primarily as a thermal problem (in connexion with the risk of overheating) that can undoubtedly exert an unfavourable influence upon the human body. This difficulty can be avoided by general design measures such as rational planning and optimum orientation of buildings and provision of green belts and water reservoirs, as well as by special means of protection against excessive sunlight, such as the use of heat-resistant walls, blinds, awnings, shields, climbing plants, and light-coloured paints. All this is particularly important in regions with hot climates. Conversely, it must be remembered that in colder regions, the use of radiation to warm the microclimate within dwellings is very important, as in such regions dwellings frequently have inadequate insolation and illumination because of incorrect orientation (as may occur when builders consider only the wind). Planning of this type is justified, it is argued, as it protects buildings against the infiltration of cold air and ensures the maintenance of an adequate temperature within them.

Analysis of meteorological observations and the results of special studies carried out over many years in the northern regions of the USSR by Lampert & Makeeva (1962), Murav'eva (1963) and others have shown, however, that in these regions southerly winds are the most frequent and the strongest. These winds are, as a rule, accompanied by higher outdoor temperatures and thus have a favourable effect upon indoor conditions.

On the other hand, lighter winds blowing from the north cause a marked fall in outdoor (and consequently indoor) temperatures. This means that, even in cold regions, better insolation and illumination and a more satisfactory microclimate can be achieved by making buildings face the sun. However complex the task of protecting dwellings in cold regions against excessive infiltration of outer air may be, it can certainly be solved technically, and the solution should always include maximum use of direct sunlight for the living quarters.

The design of the so-called "suntrap" houses, which have been widely discussed in the press, is by no means arbitrary (Aronin, 1953). These buildings are based on the principle of maximum accumulation of the heat supplied by the sunlight that falls on them. This idea might have successful application in appropriate climatic and geographic areas.

Infrared radiation is the main cause of heatstroke and heat prostration. Complete protection against the thermal effects of infrared radiation is not technically insoluble; protection can be provided not only by general planning measures such as green belts around settled areas, provision of water reservoirs and of air-conditioning or artificial cooling systems, but also by special means of protection against the sun, based upon one of the following concepts: provision of shade, reflection of light, and the use of insulating materials in construction. The most effective protection against infrared radiation will naturally be achieved by a combination of such measures.

#### *Physiological standards of visual comfort*

From the point of view of health, it would seem that the efficiency of illumination in dwellings could most appropriately be characterized by an index of "physiological light comfort", based upon a combination of quantitative and qualitative factors ensuring the most favourable conditions for the general and visual working capacity of the occupants.

This complex index should be based upon the assessment of the functional state of the central nervous system. Conditions of visual comfort within the living quarters will prevail only if excitation and inhibition of the central nervous system are in equilibrium (Pavlov, 1951c) — i.e., if optimum health standards are achieved. Such standards must be based on the establishment of comfortable living and working condi-

tions for the inhabitants. These include everything necessary for the most effective functioning of the visual apparatus.

*Basic health requirements with respect to illumination*

Standards for domestic illumination must comply with the following basic physiological and health requirements:

- (1) optimum intensity of illumination in all working places and in their surroundings within the field of vision;
- (2) avoidance of great variations in brightness within the field of vision, thus avoiding interference with the normal adaptation of the eye;
- (3) protection of the eye against glare from direct or reflected light;
- (4) avoidance of sharp shadows on working surfaces;
- (5) adequate contrasts in brightness and in colour between details and background; and
- (6) optimal biological activity of the light.

It must be remembered that the present standards of illumination in the USSR are adequate for no more than 30 % of the population.

Adequate illumination is particularly important for schoolchildren, since their eyes are still incompletely developed and thus require special protection against harmful conditions. Furthermore, present standards of illumination are inadequate for middle-aged and elderly persons whose vision is deteriorating.

Rising educational standards and a widening range of human activities are leading to a demand for a greater intensity of illumination in the home than was acceptable in the past. Fortunately, modern technological advances now permit the provision of optimum illumination indicated by human physiological requirements.

NATURAL LIGHT IN RELATION TO INSOLATION  
AND THE PLACEMENT OF WINDOWS AND DOORS

Natural illumination varies widely within the course of a day. At sunrise and at sunset, the intensity of natural illumination is but a few hundred lux, rising to about 100 000 lux at noon on a sunny day. After sunset, it may fall to a fraction of a lux.

The intensity of diffuse illumination that is typical of natural light in the middle latitudes has been known to vary between 800 and 6000 lux. The highest intensity of natural illumination in middle latitudes in the Northern Hemisphere is reached at noon during the summer (July and



August); in December and January, the mean monthly natural illumination decreases to 4000-5000 lux.

In the presence of low clouds, and with the sun at a low elevation, the intensity of natural illumination may fall to only several hundred lux. The sensitivity of the eye is not constant and can rise or fall depending on conditions of illumination. In the course of adaptation to light or darkness, the sensitivity of the eye to sunlight may vary by a factor as large as  $10^8$ . The light characteristics of a given locality may be expressed by mean monthly curves of the horizontal total and diffuse illumination under the open sky at different times of day. From these data, it is possible to calculate rather precisely the intensity of illumination in any part of the premises at any time of day and in any month for a given value of the daylight factor (see p. 49).

The utilization of natural illumination is, however, complicated by the unstable character of natural light, which may change completely within a few minutes, and by the tendency of the building industry to use windows of standard shapes and sizes.

It is often difficult to obtain the minimum necessary intensity of light in premises that are illuminated by natural light, and in winter it is impossible in many regions. Determination of the daylight factor has, therefore, been accepted for regulation of the natural illumination.

In homes, natural light is admitted through windows and reflected from inner surfaces such as walls and ceilings, so that the illumination is diffuse and more or less evenly distributed throughout the room. Daylight gives a feeling of direct contact with the outside world; this emotional factor is of particular importance for living premises.

TABLE 7. SIMPLIFIED SCHEME FOR THE PLANNING AND CALCULATION OF NATURAL ILLUMINATION \*

Illumination requirements for various kinds of work	Minimum daylight factor (%)	Ratio between minimum and average illumination	Horizontal illumination (lux)	
			Average	Minimum
Low	1	1:2.5	6 000	2 400
Moderate	2	1:1.5	6 000	4 000
High	5	1:1.5	5 000	3 500
Very high	10	1:1.5	6 000	4 000

\* Data from Krochman (1961).

Detailed standards for natural illumination have been set out by Krochman (1961) and are summarized in Table 7. These data are

particularly valuable because they are related to various requirements for minimum and average illumination. Natural illumination, insolation, and orientation of the buildings must always be considered together. Insolation of living quarters should provide the most favourable conditions for the occupants throughout the year. A correct qualitative assessment of insolation from the health point of view can be made only if the duration, area, and extent of the insolation are taken into account (Dunaev, 1962).

On the basis of the above considerations, Dancig (1963) recommended the orientations shown in Table 8 for windows in dwellings. He groups rooms into three categories, according to their purposes: (a) rooms requiring maximum insolation, (b) rooms that should be protected against insolation, and (c) rooms with no particular requirements with regard to insolation. He also distinguishes between buildings in the northern and southern regions of the USSR, taking latitude  $50^{\circ}$  N as the dividing line. This classification is obviously very approximate. It is based on the following principles:

(1) all dwellings should have at least three hours of continuous direct sunlight per day in all geographical zones of the USSR (for the whole period between 22 March and 22 September);

(2) the amount of direct sunlight falling on dwellings and built-up areas in regions of the USSR situated south of latitude  $50^{\circ}$  N should be limited, where necessary.

In the USSR, these principles are embodied in the official *Sanitary Standards and Regulations for Insolation of Dwellings and Public Buildings* (1963). These require that, during the period between the vernal and autumnal equinoxes, the minimum insolation should average three hours per day. Dwellings constructed in accordance with the requirement would have a mere 30 minutes insolation per day during the winter (Dunaev, 1962). However, three to four hours of insolation are required to provide the minimum prophylactic dose of ultraviolet radiation to a person remaining indoors in the middle latitudes of the USSR.

Somewhat different standards have been accepted in other countries. In Belgium, the accepted standard is 1.9 hours of insolation on 22 December (i.e., at the winter solstice, when the daily sunlight is least). In Great Britain, two standards are accepted: for England, the requirement is one hour daily during December (when the days are shortest); for Scotland, it is one hour daily for the 10 months from mid-January to mid-November. In Poland, France, and the Netherlands, the accepted minimum is one hour daily from 22 February to 22 October (eight months).

TABLE 8. RECOMMENDED ORIENTATION OF ROOM WINDOWS IN THE USSR \*

Type of room	Subgroup	Description of room (examples)	Orientation of windows			
			Latitudes below 50 °N		Latitudes above 50 °N	
			Recommended	Permissible	Recommended	Permissible
Rooms requiring maximal insulation	<i>Subgroup A:</i> rooms in constant use, requiring orientation to prevent overheating and excess illumination	Living rooms (bedrooms and common living rooms)	South	South-east	South, south-east	South-west
	<i>Subgroup B:</i> rooms used only in daytime, thus permitting a wider choice of orientation	Living rooms (dining rooms, spare rooms), storage rooms	South, south-east	East, north-east, north-west	South, south-east, south-west	North-east, north-west, south-west
Rooms to be protected against isolation	Rooms requiring full protection against overheating	Kitchens; laundry, ironing, and drying rooms	North	North-east	North	North-east, north-west
Rooms with no particular insulation requirements	Rooms with no particular orientation requirements	Rooms other than those listed above	Any orientation			

\* Data from Dancig (1963). The orientation, of course, depends upon the purposes for which the rooms are used and upon the geographic location of the building.

It is obvious that the standards cited above are mainly determined by latitude. The territory of the USSR extends from  $35^{\circ}$  N, where the sun remains high in the sky throughout the year, to  $75^{\circ}$  N, where polar night prevails for several months. The territories of the European states mentioned above are confined to zones of five to six degrees of latitude, mostly within the temperate zone — i.e., between  $45^{\circ}$  N and  $60^{\circ}$  N. However, there are other factors that effect standards for insolation (Maslennikov, 1962).

The German authors Liese & Lutz (1955) recommend that, in the Northern Hemisphere, living quarters should face approximately  $30^{\circ}$  to the east or west of due south. They point out that, if this is done, the northern side of the building will receive more sunlight, and in winter the loss of sunlight on its southern side will be reduced. Dwellings should not be constructed so as to face north, north-west or north-east.

The closer to the equator a building is situated, the more important is its correct orientation, since excessive sunlight must be avoided in tropical areas. Thus, in Colombia, which is situated on the equator, the longitudinal axis of most administrative buildings and dwellings is positioned in a north-south direction.

To ensure an even indoor distribution of daylight, the sky must be visible, not only from near the window, but also from most places within the room. Whether or not this is possible depends on the size and position of the windows and on the presence or absence of obstacles, such as other buildings and vegetation, outside them. The usual rule of thumb is that no obstacle should increase the angle at which sunlight enters the room to more than  $15-18^{\circ}$  from the level of the window-sill. Sunlight falling upon the sides of buildings or entering between them is particularly valuable, since it enters the windows at a low angle and reaches the remotest corners of the rooms. Where it is impossible to plan an angle of entry of less than  $18^{\circ}$  for sunlight, open-patterned streets, with spaces between the buildings, are to be preferred to continuous lines of buildings. This solution, which is particularly effective in areas in which the streets are lined by blocks of flats, has long been used in continental Europe.

The Committee on Natural Illumination of the Illuminating Engineering Society, in the USA, has given extremely valuable advice regarding natural illumination and the planning of light in homes, public buildings, and industrial plants.

#### ARTIFICIAL ILLUMINATION

The last few decades have seen great technical advances in the provision of artificial light. Gas-discharge tubes with various emission

spectra are used more and more extensively. New sources of light are being introduced at an ever-increasing rate, and the time is near when artificial light will undergo essential qualitative changes. Indeed, this process may be said to have begun already.

The introduction of fluorescent lamps, with their special spectral characteristics, has brought about a new type of lighting, described as "artificial daylight". This means that, even after sunset, man may enjoy lighting conditions approaching those of daylight. However, it can hardly be claimed that "artificial daylight" is equal in value to natural daylight, particularly with regard to its biological effects. The question arises as to what degree artificial illumination that simulates daylight can create conditions for the functioning of the human body and of the visual apparatus that are similar to those provided by natural light. It is clear that the stimulus provided by artificial light is not fully equivalent to that of daylight. Numerous experimental studies have shown that fluorescent lamps have a more favourable effect than do incandescent lamps, particularly for colour discrimination. Volockij (1961), in comparing diffuse daylight, fluorescent daylight lamps, white lamps, and ordinary incandescent lamps, has shown that the colour effect produced by fluorescent daylight lamps is very similar to that of natural daylight (colour distortion not exceeding one unit).

Dancig & Belikova (1950) measured the electrical sensitivity of the eye exposed to the light of incandescent and fluorescent lamps and to daylight at an intensity of 200 lux. It was found that with the use of light from fluorescent lamps, the rheobasis and the chronaxia were almost identical to those measured in daylight, but that these values were much lower in light produced by incandescent lamps.

Zil'ber (1963) compared weight changes in three groups of mice kept under identical conditions and on the same diet but exposed to the light of incandescent and fluorescent lamps and to daylight. He showed that the animals exposed to incandescent light gained weight at a slower rate than "daylight mice", whereas there was hardly any difference in weight gain between the latter and the mice exposed to fluorescent light.

The studies of Černilovskaja (1964), Šajkevič (1962), Zil'ber (1963), Velikson & Černilovskaja (1960), Nejštadt (1952) and others also have shown that light from fluorescent lamps has a more beneficial physiological effect than light from incandescent lamps.

The health requirements for fluorescent indoor lighting can be summed up as follows:

(a) improvement of the spectrum of light emitted by fluorescent lamps destined for homes;

(b) elimination of the glare caused by the source of light and all surrounding surfaces;

- (c) establishment of the optimum distribution of brightness within a room;
- (d) elimination of the stroboscopic effect;
- (e) reduction in flickering to such a level that visual comfort and working efficiency are not impaired.

The most important quantitative factor involved in the provision of comfortable illumination is an adequate degree of brightness on all surfaces within the field of vision. As with natural lighting, there is no single physiological criterion that can serve as the basis for standards of visual comfort under artificial light. A different optimum degree of illumination exists for each type of visual work. As long ago as 1934, Luckiesh emphasized that, under the most unfavourable conditions of discrimination, the level of illumination that is optimum for vision lies in the range of 20 000-30 000 lux.

Later, Luckiesh & Moss (1940) voiced the opinion that maximum comfort (superthreshold of vision A) cannot be measured directly and can be defined only on the basis of subjective sensations. It seems that during the performance of tasks demanding appreciable visual effort, visual comfort is provided by a level of illumination that ensures the functional stability of the entire visual apparatus throughout the working period.

When there is no demand for special visual effort, as when vision is used only for orientation, the reactivity of the central nervous system can serve as a criterion for light comfort. The level of reactivity can be estimated from the relative strengths of the excitatory and inhibitory processes.

There is good reason to believe that any shift in the equilibrium between the human body and the illumination of its environment in the direction of inhibition indicates an impairment of the conditions of visual comfort. This view is confirmed by observations on the physiological effects of the reduction in daylight at dusk, which has been shown to have a marked inhibitory effect on the higher centres of the nervous system, causing a slowing down of the metabolic processes and certain other changes (Zil'ber, 1963).

In addition, with regard to fluorescent lighting, it has been established that inadequate illumination has an unfavourable effect upon working capacity and productivity (Dancig, 1963; Šajkevič, 1962).

It must be emphasized that it is very difficult to draw a clear distinction between conditions of illumination that should be judged from the standpoint of visual comfort and those for which general physiological criteria should be used. It seems probable, however, that whenever the criteria of visual comfort are satisfied, the illumination will automatically

conform to the conditions of general physiological comfort. It is thus impossible to establish standards of illumination to ensure conditions of visual comfort independently of consideration of the quality of the illumination.

The accepted standards for indoor illumination have changed markedly over the past few decades, as indicated in Table 9. On the basis of special physiological studies, Dancig (1963) drew up standards for artificial illumination in various kinds of living quarters and rooms for communal use. These standards have been accepted in the USSR and are presented in Table 10. In the USA, standards for artificial illumination are determined according to the visual effort (that is, by the amount of eye strain) involved in the type of work being done. These standards require intensities of illumination between 300 and 2000 lux (Table 11). In Germany, new standards for indoor illumination were accepted in 1962. Some of the recommendations are given in Table 12.

It appears that technological advances in illumination and ever-increasing cultural demands have led to a continuous increase in the required levels of indoor illumination. At the time of the wax candle and the oil lamp, light intensities of the order of only 10-15 lux were considered adequate. After the introduction of the incandescent tungsten-filament lamp, the requirement was increased to 100-200 lux. However, with the availability of gas-discharge tubes that emit abundant light and provide a good colour effect, such intensities are now considered to be inadequate.

TABLE 9. MINIMUM STANDARDS OF INDOOR ILLUMINATION  
ACCEPTED IN 1922 AND IN 1962 \*

Type of space	Minimum illumination (lux)	
	1922	1962
Living rooms, bedrooms. . . . .	8-10	60-120
Simple living rooms. . . . .	25-75	60-120
Institutions . . . . .	50-70	600-1 000
Factories:		
heavy work . . . . .	15-20	120-250
precision work . . . . .	50-70	600-1 000
Hotels . . . . .	60-80	120-250
Schools . . . . .	20-50	120-250
Draughtsmen's rooms. . . . .	60-80	250-1 000

\* Data from Arndt (1963).

TABLE 10. STANDARDS FOR ILLUMINATION ACCEPTED IN THE USSR  
FOR VARIOUS KINDS OF LIVING QUARTERS  
AND ROOMS FOR COMMUNAL USE \*

Type of room	Required illumination (lux)	
	Over-all	Working areas
Living rooms in flats . . . . .	100	200
Bedrooms in hostels . . . . .	50	—
Study rooms (communal quarters in colleges)	100	300
Dining rooms in canteens . . . . .	75	150
Kitchens . . . . .	50-75	150

\* After Dancig (1963).

TABLE 11. STANDARDS FOR INDOOR ILLUMINATION IN THE USA  
(BASED ON VISUAL EFFORT ENTAILED BY WORK BEING PERFORMED)

Type of work	Illumination (lux)
Reading of books, etc. . . . .	about 300
Drawing . . . . .	700
Simple needlework . . . . .	1 000
Fine needlework . . . . .	2 000

TABLE 12. STANDARDS FOR INDOOR ILLUMINATION  
ACCEPTED IN GERMANY, 1962

Illumination requirements	Over-all illumination (lux)		Illumination of working areas (lux)	
	In conditions satisfactory for vision and work	In conditions not satisfactory for vision and work	In conditions satisfactory for vision and work	In conditions not satisfactory for vision and work
Very low	30	60	—	—
Low	60	120	—	—
Moderate	120	250	250	500
High	250	500	500	1 000
Very high	600	1 000	1 000	2 000
Extreme	—	—	4 000	4 000-8 000



The need for much higher intensities of illumination has been confirmed by the work of Nejstadt (1952), who carried out physiological studies on changes in the visual function, such as speed of detail perception, visual acuity, and frequency of spontaneous blinking. He established that, with fluorescent illumination, the following levels of intensity are optimum: (a) 1000-1200 lux for work requiring no special visual effort, and (b) 1300-1500 lux for work requiring fine vision.

In setting up standards for artificial illumination the aim should be a marked improvement, both quantitatively and qualitatively, in indoor lighting, so as to produce conditions of visual comfort; the spectrum of the artificial light should be made to resemble, as closely as possible, that of sunlight and should be enriched with biologically active ultraviolet rays of relatively long wavelengths.

In this context, the investigations carried out over many years in the USSR in regard to health standards for the longwave ultraviolet components of light from various sources (establishment of the minimum and maximum permissible doses of ultraviolet radiation) are of considerable interest. These studies have established that exposure to one-eighth of the erythema-producing dose for seven hours daily (10 milli-erythemic units/m<sup>2</sup>/hour) is the minimum dose for a prophylactic effect (Dancig & Zabalueva, 1953). Later studies showed that a dose equal to one-eighth of the erythema-producing dose per day does not always ensure a reliable effect, so that the amount can be increased to one-third of the erythema-producing dose for seven hours per day (about 29 milli-erythemic units/m<sup>2</sup>/hour) (Kričagin, 1958).

Clinical, physiological, and anthropological observations carried out in a number of towns in the north of the USSR have shown that the provision of ultraviolet radiation in sources of artificial illumination, to the extent of about one-quarter of the erythema-producing dose, exerts a favourable effect upon general health.

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## ACOUSTIC COMFORT IN THE HOME

### THE INFLUENCE ON MAN OF NOISE IN THE HOME

In the first report of the WHO Expert Committee on the Public Health Aspects of Housing (1961) it was rightly emphasized that, with the increasing mechanization of society, the problem of sound insulation is growing in urgency.

People who live in towns spend a large proportion of their time indoors. However, most modern buildings do not offer sufficient protection against noise that originates either outside or inside. Such noise not only causes annoyance, but can interfere with mental work and disturb rest and sleep.

The problem is complex, as there is a need for effective methods of acoustic insulation and means of preventing or attenuating noise at its source. Furthermore, studies of the physiological and psychological reactions of people to noise must be made to determine permissible sound levels in the home.

From the physical point of view, sound may be characterized in terms of the sound-pressure level (which determines its loudness), its spectral composition, and the way in which these characteristics vary with time. Noise in dwellings consists mainly of low-frequency sounds which, although low in intensity, are maintained for long periods and must, therefore, be regarded as one of the most common environmental stimuli.

The complete range includes soothing sounds, stimulating or disturbing sounds, and sounds that are definitely harmful. The stimulating and disturbing sounds range in intensity from 30 to 65 decibels (dB) and cause chiefly psychological symptoms (Beranek, 1957; Lehmann & Tamm 1956; Schröder, 1957; Tomatis, 1959).

The psychological stimulating action of sound is related to its influence on the central nervous system (Lehmann & Tamm, 1956). Many authors consider that the irritation caused by low-intensity noise is attributable to fatigue resulting from a large number of warning signals that evoke

a reaction related to fear or uneasiness (Smith & Laird, 1930; Moles, 1955).

Until recently, the influence of noise on people in buildings, including the home, was studied chiefly by inquiring into the sensations associated with individual noises (Parkin & Stacy, 1955; Broadbent, 1957; Parrack, 1957; Chapman, 1948; Beranek, 1957). This method has yielded interesting results descriptive of the response of people to noise. However, in reviewing these results it must be remembered that any subjective evaluation of the action of sound depends upon many factors, including such important considerations as condition of health, age, and profession (Effenberger, 1954).

The reaction of a group of people to sound is also very variable and complex and is conditioned by a variety of social, economic, and other factors (Stevens et al., 1955; Rudnick, 1957).

Investigations aimed at obtaining objective data on the influence of domestic noise on the human organism are thus of special value. In the USSR, studies of this kind have been carried out by Vajnštein, Leušin & Šafir (1960) and Karagodina (1959).

The starting point for these studies was the account given by Pavlov (1911) of the relationship between the auditory system and other sense organs. Hearing is but one link in a complex chain concerned with the perception of sound, a chain that connects numerous elements of the central nervous system and that influences the entire body.

Study of reactions to sound of moderate and low intensity has shown that the prolonged action of certain sounds to which persons are exposed in the home may lead to functional disturbances of the central nervous system. Such disturbances may manifest themselves in a variety of ways and cause fatigue and reduced activity of the cortical processes.

One of the principal functions of the modern dwelling is to provide conditions for normal rest. In the daily rhythm of life, periods of physiological activity should alternate with those of rest. If this is not the case, fatigue may set in prematurely, reducing the ability to work and, in many cases, resulting in pathological reactions. For this reason, the prevention of noise in the home is particularly important, because noise interferes with rest and sleep.

In certain instances the level of sound in the home may be so high that its effects are not confined to the symptoms mentioned above, which are due to its action on the central nervous system. Noises of this order may play an important part in the development of cardiovascular, nervous, psychic, and many other disorders (Andreeva-Galanina, 1959; Orlova, 1958; Krylova, 1957; Lehmann, 1962; Wittgens, 1962; Koeppen, 1955; Bugard, 1958).

## SOURCES OF NOISE IN THE HOME

*Street noise*

Among the noises that penetrate into dwellings, the greatest inconvenience results from traffic noise, which causes great disturbance, interferes with rest and sleep, and adversely affects health.

With increasing urbanization and growth in the means and power of transport, street noise continues to increase. Meister & Ruhrberg (1953) have reported measurements of the transport noise in Berlin and Düsseldorf made in 1938 and in 1952. These authors found that street noises recorded in these cities in 1952 were 9 phon above the level recorded in 1938. The number of recordings showing an excessive noise level had increased from 2 % to 27 % of the total. Work in Moscow (Alekseev, 1950, 1959; Osipov, 1958) and in other cities of the USSR (Leušin, 1958; Starošćuk, 1957; Filippovskaja, 1960) has shown that there has been a continuous increase in the level of transport noise in the streets. High levels of street noise have also been reported in towns elsewhere: in Sweden by Brandt & Jerdan (1956), and in the USA by Kurpluk (1957). The last-mentioned of these studies showed that noise from vehicles may reach a level of 80-85 dB.

According to the density of the traffic, the width of the street, and the distance from the buildings, the noise level in apartments facing the street may reach levels between 56 and 85 dB (Karagodina & Osipov, 1958; Karagodina, Osipov & Šiškin, 1964). Such sound levels in the home naturally result in irritation and the disturbance of sleep and rest.

TABLE 13. COMPLAINTS RECEIVED ABOUT STREET NOISE  
FROM VARIOUS SOURCES \*

Noise level reported	Motor vehicles (%)	Trams (%)	Other than traffic (%)
Noticeable . . . . .	89	93	61
Disturbing . . . . .	22	14	12
Enough to interfere with sleep	21	16	10

\* Data from Chapman (1948). The percentages are based on the total number of answered questionnaires. The figures are not additive, since a person who reported noise "sufficient to interfere with sleep" obviously also found it "noticeable" and "disturbing".

A number of surveys, conducted in various countries, have attempted to assess the degree of irritation that street noise produces in the population. The results of one such investigation, conducted in England

(Chapman, 1948) are presented in Table 13, which deals with the sources of street noise, and Table 14, which deals with the levels of noise in different types of streets.

In many cities of the USSR (Moscow, Leningrad, L'vov and others) detailed questioning has shown that 43-87 % of the inhabitants regard street noise as very disturbing (Karagodina & Osipov, 1958; Leušin, 1958).

TABLE 14. COMPLAINTS RECEIVED ABOUT STREET NOISE IN DIFFERENT TYPES OF STREET \*

Noise level reported	Main street (%)	Quiet street (%)	Cul-de-sac (%)
Noticeable . . . . .	87	66	36
Disturbing . . . . .	26	11	4
Enough to interfere with sleep	27	9	4

\* Data from Chapman (1948). The percentages are based on the total number of answered questionnaires. The figures are not additive, since a person who reported noise "sufficient to interfere with sleep" obviously found it "noticeable" and "disturbing".

#### *Noise within the building*

Although noise originating within the building, as it affects the noise level within a room, has been investigated very much less than has street noise, data that give a clear picture of this environmental factor are nevertheless available (Bonvallet, 1919; Leušin, 1951; Šapšev, 1939).

The most accurate available information was gathered by Karagodina, Osipov & Šiškin (1964), who made an extensive study of noise levels in various buildings in Moscow and Volgograd. These authors found that the mean sound intensity in blocks of apartments of various types of construction, situated along streets with various traffic densities, was 60-69 dB when the level of street sound was 77-83 dB. The noise level in apartments whose windows opened away from the street was 56-63 dB with the windows open and 52-58 dB with the windows closed.

Plumbing installations and domestic appliances may be important sources of noise within dwellings if acoustic insulation and other protective measures are inadequate.

Many investigations have been carried out in different countries to determine the extent and effect of various kinds of noise that originate within multiple dwellings. Table 15 indicates the sound intensities of some noises of this kind (Murovannaja, 1961). Within an individual apartment, the sources of domestic noise include loud speech, radio and

TABLE 15. INTENSITIES OF VARIOUS NOISES  
THAT ORIGINATE WITHIN BUILDINGS \*

Source of noise	Sound intensity (phons)
Lift machinery . . . . .	87
Slamming of lift doors . . . . .	78
Ascending lift . . . . .	65
Heating motor . . . . .	86
Flushing of lavatories . . . . .	80
Water supply, motor and pump . . . . .	90
Boiler furnace (in boiler room) . . . . .	82
Fan and motor (enclosed) . . . . .	90

\* Data from Murovannaja (1961).

TABLE 16. SOUND LEVELS OF SOME DOMESTIC NOISES \*

Source of noise	Sound level (dB)
Speech, 2-3 people . . . . .	73
Speech on radio . . . . .	80
Music on radio . . . . .	85
Children shouting . . . . .	79
Children crying . . . . .	80
Vacuum cleaner . . . . .	76
Electric polisher . . . . .	80
Piano . . . . .	86

\* Data from Karagodina (1962).

TABLE 17. REACTIONS OF INHABITANTS OF MULTIPLE DWELLINGS  
TO SOUND ORIGINATING IN ADJACENT APARTMENTS \*

Source of sound	Inhabitants noticing noise (%)	Inhabitants complaining of noise (%)
Radio . . . . .	71	32
Movement up or down stairs . . . . .	62	37
Movement in an apartment . . . . .	60	31
Children playing . . . . .	60	26
Doors slamming . . . . .	56	46
Movement of furniture . . . . .	45	—
Lavatory cisterns . . . . .	39	28
Conversation . . . . .	35	42

\* Data from Chapman (1957).

television sets, the slamming of doors, the movement of furniture, and children playing and crying. The possible levels of some of these domestic noises, as found by Karagodina (1962) in the USSR, are shown in Table 16. Chapman (1957) has made similar studies in the United Kingdom, and some of his findings are presented in Table 17.

#### ACCEPTABLE LEVELS OF SOUND IN THE HOME

The need for establishing an acceptable level of sound in the home is now generally recognized. Many attempts to determine permissible sound levels have been made, both internationally and independently in various countries. Until recently, however, attempts to standardize this environmental factor have not been based on objective measurement of the effects of low-intensity sounds on the human body.

An attempt has been made in England to establish permissible noise levels through direct questioning (Beranek, 1957), and in the USA a statistical study has been carried out to establish a relationship between the reactions of the inhabitants of a certain area and the spectral composition of environmental noise (Stevens et al., 1955).

The International Organization for Standardization (1958-1960) has prepared a summary of proposals that have been made for standards for the noise level in homes. These proposals differ according to the method used to evaluate the noise, but all are based on the results of questions put to the populations concerned.

Attempts to determine the permissible levels of sound in dwellings, based on objective data concerning the influence of domestic noise, have been made by health workers in the USSR. For example, in order to study the influence of domestic noise over the range of 35-45 phon, within which the sound level is relatively low and the stimulus not very strong, Vajnshtejn, Leušin & Šafir (1960) used physiological methods to assess functional disturbances that chiefly affect the higher nervous activity. These authors measured disturbances in the central nervous system through changes in conditioned-reflex activity, in the cutaneous galvanic reflex, in motor activity during sleep, and in differential sound thresholds.

The results of 65 series of observations on 7 subjects exposed to special synthetic noise stimuli showed that a sound level of 45 phon causes considerable changes in conditioned-reflex activity, changes indicating a definite reduction in the activity of the cortical elements of the brain; the effect of a noise at a level of 40 phon was found to be similar but less marked. Noise at a level of 35-37 phon produced none of the

unpleasant subjective impressions evoked by level of 45 phon, and the observed effects disappeared completely when the noise was stopped. Furthermore, at a level of 35-37 phon there were no appreciable changes in the cutaneous galvanic reflex, an extremely sensitive bioelectrical reaction.

The most complete study of prolonged low-intensity noise on the function of the auditory system and the central nervous system has been made by Karagodina (1959), who worked both in the laboratory and under field conditions. In carrying out the physiological tests, the noise was presented so as to bring its net level to 65, 55, and 50 dB. The spectral composition of the sound had a low-frequency character, falling 3-6 dB per octave, with a maximum energy in the range of 50-250 Hertz (Hz). The tests were made on 13 healthy subjects between 18 and 50 years of age.

The researches of Karagodina and her associates on the measurement of auditory sensitivity, the light-sensitivity of the dark-adapted eye, and the depth of sleep in terms of recorded movements have shown that low-frequency noise at an over-all level of 50 dB, with a spectrum gradient of 3-6 dB per octave, causes no noticeable physiological disturbances. These findings are, however, at variance with the conclusion reached by the Conference on Industrial Noise (1960) that, at present, it is impossible to ascertain the noise level below which there is no adverse effect on hearing.

The findings of Karagodina and her group form the basis of the Acceptable Levels of Sound in Dwellings that were established by the State Health Inspectorate of the USSR in 1960. Because the effect of noise on man depends upon both the character and the intensity of the sound, these standards specify the permissible levels for various octave bands, with mean frequencies within the range of 63-8000 Hz.

The acceptable limits for noise during the night are more exacting than those for day-time, because background noise in the home is very much less at night and people are then more sensitive to any sound that exceeds this background level. At night, the octave-band pressure level of penetrating noise must not exceed 25 dB at a frequency of 1000 Hz; during the day, the level should not exceed 30 dB.<sup>1</sup> The permissible sound levels were calculated by Karagodina for rooms having normal furnishings and closed windows and doors. These standards envisage an approximate evaluation of noise penetrating into an apartment, by means of a sound-level meter.

<sup>1</sup> The octave-band pressure level is the effective sound pressure level of the sound energy within a given octave. The octave is specified by the geometric mean of its two limiting frequencies.



## PROTECTION OF THE HOME FROM EXTERNAL AND INTERNAL NOISE

Studies carried out in recent years have made it possible to formulate certain basic recommendations on ways in which the noise level in towns may be lowered. These include careful planning of residential areas, multiple dwellings, and streets, and certain other technical, organizational, and administrative measures. First, steps must be taken to reduce vehicular noise (particularly at night), to reduce the noise produced by plumbing and domestic appliances, and to improve the acoustic insulation of buildings. To reduce the level of noise penetrating into dwellings, the widening of streets must be considered, as should the establishment of green belts around built-up areas and arrangements for setting houses back from the roadway.

The planning of multiple dwellings is of great importance; it has been shown that, from the acoustical standpoint, the best arrangement is a series of detached buildings, whereas the least favourable arrangement is a single large building or one that is continuous with the perimeter of the building site and has a central courtyard.

In the planning of any housing estate, particular attention should be given to the organization of the space within and around the building site. Certain areas should be separated as playgrounds for children, other areas should be planted with greenery, and supplies for shops, etc., should be unloaded at some distance from the residential areas. Also, control should be exercised over vehicular traffic within and around the area.

In the planning, construction, and organization of cities, the following measures should be taken to reduce noise in the residential and other areas where the population will spend a considerable part of their time.

(1) Division of the city into zones, with particular attention to the separation of areas concerned with industry, storage, and transport. Access to such areas should not be through the residential zones. Appropriate public health measures should be taken to minimize the disturbance caused by industries that produce particularly intense noise, and measures should be taken to abate such noise at its source in the plants.

(2) The planning of highways so that through-traffic will by-pass residential areas. Special access roads should lead to the zones assigned to industry, storage, and transport.

(3) The separation of residential areas from main streets (which should serve only as traffic arteries) by means of wide green belts. House fronts should lie not less than 15 metres from the road and the intervening space should be thickly planted with trees or bushes. The buildings should be detached from each other and separated by planted areas.

(4) The widening of main streets in cities and the planting of protective belts of greenery to separate the different zones, instead of the conventional single, sparsely planted rows of trees, which have only decorative value. Also, sound-absorbing materials should be used to pave streets.

(5) The prohibition or reduction of vehicular traffic on residential streets. Heavy vehicles leaving main streets should not be routed into narrow streets, so as to minimize the number of people exposed to their noise.

(6) Strict control over the operating condition of public transport and of road surfaces.

(7) Prohibition, within dwellings, of installations that produce noise or disturb the occupants.

(8) Measures to protect the populations of new towns or residential areas from the noise of railway transport. Special districts must be demarcated, outside residential areas, for railway lines, marshalling yards, and similar installations. When these demands cannot be met, protective green belts must be laid down between these installations and residential areas.

(9) Separation, within homes and in residential areas, of areas where noise is produced from those used for rest. All installations within residential areas that are sources of noise, such as garages and unloading platforms, should be situated in a special area at a sufficient distance from the living quarters. There should also be zoning within the area, including compulsory separation of areas devoted to noisy recreational activities from living quarters and places for rest or reading. The whole of the open area of the district should be planted with trees, shrubbery, and grass.

(10) The design of blocks of flats so as to reduce the noise caused by plumbing and mechanical appliances. In addition, such buildings should be sound-proofed where necessary.

## THE PSYCHOHYGIENIC ASPECTS OF COMFORT

The general requirements for health in the modern home should be supplemented by architectural and aesthetic considerations, which are of great psychological importance. This point was convincingly set forth in the first report of the WHO Expert Committee on the Public Health Aspects of Housing (1961). It was also discussed in the fifth report of the WHO Expert Committee on Public Health Administration (1963).

Pavlov (1949) repeatedly pointed out that any environmental factor that ordinarily does not affect the human organism may, under appropriate conditions, act upon it through the central nervous system and its receptors. Thus, the beauty, comfort, and design of a dwelling and its surroundings may acquire profound scientific significance. Architectural grouping and design, the landscaping of the immediate neighbourhood, and the external appearance and internal decor of apartment blocks, houses and individual flats are all factors that undoubtedly exert an important psychological influence on health.

From the point of view of public health, it is necessary to establish standards for the construction of dwellings and their surroundings, and, in addition to observing the accepted health criteria, consideration should be given to the emotional significance of any particular means used to fulfil them.

Auditory, olfactory, visual, and other stimuli can, of course, influence both the way a person feels and his ability to work. The various external stimuli are received by the sensory receptors and, through the action of the different nervous pathways, they stimulate or inhibit the nervous activity and therefore affect the emotional state of the individual. It is well-known that factors such as the size and proportions of rooms, the character of the surroundings, the colour scheme, and even the view from a window have great psychological effects.

These facts have recently received increasing attention. For example, in the work of the Centre scientifique et technique du Bâtiment (1962),

it is laid down that the interior decor, the shape and proportions of rooms, etc. should be aesthetically satisfying.

Nevertheless, such problems have not yet received adequate attention from the point of view of mental health, and serious experimental investigations in this direction have only recently been initiated, in the USSR and France.

From the point of view of health, the most important function of dwellings is the provision of rest and sleep. This function cannot be fulfilled satisfactorily unless the person concerned is able to free his mind completely from all thoughts of the day's work; to this end, favourable living conditions are essential. Consequently, it should be possible to pass from the noise of the town or factory into a region of quietness and peacefulness that gives rise to totally different sensations.

It is, of course, obvious that the problem of how to provide psychologically satisfying surroundings in the home cannot be solved independently of the general problem of establishing adequate living conditions for the entire population. The successful solution of the housing problem depends upon the realization of the fundamental aims of one apartment per family and a separate room for each adult. The favourable effect of these two factors on mental health and on quiet rest is immediately evident.

The possibility of constant proximity to nature is profoundly important for health. It would be difficult to overestimate the soothing influence of a rural environment or of country-like surroundings. Sun, fresh air, and green plants must be included among the numerous factors that influence man and his higher nervous activity and provide favourable sense impressions during periods of creative activity and rest. All of these things can be provided in the planning of city districts, as has been shown by modern practice in the USSR and other countries.

Psychological factors must be considered in planning the internal decor, colour scheme, and other aspects of the home. Although these problems may be left for the occupants to solve according to their own taste, an effort should be made to educate the people to the importance of such factors from the point of view of health.

Much is already known concerning the psychological effects of the colour of the surroundings, the so-called "colour climate", and it is possible to utilize the relevant results of studies that have been made in industry, where wide use is made of colour in buildings and on equipment.

Observations made in this field have permitted the establishment of colour standards in the USSR, Czechoslovakia, the United Kingdom, France, and elsewhere. These standards are based on the soothing or stimulating effects of various parts of the colour spectrum and on studies of visual fatigue in relation to colour (Köhler & Luckhardt, 1956).

Many studies have been made of the effects of the colours of walls and equipment on labour productivity, and hence on the economic importance of environmental colour (Fere, 1904; Tilgiani, 1956). In recent years, a great deal of attention has also been paid to colour in hospitals (Gorsdorf, 1959; Koerner, 1960; Paschke, 1958).

From the point of view of public health, the problem of the colour climate is of special interest, because the rational use of colour can produce a restful effect, favouring recuperation after physical or mental effort. In this connexion, the concept of "warm" and "cold" tones is generally accepted but lacks sound experimental justification (Murray, 1952; Birren, 1959).

It is known that it is best to colour walls in tones related to shades commonly found in nature — i.e., yellow, pale blue, or green. White, pale yellow, pale blue, and pale green reflect 70-80 % of the incident light and so make a room lighter; the reflectivity of a dark-blue or brown surface is less than 10 %.

It has been shown that yellow, green, and even white exert a stimulating influence on the visual system, reducing visual fatigue and enhancing the strength of chromatic and achromatic vision. The particular effect of these colours of medium wave-length is related to the spectral sensitivity of the human eye (Rabkin, 1964). Further experimental work on the psychophysiological effects of colour on man must be taken into account in establishing relevant health standards. In this connexion, note should be made of the important work of Kravkov (1948) on the interaction of the different sensory systems.

The psychological significance of the so-called law of proportion in living premises — i.e., the correct relationship between height, width, and length of rooms — has been emphasized in many works (Šafir, 1963). The proportions of living quarters are of major importance to feelings of well-being.

Ceiling height is important, in relation to not only the area of a room, but also its length. Rooms with low ceilings appear to be larger than rooms of the same area with high ceilings, but they may create an unpleasant impression. In small, low-ceilinged rooms encumbered with furniture, the cramped space may exert an unfavourable psychological influence; there is no feeling of spaciousness and such rooms are often not conducive to relaxation and rest. On the other hand, rooms with ceilings that are too high (that is, above 5 metres) may adversely affect the mood of persons in them. The same is true of rooms that are disproportionately long.

Many formulae have been suggested for the determination of the optimum ratios between ceiling height and the other dimensions of a room. For example, it has been suggested that ceiling height should be

(a) more than one-third of the combined length and width of the room; (b) less than two-thirds but greater than one-quarter of the length of the room; (c) more than one-half the distance between diagonally opposite corners of the room; and (d) somewhat greater than one-half of the room's length or two-thirds of its width. It is also recommended that windows be placed as near the ceiling as possible.

All the above other formulae have a certain value, but none of them constitutes an absolute rule. However, any decisions that are made on the proportions of rooms for habitation must be based on extensive study of the influence of environmental conditions on physiological functions and must take into account psychological factors.

It must be emphasized that the considerations discussed above have been offered in order to emphasize the necessity for further studies of factors influencing mental health in the home. In such investigations, as in others that are related to domestic hygiene, attention must be paid to the fundamental principles of environmental health.

Comfort may be defined as the state of the environment that a person prefers to all others. Prolonged studies will be necessary to determine conditions of comfort accurately. Experiments and observations are required to find out what intensities and durations of various environmental factors are harmless, of no significance, or deleterious as far as human well-being is concerned. Increased theoretical knowledge in this realm will lead to the solution of many present-day problems of housing construction and will assist in drawing up standards for the promotion and protection of the health of mankind.

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NEW MATERIALS OF PUBLIC HEALTH  
IMPORTANCE IN HOUSING CONSTRUCTION

In recent years, new synthetic materials have been increasingly used in the construction and equipment of living premises and of social and industrial establishments. Plastics that have been employed in building include polyethylene, polystyrene, polyvinyl alcohol, polyvinyl acetate, phenol-formaldehyde resins, polyamides, melamine-formaldehyde resins, polyurethanes, polysiloxanes, and the epoxy and coumarone resins.

Polymers are used for, among other things, floor coverings, internal linings for walls, the insulation of pipes against heat and sound, and protection against moisture. Particular attention has been given to the use of polyvinyl chloride floor coverings, and laminated wood or chip-board bonded with synthetic resins. New adhesives based on various resins, and paints based on polyvinyl acetates, styrene-butadienes, alkyl styrenes, and other polymers have been introduced.

However, despite the widespread use of such materials, few studies have been made of their implications for health, and there are as yet no established standards.

The hygienic advantages of plastics are their smooth, polished surface, which is not easily contaminated and is readily freed from dust, their relatively low thermal conductivity, and their good sound-insulation properties. Some of them are transparent to ultraviolet radiation and at the same time offer protection against the direct action of sunlight. Studies have shown that some polymers — e.g., materials made from polyvinyls, nitrocellulose, and chlorinated rubber in conjunction with the new halogenated phenol derivatives — may have antimicrobial properties (Rudat, 1958).

On the other hand, some studies made in recent years have revealed that certain polymers may have unfavourable properties. Some materials used for floor coverings provide inadequate insulation (Goromosov, Ciper & Solomatova, 1963). Measurements made on adults and children in winter have revealed that unbacked floor coverings such as polyvinyl

chloride tiles and coumarone resins may have unfavourable thermal properties (Stankevič et al., 1961; Bokov, Fedorčuk & Prokopenko, 1963).

A special study has been made in Leningrad of the temperature and humidity in an experimental house in which maximum use was made of plastics. Wall and ceiling panels were made of glass fibre bonded with a polyester resin, polystyrene foam was used for thermal insulation, and the flooring was composition wooden slabs covered with polyvinyl chloride material. Warm panels were used for heating, and an extraction-type ventilator was used. In winter, it was found that the air in the house was drier (relative humidity 15-26 %) than during the summer, although the air temperature was comfortable (Grigor'eva, 1963). In many cases, it was found that some residual monomers and certain volatile components, such as formaldehyde, phenol, dibutyl phthalate, isopropylbenzene, and hydrogen peroxide were present in the material as a result of incomplete polymerization (Bokov & Chujko, 1962).

Stankevič et al. (1961) demonstrated that organo-chlorine compounds and some other substances break down at temperatures above 50° C, so that such materials cannot be used for housing construction in hot climates.

Certain monomers may have toxic properties. Some, such as vinyl acetate, vinyl propionate, and vinyl butyrate, exert an irritating action; compounds such as vinyl acetate, vinyl chloride, styrene, and others exert a nonspecific narcotic action; and monomeric styrene, methylstyrene, distyrene, etc. affect the circulation system (Daniševskij, 1964; Rylova, 1953; Gadaskina, 1957).

Certain additives used in the manufacture of plastics, such as plasticizers, promoters, and accelerators, have been shown to be toxic. The plasticizers, which do not combine with the organic material during the production of the plastic, present the greatest danger, as they may be gradually liberated into the environment.

Other constituents of a plastic may also enter the air as the material decomposes with age (Brojtman, 1964). Little attention has been given to the health aspects of the ageing of plastics (a process that involves the liberation of the original monomers and the additives) although, in other respects, it has been extensively studied. This deficiency should be remedied by thorough investigation, because the substances given off may well produce adverse physiological effects. Ageing takes place under the influence of normal environmental factors, such as temperature, atmospheric oxygen, and solar radiation. It has been found that phenol-formaldehyde, urea, resorcinol-formaldehyde, and epoxy resins and similar materials exert a toxic action on animals and liberate volatile substances at temperatures above 60° C (Galibin, 1963).



It should be remembered that some plastics may burn or decompose at temperatures of 160-240° C. When heated, some polymers may evolve harmful substances. Thus, the copolymer of styrene with acrylonitrile compositions may give off hydrogen cyanide, carbon monoxide, dibutyl phthalate, and styrene; low-pressure polyethylene may give off carbon monoxide, aldehydes, and organic substances containing chlorine (Kulagina & Kočetkova, 1961).

Polymers may be decomposed by the action of atmospheric oxygen. Thus, polyesters that have been hardened with styrene may give off benzaldehyde, the oxidation product of styrene. Polyethylene is also unstable and is readily oxidized. It is known that, at normal temperatures, the combined action of sunlight and atmospheric oxygen may cause the breakdown of polyethylene; it also decomposes polyvinyl with the liberation by the latter of hydrogen chloride or organic chlorides. The decomposition of polyvinyl chloride is particularly great under the action of light with a wavelength of 3100 Å (Daniševskij & Egorov, 1961; Oswitch, 1964; Wright, 1963).

Many ingredients of the synthetic resins, such as vinylcarbazole and epichlorohydrin, cause sensitization, so that the body begins to react to very small amounts of substances that initially had no effect (Rylova, 1953; Pet'ko, 1961).

In listing substances that sensitize the skin, Piriälä (1958) distinguished 43 compounds used in the manufacture of plastics, among them 29 accelerators and 11 antioxidants. Other authors also have described the development of cutaneous allergy. Many investigators have pointed out the necessity of investigating the possibility that substances present in plastics exert a combined action, even if the amounts of the individual compounds are extremely small. If this is the case, the maximum permissible concentrations of the individual chemicals must be much lower than is usually assumed (Sljusar', 1963; Stankevič & Ivanova, 1961). This consideration must be borne in mind in the hygienic control of the air in dwellings in which plastics have been used.

Highly dispersed dust of various kinds may contaminate the air within dwellings and may enter the digestive tract or the respiratory system. It is not impossible that such substances may eventually lead to pulmonary disease (Sljusar', 1963; Golovatjuk, 1963). There are some indications concerning the action on the body of dust from a number of phenolic and amino resins (Arhangel'skaja, 1959), and of dust of the polyvinyl chloride synthetics; this point is important in relation to the cleaning of houses in which these materials are used. Some authors have pointed out that plastic floor-coverings tend to wear rather rapidly.

A great deal of attention has recently been paid to the survival of micro-organisms on plastics. This is important in the home and even

more so in hospitals. It has been shown that a culture of *Staphylococcus aureus* can survive in darkness for almost 40 days on polyvinyl chloride, and a culture of *B. coli* for nearly 30 days. Plastics may thus serve as substrates for the development of microflora and should be treated with disinfectants. Solutions of lysol and of carbolic soap and preparations containing chlorine, to which surface-active agents have been added, are good disinfectants for plastics (Ramkova, 1961). It has been shown that such disinfectants have no adverse effect on the mechanical strength of the plastics, but no investigation has been made of the possibility that they may affect plastics chemically.

A further problem is the accumulation of electrostatic charges on plastic surfaces such as floors and walls. Strong electrostatic fields may sometimes be produced, giving rise to unpleasant sensations. Studies have shown that even in the spring, when the humidity is high, the movement of people across plastic flooring may produce an electric charge exceeding several thousand volts per cm<sup>2</sup> (Rapoport, 1962). Further investigation of this phenomenon is necessary.

Synthetic materials are being ever more widely used for the construction of pipes for the distribution of drinking water. Studies of the effects of this practice have led to contradictory results. Some investigators (Noble, 1958; Köhler, 1957; Tiedeman, 1954) have failed to produce any data that would justify a restriction in the use of polyethylene, polyvinyl chloride, polypropylene, and acrylonitrile. Some other workers, however, insist on strict control for water pipes (Ahrens et al., 1957; Hermanowicz & Trywianski, 1960; Nicolas & Meyer, 1961). These investigators reported increased bacterial contamination of the water in pipes made of the above materials and found that lead or zinc compounds used as stabilizers in polyvinyl chloride were leached out into the water.

Ahrens et al. (1957) found that most plastic pipes have no effect on the odour, taste, or colour of the water. In the USSR and other countries, polyvinyl chloride pipes have been found to be unsatisfactory and studies showed that many vinyl, polyethylene, and glass-fibre pipes are also unsuitable for use as water conduits. Some materials give the water an unpleasant taste and release stabilizers, including lead and other metals, into it. No significant difference was found between the bacterial contamination of water left in contact with any of the pipe samples and that of water in control pipes (Čerkinskij, Akulov & Rubleva, 1959, 1961, 1963).

Studies of high-pressure polyethylene water pipes, made over many years, have shown that such pipes do not affect the organoleptic or physicochemical properties of the water supplied by them (Šeftel', 1963).

Wilson & McCormick (1955) have published data on the toxicological properties of 15 groups of polymeric resins, including coumarones and polyvinyl chlorides; these showed no definite harmful effect. In the USSR, extensive studies of this type have been made at the Institute of General and Public Health, at the Institute of Industrial Hygiene and Occupational Diseases of the AMS USSR, and at the Institute of Industrial Hygiene, which is attached to the Trades Union Council of the USSR.

The physiological effects of the new synthetic materials present a problem of great current interest. Further investigations should be carried out so as to establish physical and chemical standards that will ensure not only an optimum physiological state, but also the complete absence of any factors that might induce pathological changes.

Although studies in this direction have only just begun, it is quite evident that a combination of many approaches must be used to establish such standards. They should include sanitary, toxicological, physiological, and general biological studies.

Synthetic materials used in the construction and equipment of dwellings must meet the following eight requirements.

(1) They should have the maximum possible chemical stability, so that no harmful substances will be liberated from them into the environment. This is particularly important since people spend a major part of their lives in their homes or in public buildings, making it practically impossible to isolate them from any unfavourable effects of plastics used in construction.

(2) They should be appropriate to the climate where they are used; special attention must be given to the possible decomposition of such materials due to the effect of high temperature, bright sunlight, and other climatic factors.

(3) They should be odourless. If plastic water pipes are used, they must have no effect on the taste, odour, colour, or other organoleptic properties of the water.

(4) They should not accumulate electrostatic charges greater than those accumulated by natural materials.

(5) Their thermal-insulation properties must be such as to ensure thermal comfort in both summer and winter.

(6) They must have adequate mechanical strength and durability, must not produce dust when the floors and walls are cleaned, and must be easy to clean.

(7) They must fulfil the same physical and hygienic requirements as conventional materials. Since many plastics have low thermal stability, care must be taken to ensure that materials situated near heating or lighting installations are sufficiently stable at elevated temperatures.

(8) Since certain plastics (particularly polyethylene pipes) may favour the growth of bacterial flora, microbiological control will sometimes be required when they are used.

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HOUSING SANITATION IN RELATION  
TO EFFECTIVE COMMUNITY PLANNING

Modern community planning and sanitary measures related to multiple dwellings should be combined and should begin with the preliminary layout of the area to be inhabited, so as to avoid pollution of the atmosphere, water, and soil. Such combined planning should continue into consideration of the best ways to equip, decorate, and furnish the individual dwellings.

Healthful living conditions depend, to a large extent, upon the planning of the individual town or settlement. A dwelling is not merely a room or an apartment; it forms an integral part of the building, the street, and the town in which it is situated. Well laid-out parks and gardens in residential areas should be regarded as important extensions of the individual dwellings.

The problems of healthful conditions in the home are inseparable from the general problems of urban sanitation and the provision of outdoor recreational facilities. The complexity of the problems involved has been stressed by the WHO Expert Committees on the Public Health Aspects of Housing,<sup>1</sup> Public Health Administration,<sup>2</sup> and Environmental Aspects of Metropolitan Planning and Development.<sup>3</sup>

Measures to ensure the provision of public amenities in new settlements should be taken at the planning stage. The urgency of this task is emphasized by the early estimates of town planners that in the USSR more than one million hectares of land will be required for urban development within the next 15-20 years. For volume of housing construction, the USSR holds a leading place: in 1961, the number of new apartments constructed per 1000 population was 12.4; this compares with 6.9 in the USA and France and 5.9 in the United Kingdom. At the same time as providing low-rental housing, the USSR provides adequate

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<sup>1</sup> *Wld Hlth Org. techn. Rep. Ser.*, 1961, 225.

<sup>2</sup> *Wld Hlth Org. techn. Rep. Ser.*, 1963, 250.

<sup>3</sup> *Wld Hlth Org. techn. Rep. Ser.*, 1965, 297.

public services, the planting of green areas, and physical training centres and other services to satisfy recreational needs.

As was pointed out at the Fifth International Architectural Congress (Moscow, July, 1958), in the period immediately following the Second World War considerable advances were made in many countries in planned development of towns, methods of construction, organization of traffic and transport, effective utilization of natural conditions in relation to planning, and construction of residential districts and multiple dwellings.

The provision of public services should not lag behind housing construction. Failure in this respect may cause serious problems of sanitation. Indeed, housing construction should not begin until the streets have been laid out and all underground installations have been completed.

As discussed in Chapter 2, one of the most important hygienic requirements is appropriate ventilation and correct control of air-renewal systems. The extent to which this is necessary will depend, to a large extent, upon the quality of the outside air. This, in turn, depends upon rational planning, the planting of green areas, the adequate separation of industrial from residential areas, and measures for the control of pollution from industrial plants.

In the establishment of new communities, much depends upon the choice of the town site and upon the siting of the various residential areas within it. It is clear that all such areas should be healthful, free from harmful industrial influences, near the principal places of employment, adequately provided with green spaces, and not subject to flooding.

The town site having been selected, the following are some of the factors that must be considered in planning construction. (1) Industrial plants that produce harmful wastes must be separated from residential areas by green belts. (2) A rational system of roads must be constructed. (3) Traffic must be well organized. (4) Throughout the town, and especially in the residential areas, there must be adequate green areas, connected with natural parkland. Furthermore, planning must be done on a regional basis, and a network of cultural, medical, commercial, and other services connected with the daily lives of the people must be organized. In regions with hot climates, it will also be necessary to provide a favourable microclimate by means of irrigation and large-scale planting of vegetation. It has been established that the cooling effect provided by gardens, parks and indoor plants protects the population from the adverse effects of high temperatures and effectively lowers the prevailing temperature by 5° C or more (Šelejhovskij, 1948).

Observations in Leningrad have demonstrated the existence of a relationship between the level of planning and organization, including the provision of greenery outdoors and indoors in the built-up areas, and

the number of children and adults making use of these amenities. It was found that, in well-planned areas, the recreational areas were utilized by 45 % of the inhabitants in general, and by 80 % of the children (Šafir, 1963).

Many of the principles that have been outlined in the preceding chapters (e.g., the provision of greenery and of maximum insolation and air circulation, and protection from street noise and dust) are already being applied to the design of towns in the USSR and other countries. At the same time, schools, nurseries, cinemas, medical-care centres, shops, and other community services are being provided. The study of such ways of improving housing and town-planning is one of the principal concerns of environmental health.

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## REFERENCES

- Abrosimov, V. I. (1955) *Ž. Mikrobiol. (Mosk.)*, No. 5, 96
- Adolf, E. F. et al. (1952) *Physiology of man in the desert*
- Ahrens, W., (1957) *WassWirt. WassTech.*, 7, 348
- Alekseev, S. M. (1950) [*A study of noise in Moscow*]
- Alekseev, S. M. (1959) [*Work of the station for the prevention of city noises*]. In: *Gorodskoe hozjajstvo g. Moskvy*, 2, 32
- American Public Health Association, Committee on the Hygiene of Housing (1938) *Amer. J. publ. Hlth*, 28, 351
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (1960) *ASHRAE guide*
- Andreeva-Galanina, E. C. (1959) *Gig. i Sanit.*, No. 4, 52
- Arhangel'skaja, G. V. (1959) [*On the problem of significance for health of dust from condensation plastics*]. In: *Voprosy gigieny*, Kiev, vol. 5
- Arndt, W. (1963) *Int. Ltg. Rev.*, 14, 260
- Aronin, J. E. (1953) *Climate and architecture*, New York
- Aschoff, Y. (1955) *Klin. Wschr.*, 23, 545
- Atkinson, G. A. (1950) *J. roy. inst. Brit. Archit.*, 57, 313
- Bazett, H. C. (1949a) *J. Amer. med. Ass.*, 218, 483
- Bazett, H. C. (1949b) *Physiology of heat regulation and the science of clothing*, Philadelphia & London, Newburgh, ch. 4
- Becher, P. (1961) *Boligventilation*, Copenhagen
- Bedford, T. (1946) *Environmental warmth and its measurement*, London, H. M. Stationery Office (Medical Research Council, War Memorandum No. 17)
- Bedford, T. (1948) *Basic principles of ventilation and heating*, London, Lewis
- Bedford, T. (1954) *Heating and ventilation requirements and methods*. In: Merewether, E.R.A., ed., *Industrial medicine and hygiene*, London, Butterworth, vol. 2, ch. 10
- Belding, H. S. & Hatch, T. F. (1955) *Heat. Pip. Air Condit.*, 27, 129
- Belikova, V. K. (1957) *Gig. i Sanit.*, No. 11, 8
- Benoit, J. (1935) *C. R. Soc. Biol.*, 113, 664
- Beranek, L. L. (1957) *Noise Control*, 3, 19
- Birren, F. (1959) *Amer. J. occup. Ther.*, 13, 125

- Bokov, A. N. et al. (1964) [The sanitary and toxicological characteristics of certain plastics as floor coverings]. In: [Transactions of the 2nd Conference on the Toxicology and Hygiene of High-Molecular-Weight Compounds... Leningrad, 1964], p. 117
- Bokov, A. N. & Cujko, A. V. (1962) *Gig. i Sanit.*, No. 1, 70
- Bokov, A. N., Fedorčuk, V. V. & Prokopenko, V. A. (1963) [A hygienic evaluation of plastics for floor coverings]. In: [Transactions of the Final Republican Scientific Conference on Hygiene, Leningrad, June 11-14, 1963].
- Bonvallet, G. L. (1949) *J. acoust. Soc. Amer.*, **21**, 463
- Bourdillon, R. (1948) *Studies in air hygiene*, London
- Brandt, O. & Jerdan, V. L. (1956) *Ingeniøren*, **29**, 582
- Brojtman, A. Ja. et al. (1964) [On the toxicology of stabilizers for plastics]. In: [Transactions of the 2nd Conference on the Toxicology and Hygiene of High-Molecular-Weight Compounds... Leningrad, 1964], p. 72
- Brown-Séquard, C. (1893) *Experimental researches applied to physiology and pathology*
- Buchbinder, I. (1942) *Aerobiology*, Washington, D. C., p. 267
- Bugard, P. (1958) *Arch. Mal. prof.*, **19**, 21
- Bürgers, I. B. (1932) [The hygienic importance of heating and ventilation]. In: Ritišel', G. & Greber, G. [Handbook of heating and ventilation], Moscow, Gosstroizdat, p. 197
- Burton, A. C. & Edholm, O. E. (1955) *Man in a cold environment*, London
- Buštueva, K. A., Poležaev, E. F. & Semenenko, A. D. (1960) *Gig. i Sanit.*, No. 1, 57
- Bykov, K. M. (1947) [The cerebral cortex and the internal organs], Moscow & Leningrad, 2nd ed.
- [Centre scientifique et technique du Bâtiment] (1962) Les entrées d'air de ventilation, *Cah. Cent. scient. tech. Bâtim.*, 59
- Čerkinskij, S. N., Akulov, K. I. & Rubleva, M. N. (1959) *Gig. i Sanit.*, No. 7, 69
- Čerkinskij, S. N., Akulov, K. I. & Rubleva, M. N. (1961) *Gig. i Sanit.*, No. 1, 95
- Čerkinskij, S. N., Akulov, K. I. & Rubleva, M. N. (1963) [On a method for the evaluation of the hygienic properties of the new polymers used for domestic water supply]. In: [Transactions of the Final Republican Scientific Conference on Hygiene, Leningrad, June 11-14, 1963]
- Černilovskaja, F. M. (1964) [Health significance of fluorescent lighting in industry], Leningrad, "Medicina"
- Chapman, D. A. (1948) *A survey of noise in British homes*, London
- Chrenko, F. A. (1953) *J. Instn heat. vent. Engrs*, **20**, 375
- Chrenko, F. A. (1957) *Brit. J. industr. Med.*, **14**, 13
- Ciper, N. A. & Solomatova, N. A. (1963) *Gig. i Sanit.*, No. 2, 95
- Crowden, O. P. (1951) *J. roy. sanit. Inst.*, **72**, 108
- Crowden, O. P. (1952) *Practitioner*, **168**, 593
- Dancig, N. M. (1953) *Gig. i Sanit.*, No. 9, 13
- Dancig, N. M. (1963) [Illumination of dwellings and communal buildings]. In: [Guide to communal hygiene], Moscow, Medgiz, vol. 3, 123
- Dancig, N. M. & Belikova, V. K. (1949) Some health problems of fluorescent lighting, Part 1, *Gig. i Sanit.*, No. 10, 28
- Dancig, N. M. & Belikova, V. K. (1950) *Ibid.*, Part 2, *Gig. i Sanit.*, No. 8, 17,

- Dancig, N. M., Mac, L. I. & Belikova, V. K. (1958) [*The resistance of animal organisms to infection under the influence of ultraviolet radiation*]. In: [*Ultraviolet radiation*], Moscow, Medgiz
- Dancig, N. M. & Zabalueva, A. P. (1953) *Ž. vračebnoe Delo*, No. 12, 1119
- Daniševskij, S. L. (1964) [*On the criteria for the hygienic evaluation of synthetic resins*]. In: [*Transactions of the 2nd Conference on the Toxicology and Hygiene of High-Molecular-Weight Compounds...* Leningrad, 1964]
- Daniševskij, S. L. & Egorov, N. M. (1961) In: [*Transactions of a Meeting on the Toxicology of High-Molecular-Weight Compounds...*], Leningrad, p. 5
- Douglas, H. E. (1953) *Physiological objectives in hot weather housing...* Washington, D. C.
- Drysdale, J. M. (1951) *J. Instr. heat. vent. Engrs*, 18, 401
- Du Bois, E. F. (1937) *Mechanism of heat loss and temperature regulation*, Stanford University Publ., Univ. Ser. M.Sc., 3, 323 (Lane Medical Lectures)
- Du Bois, E. F. (1951) *West. J. Surg.*, 59, 476
- Dubrovskaja, F. I. (1957) [*Hygienic evaluation of the degree of atmospheric pollution with sulfur dioxide in a large city*]. In: [*Permissible limits of atmospheric pollution*], Moscow, vol. 3, p. 44
- Dufton, A. F. (1932) *The equivalent temperature of a room and its measurement*, London, H. M. Stationery Office (Building Research Technical Paper 13)
- Dunaev, B. A. (1962) *Insolation of dwellings*, Moscow
- Effenberger, E. (1954) *Arch. Hyg. (Berl.)*, 138, No. 7, 533
- Efimov, V. V. & Kazimirova, S. A. (1936) *Bjull. ėsksp. Biol. Med.*, No. 2
- Eliseeva, O. V. (1964) *Gig. i Sanit.*, No. 8, 10
- Flügge, K. (1881) *Lehrbuch der hygienischen Untersuchungsmethoden*, Leipzig
- Flügge, R. (1925) *Das warme Wohnhaus*, Halle
- Frank, G. M. (1950) [*Special features of the biological action of ultraviolet of various wavelengths*]. In: [*Ultraviolet radiation and hygiene*], Moscow, Izd. AMN SSSR, 7
- Gaage, A. P. (1941) *Standard operative temperature...* New York, Reinhold
- Gadaskina, I. D. (1957) In: [*Transactions of the Jubilee Session of the Leningrad Scientific Research Institute for Industrial Hygiene and Occupational Diseases...*], p. 351
- Galanin, N. F. (1952) [*Radiant energy and its health significance*], Leningrad
- Galanin, N. F. (1958) [*The problem of compensation for the natural ultraviolet insufficiency in the north*]. In: [*Ultraviolet radiation*], Moscow, Medgiz
- Galibin, G. P. (1963) [*Experimental research on the effect of synthetic resins on animals*]. In: [*Toxicology of new industrial chemical substances*], Moscow, p. 45
- Gaske, O. D. (1949) *Ucenye Zapiski* (Odessa Psychoneurological Institute), 1, 101
- Ginecinskij, A. G. & Lebedinskij, A. V. (1956) [*Course of normal physiology*], Moscow
- Gol'dfel'd, A. Ja. & Kazbekova, E. P. (1939) [*Collected works on the biological action of ultraviolet radiation*], Moscow, Medgiz
- Golovatjuk, I. (1963) *Vrač. Delo*, No. 11, 107
- Goromosov, M. S. (1951) *Gig. i Sanit.*, No. 8, 3
- Goromosov, M. S. (1954) [*The hygienic basis for the establishment of microclimatic standards for dwellings in various climatic zones*]. In: [*Experience of study of the regulation of physiological functions*], Moscow & Leningrad, vol. 3, p. 162

- Goromosov, M. S. (1957) *Gig. i. Sanit.*, No. 6, 20
- Goromosov, M. S. (1958) *Gig. i. Sanit.*, No. 7, 66
- Goromosov, M. S. (1963) [*The microclimate of dwellings and its hygienic standardization*], Moscow
- Goromosov, M. S. & Ciper, N. A. (1954) *Gig. i. Sanit.*, No. 7, 8
- Goromosov, M. S., Ciper, N. A. & Ugrjomora, E. K. (1952) *Gig. i. Sanit.*, No. 1, 10
- Gorsdorf, K. (1959) *Med. Mschr.*, **13**, 15
- Grigor'eva, M. N. (1963) [*Temperature and humidity conditions in an experimental house constructed of plastics*]. In: [*Transactions of the Final Republican Scientific Conference on Hygiene, Leningrad, June 11-14, 1963*].
- Hasama, B. I. (1937) *Pflügers Arch. ges. Physiol.*, **238**, 758
- Hecht, S., Schlaer, S. & Pirenn, M. (1942) *J. gen. Physiol.*, **25**, 819
- Helmke, R. (1935) *Zbl Bakt., I Abt. Orig.*, **163**, 38
- Hermanowicz, W. & Trywianski, Z. (1960) *Gaz Woda Tech. sanit.*, **34**, 317
- Hill, L. & Vernon, H. M. (1923) *The katathermometer in studies of body heat and efficiency*, London, H. M. Stationery Office (Medical Research Council, No. 73)
- Hlopin, G. V. (1921-1923) [*The rudiments of hygiene*], Moscow, 2 vols.
- Hlopin, G. V. (1930) [*Course of general hygiene*], Moscow & Leningrad
- Hocjanov, L. K. et al. (1949) *Gig. i. Sanit.*, No. 1, 22
- Hollwich, F. (1955) *Der Einfluss des Augenlichtes auf die Regulation des Stoffwechsels*. In: *Auge und Zwischenhirn*, Stuttgart, p. 95
- Houghten, F. G. & McDermot, P. (1933) *Heat. Pip. Air Condit.*, **5**, 53
- Houghten, F. G. & Yaglou, C. P. (1923) *J. Amer. Soc. heat. vent. Engrs*, **29**, 361
- Il'ina, A. A. (1945) *Fiziol. Ž. (Mosk.)*, **35**, No. 3, 338
- Jores, A. (1934) *Klin Wschr.*, **13**, 1269
- Jores, A. (1935) *Klin. Wschr.*, **14**, 1713
- Kalabuhov, N. I. (1946) *Ž. obšč. biol.*, **7**, No. 6, 417
- Kandrор, I. S. (1961) [*Maintenance of the energy balance of the body as the basis of the process of adaptation*]. In: [*Experimental investigation of the regulation of physiological functions*], Moscow, vol. 5, p. 73
- Kandrор, I. S., Rapoport, K. A. & Soltyskij, E. I. (1957) *Vo.-med. Ž.*, No. 1, 61
- Karagodina, I. L. (1959) *Gig. i. Sanit.*, No. 12, 7
- Karagodina, I. L. & Osipov, G. L. (1958) *Arhit. Stroit. (Mosk.)*, No. 6, 25
- Karagodina, I. L., Osipov, G. L. & Šiškin, I. A. (1964) [*Noise in towns and communal dwellings and its prevention*], Medicina
- Kaufmann, W., Thauer, R., & Zöllner, O. (1955) *Pflügers Arch. ges. Physiol.*, **261**, 189
- Kazbekova, E. P. (1941) *Arh. biol. Nauk.*, No. 12, p. 17
- Koeppen, S. (1955) *VDI Z.*, **97**, 1055
- Koerner, M. (1960) *Dtsch. Gesundh.-Wes.*, **15**, 1590
- Köhler, E. (1957) *Werkstoffe Korros., Mannheim*, **8**, 62
- Köhler, W. & Luckhardt, W. (1956) *Lichtarchitektur*, Berlin
- Kollmar, A. & Liese, W. (1955) *Gesundheitsingenieur*, **76**, 1
- Koškin, M. L. (1946) *Tr. Khar'kov. med. Inst.*, vol. 1, 393

- Koškin, M. L. (1962) [*Disinfection of the air in paediatric and therapeutic establishments by ultraviolet radiation*], Kiev
- Koškin, M. L. (1963) In: [*Problems of public and private hygiene*], Kiev, Gosmedizdat UkrSSR, 191
- Kravkov, S. V. (1946) [*An outline of the general psychophysiology of the sensory organs*], Moscow
- Kravkov, S. V. (1948) [*The interaction of the sensory organs*], Moscow
- Kravkov, S. V. (1950) [*The eye and its operation*], Moscow & Leningrad
- Kričagin, V. I. (1958) [*Standardization of ultraviolet radiation used for prophylactic purposes*]. In: [*Ultraviolet radiation*], Moscow, Medgiz, p. 238
- Krochman, T. (1961) *Lichttechnik, Berl.*, 7, 363
- Krotkov, F. G. (1962) [*A textbook of military hygiene*], Moscow
- Krylova, I. N. (1957) [*A study of the effect of noise on certain functions of the body*]. In: *Voprosy truda. Informacionnyj bjulleten' Mosk. naučno-issledovatel'skogo in-ta im. F. F. Erizmana*, No. 6-7, 50
- Kudrjavcev, S. I. (1960) [*Ultraviolet irradiation of the air of communal dwellings as a method of prophylaxis against aerial infection*]. In: [*Ultraviolet radiation*], Moscow
- Kulagina, V. & Kočerikova, A. (1961) [*On the thermal destruction of a methylphenyl-polysiloxane resin*]. In: [*Transactions of a Meeting on the Toxicology of High-Molecular-Weight Compounds...*], Leningrad
- Kuno, Ja. S. (1961) [*Perspiration in man*], Moscow
- Kurpluk, K. (1957) *Medizin und Stadtebau*, Munich
- Lampert, F. F. (1963) *Gig. i. Sanit.*, No. 4, 60
- Lampert, F. F. & Makeeva, M. G. (1962) [*Health problems in the construction of dwellings in the extreme north*]. In: [*Problems of the north*], No. 6, 77
- Lazarev, P. P. (1947) [*Studies of adaptation*], Moscow & Leningrad
- Lehmann, G. (1962) *Landarzt*, 38, 336
- Lehmann, G. & Tamm, J. (1956) *Int. Z. angew. Physiol.*, 16, 217
- Lekiš, M. (1934) [*Light and the work of the GTTI*], Moscow & Leningrad
- Letavet, A. A. & Malyševa, A. E. (1941) *Gig. i. Zdorov'e*, No. 4, 25
- Letavet, A. A., Malyševa, A. E. & Kljugin, S. A. (1948) *Gig. i. Sanit.*, No. 2, 37
- Leušin, P. I. (1951) *Gig. i. Sanit.*, No. 10, 10
- Leušin, P. I. (1958) [*The characteristics of noise from the point of view of health, and its prevention in the main streets of Leningrad*]. In: [*Noise prevention and the action of noise on the organism*], Leningrad, No. 11
- Levickij, V. A. (1933) *Central'nyj medicinskij ž.*, 12, No. 6, 797
- Lidwell, O. M. & Williams, E. O. (1960) *J. Hyg. (Lond.)*, 58, 449
- Liese, W. (1933) *Dtsch. med. Wschr.*, 59, 1172
- Liese, W. & Lutz (1955) [*Minimum health requirements in housing construction*], 2nd ed., Stuttgart, Forschungsgemeinschaft Bauen und Wohnen
- Livčak, I. F. (1956) *Vodosnab. sanit. Teh.*, No. 2
- Lotz, R. (1951) *Strahlentherapie*, 86, 149
- Luckiesh, M. & Moss, F. (1940) *Trans. illum. Engng Soc.*, 35, 1
- Malyševa, A. E. (1956) *Gig. i. Sanit.*, No. 2, 37

- Malyševa A. E. (1963) [*Health problems of radiative heat exchange between man and his environment*], Moscow, Medgiz
- Markelov, G. I. (1945) *Ž. Nevrol. Psihiat.*, 14, No. 3, p. 3
- Maršak, M. E. (1931) [*The meteorological factor in industrial hygiene*], Moscow
- Maršak, M. E. (1957) [*Physiological foundations of resistance of the human organism*], Moscow
- Maslennikov, D. S. (1962) [*Recommendations for meeting the insolation requirements in building. Studies of the physics of building and of the microclimates of built-up areas and of buildings*], No. 2, Gosstrojizdat
- Martynjuk, V. Z. (1957) [Chronic carbon-monoxide poisoning]. In: *Sborn. nauč. Rab. L'vov. gos. med. Inst., Ser. gig.*, 17
- Meister, F. & Ruhrberg, W. (1953) *VDI Z.*, 95, 373
- Meškov, V. V. (1947) [*Lighting installations*], Moscow & Leningrad, Energoizdat
- Meškov, V. V. & Brjulova, N. B. (1941) [*Consideration of the effect of brightness on the discernibility of objects*]. In: [*Problems of physiological optics*], Izd. AN SSSR, vol. 1
- Minh, A. A. (1958) [*The ionization of the air and its importance*], Moscow
- Missenard, F. A. (1955) *Etude physiologique et technique de la ventilation*, Paris
- Missenard, F. A. (1959) [*Radiant heating and cooling*], Paris
- Moles, A. (1955) *Nature (Paris)*, 83, 103
- Munro, A. F. & Chrenko, F. A. (1949) *J. Hyg. (Lond.)*, 47, 3
- Murav'eva, G. I. (1963) *Gig. i. Sanit.*, No. 11, 22
- Murovannaja, S. I. (1961) [*Everyday noise and its prevention*], Moscow
- Murray, H. (1952) *Colour in theory and practice*, London
- Nejšadt, Ja. E. (1952) [*New sources of light and their action on man*], Moscow
- Nicolas, H. & Meyer, W. (1961) *Kunststoffe*, 51, 2
- Nielsen, M. & Pedersen, L. (1952) *Acta physiol. scand.*, 27, 272
- Nieven, C. D. (1950) *J. Instn Heat. Vent. Engrs*, 18, 182
- Noble, R. A. (1958) *Kunststoffe*, 48, 21
- Orlova, T. A. (1958) [*Some neurodynamic effects of sound stimuli of various intensities*]. In: [*Noise prevention and the action of noise on the organism*], Leningrad, No. 11
- Osipov, G. L. (1958) *Gig. i. Sanit.*, No. 2, 21
- Oster, J. (1955) *Light scattering*. In: *Physical techniques in biological research*, New York, p. 51
- Palmai, G. (1962) *Med. J. Aust.*, 1, 9
- Parfenov, A. P. (1963) [*Sunlight deficiency in man*], Leningrad, Gos. izd. med. lit.
- Parkin, P. H. & Stacy, E. F. (1955) *Noise Control*, 1, 40
- Parrack, H. O. (1957) *Community reaction to noise*. In: Harris, C. M., ed., *Handbook of noise control*, New York, McGraw-Hill, ch. 36
- Paschke, M. (1958) *Dtsch. Gesundh.-Wes.*, 13, 779
- Pavlov, I. P. (1949) [*Collected works*], Moscow, vol. 3, p. 496
- Pavlov, I. P. (1951a) [*Complete collected works*], Moscow & Leningrad, vol. 1, p. 494
- Pavlov, I. P. (1951b) *Ibid.*, vol. 2, book 1, p. 128
- Pavlov, I. P. (1951c) *Ibid.*, vol. 4

- Pet'ko, L. I. (1961) [*Problems of industrial hygiene in work with epoxy resins*]. In: [*Transactions of a Combined Scientific Meeting on Problems of Industrial Hygiene and the Prevention of Occupational Diseases and Accidents*], Gor'kij
- Pirilă, V. (1958) *Igiena (Buc.)*, 7, 199
- Plummer, I. K., Ionides, M. & Siple, P. A. (1945) *Report of the climatological and environmental protection section, Office of the Quartermaster General [U. S. Army]*, Washington, D. C.
- Pomorcev, V. P. (1934) [*Building hygiene and sanitation*], Moscow
- Ponomareva, N. K. (1954) [*Fundamental hygienic parameters of radiant heating systems*]. In: [*Abstracts of reports of the All- Union Conference at the Institute of General and Communal Hygiene, AMN SSSR*], Moscow
- Ponugava, A. G. (1949) [*Features of thermal regulation in radiant heat losses*]. In: [*Experimental study of the regulation of physiological functions*], Moscow & Leningrad, p. 57
- Postnikov, B. N. (1957) [*Thermal burns*], Moscow, Medgiz
- Rabkin, E. B. (1964) [*Rational colour finishing*], Moscow
- Ramkova, N. V. (1961) *Tr. nauchno-issled. Inst. Dezinfekc.*, No. 14, 99
- Razenzov, I. P. (1939) *Ž. Fizioterapija*, No. 3, 3
- Rečmenskij, S. S. (1961) [*The problem of aerial infections*], Moscow
- Rjazanov, V. A. (1961) [*Atmospheric hygiene*]. In: [*An introduction to communal hygiene*], Moscow, vol. 1
- Robinson, S., Turrell, E. S., & Gerking, S. D. (1945) *Amer. J. Physiol.*, **143**, 21
- Rubleva, M. N. (1956) *Vodosnab. i sanit. Teh.*, No. 1, 22
- Rubner, M. (1907) *Lehrbuch der Hygiene*, Wien
- Rudat, K. D. Z. (1958) *Z. ges. Hyg.*, **4**, 272
- Rudnick, I. (1957) *Propagation of sound in the open air*. In: Harris, C. M., ed., *Hand-book of noise control*, New York, McGraw-Hill, ch. 3
- Rylova, M. L. (1953) *Gig. i Sanit.*, No. 10, 27
- Rylova, M. L. (1955) *Gig. i Sanit.*, No. 5, 21
- Šafir, A. I. (1963) [*The hygiene of planning, arrangement, and contents of dwellings*]. In: [*A guide to communal hygiene*], Moscow, vol. 3
- Šafir, A. I., Panšinskaja, N. M. & Solomonova, E. I. (1957) *Gig. i. Sanit.*, No. 1, 18
- Šahbazjan, G. H. (1940) *Gig. i. Sanit.*, No. 10, 4
- Šahbazjan, G. H. (1951) [*The health significance and associations with comfort of convective and radiative effects of heat and cold on the body*] In: [*Proceedings of a scientific meeting of the Institute for Industrial Hygiene*], Moscow
- Šajkevič, A. C. (1962) [*The quality and further improvement of industrial lighting*], Moscow & Leningrad, Gosenergoizdat
- Samsonova, V. G. (1939a) *Fiziol. Z. SSSR*, No. 26, 142
- Samsonova, V. G. (1939b) *Fiziol. Z. SSSR*, No. 26, 173
- Šapšev, K. N. (1939) [*A study of the propagation of noises in apartments of various types*], Leningrad
- Ščerbakova, O. P. (1937) *Bjull. ěxsp. Biol. Med.*, No. 4, 335
- Schröder, K. (1957) *Dtsch. Gesundh.-Wes.*, **42**, 1309
- Seftel', V. O. (1963) *Gig. i Sanit.*, No. 5, 83

- Šeftel', V. O. (1964) In: [*Transactions of the 2nd Conference on the Toxicology and Hygiene of High-Molecular-Weight Compounds... Leningrad, 1964*]
- Selejnovskij, G. V. (1948) [*The microclimate of southern towns*], Moscow
- Semenovskaja, E. N. (1931) *Russ. oftal. Ž.*, No. 4, 6
- Sergeev, E. P., Bobrov, N. I. & Žerdev, G. M. (1963) *Vo.-med. Ž.*, No. 11, 56
- Sljusar', M. P. (1963) [*Problems of general and individual hygiene*], Kiev, p. 119
- Slonim, A. D. (1952) [*Animal heat and its regulation in the organism of mammals*], Moscow & Leningrad
- Slonim, A. D. (1961) [*Fundamentals of the general ecological physiology of mammals*], Moscow & Leningrad
- Smith, E. L. & Laird, D. A. J. (1930) *J. acoust. Soc. Amer.*, **2**, 94
- Smorodincev, O. A. (1943) *Ž. Mikrobiol. (Mosk.)*, No. 10, 17
- Stankevič, K. I. (1961) *Gig. i Sanit.*, No. 6, 21; No. 12, 81
- Stankevič, V. V. & Ivanova, Z. V. (1961) [*The toxicology of substances formed by the heating of phenolic and amino resins*]. In: [*Transactions of a Meeting on the Toxicology of High-Molecular-Weight Compounds...*], Leningrad, p. 36
- Starošćuk, H. V. (1957) [*Street noise in towns*], *Vrac. Delo* [supplement]
- Steinmann, B., Jaggi, U. & Widmer, J. (1955) *Cardiologia (Basel)*, **27**, 223
- Stevens, K. N., Rosenblith, W. A. & Bolt, R. H. (1955) *Noise Control*, **1**, 63
- Šul'ga, T. M. (1961) *Gig. i. Sanit.*, No. 3, 3
- Tiedeman, W. D. J. A. (1954) *Water Work Ass.*, **46**, 775
- Tihomirov, K. V. (1951) *Gig. i Sanit.*, No. 5, 9
- Tilgiani, G. (1956) *Rass. Med. industr.*, **3**, 158
- Tomatis, A. (1959) *Méd. aéro.*, **14**, 163, 289
- Troickaja, M. N. (1958) *Gig. i Sanit.*, No. 2, 15
- Turner, D. (1955) *J. Hyg. (Lond.)*, **53**, 33
- Turžeckij, K. I. & Olen'eva, E. I. (1957) *Gig. i Sanit.*, No. 3, 45
- Vajnštejn, M. R., Leušin, P. I. & Safir, A. I. (1960) *Gig. i. Sanit.*, No. 3, 23
- Van Zwillen, D. (1940) *Gesundheitsingenieur*, **63**, 353
- Vasil'ev, B. F. (1957) [*Natural studies of temperature and humidity conditions in dwellings*], Moscow
- Vavilov, S. I. (1936) [*Fluctuations of light and their measurement*]. In: [*Proceedings of the First Conference on Physiological Optics*], Moscow & Leningrad, 332
- Vavilov, S. I. (1949) [*"Warm" and "cold" light*], Moscow, Izd. AN SSSR
- Velikson, I. M. & Cernilovskaja, F. M. (1960) *Fiziol. Ž. (Mosk.)*, No. 7, 795
- Vernon, H. M. (1932) *J. industr. Hyg.*, **14**, 95
- Vetoškin, S. I. (1955) [*Sanitary protection of dwellings*], Moscow
- Vetoškin, S. I. et al. (1954) [*The hygienic basis for the planning and construction of dwellings in hot and dry climatic conditions in Central Asia*]. In: [*Aspects of municipal hygiene in... Central Asia*], Moscow, Medgiz, p. 53
- Vitte, N. K. (1956) [*Heat exchange in man and its health significance*], Kiev
- Vojtkevič, A. A. (1944) *Dokl. Akad. Nauk SSSR*, **45**, No. 6, 377
- Voločkij, N. V. (1961) [*Light engineering*], Moscow
- Webb, C. G. (1959) *Brit. J. industr. Med.*, **16**, 297



- Wells, W. P. & Wells, M. W. (1943) *Am. J. med. Sci.*, **206**, 11
- WHO Expert Committee on Public Health Administration (1963) Fifth report (*Wld Hlth Org. techn. Rep. Ser.*, **250**)
- WHO Expert Committee on the Public Health Aspects of Housing (1961) First report (*Wld Hlth Org. techn. Rep. Ser.*, **225**)
- Wilson, R. H. & McCormick, N. S. (1955) *Industr. Med. Surg.*, **24**, 491
- Winslow, C. E. A. & Herrington, L. P. (1949) *Temperature and human life*, Princeton, N. J., Princeton University Press, vol. 3, 62
- Winslow, C. E. A., Herrington, L. P. & Gaage, A. P. (1938) *Amer. J. Physiol.*, **124**, 30
- Wittgens, H. (1962) *Int. J. prophyl. Med.*, **6**, No. 2, 35
- Wright, B. (1963) *Plastics (Lond.)*, **28**, 125, 130
- Yaglou, C. P. (1938) *Heat. Ventn*, **35**, 34
- Yaglou, C. P. (1949) *Indices of comfort*. In: *Physiology of heat regulation and the science of clothing*, ed. by L. M. Newburgh, London, p. 277
- Yaglou, C. P. & Masser, A. (1941) *J. Amer. med. Ass.*, **117**, 1261
- Zajdšnur, I. A. (1960) [*Physical factors of the environment*], Moscow
- Zil'ber, D. A. (1963) [*Industrial illumination*]. In: [*Guide to industrial hygiene*], Moscow, Medgiz, p. 425

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