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Ventilation for buildings — Design criteria for the indoor environment

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National foreword

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Ventilation for buildings - Design criteria for the indoor environment

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Contents

Foreword

This Technical Report has been prepared by Technical Committee CEN/TC 156, Ventilation for buildings. It received approval from the CEN Technical Board on 199X.

Annexes A to H are all informative. Annexes A to G cover the details of development and determination of design criteria, practical examples, data, WHO guidelines, ventilation effectiveness, guidelines for low-polluting buildings. Annex H is a bibliography.

Introduction

This Technical Report is intended to assist in providing an acceptable indoor environment for people in ventilated buildings. The indoor environment comprises the thermal environment, the air quality and the acoustic environment. Good ventilation provides a comfortable indoor environment with a low health risk for the occupants and uses a small amount of energy. Reducing the indoor sources of pollution and preferably adapting the ventilation rate to the actual demand are more important than increasing the outside airflow rate.

The quality of the indoor environment may be expressed as the extent to which human requirements are met. Requirements vary, however, for different individuals. Some people are rather sensitive to an environmental parameter and are difficult to satisfy, whereas others are less sensitive and are easier to satisfy. To cope with these individual differences the environmental quality can be expressed by the percentage of persons who find an environmental parameter unacceptable (= % dissatisfied). If there are few dissatisfied, the quality of the environment is high. If there are many dissatisfied, the quality is low. Prediction of the percentage of dissatisfied is used to establish requirements for the thermal environment and for ventilation. A predicted value may not be equal to the actual percentage of dissatisfied in practice, where other factors such as stress can have an influence. This Technical Report is intended to specify the requirements whilst also indicating methods currently in use and those under development.

Although aspects of the indoor environment (thermal, air quality and acoustic) are dealt with separately, the indoor environment is considered as a whole. Conflict can arise between the different environmental requirements and designers may therefore be required to find a compromise.

A ventilation or air-conditioning system is usually designed to operate under certain assumptions concerning the application of the building, internal loads, meteorological conditions etc. The desired indoor environment will therefore only be provided when these assumptions are valid.

> NOTE A rationale which specifies how the quality of the indoor environment can be expressed is provided in annex A. Annex B gives a step-by-step method for determining the criteria. The application of annex A is illustrated in annex C by a number of practical examples. The examples cover spaces in different types of buildings under conditions frequently occurring in practice.

1 Scope

This Technical Report specifies the requirements for, and methods of expressing the quality of the indoor environment for the design, commissioning, operation and control of ventilation and air-conditioning systems.

This Technical Report covers indoor environments where the major concern is the human occupation but excludes dwellings. This Technical Report does not cover buildings where industrial processes or similar operations requiring special conditions are undertaken.

The practical procedures, including selection of parameters to be measured during commissioning, control and operation, are not covered.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Technical Report. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

EN ISO 7730, *Moderate thermal environments — Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.*
ISO 9920, *Ergonomics of the thermal environment — Estimation of the thermal insulation and evaporative resistance of a clothing ensemble.*
ISO 8996, *Ergonomics — Determination of metabolic heat production.*
EN ISO 11201, *Acoustics — Noise emitted by machinery and equipment. Guideline for the preparation of test code of engineering grade requiring noise measurements at the operator's or bystander's position.*
EN ISO 3744, *Acoustics — Determinators of sound power levels of noise sources — Engineering methods for free field conditions over a reflecting plane.*

3 Definitions

For the purposes of this Technical Report, the following definitions apply:

3.1
draught
unwanted local cooling of the body caused by air movement and temperature

3.2
draught rating (*DR*)
percentage of people predicted to be dissatisfied due to draught

3.3
external work
energy spent in overcoming external mechanical forces on the body; also expressed as a fraction of metabolic energy production, where the fraction value defines the mechanical efficiency.

NOTE For most activities external work may be disregarded.

3.4
humidity, absolute
absolute amount of water vapour in the ambient air expressed in g/kg or m³ dry air. It can also be expressed by the partial water vapour pressure (p_v) in Pa or by the dewpoint (t_d) in °C

3.5

humidity, relative

mass of water vapour in the air by volume divided by mass of water vapour by volume at saturation at the same temperature

3.6

insulation, clothing (i_{cl})

resistance to sensible heat transfer provided by a clothing ensemble (i.e. more than one garment)

NOTE It is described as the intrinsic insulation from the skin to the clothing surface, not including the resistance provided by the air layer around the clothed body and is expressed in the clo unit or in $m^2 \times K/W$; 1 clo = 0,155 $m^2 \times K/W$.

3.7

insulation, garment (i_{clu})

increased resistance to sensible heat transfer obtained from adding an individual garment over the nude body; the effective increase in overall insulation attributable to the garment and expressed in the clo unit or in $m^2 \times K/W$

3.8

metabolic rate (M)

rate of energy production of the body

NOTE The metabolic rate varies with the activity. It is expressed in the met unit or in W/m^2; 1 met = 58,2 W/m^2. One met is the energy produced per unit surface area of a sedentary person at rest. The surface area of an average person is about 1,8 m^2.

3.9

perceived air quality in decipol (c_c)

perceived air quality in a space with a sensory pollution load of 1 olf ventilated by 10 l/s of clean air

3.10

predicted mean vote (PMV)

index that predicts the mean value of the thermal sensation votes of a large group of persons on a 7-point scale

3.11

predicted percentage of dissatisfied (PPD)

index that predicts the percentage of a large group of people likely to feel thermally dissatisfied for the body as a whole, i.e. either too warm or too cool

3.12

sensory pollution load in olf

1 olf is the sensory load on the air from an average sedentary adult in thermal neutrality

3.13

sound pressure level in decibel

ten times the logarithm to the base 10 of the ratio of the square of the sound pressure to the square of the reference sound pressure

NOTE The weighting network used is indicated: for example, A-weighted sound pressure level, dB(A). The reference sound pressure is 20 μPa.

3.14

sound power level in decibel

ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power

NOTE The weighting network used is indicated: for example, A-weighted sound power level. The reference sound power is 1 pW (= 10^{-12} W).

3.15

temperature, mean radiant ($\overline{t_r}$)

uniform surface temperature of an enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform enclosure

3.16
temperature, operative (t_o)
uniform temperature of an enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment

3.17
temperature, optimum operative
operative temperature that satisfies the greatest possible number of people at a given clothing and activity level

3.18
temperature, plane radiant (t_{pr})
uniform temperature of an enclosure where the radiance on one side of a small plane element is the same as in the non-uniform actual environment

3.19
temperature asymmetry, radiant (Δt_{pr})
difference between the plane radiant temperature of the two opposite sides of a small plane element

3.20
temperature difference, vertical air
air temperature difference between head and ankles of a person

NOTE For a sedentary person this is 1,1 and 0,1 m above the floor

3.21
thermal comfort
that condition of mind which expresses satisfaction with the thermal environment

3.22
thermal environment
characteristics of the environment which affect the heat exchange between the human body and the environment

3.23
thermal sensation
conscious feeling commonly graded into the categories, cold, cool, slightly cool, neutral, slightly warm, warm and hot

3.24
turbulence intensity (Tu)
ratio of the standard deviation of the air velocity to the mean air velocity

3.25
velocity, relative air (v_{ar})
air velocity relative to the occupant, including body movements

3.26
ventilation effectiveness (ε_v)
measure of the relationship between the pollutant concentration in the exhaust air and the pollutant concentration in the breathing zone

NOTE Another term frequently used for the same concept is "contaminant removal effectiveness".

3.27
zone, occupied
that part of a space designed for human occupancy and where the design criteria are required to be met

4 Categories of indoor environment

This Technical Report specifies categories of environmental quality which shall be selected for a space to be ventilated. Category A corresponds to a high level of expectation, category B to a medium level of expectation and category C to a moderate level of expectation.

NOTE Designers may also select different levels using annex A. A different category may be selected for the thermal environment, the indoor air quality and the acoustic environment for a space or building. A different category may be selected for summer and winter.

5 Design assumptions

A ventilation or air-conditioning system shall be designed to provide the required indoor environment under specified conditions. The designer shall specify the conditions and any assumptions made including the indoor environmental requirements the system is designed to achieve.

Information on the following assumptions is required:

- application and flexibility of the space, including a specification of the occupied zone;
- number of occupants present (per m² floor) and their estimated activity and clothing behaviour;
- pollution load caused by materials used in the building including carpets and furnishing;
- percentage of smokers, if smoking is permitted;
- available outdoor air quality;
- outdoor noise level.

Consideration shall be given to the following:

- maximum and minimum outdoor weather conditions, e.g. corresponding to a certain percentage of a normal year;
- area of glass and the transmission of glass;
- the possibility of opening the windows;
- application of solar shading devices;
- cooling/heating load caused by occupants, machines, illumination, solar radiation, etc;
- physical properties of the materials used in the building;
- room reverberation time;
- proper commissioning and maintenance of the ventilation or air-conditioning system;
- proper cleaning of the spaces;
- proper use of the ventilation or air-conditioning system.

The design assumptions shall be listed in the operational guide for the ventilation or air-conditioning system and it shall be stated that the indoor environment for which the system is designed can only be achieved if these conditions are met. Owners and users of the building shall be warned that changes in the application of spaces, or in thermal load or pollution load, can result in the system being unable to meet the indoor environmental requirements for which it was designed.

6 Design criteria

The design criteria specified in Table 1 are derived under certain assumptions and include the minimum requirements for the design of a ventilation or air-conditioning system for the appropriate application.

For the thermal environment the criteria for the operative temperature are based on typical levels of activity given in Table 1 for a clothing of 0.5 clo during summer (cooling season) and 1.0 clo during winter (heating season). The criteria for the mean air velocity apply for a turbulence intensity of approximately 40 % (mixing ventilation). The design criteria for the required ventilation rate comprises a minimum ventilation rate to handle the pollution caused by the occupants only, plus an additional ventilation rate to handle the pollution caused by the building (including building materials, furnishings and HVAC equipment). Table 1 applies for low-polluting buildings. Annex G provides guidelines for such buildings. Ventilation rates for different types of building, including those that are not low-polluting are given in annex C (Table C.1). If smoking is permitted, additional ventilation is required. The last column of Table 1 specifies the additional ventilation required for comfort if 20 % of the occupants are smokers. The health risk of passive smoking should be considered separately. The ventilation rates in Table 1 are based on the assumption that the ventilation effectiveness is one and that outdoor air of excellent quality is available. The design criteria in Table 1 are only valid for the occupancy conditions described in the table. For occupancy densities other than those listed in Table 1, the required ventilation can be modified using information in Table 2. In practice, partial load conditions can often prevail during the normal hours of occupancy, and in such cases the ventilation should be matched to the actual demand.

NOTE Table 1 may also be used for other types of spaces with similar use as the spaces given in the table.

The designer may also decide to assume that the occupants are the only pollution source in a space, i.e. that the building does not pollute at all, in which case the required ventilation rate shall be determined per occupant from Table 2. Table 2 also takes into account the level of tobacco smoking, if any, occurring in a space. Knowing the occupancy density, expressed in persons/(m^2 floor), the ventilation rate can then be expressed in l/s (m^2 floor).

NOTE Buildings may not satisfy the conditions specified in Tables 1 and 2, in which case the design criteria may be determined from annex A.

Table 1 — Design criteria for spaces in different types of buildings[a)]

Type of building/ space	Activity met	Occupancy person/ m²	Category	Operative temperature[b)] °C Summer (cooling season)	Winter (heating season)	Maximum mean air velocity m/s Summer (cooling season)	Winter (heating season)	Sound pressure dB (A)	Ventilation rate l/s x m²	Additional ventilation when smoking is allowed[c),d)] l/s x m²
Single office (cellular office)	1,2	0,1	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	30	2,0	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	1,4	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	0,8	—
Landscaped office	1,2	0,07	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	35	1,7	0,7
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	40	1,2	0,5
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	45	0,7	0,3
Conference room	1,2	0,5	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	30	6,0	5,0
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	4,2	3,6
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	2,4	2,0
Auditorium	1,2	1,5	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	30	16[(e)]	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	33	11,2	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	35	6,4	—
Cafeteria or restaurant	1,2	0,7	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	35	8,0	—
			B	24,5 ± 2,0	22,0 ± 2,5	0,22	0,18	45	5,6	5,0
			C	24,5 ± 2,5	22,0 ± 3,5	0,25	0,21	50	3,2	2,8
Classroom	1,2	0,5	A	24,5 ± 0,5	22,0 ± 1,0	0,18	0,15	30	6,0	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	4,2	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	2,4	—
Kindergarten	1,4	0,5	A	23,5 ± 1,0	20,0 ± 1,0	0,16	0,13	30	7,1	—
			B	23,5 ± 2,0	20,0 ± 2,5	0,20	0,16	40	4,9	—
			C	23,5 ± 2,5	20,0 ± 3,5	0,24	0,19	45	2,8	—
Department store	1,6	0,15	A	23,0 ± 1,0	19,0 ± 1,5	0,16	0,13	40	4,2	—
			B	23,0 ± 2,0	19,0 ± 3,0	0,20	0,15	45	3,0	—
			C	23,0 ± 3,0	19,0 ± 4,0	0,23	0,18	50	1,6	—

NOTES

a) This table applies for the occupancy listed in the table and for a ventilation effectiveness of one.

b) For many types of buildings and spaces with moderate heating or cooling loads the air temperature will be approximately equal to the operative temperature. For design, the upper end of the temperature range can be used during summer and the lower end during winter.

c) Additional ventilation required for comfort when 20 % of the occupants are smokers. The health risk of passive smoking shall be considered separately.

d) Where no value is listed, data from Table 2 may be used.

e) It may be difficult to meet the Category A draught criteria.

Table 2 — Required ventilation rate per occupant[a), b)]

Category	Required ventilation rate l/s × occupant			
	No smoking	20 % smokers	40 % smokers[c)]	100 % smokers[c)]
A	10	20	30	30
B	7	14	21	21
C	4	8	12	12

NOTES

a) This table applies if it is assumed that the occupants are the only source of pollution.

b) The table applies to a non-smoking environment and for different levels of tobacco smoking.

c) For 40–100 % smokers, the required ventilation is equal to the value for 40 % smokers, since smokers are more tolerant towards environmental tobacco smoke than non-smokers.

Annex A (informative)

Development of design criteria

A.1 General

This annex specifies how the quality of the indoor environment can be expressed; **A.2** deals with the quality of the thermal environment ; **A.3** with the quality of the indoor air; and **A.4** with the requirements for the acoustic environment. A step-by-step method for determination of design criteria is given in annex B.

A.2 Thermal environment

A.2.1 *Criteria*

The design criteria for the thermal environment are based on EN ISO 7730. The human response to the thermal environment is expressed by the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) indices which predict the percentage of the occupants feeling too warm or too cool for the body as a whole. The human response is also expressed by the percentages of occupants predicted to feel dissatisfied due to different types of local thermal discomfort. Such discomfort may be caused by draught, by an abnormally high vertical temperature difference, by too warm or too cool a floor or by too high a radiant temperature asymmetry.

A.2.2 *Thermal indices*

The PMV is an index that predicts the mean value of the thermal sensation votes of a large group of persons on the following 7-point scale:

+3	hot
+2	warm
+1	slightly warm
0	neutral
-1	slightly cool
-2	cool
-3	cold

The PMV depends on the following six parameters:

- the occupants' physical activity (metabolic rate);
- the thermal resistance of their clothing;
- air temperature;
- mean radiant temperature;
- air velocity;
- partial water vapour pressure.

The last four are the environmental parameters.
Tables and mathematical relations between these six parameters and PMV are given in EN ISO 7730. An estimate is required of the occupants' metabolic rate and of the thermal insulation of their clothing. Such data for typical applications are given in annex D.

The PPD index predicts the percentage of a large group of people likely to feel thermally dissatisfied, i.e. feel too warm or too cool. The PPD depends on PMV as shown in Figure A.1.

The PPD is one measure of the quality of the thermal environment. A certain quality (defined by a permissible PPD value) may be selected for a space; the corresponding PMV range can be found from Figure A.1. The corresponding permissible range of operative temperatures in the space can then be found from PMV tables or a computer program, e.g. in EN ISO 7730.

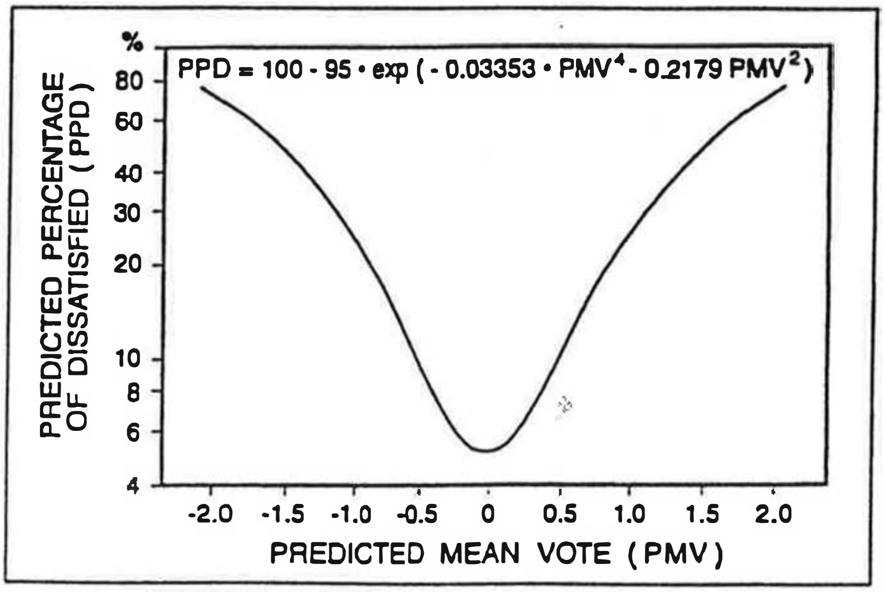


Figure A.1 — Predicted percentage of dissatisfied (PPD) as a function of predicted mean vote (PMV)

A.2.3 *Local thermal discomfort*

The PMV and PPD indices express warm and cold discomfort for the body as a whole. But thermal dissatisfaction may also be caused by unwanted cooling (or heating) of one particular part of the body (local discomfort). The most common cause of local discomfort is draught. But local discomfort may also be caused by an abnormally high vertical temperature difference between head and ankles, by too warm or too cool a floor or by too high a radiant temperature asymmetry.

People engaged in light sedentary activity are most sensitive to local discomfort. **A.2.4.3** to **A.2.4.6** apply to this group of people with a thermal sensation for the whole body close to neutral. When engaged in more vigorous activities, people are less thermally sensitive and consequently the risk of local discomfort is lower.

A.2.4 Categories of thermal environment

A.2.4.1 *General*

The desired thermal environment for a space may be selected among the three categories, A, B and C, listed in Table A.1. All the criteria should be satisfied simultaneously for each category.

Table A.1 — Three categories of thermal environment

Category	Thermal state of the body as a whole		Local discomfort			
	Predicted percentage of dissatisfied PPD %	Predicted mean vote PMV	Percentage of dissatisfied due to draught *DR* %	Percentage of dissatisfied due to air temperature difference %	Percentage of dissatisfied due to warm or cool floor %	Percentage of dissatisfied due to radiant asymmetry %
A	<6	-0.2<PMV<+0.2	<15	<3	<10	<5
B	<10	-0.5<PMV<+0.5	<20	<5	<10	<5
C	<15	-0.7<PMV<+0.7	<25	<10	<15	<10

Each category prescribes a maximum percentage of dissatisfied for the body as a whole (PPD) and for each of the four types of local discomfort. Some requirements are hard to meet in practice, while others are quite easily met. The different percentages shown represent the balance between as few dissatisfied as possible and what is practically obtainable using existing technology.

The three categories in Table A.1 apply to spaces where people are exposed to the same thermal environment. It is an advantage if some kind of individual control of the thermal environment can be established for each person in a space. Individual control of the local air temperature, mean radiant temperature or air velocity may contribute to balance the rather large differences between individual requirements and therefore provide fewer dissatisfied.

Modification of the clothing may also contribute to balance individual differences. The effect of adding (or removing) different garments on the optimum operative temperature is listed in annex D, Table D.3.

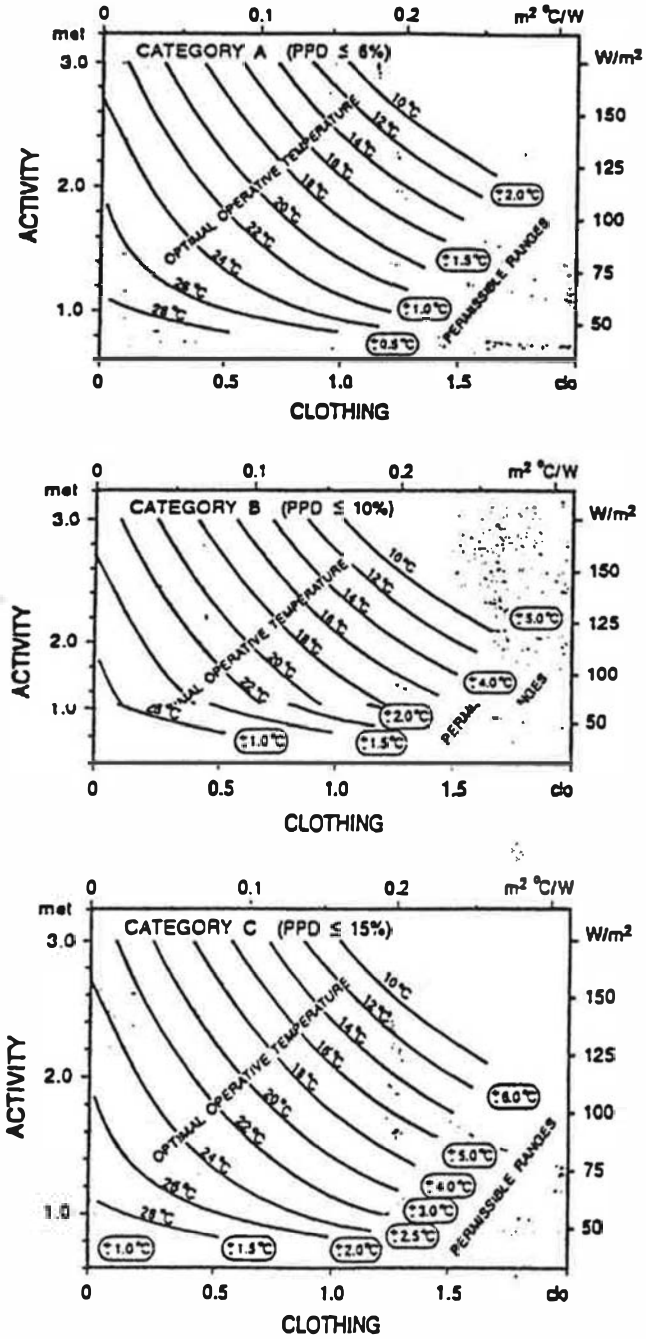
A.2.4.2 *Operative temperature range*

For a given space there exists an optimum operative temperature corresponding to PMV = 0, depending on the activity and the clothing of the occupants. Figure A.2 shows the optimum operative temperature and the permissible temperature range as a function of clothing and activity for each of the three categories. The optimum operative temperature is the same for the three categories, while the permissible range around the optimum operative temperature varies.

The operative temperature at all locations within the occupied zone of a space should at all times be within the permissible range. This means that the permissible range should cover both spatial and temporary variations, including fluctuations caused by the control system.

Figure A.2 applies for a relative humidity of 50 %; however, in moderate environments the air humidity has only a modest impact on the thermal sensation. Typically a 10 % higher relative humidity is felt as being as warm as a 0,3 °C higher operative temperature. Non-thermal aspects of air humidity in relation to indoor air quality are discussed in **A.3.8**.

NOTE The most common applications are for offices and similar spaces with occupants involved in light, mainly sedentary activity. For such applications the metabolic rate is around 1,2 met and the typical thermal resistance of clothing insulation is around 1 clo during winter (heating season) and 0,5 clo during summer (cooling season). Figure A.2 should be referred to when designing the ventilation/air-conditioning system. During operation of the system, however, the temperature ranges in Figure A.2 should only be used as a guide. People occupying a particular space at a particular time may happen to prefer a lower or a higher temperature level than shown in Figure A.2. A temperature level should of course be selected to minimize the discomfort among the actual users. Hot weather will usually make people select light clothing and therefore high indoor temperatures as shown in Figure A.2. Long periods of hot weather may even cause some people to adapt and accept a higher upward deviation from the optimal temperature than that given in Figure A.2.



NOTE 1 The air velocity in the space is assumed to be < 0,1 m/s. The relative air velocity, v_{ar}, caused by body movement is estimated to be zero for a metabolic rate, *M*, less than 1 met and $v_{ar} = 0{,}3\ (M-1)$ for $M > 1$ met. The diagrams are determined for a relative humidity of 50 %, but the humidity only has a slight influence on the optimum and permissible temperature ranges.

NOTE 2 The three diagrams show also the permissible range around the optimum temperature for the three categories.

Figure A.2 — The optimum operative temperature as a function of clothing and activity for the three categories of the thermal environment

A.2.4.3 *Draught*

Draught is an unwanted local cooling of the body caused by air movement and temperature. It is the most common cause for complaint in many ventilated spaces. A draught rating may be expressed as the percentage of people predicted to be bothered by draught. The draught rating is calculated by the following equation (model of draught):

$$DR = (34 - t_a)(v - 0{,}05)^{0{,}62}(0{,}37 \bullet v \bullet Tu + 3{,}14) \quad \text{(A.1)}$$

where:

DR is the draught rating, i.e. the percentage of people dissatisfied due to draught, in per cent (%);
t_a is the local air temperature ($19 < t_a < 27$ °C), in degrees Celsius (°C);
v is the local mean air velocity, in metres per second (m/s);
Tu is the local turbulence intensity, in per cent (%).

This model of draught applies to people with a thermal sensation for the whole body close to neutral. The risk of draught is lower for people feeling warmer than neutral and higher for people feeling cooler than neutral for the whole body. For people feeling warm in their body as a whole, an increased air movement will decrease the warm discomfort (as calculated by the PMV index) and will therefore normally be felt to be beneficial.

The permissible mean air velocity is given in Figure A.3 for the three categories. The mean air velocity is a function of local air temperature and turbulence intensity. The turbulence intensity may vary between 30 % and 60 % in spaces with mixing flow air distribution. In spaces with displacement ventilation or without mechanical ventilation, the turbulence intensity may be lower.

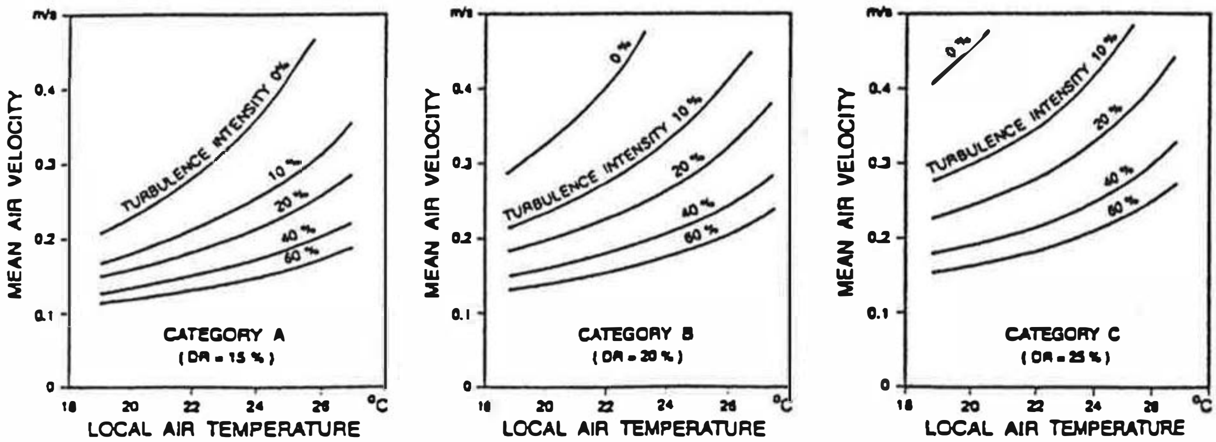


Figure A.3 — Permissible mean air velocity as a function of local air temperature and turbulence intensity for the three categories of the thermal environment

A.2.4.4 *Vertical air temperature difference*

A high vertical air temperature difference between head and ankles may cause discomfort. In Figure A.4 the percentage of dissatisfied is shown as a function of the vertical air temperature difference between head and ankles (1,1 and 0,1 m above the floor). The figure applies when the temperature increases upwards.

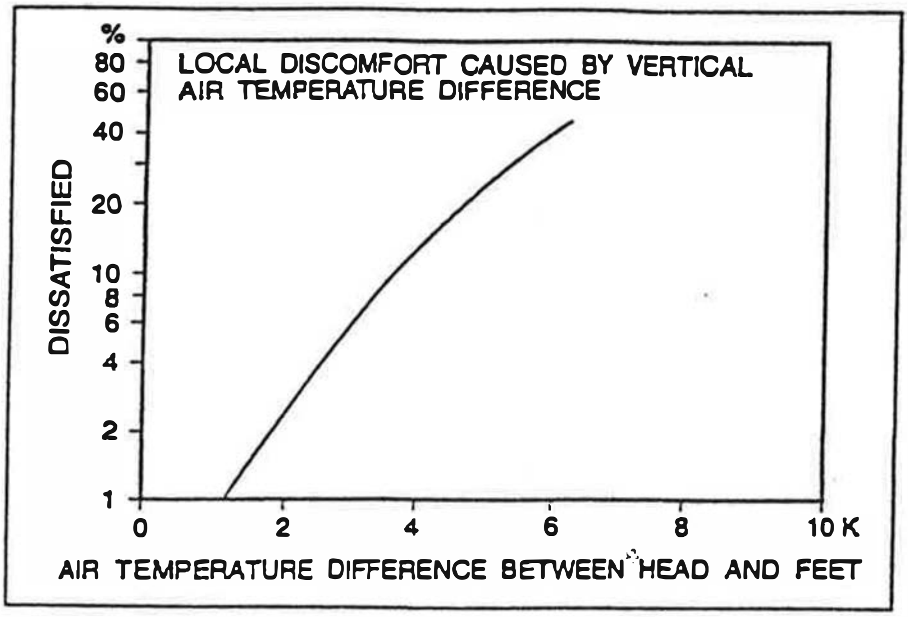


Figure A.4 — Local discomfort caused by vertical air temperature difference

NOTE This applies when the temperature increases upwards.

The permissible vertical temperature difference is given in Table A.2 for the three categories.

Table A.2 — Permissible vertical air temperature difference between head and ankles (1,1 and 0,1 m above the floor) for the three categories of the thermal environment

Category	Air temperature difference °C
A	<2
B	<3
C	<4

A.2.4.5 *Warm and cool floors*

If the floor is too warm or too cool, the occupants may feel uncomfortable due to warm or cool feet. For people wearing light indoor shoes, it is the temperature of the floor rather than the material of the floor covering which is important for the comfort. In Figure A.5 the percentage of dissatisfied is shown as a function of the floor temperature. Cool floors may occur in spaces where displacement ventilation systems are used, while warm floors are rarely a problem in air-conditioned spaces. It is recommended that floor temperatures higher than 26 °C should be avoided on most occasions.

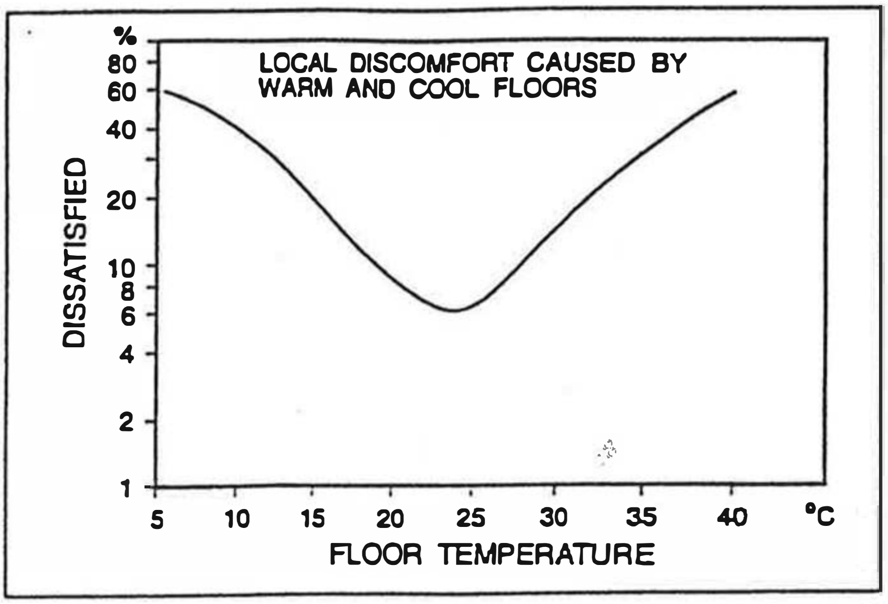


Figure A.5 — Local discomfort caused by warm and cool floors

The permissible range of the floor temperature is given in Table A.3 for the three categories.

Table A.3 — Permissible range of the floor temperature for the three categories of the thermal environment

Category	Range of surface temperature of the floor °C
A	19 – 29
B	19 – 29
C	17 – 31

A.2.4.6 *Radiant asymmetry*

Radiant asymmetry may also cause discomfort. People are most sensitive to radiant asymmetry caused by warm ceilings or cool walls (windows). In Figure A.6 the percentage of dissatisfied is shown as a function of the radiant temperature asymmetry caused by a warm ceiling, a cool wall, a cool ceiling or by a warm wall. Radiant asymmetry is rarely a problem in ventilated/air-conditioned spaces, except at high illumination levels and at large window areas. Direct solar radiation should be avoided in the occupied zone, by means of building design or solar shading devices.

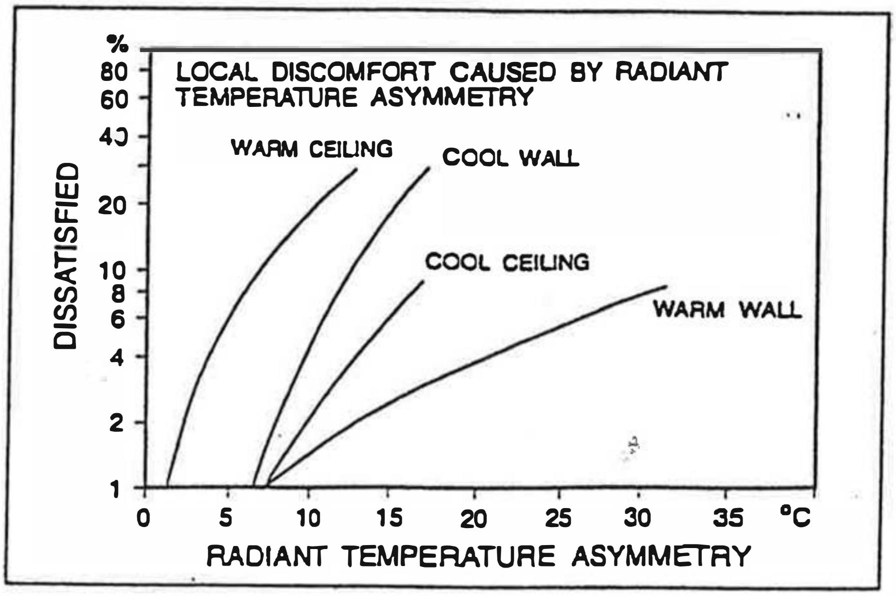


Figure A.6 — Local discomfort caused by radiant temperature asymmetry

The permissible radiant temperature asymmetry is given in Table A.4 for the three categories.

Table A.4 — Permissible radiant temperature asymmetry for the three categories of the thermal environment

Category	Radiant temperature asymmetry °C			
	Warm ceiling	Cool wall	Cool ceiling	Warm wall
A	< 5	< 10	< 14	< 23
B	< 5	< 10	< 14	< 23
C	< 7	< 13	< 18	< 35

A.3 Indoor air quality

A.3.1 *General*

The requirements of the occupants for the air quality in a space are first that the health risk of breathing the air should be negligible and second that the air should be perceived to be fresh and pleasant rather than stale, stuffy and irritating.

Indoor air quality may be controlled by a combination of source control and ventilation. The ventilation required for controlling the health risk from a specific air pollutant should be evaluated separately from the ventilation required to obtain a desired and perceived air quality. It is recommended that the highest of these values should be used for the design. In practice comfort usually determines the required ventilation.

A.3 prescribes how the required ventilation rate should be determined. The required ventilation rate depends on the desired indoor air quality, on the indoor air pollution sources, on the outdoor air quality and on the ventilation effectiveness. Each of these topics is discussed in the following subclauses. The procedure to determine the required ventilation rate is summarized in annex B where a step-by-step method is given. At commissioning it is sufficient to verify the flow rates required.

A.3.2 *Health aspects of indoor air quality*

Exposure to pollutants in the air may cause some risk to health. Adverse effects may be short-term, distinct and acute or long-term, such as cancer.

To limit the health risk to a low level, it would be useful to establish an extensive list of maximum permissible concentrations and the corresponding exposure times for individual chemicals in the air. The health effects of certain air pollutants have been evaluated and guideline values for more than 25 chemicals listed by WHO (see annex E) [1]. The guidelines apply to both outdoor and indoor air. The guideline values in this list may be used as limits for individual chemicals in indoor air. When many pollutants at low levels are present, their combined health effects on individuals are not predictable with present knowledge.

> NOTE For industrial premises, national authorities have decided upon Threshold Limit Values (TLV). These values apply to work places where chemicals are used routinely in the production process. On industrial premises workers are typically exposed to one or a few chemicals at a time. In offices and similar work places exposure to any individual pollutant is typically much lower than in industry. Instead the exposure is characterized by a wide spectrum of compounds at low levels from building materials, furniture, office equipment, human metabolism, environmental tobacco smoke and outdoor air. Due to the multitude of pollutants, much lower levels of individual chemicals should be aimed at. This applies also to kindergartens, nursing homes and similar spaces, where people may spend a longer time than at the work place, or where the occupants include more susceptible persons, e.g. children and the elderly. Some countries use a certain fraction of TLV to be applied as a limit value for non-industrial premises.

A.3.3 *Perceived air quality*

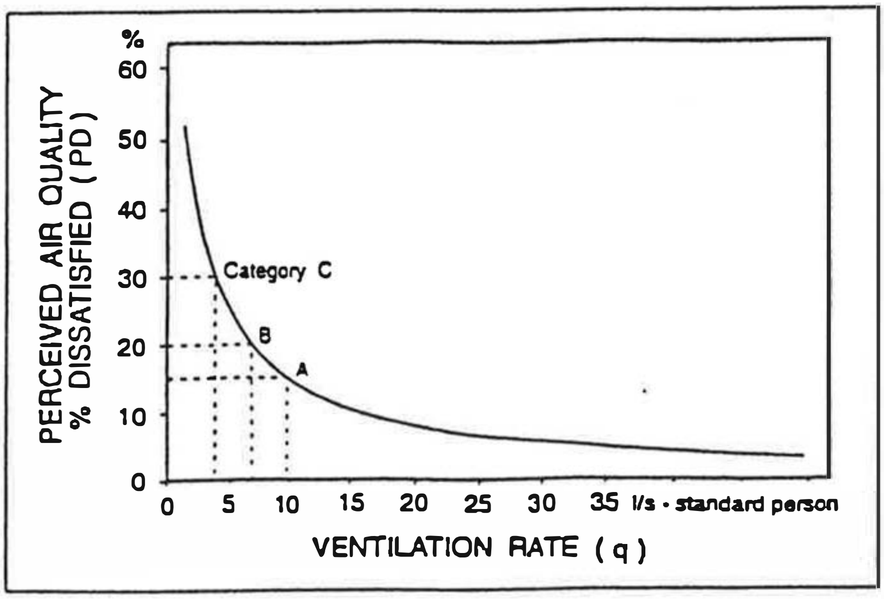
A.3.3.1 *General*

Humans perceive the air by two senses. The olfactory sense is situated in the nasal cavity and is sensitive to several hundred thousand odorants in the air. The general chemical sense is situated all over the mucous membranes in the nose and the eyes and is sensitive to a similarly large number of irritants in the air. It is the combined response of these two senses that determines whether the air is perceived fresh and pleasant or stale, stuffy and irritating.

Perceived air quality may be expressed as the percentage of dissatisfied, i.e. persons predicted to perceive the air as being unacceptable just after entering a space. For air polluted by human bioeffluents Figure A.7 shows the percentage of dissatisfied as a function of the ventilation rate per standard person (average sedentary adult office worker feeling thermally neutral). The pollution generated by such a standard person is called "one olf".

The strength of most pollution sources indoors may be expressed as "person equivalents", i.e. the number of standard persons (olfs) required to make the air as annoying (causing as many dissatisfied) as the actual pollution source.

Perceived air quality may also be expressed in decipol (dp), where 1 dp is the air quality in a space with a pollution source strength of one olf, ventilated by 10 l/s of clean air, i.e. 1 dp = 0,1 olf/(l/s). The relation between perceived air quality expressed as a percentage of dissatisfied visitors in dp is given in the 1992 EC Commission Report No. 11 [2].



NOTE The curve is given by the following equations:

$PD = 395 \times \exp(-1{,}83 \times q^{0{,}25})$ for: $q \geq 0{,}32$ l/s × olf

$PD = 100$ for: $q < 0{,}32$ l/s × olf

Figure A.7 — Dissatisfaction caused by a standard person (one olf) at different ventilation rates

A.3.3.2 *Categories of perceived indoor air quality*

The desired perceived indoor air quality in a space may be selected from the three categories A, B and C listed in Table A.5.

Table A.5 — Three categories of perceived indoor air quality

Category	Perceived air quality		Required ventilation rate[1]
	dissatisfied %	dp	l/s × olf
A	15	1,0	10
B	20	1,4	7
C	30	2,5	4

[1] The ventilation rates given are examples referring exclusively to perceived air quality. They apply only to clean outdoor air and a ventilation effectiveness of one.

The perceived air quality in Table A.5 refers to a person's initial judgement when entering a space (referred to as "visitors"). The first impression is essential, i.e. it is important that the air is immediately perceived as acceptable.

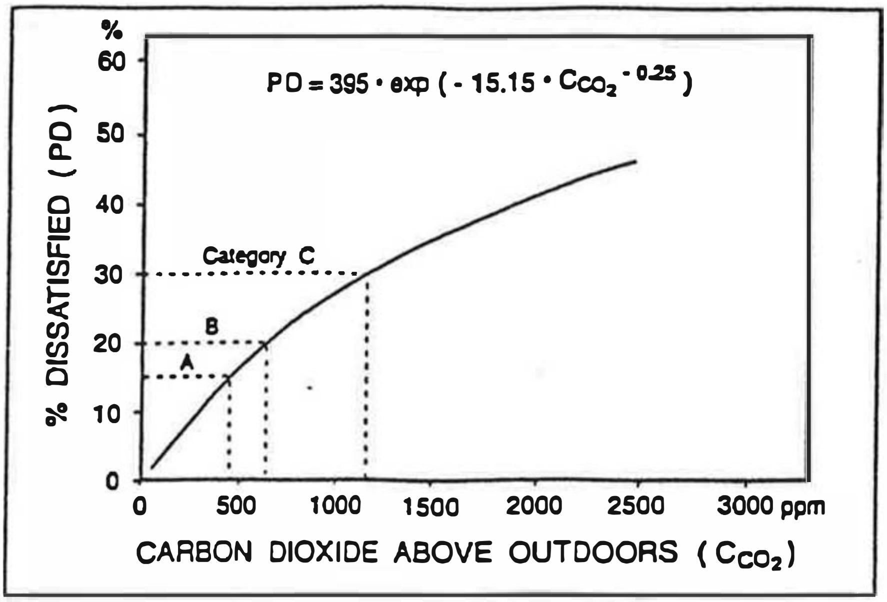
However, some adaptation to bioeffluents takes place during occupancy while little adaptation, if any, occurs for tobacco smoke and pollutants from many building materials.

It is important to realize that some harmful air pollutants are not sensed at all and that the sensory effects of other pollutants are not quantitatively linked with their toxicity. Therefore, perceived air quality is not a universal measure of adverse health effects. Yet, it is also true that when air quality that is perceived as poor in a building is improved by removing pollution sources and increasing ventilation, the risk of adverse health effects is normally also reduced.

A.3.3.3 *Carbon dioxide*

Humans produce carbon dioxide (CO_2) proportional to their metabolic rate. In terms of quantity it is the most important human bioeffluent. Although at the low concentrations typically occurring indoors, CO_2 is harmless and not perceived by humans, still it is a good indicator of the concentration of other human bioeffluents being perceived as a nuisance. CO_2 has been used quite successfully as an indicator of human bioeffluents for more than a century. Figure A.8 shows the percentage of dissatisfied visitors as a function of the CO_2 concentration (above the outdoor level) for spaces where sedentary occupants are the exclusive pollution sources. In lecture theatres, assembly halls and similar rooms with a high occupancy which may change in a short time, CO_2-monitoring is a well-established practice for controlling the supply of outdoor air. Although CO_2 is a good indicator of pollution caused by sedentary human beings, it is often a poor general indicator of perceived air quality. It does not acknowledge the many perceivable pollution sources not producing CO_2 and certainly not the non-perceivable hazardous air pollutants such as carbon monoxide and radon.

If sedentary occupants are assumed to be the only source of pollution, the CO_2 concentration above the outdoor level corresponding to the three categories is A: 460 ppm, B: 660 ppm and C: 1190 ppm.



NOTE The curve shows the perceived air quality (% dissatisfied) as a function of the carbon dioxide concentration above outdoors. It applies to spaces where sedentary occupants are the exclusive pollution source and is based on the same data as Figure A.7. The concentration of carbon dioxide outdoors is typically around 700 mg/m³ (350 ppm) (see Table A.9).

Figure A.8 — Carbon dioxide as an indicator of human bioeffluents

A.3.4 ***Air pollution sources***

A.3.4.1 *General*

The pollution sources in a building are the occupants and their activities, including possible tobacco smoking. Furthermore, materials in the building, including furnishing, carpets, household chemicals and the ventilation or air-conditioning system, may contribute significantly to the pollution of the air. Some materials pollute a lot, some a little, but they may all contribute to the deterioration of the indoor air quality. It is recommended that low-polluting materials are used in buildings from the time the building is occupied. It is also important to reduce pollution sources in the ventilation or air-conditioning system.

Many pollution sources emit hundreds or thousands of chemicals but usually in small quantities. The pollution sources provide a pollution load on the air in the space. This load may be expressed as a chemical pollution load and as a sensory pollution load. The chemical load can be expressed as the emission of individual chemicals from the sources. The sensory load can be quantified by the olf unit which integrates the effect of the many chemicals as perceived by human beings. The chemical and sensory pollution loads are discussed separately below.

If an air cleaner or other device capable of improving the air quality is present in a space or in a ventilation and air-conditioning system, it can produce a negative pollution load on the air in the space.

A.3.4.2 *Chemical pollution load*

The source strength of a material may be expressed as the emission rate (or emission factor) of individual chemicals in µg/s or $\mu g/(m^2 \cdot s)$. The chemical pollution load of each individual chemical on the air in the space can then be estimated by addition of the source strengths and expressed in µg/s.

> NOTE Unfortunately, little information is usually available on the emission rate from the many materials used in practice. In addition, it may be rather impractical to account for the source strength of each of the hundreds or thousands of chemicals occurring in indoor air. In some cases, though, where an individual chemical is suspected of being an important pollutant because of its toxic potential, an estimate of the pollution load of that particular chemical in a space may be possible.

Table A.6 lists the chemical load caused by smoking and non-smoking occupants, expressed in terms of carbon monoxide and carbon dioxide.

A.3.4.3 *Sensory pollution load*

The sensory pollution load on the air is caused by those pollution sources having an impact on the perceived air quality. The sensory pollution load in a space may be found by adding the loads caused by all the different pollution sources in the space. The pollution sources usually comprise the occupants and the building, including furnishing, office machines, carpeting and ventilation or air-conditioning system. A few studies have shown that the addition of sensory pollution sources seems to be a reasonable first approximation, but research involving a much wider range of pollution sources needs to be performed in order to check whether this addition can generally be accepted.

The occupants emit bioeffluents and smokers also produce tobacco smoke. A standard person (non-smoking) produces 1 olf, while an average smoker produces 6 olf. Table A.6 lists the pollution load from adult occupants engaged in different activities, the load with no smokers, and that with different percentages of smokers among the occupants. The pollution load from children is also given. Furthermore, Table A.6 lists the human production of carbon dioxide, carbon monoxide and water vapour. The predicted occupancy per m² floor of the spaces should be used. Table A.7 lists examples of occupancy per m^2 floor in various spaces.

Table A.8 shows data from measured pollution loads caused by different types of existing buildings. The pollution load caused by the building is often high and varies widely from building to building. It is essential that new buildings be designed as low-polluting buildings. The pollution load listed in Table A.8 for low-polluting buildings is a target value for the design. It requires a systematic selection of low-polluting materials for the building including furnishing, carpets and ventilation or air-conditioning system (see annex G).

Table A.6 — Pollution load caused by occupants

	Sensory pollution load olf/occupant	Carbon dioxide l/(h × occupant)	Carbon monoxide[a)] l/(h × occupant)	Water vapour[b)] g/(h × occupant)
Sedentary, 1–1.2 met				
0 % smokers	1	19		50
20 % smokers [c)]	2	19	11×10^{-3}	50
40 % smokers [c)]	3	19	21×10^{-3}	50
Physical exercise				
low level, 3 met	4	50		200
medium level, 6 met	10	100		430
high level (athletes), 10 met	20	170		750
Children				
kindergarten, 3-6 years, 2,7 met	1,2	18		90
school, 14–16 years, 1–1,2 met	1,3	19		50

[a)] From tobacco smoking.
[b)] Applies for persons close to thermal neutrality.
[c)] Average smoking rate 1,2 cigarettes/h per smoker, emission rate 44 ml CO/cigarette.

Table A.7 — Examples of occupancy in spaces

	Occupants/(m² floor)
Offices	0,07
Conference rooms	0,5
Assembly halls, theatres, auditoria	1,5
Schools (classrooms)	0,5
Kindergartens	0,5

Table A.8 — Pollution load caused by the building, including furnishing, carpets and ventilation system

	Sensory pollution load olf/(m² floor)	
	Mean	Range
Existing buildings		
Offices[a)]	0,3[d)]	0,02–0,95
Offices[b)]	0,6[c)]	0–3
Schools (classrooms)[a)]	0,3	0,12–0,54
Kindergartens[a)]	0,4	0,20–0,74
Assembly halls[a)]	0,3[d)]	0,13–1,32
New buildings (no tobacco smoking)		
Low-polluting buildings (see annex G)	0,1	
Non-low-polluting buildings	0,2	

[a)]Data based on more than 40 mechanically ventilated buildings in Denmark.

[b)]Data based on European Audit Project to Optimize Indoor Air Quality and Energy Consumption in Office Buildings, 1992–1995 [3].

[c)]Includes load caused by present and previous tobacco smoking.

[d)]Includes load caused by previous tobacco smoking.

NOTE Little information is usually available on the pollution load from many materials used in practice. Still it is essential to try to minimize the pollution load from the building. Work is in progress to provide information on and decrease the pollution load from materials. Annex G offers some guidelines for low-polluting buildings.

A.3.5 *Outdoor air quality*

The required ventilation also depends on the quality of the available outdoor air. If local data on the air surrounding the building are available, they should be used. Table A.9 lists examples of characteristic levels of outdoor perceived air quality and of typical outdoor pollutants. The outdoor air quality can be much worse than shown in Table A.9. In such cases it may be necessary to clean the air before it is suitable for ventilation, or accept a lower indoor air quality.

It is the quality of the outdoor air at the air intake that counts. Consequently, a proper location of the air intake is important.

Table A.9 — Examples of outdoor levels of air quality

	Perceived air quality dp	Air pollutants				
		Carbon dioxide mg/m³	Carbon monoxide mg/m³	Nitrogen dioxide µg/m³	Sulfur dioxide µg/m³	Particulates µg/m³
Excellent	0	680	0–0,2	2	1	<30
In towns, good air quality	< 0,1	700	1–2	5–20	5–20	40–70
In towns, poor air quality	> 0.5	700–800	4–6	50–80	50–100	>100

NOTE There is no direct relation between perceived air quality and the pollutants listed in this table. The values for the perceived air quality are typical daily average values. The values for the four air pollutants are annual average concentrations.

A.3.6 *Ventilation effectiveness*

The air quality may not be the same throughout a ventilated space. What really counts for the occupants is the air quality in the breathing zone. Such an inhomogeneity of the air quality in a space has an impact on the ventilation requirement. This is expressed by the ventilation effectiveness:

$$\varepsilon_v = \frac{C_e - C_s}{C_i - C_s}$$

where:

ε_v is the ventilation effectiveness;
C_e is the pollution concentration in the exhaust air;
C_s is the pollution concentration in the supply-air;
C_i is the pollution concentration in the breathing zone.

The ventilation effectiveness depends on the air distribution and the location of the pollution sources in the space. It may, therefore, have different values for different pollutants. If there is complete mixing of air and pollutants, the ventilation effectiveness is one. If the air quality in the breathing zone is better than in the exhaust, the ventilation effectiveness is higher than one, and the desired air quality in the breathing zone can be achieved with a lower ventilation rate. If the air quality in the breathing zone is poorer than in the exhaust air, the ventilation effectiveness is lower than one and more ventilation is required.

Ventilation effectiveness is a function of location and characteristics of air terminal devices and of pollution sources. It is furthermore a function of temperature and flow rate of the supply-air. The ventilation effectiveness may be calculated by numerical simulation or measured experimentally. Examples of ventilation effectiveness are given in annex F for different ventilation principles.

A.3.7 *Required ventilation rate*

The ventilation rate required for comfort and health should be calculated separately and the highest value used for design.

The required ventilation rate for comfort can be calculated from the equation:

$$Q_c = 10 \bullet \frac{G_c}{C_{c,i} - C_{c,o}} \bullet \frac{1}{\varepsilon_v}$$

where:

Q_c is the ventilation rate required for comfort, in litres per second (l/s);
G_c is the sensory pollution load, in olf (olf);
$C_{c,i}$ is the desired perceived indoor air quality, in decipol (decipol);
$C_{c,o}$ is the perceived outdoor air quality at air intake, in decipol (decipol);
ε_v is the ventilation effectiveness.

The ventilation rate required from a health point of view is calculated by this equation:

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \bullet \frac{1}{\varepsilon_v} \qquad \text{(A.3)}$$

where:
Q_h is the ventilation rate required for health, in litres per second (l/s);
G_h is the pollution load of a chemical, in micrograms per second (µg/s);
$C_{h,i}$ is the guideline value of a chemical, see annex E, in micrograms per litre (µg/l);
$C_{h,o}$ is the outdoor concentration of a chemical at air intake, in micrograms per litre (µg/l);
ε_v is the ventilation effectiveness.

$C_{h,i}$ and $C_{h,o}$ may also be expressed as ppm (*vol/vol*). In this case the chemical pollution load G has to be expressed as l/s.

Equations (A.2) and (A.3) apply to steady-state conditions and when the outdoor air is better than the indoor air quality.

Please note that research is still in progress to validate Equation (A.2) and to study pollution loads and perceived air quality indoors and outdoors for a wide range of conditions in different types of buildings.

A step-by-step method for determining the ventilation requirement is given in annex B. To calculate the ventilation rate required to avoid health problems from Equation (A.3), it is necessary to identify the most critical chemical (or group of chemicals) and to estimate the pollution load of that chemical in the space. Furthermore, a guideline value should be available for that chemical (see annex E).

Field studies in many buildings indicate that for spaces ventilated for comfort, the concentration of chemicals will usually be very low and typically orders of magnitude lower than the TLV values. Still, pollution sources of concern from a health point of view may occur. Rather than diluting the pollutants from such sources by ventilation, it is recommended to avoid or control such sources and use low-polluting materials in the building.

Total volatile organic compounds (TVOC) have been suggested as an indicator of both comfort and health, e.g. in the 1991 SCANVAC guidelines and specification [4]. If data become available for guideline values and chemical load, Equation (A.3) may be employed to calculate the required ventilation rate. Equation (A.3) may also be employed to calculate the ventilation rate required for comfort, using CO_2 as an indicator in spaces where the occupants are, or are assumed to be, the only source of pollution (Figure A.8 and Table A.6).

A.3.8 *Air humidity*

The humidity in the indoor air may have an impact directly or indirectly on the occupants. The humidity has an influence on the thermal sensation. This is discussed in **A.2.4.2** in relation to the thermal environment. High air humidity may also stimulate the growth of moulds and other fungi etc., which can cause allergy and malodours. Increased humidity may also enhance the emission of chemicals like formaldehyde from materials. A low humidity may cause a sensation of dryness and irritation of skin and mucous membranes of some occupants. Normally few problems occur when the relative humidity is between 30 % and 70 %, assuming that no condensation takes place. However, a high relative humidity stimulates the growth of house dust mites which may pose a serious allergy risk, particularly in dwellings. Where water occurs, e.g. at cooling coils or humidifiers in ventilation or air-conditioning systems, there is a risk of growth of fungi and other micro-organisms. To avoid this, careful design, cleaning and maintenance are essential. A high indoor air humidity may also have a negative impact on the materials in the building construction. The relative humidity in the space does not necessarily reflect relative humidity in or on walls, floors, ceiling or in the building envelope in general. Relative humidities between 30 % and 70 % in the room do not guarantee the absence of humidity problems in the building. It may be necessary to protect the building construction by means of vapour barriers and proper insulation.

A.4 Acoustic environment

A.4.1 *General*

Protection against noise is an essential requirement of building design. The ventilation or air-conditioning system should be designed and built in such a way that noise perceived by the occupants in the building or people nearby is kept at a level that will not cause a significant nuisance or adverse health effects and will not disturb rest or work. The ventilation or air-conditioning system can be a source or a means of transporting noise which can be a major nuisance. It should therefore be evaluated with a view to these requirements. The following three aspects should be considered:

a) equipment and aerodynamic noise;

b) airborne noise from the outdoor environment through the ventilation system or equipment;

c) noise from other spaces transmitted by the ventilation system or equipment.

Sources of equipment and aerodynamic noise are for example:

— fans, condensers, cooling towers, compressors etc;

— supply and exhaust air devices;

— return air grilles.

Pathways for outside noise are:

— air inlet and outlet louvres;

— wall mounted fans.

Pathways for noise from other spaces are:

— internal transfer air grilles;

— ductwork.

Components of ventilation or air-conditioning systems can also be sources of outside noise, for instance exhaust fans, cooling towers and air cooled condensers.

Noise generated and/or transmittted by the ventilation system is usually broad band noise and therefore, the "A" weighted sound pressure level will be used as a category rating.

The desired category of the acoustic environment with respect to the protection against noise is to be selected from Table A.10.

The requirement should be satisfied for all three aspects of noise a), b) and c), separately.

A.4.2 *Methods for assessing and predicting acoustic performance*

Any method for evaluating a priori the acoustic performance of a ventilation or air-conditioning system requires assumptions that should be clearly stated (from outdoor noise, furnishing etc.). The sound attenuation or transmission of a specific noise (traffic, airport, etc.) and sound power level of the equipment by octave band or sound pressure levels with specific absorption of the test room are required from the equipment manufacturers.

Calculation methods based on fundamental and empirical approaches are the most common way to assess the appropriate choice of VAC components with respect to the acoustic criteria.

Besides the calculation methods, alternative approaches for assessing and predicting the acoustic performance of a ventilation system are testing with full-scale experiments or mock-up and descriptive methods based on the description of design that have been found satisfactory.

A.4.3 *Noise from equipment*

The ventilation or air-conditioning system should be evaluated with respect to this design criterion. Noise from the equipment may be generated either within the space, or outside the space with transmission by the ductwork or the structure of the building. Besides the product characteristics, the key parameters of the evaluation approaches are the sound power level of the ventilation network and the reverberation time of the room.

If the user can personally control his environment locally (air volume or air velocity), then the sound pressure level within this space may be 5 dB(A) higher than the requirement stated in Table A.10 for higher volumes or velocities than the nominal.

A.4.4 *Airborne noise from outdoors*

Air inlet louvres as well as system air inlet grilles are part of the building façade and may be a major path for the transmission of noise from outdoors. If this transmission of noise is not included in the acoustic performance of the respective façade, then its influence should be considered with respect to design criteria.

A.4.4.1 *Airborne noise between enclosed spaces*

Air transfer grilles may be part of the internal partitioning of spaces and as such form paths for sound transmission between spaces. Their performance regarding direct sound reduction should be stated and tied to the performance of the wall. Noise generated in one space and transmitted to another through the ventilation system is relevant and should be estimated..

A.4.5 *Specific problems*

When tonal components occur, it is necessary to use a more stringent criterion than for the broad band noise. Tonal components are present if a third-octave-band level is 5 dB higher than the adjacent third-octave levels. In this case the A-weighted sound pressure levels should be 5 dB(A) lower than given in Table A.10.

Low frequency noise components that do occur will require specific acoustic analysis in order to quantify them which is beyond the scope of this Technical Report. Further, concert halls, studios and such like, where the acoustic properties are of paramount importance will require special and individual consideration and are therefore also beyond the scope of this Technical Report.

Table A.10 — Permissible A-weighted sound pressure level generated and/or transmitted by the ventilation or air-conditioning system in different types of spaces for three categories

Type of building	Type of space	Category [a] dB(A)		
		A	B	C
Child care institutions	Nursery schools	30	40	45
	Day nurseries	30	40	45
Places of assembly	Auditoriums	30	33	35
	Libraries	30	33	35
	Cinemas	30	33	35
	Court rooms	30	35	40
Commercial	Retail shops	35	40	50
	Department stores	40	45	50
	Supermarkets	40	45	50
	Computer rooms, large	40	50	60
	Computer rooms, small	40	45	50
Hospitals	Corridors	35	40	45
	Operating theatres	35	40	45
	Wards	25	30	35
Hotels	Lobbies	35	40	45
	Reception rooms	35	40	45
	Hotel rooms (during night-time)	25	30	35
	Hotel rooms (during daytime)	30	35	40
Offices	Small offices	30	35	40
	Conference rooms	30	35	40
	Landscaped offices	35	40	45
	Office cubicles	35	40	45
Restaurants	Cafeterias	35	40	50
	Restaurants	35	45	50
	Kitchens	40	55	60
Schools	Classrooms	30	35	40
	Corridors	40	45	50
	Gymnasiums	35	40	45
	Teachers' rooms	30	35	40
Sport	Covered sports stadia	35	45	50
	Swimming baths	40	45	50
General	Toilets	40	45	50
	Locker rooms	40	45	50

[a] The letters A, B and C define merely one of the three categories and they have no relation to the weighting curves like dB(A).

Annex B (informative)

Step-by-step method for determination of design criteria

B.1 Thermal environment

a) Estimate activity level of occupants (annex D, Table D.1).

b) Estimate clothing insulation of occupants in winter and summer (annex D, Tables D.2 and D.3).

c) Determine optimum temperature from Figure A.2 or from tables or computer program in EN ISO 7730.

d) Select desired maximum PPD , e.g. category A, B or C (Table A.1), and find permissible temperature range in Figure A.2.

e) Select desired maximum percentage dissatisfied due to draught (Table A.1) and find the permissible mean air velocity in Figure A.3, assuming a turbulence intensity depending on the ventilation system. A turbulence intensity of 40 % may be used as default value.

f) Select desired maximum percentage dissatisfied due to vertical air temperature difference (Table A.1) and find the permissible air temperature difference from Figure A.4 or Table A.2.

g) Select desired maximum percentage dissatisfied due to warm or cool floor (Table A.1) and find the permissible range of floor temperature from Figure A.5 or Table A.3.

h) Select desired maximum percentage dissatisfied due to radiant asymmetry (Table A.1) and find the permissible radiant temperature asymmetry from Figure A.6 or Table A.4.

B.2 Indoor air quality

a) Calculate ventilation rate required for comfort by:

1) estimating the expected occupancy (Table A.7) and the sensory pollution load caused by occupants taking into account smokers, if any (Table A.6). Separation of smokers and non-smokers should be considered;

2) estimating the expected sensory pollution load from the building (Table A.8);

3) calculating the total sensory pollution load by adding the values from 1) and 2);

4) selecting the desired indoor air quality from Table A.5;

5) estimating the outdoor air quality (Table A.9) and the ventilation effectiveness (annex F);

6) calculating the required ventilation rate from Equation (A.2).

b) Calculate ventilation rate required from a health point of view by:

1) identifying the most critical chemical(s) and estimate the pollution load of that (those) chemical(s) in the space, if available;

2) finding the guideline value of the critical chemical(s), if available (annex E);

3) calculating the required ventilation ratc for health from Equation (A.3).

c) Use the highest value of the two values calculated under a) and b) as the required ventilation rate.

d) Calculate airflow rate for thermal design by:

1) determining the cooling load;

2) determining/selecting the supply-air temperature;

3) determining the required supply-air flow rate for thermal design as the ratio of cooling load and difference between room temperature and supply-air temperature times 1.2.

B.3 Acoustic environment

Select permissible A-weighted sound pressure level generated and/or transmitted by the ventilation or air-conditioning system in Table A.10.

Annex C (informative)

Practical examples

C.1 Design criteria and assumptions

The application of annex A is illustrated in this annex C by a number of practical examples. The examples cover spaces in different types of buildings under conditions frequently occurring in practice. It is shown how design criteria are determined for these typical examples. The user of this Technical Report may go directly to Table 1 if the building/space to be ventilated is similar to the examples and the assumptions under which they apply. The following practical examples cover these types of buildings/spaces: an office building, an auditorium, a restaurant, a classroom, a kindergarten and a department store.

For each of the buildings/spaces the assumptions are listed under which the design criteria for the indoor environment should be met. The separate thermal design criteria during summer and winter are found in **A.2.4.2** to **A.2.4.6**. They comprise a range of operative temperatures and a maximum mean air velocity. The design criteria for the indoor air quality are found in **A.3.3** to **A.3.7** and comprise the required ventilation rates for comfort, calculated by using alternative methods. The required ventilation rates found in the samples are summarized for different types of space in Table C.1. The ventilation rate is provided for persons only plus a rate for a low-polluting or a non-low-polluting building, plus a rate for smoking if it occurs. The sum of the ventilation rates in Table C.1 for persons only and for low-polluting buildings is the ventilation rate given in Table 1. The design criteria for the acoustic environment are found in **A.4** and are given as the highest permissible A-weighted sound pressure level. In a given building different quality categories (A, B or C) may be selected for the thermal environment, for the air quality and for the acoustic environment.

Before the practical examples are presented, some information is provided on the design of the ventilation/air-conditioning system.

Table C.1 — Design criteria for spaces in different types of building

Type of building/ space	Occupancy person/m²	Category	Minimum ventilation rate, i.e. for occupants only	Additional ventilation for building (add only one)		Additional ventilation when smoking is allowed [a)]
				low-polluting building[b)]	non low-polluting building	
			l/s × m²	l/s × m²	l/s × m²	l/s × m²
Single office	0,1	A	1,0	1,0	2,0	-
(cellular office)		B	0,7	0,7	1,4	-
(see C.3.3)		C	0,4	0,4	0,8	-
Landscaped	0,07	A	0,7	1,0	2,0	0,7
office		B	0,5	0,7	2,4	0,5
(see C.3.4)		C	0,3	0,4	0,8	0,3
Conference	0,5	A	5,0	1,0	2,0	5,0
room		B	3,5	0,7	1,4	3,6
(see C.3.5)		C	2,0	0,4	0,8	2,0
Auditorium	1,5	A	15	1,0	2,0	-
(see C.4)		B	10,5	0,7	1,4	-
		C	6,0	0,4	0,8	-
Restaurant	0,7	A	7,0	1,0	2,0	-
(see C.5)		B	4,9	0,7	1,4	5,0
		C	2,8	0,4	0,8	2,8
Classroom	0,5	A	5,0	1,0	2,0	-
(see C.6)		B	3,5	0,7	1,4	-
		C	2,0	0,4	0,8	-
Kindergarten	0,5	A	6,0	1,0	2,0	-
(see C.7)		B	4,2	0,7	1,4	-
		C	2,4	0,4	0,8	-
Department	0,15	A	2,1	2,0	3,0	-
store		B	1,5	1,4	2,1	-
(see C.8)		C	0,9	0,8	1,2	-

[a)] Additional ventilation required for comfort when 20 % of the occupants are smokers. The health risk of passive smoking should be considered separately.

[b)] It is recommended that low-polluting materials, etc. are used for low-polluting buildings (see Annex G: Guidelines for low-polluting buildings).

NOTE This table applies for the occupancy listed in the table and for a ventilation effectiveness of one.

C.2 Design of system

The design of a ventilation/air-conditioning system should be carried out so that the design criteria for the indoor environment are met.

The thermal design includes a determination of the supply-air flow rate and temperature required to maintain the temperature in the space on a design day. This design day is usually a summer day (and a winter day) with more or less severe weather conditions, depending on the selected design assumption. If the thermal design criteria can be met under these conditions, they can also usually be met under less severe weather conditions.

An important part of the design of a ventilation/air-conditioning system is a proper design of the air distribution system in the space. Some estimation of the distribution of temperatures, velocities and air quality in the occupied zone is required during the design. This estimation may be based on professional engineering judgement, on data for air terminal devices, on analyses using computational fluid dynamics, or on results of model or full-scale experiments.

During the design phase, simplifications can often be made, some of which are described as follows.

— In spaces without cooling or heating panels or large window areas, the mean radiant temperature is often close to the air temperature, i.e. the operative temperature is approximately equal to the air temperature; radiant asymmetries need not be taken into account and may be discounted. But it should be noted that the permissible temperature range should cover both the spatial and temporary variations which may occur inside the occupied zone during the occupied hours.

— Where ventilation/air-conditioning systems use mixed ventilation, the air temperature (and air quality) is usually quite uniform in the space, i.e. the temperature differences are small.

— The turbulence intensity may be estimated to be 40 % for mixed ventilation and 20 % for displacement ventilation.

C.3 Office building

C.3.1 *General*

An office building is planned to be heated and air-conditioned. The environmental design criteria are determined for these typical spaces in the building: a single office (cellular office), a landscaped office and a conference room. The environmental design criteria specified below should be met under the following assumptions.

C.3.2 *General design assumptions*

a) The building is occupied from 08:00 h to 18:00 h during weekdays. The environmental design criteria should be met during the occupied hours of a design day in the summer. 99 % of the occupied hours during the year will be less severe than the design day.

b) e spaces in the office building are used for ordinary office work inside this occupied zone: a distance larger than 0,6 m from walls and heating and air terminal devices, and up to a height of 1,8 m above the floor.

c) The activity of the occupants is mainly sedentary office work, 1,2 met and the clothing insulation is 1,0 clo in winter and 0,5 clo in summer.

d) The window area is 50 % of the exterior wall area with double clear panes and venetian blinds. Walls, ceilings and floors are medium weight and have a heat transmission coefficient of 0,4 W/m² × °C.

e) The air temperature is equal to the operative temperature.

f) A mixing ventilation system is applied with a ventilation effectiveness of 1,0 and a turbulence intensity of 40 % in the occupied zone.

g) Low-polluting building materials and furnishing are systematically selected, providing a pollution load of 0,1 olf/(m² floor), which corresponds to 1,0, 0,7 and 0,4 l/s (m² floor) respectively for categories A, B and C.

h) Smoking is not permitted.

The building is situated in an area with excellent outdoor air quality (0 dp) and the levels of outdoor air pollutants are of no health concern.

C.3.3 *Single office (cellular office)*

C.3.3.1 *Design assumptions:*

— the occupancy is 0,1 person/m² floor; and

— the cooling load caused by occupants, machines, illumination, solar radiation etc. is 50 W/m² floor.

C.3.3.2 *Thermal design criteria*

Summer

Operative temperature (Figure A.2):

Category A:	24,5 °C ± 1,0 °C
Category B:	24,5 °C ± 1,5 °C
Category C:	24,5 °C ± 2,5 °C

Mean air velocity (Figure A.3):

Category A:	0,18 m/s
Category B:	0,22 m/s
Category C:	0,25 m/s

Winter

Operative temperature (Figure A.2):

Category A:	22,0 °C ± 1,0 °C
Category B:	22,0 °C ± 2,0 °C
Category C:	22,0 °C ± 3,0 °C

Mean air velocity (Figure A.3):

Category A:	0,15 m/s
Category B:	0,18 m/s
Category C:	0,21 m/s

C.3.3.3 *Air quality design criteria*

Alternative 1

Sensory pollution load (Tables A.6 and A.8):

Occupants:	1 × 0,1 =	0,1 olf/(m² floor)
Building:		0,1 olf/(m² floor)
Total sensory pollution load:		0,2 olf/(m² floor)

Required ventilation rate for comfort (Equation (A.2) and Table A.5):

Category A: $Q_c = 10 \times 0{,}2/(1{,}0\text{-}0) \times 1/1 = 2{,}0$ l/s(m² floor)
Category B: $Q_c = 10 \times 0{,}2/(1{,}4\text{-}0) \times 1/1 = 1{,}4$ l/s(m² floor)
Category C: $Q_c = 10 \times 0{,}2/(2{,}5\text{-}0) \times 1/1 = 0{,}8$ l/s(m² floor)

Alternative 2

Based on CO_2, ignoring the building as a pollution source:

Required ventilation (Equation A.3, Table A.6, Figure A.8)

Category A: $Q_c = 0{,}1 \times 19/3\,600 \times 460 \times 10^{-6} = 1{,}0$ l/s (m² floor)
Category B: $Q_c = 0{,}1 \times 19/3\,600 \times 660 \times 10^{-6} = 0{,}7$ l/s (m² floor)
Category C: $Q_c = 0{,}1 \times 19/3\,600 \times 1\,190 \times 10^{-6} = 0{,}4$ l/s (m² floor)

Required supply-air flow rate for thermal design:

If an all-air air-conditioning system is used with a supply-air temperature of 14 °C and the cooling load is 50 W/(m² floor), the required supply-air flow rate for Category A for the thermal design is 4 l/s (m² floor) during summer conditions.

C.3.3.4 *Acoustic design criteria*

Sound pressure (Table A.10):

Category A: 30 dB(A)
Category B: 35 dB(A)
Category C: 40 dB(A)

C.3.4 *Landscaped office*

C.3.4.1 *Design assumptions:*

- the occupancy is 0,07 person/(m² floor); and
- the cooling load caused by occupants, machines, illumination, solar radiation etc. is 50 W/(m² floor).

C.3.4.2 *Thermal design criteria*

Summer

Operative temperature (Figure A.2):

Category A: 24,5 °C ± 1,0 °C
Category B: 24,5 °C ± 1,5 °C
Category C: 24,5 °C ± 2,5 °C

Mean air velocity (Figure A.3):

Category A: 0,18 m/s
Category B: 0,22 m/s
Category C: 0,25 m/s

Winter

Operative temperature (Figure A.2):

Category A: 22,0 °C ± 1,0 °C
Category B: 22,0 °C ± 2,0 °C
Category C: 22,0 °C ± 3,0 °C

Mean air velocity (Figure A.3):

Category A: 0,15 m/s
Category B: 0,18 m/s
Category C: 0,21 m/s

C.3.4.3 *Air quality design criteria*

Alternative 1

Sensory pollution load (Table A.6 and Table A.8):

Occupants:	1 × 0,07 =	0,07 olf/(m^2 floor)
Building:		0,1 olf/(m^2 floor)
Total sensory pollution load:		0,17 olf/(m^2 floor)

Required ventilation rate for comfort (Equation (A.2) and Table A.5):

Category A: $Q_c = 10 \times 0{,}17/(1{,}0\text{-}0) \times 1/1 = 1{,}7$ l/s (m^2 floor)
Category B: $Q_c = 10 \times 0{,}17/(1{,}4\text{-}0) \times 1/1 = 1{,}2$ l/s (m^2 floor)
Category C: $Q_c = 10 \times 0{,}17/(2.5\text{-}0) \times 1/1 = 0{,}7$ l/s (m^2 floor)

Alternative 2

Based on CO_2, ignoring the building as a pollution source:

Required ventilation (Equation (A.3), Table A.6, Figure A.8):

Category A: $Q_c = 0{,}07 \times 19/3\,600 \times 460 \times 10^{-6} = 0{,}7$ l/s (m^2 floor)
Category B: $Q_c = 0{,}07 \times 19/3\,600 \times 660 \times 10^{-6} = 0{,}5$ l/s (m^2 floor)
Category C: $Q_c = 0{,}07 \times 19/3\,600 \times 1\,190 \times 10^{-6} = 0{,}3$ l/s (m^2 floor)

Required supply-air flow rate for thermal design:

If an all-air air-conditioning system is used with a supply-air temperature of 14 °C and the cooling load is 50 W/(m^2 floor), the required supply-air flow rate for Category A for the thermal design is 4 l/s (m^2 floor) during summer conditions.

Additional ventilation rate when 20 % of the occupants are smokers (Table 1 or 2):

Category A: Q_{add} = 0,7 l/s (m^2 floor)
Category B: Q_{add} = 0,5 l/s (m^2 floor)
Category C: Q_{add} = 0,3 l/s (m^2 floor)

C.3.4.4 *Acoustic design criteria*

Sound pressure (Table A.10):

Category A: 35 dB(A)
Category B: 40 dB(A)
Category C: 45 dB(A)

C.3.5 *Conference room*

C.3.5.1 *Design assumptions:*

- the occupancy is 0,5 person/(m^2 floor); and
- the cooling load caused by occupants, machines, illumination, solar radiation etc. is 70 W/(m^2 floor).

C.3.5.2 *Thermal design criteria*

	Summer		**Winter**
Operative temperature (Figure A.2):		*Operative temperature (Figure A.2):*	
Category A:	24,5 °C ± 1,0 °C	Category A:	22,0 °C ± 1,0 °C
Category B:	24,5 °C ± 1,5 °C	Category B:	22,0 °C ± 2,0 °C
Category C:	24,5 °C ± 2,5 °C	Category C:	22,0 °C ± 3,0 °C
Mean air velocity (Figure A.3):		*Mean air velocity (Figure A.3):*	
Category A:	0,18 m/s	Category A:	0,15 m/s
Category B:	0,22 m/s	Category B:	0,18 m/s
Category C:	0,25 m/s	Category C:	0,21 m/s

C.3.5.3 *Air quality design criteria*

Alternative 1

Sensory pollution load (Tables A.6 and A.8):

Occupants:	1 × 0,5 =	0,5 olf/(m^2 floor)
Building:		0,1 olf/(m^2 floor)
Total sensory pollution load:		0,6 olf/(m^2 floor)

Required ventilation rate for comfort (Equation (A.2) and Table A.5):

Category A: $Q_c = 10 \times 0{,}6/(1{,}0\text{-}0) \times 1/1 = 6{,}0$ l/s (m^2 floor)
Category B: $Q_c = 10 \times 0{,}6/(1{,}4\text{-}0) \times 1/1 = 4{,}3$ l/s (m^2 floor)
Category C: $Q_c = 10 \times 0{,}6/(2{,}5\text{-}0) \times 1/1 = 2{,}4$ l/s (m^2 floor)

Alternative 2

Based on CO_2, ignoring the building as a pollution source:

Required ventilation (Equation A.3, Table A.6, Figure 8)

Category A: $Q_c = 0{,}5 \times 19/3\,600 \times 460 \times 10^{-6} = 5{,}0$ l/s (m^2 floor)
Category B: $Q_c = 0{,}5 \times 19/3\,600 \times 660 \times 10^{-6} = 3{,}5$ l/s (m^2 floor)
Category C: $Q_c = 0{,}5 \times 19/3\,600 \times 1\,190 \times 10^{-6} = 2{,}0$ l/s (m^2 floor)

Required supply-air flow rate for thermal design:
If an all-air air-conditioning system is used with a supply-air temperature of 14 °C and the cooling load is 70 W/(m^2 floor), the required supply-air flow rate for Category A for the thermal design is 5 l/s (m^2 floor) during summer conditions.

C.3.5.4 *Acoustic design criteria*

Sound pressure (Table A.10):

Category A: 30 dB(A)
Category B: 35 dB(A)
Category C: 40 dB(A)

C.4 Auditorium

C.4.1 *General*

An auditorium is without any external surfaces inside an air-conditioned building. The environmental design criteria specified below should be met under the following assumptions:

C.4.2 *Design assumptions*

a) The building is occupied for 1 to 8 hours per day. The environmental design criteria should be met during the whole time of occupancy.

b) The space in the auditorium is used for a sedentary audience inside this occupied zone: a distance larger than 2,0 m from walls and heating and air terminal devices, and up to a height of 1,8 m above the floor.

c) The occupancy is 1,5 persons/(m^2 floor).

d) The activity of the occupants is mainly sedentary, 1,2 met and the clothing insulation is assumed to be 0,5 clo in the summer and 1,0 clo in the winter.

e) All adjacent spaces have the same temperature as the auditorium.

f) The air temperature is equal to the operative temperature.

g) A mixing ventilation system is applied with a ventilation effectiveness of 1,0 and a turbulence intensity of 40 % in the occupied zone.

h) The cooling load caused by occupants, illumination, etc. is 100 W/(m^2 floor).

i) Low-polluting building materials and furnishing are systematically selected, providing a pollution load of 0,1 olf/(m^2 floor).

j) Smoking is not permitted.

k) The building is situated in an area with excellent outdoor air quality (0 dp) and the levels of outdoor air pollutants are of no health concern.

C.4.3 *Thermal design criteria*

Summer

Operative temperature (Figure A.2):

Category A:	24,5 °C ± 1,0 °C
Category B:	24,5 °C ± 1,5 °C
Category C:	24,5 °C ± 2,5 °C

Mean air velocity (Figure A.3):

Category A:	0,18 m/s
Category B:	0.22 m/s
Category C:	0,25 m/s

Winter

Operative temperature (Figure A.2):

Category A:	22,0 °C ± 1,0 °C
Category B:	22,0 °C ± 2,0 °C
Category C:	22,0 °C ± 3,0 °C

Mean air velocity (Figure A.3):

Category A:	0,15 m/s
Category B:	0,18 m/s
Category C:	0,21 m/s

C.4.4 *Air quality design criteria*

Alternative 1

Sensory pollution load (Table A.6 and Table A.8):

Occupants:	1 × 1,5 =	1,5 olf/(m² floor)
Building:		0,1 olf/(m² floor)
Total sensory pollution load:		1,6 olf/(m² floor)

Required ventilation rate for comfort (Equation (A.2) and Table A.5):

Category A: $Q_c = 10 \times 1{,}6/\ (1{,}0\text{-}0) \times 1/1 = 16{,}0$ l/s (m² floor)
Category B: $Q_c = 10 \times 1{,}6/\ (1{,}4\text{-}0) \times 1/1 = 11{,}4$ l/s (m² floor)
Category C: $Q_c = 10 \times 1{,}6/\ (2{,}5\text{-}0) \times 1/1 = 6{,}4$ l/s (m² floor)

Alternative 2

Based on CO_2, ignoring the building as a pollution source:

Required ventilation (Equation A.3, Table A.6, Figure A.8)

Category A: $Q_c = 1{,}5 \times 19/3\ 600 \times 460 \times 10^{-6} = 15{,}0$ l/s (m² floor)
Category B: $Q_c = 1{,}5 \times 19/3\ 600 \times 660 \times 10^{-6} = 10{,}5$ l/s (m² floor)
Category C: $Q_c = 1{,}5 \times 19/3\ 600 \times 1\ 190 \times 10^{-6} = 6{,}0$ l/s (m² floor)

Required supply-air flow rate for thermal design:

If an all-air air-conditioning system is used with a supply-air temperature of 14 °C and the cooling load is 100 W/(m² floor), the required supply-air flow rate for Category A for the thermal design is 8 l/s (m² floor) during summer conditions.

C.4.5 *Acoustic design criteria*

Sound pressure (Table A.10):

Category A:	30 dB(A)
Category B:	33 dB(A)
Category C:	35 dB(A)

C.5 Restaurant

C.5.1 *General*

A restaurant is planned to be air-conditioned. The environmental design criteria specified below should be met under the following assumptions:

C.5.2 *Design assumptions*

a) The restaurant is occupied from 08:00 h to 23:00 h every day. The environmental design criteria should be met during the occupied hours of a design day.

b) The space in the restaurant building is used for ordinary dining inside this occupied zone; a distance larger than 0,6 m from walls and heating and air terminal devices, and up to a height of 1,8 m above the floor.

c) The occupancy is 0,7 persons/(m^2 floor).

d) The activity of the occupants is mainly sedentary dining and serving (employees), 1,2 met and the clothing insulation is 0,5 clo in summer and 1,0 clo in winter.

e) The window area is 35 % of the exterior wall area with a shading factor of 0,6 and a heat transmission coefficient of 3 $W/m^2 \times °C$.

Walls, ceilings and floors have a heat transmission coefficient of 0,4 $W/m^2 \times °C$.

f) The air temperature is equal to the operative temperature.

g) A mixing ventilation system (supply and return in the ceiling) is applied with a ventilation effectiveness of 1,0 and a turbulence intensity of 40 % in the occupied zone.

h) The cooling load caused by occupants, illumination, solar radiation etc. is 80 W/(m^2 floor).

i) Low-polluting building materials and furnishing are systematically selected, providing a pollution load of 0,1 olf/(m^2 floor).

j) Smoking is not permitted.

k) The building is situated in an area with excellent outdoor air quality (0 dp) and the levels of outdoor air pollutants are of no health concern.

C.5.3 *Thermal design criteria*

	Summer		*Winter*
Operative temperature (Figure A.2):		*Operative temperature (Figure A.2):*	
Category A:	24,5 °C ± 1,0 °C	Category A:	22,0 °C ± 1,0 °C
Category B:	24,5 °C ± 2,0 °C	Category B:	22,0 °C ± 2,5 °C
Category C:	24,5 °C ± 2,5 °C	Category C:	22,0 °C ± 3,5 °C
Mean air velocity (Figure A.3):		*Mean air velocity (Figure A.3):*	
Category A:	0,18 m/s	Category A:	0,15 m/s
Category B:	0,22 m/s	Category B:	0,18 m/s
Category C:	0,25 m/s	Category C:	0,21 m/s

C.5.4 *Air quality design criteria*

Alternative 1

Sensory pollution load (Table A.6 and Table A.8):

Occupants:	$1 \times 0,7 =$	0,7 olf/(m^2 floor)
Building:		0,1 olf/(m^2 floor)
Total sensory pollution load:		0,8 olf/(m^2 floor)

Required ventilation rate for comfort (Equation (A.2) and Table A.5):

Category A: $Q_c = 10 \times 0,8/(1,0\text{-}0) \times 1/1 = 8,0$ l/s (m^2 floor)
Category B: $Q_c = 10 \times 0,8/(1,4\text{-}0) \times 1/1 = 5,7$ l/s (m^2 floor)
Category C: $Q_c = 10 \times 0,8/(2,5\text{-}0) \times 1/1 = 3,2$ l/s (m^2 floor)

Alternative 2

Based on CO_2, ignoring the building as a pollution source:

Required ventilation (Equation (A.3), Table A.6, Figure A.8)

Category A: $Q_c = 0,7 \times 19/3\,600 \times 460 \times 10^{-6} = 7,0$ l/s (m^2 floor)
Category B: $Q_c = 0,7 \times 19/3\,600 \times 660 \times 10^{-6} = 4,9$ l/s (m^2 floor)
Category C: $Q_c = 0,7 \times 19/3\,600 \times 1\,190 \times 10^{-6} = 2,8$ l/s (m^2 floor)

Required supply-air flow rate for thermal design:

If an all-air air-conditioning system is used with a supply-air temperature of 14 °C and the cooling load is 80 W/(m^2 floor), the required supply-air flow rate for Category A for the thermal design is 6 l/s (m^2 floor) during summer conditions.

C.5.5 *Acoustic design criteria*

Sound pressure (Table A.10):

Category A: 35 dB(A)
Category B: 45 dB(A)
Category C: 50 dB(A)

C.6 Classroom

C.6.1 *General*

A classroom in a school building is planned to be mechanically ventilated. The environmental design criteria specified below should be met under the following assumptions:

C.6.2 *Design assumptions*

a) The building is occupied from 08:00 h to 16:00 h during weekdays. Occasionally the building is also occupied during evenings and weekends. The environmental design criteria should be met during the occupied hours of a design day in winter and in summer. 85 % of the occupied hours during the school year will be less severe than the design days.

b) The classroom is utilized for ordinary class work inside this occupied zone: a distance larger than 0,6 m from walls and heating and air terminal devices, and up to a height of 1,8 m above the floor.

c) The occupancy is 0,5 persons/(m^2 floor).

d) The activity of the occupants is mainly sedentary, 1,2 met and the clothing insulation is 1,0 clo in winter and 0,5 clo in summer.

e) The window area is 35 % of the exterior wall area with a shading factor of 0,6 and a heat transmission coefficient of 3 $W/m^2 \times °C$.

Walls, ceilings and floors have a heat transmission coefficient of 0,4 $W/m^2 \times °C$.

f) The air temperature is equal to the operative temperature.

g) A mixing ventilation system (supply and return in the ceiling) is applied with a ventilation effectiveness of 1,0 and a turbulence intensity of 40 % in the occupied zone.

h) The cooling load caused by occupants, illumination, solar radiation etc. is 60 W/m^2 floor.

i) Low-polluting building materials and furnishing are systematically selected, providing a pollution load of 0,1 olf/m^2 floor.

j) Smoking is not permitted.

k) The building is situated in an area with excellent outdoor air quality (0 dp) and the levels of outdoor air pollutants are of no health concern.

C.6.3 *Thermal design criteria*

	Summer	*Winter*
Operative temperature (Figure A.2):		
Category A:	24,5 °C ± 1,0 °C	22,0 °C ± 1,0 °C
Category B:	24,5 °C ± 1,5 °C	22,0 °C ± 2,0 °C
Category C:	24,5 °C ± 2,5 °C	22,0 °C ± 3,0 °C
Mean air velocity (Figure A.3):		
Category A:	0,18 m/s	0,15 m/s
Category B:	0,22 m/s	0,18 m/s
Category C:	0,25 m/s	0,21 m/s

C.6.4 *Air quality design criteria*

Alternative 1

Sensory pollution load (Table A.6 and Table A.8):

Occupants:	$1 \times 0{,}5 =$	0,5 olf/(m^2 floor)
Building:		0,1 olf/(m^2 floor)
Total sensory pollution load:		0,6 olf/(m^2 floor)

Required ventilation rate for comfort (Equation (A.2) and Table A.5):

Category A: $Q_c = 10 \times 0{,}6/(1{,}0\text{-}0) \times 1/1 = 6{,}0$ l/s (m^2 floor)
Category B: $Q_c = 10 \times 0{,}6/(1{,}4\text{-}0) \times 1/1 = 4{,}3$ l/s (m^2 floor)
Category C: $Q_c = 10 \times 0{,}6/(2{,}5\text{-}0) \times 1/1 = 2{,}4$ l/s (m^2 floor)

Alternative 2

Based on CO_2, ignoring the building as a pollution source:

Required ventilation (Equation (A.3), Table A.6, Figure A.8)

Category A: $Q_c = 0{,}5 \times 19/3\,600 \times 460 \times 10^{-6} = 5{,}0$ l/s (m^2 floor)
Category B: $Q_c = 0{,}5 \times 19/3\,600 \times 660 \times 10^{-6} = 3{,}5$ l/s (m^2 floor)
Category C: $Q_c = 0{,}5 \times 19/3\,600 \times 1\,190 \times 10^{-6} = 2{,}0$ l/s (m^2 floor)

Required supply-air flow rate for thermal design:

If an all-air system is used with a supply-air temperature of 14 °C and the cooling load is 60 W/(m^2 floor), the required supply-air flow rate for Category A for the thermal design is 5 l/s (m^2 floor) during summer conditions.

C.6.5 *Acoustic design criteria*

Sound pressure (Table A.10):

Category A: 30 dB(A)
Category B: 35 dB(A)
Category C: 40 dB(A)

C.7 Kindergarten

C.7.1 *General*

A kindergarten is planned to be mechanically ventilated. The environmental design criteria specified below should be met under the following assumptions:

C.7.2 *Design assumptions*

a) The building is occupied from 08:00 h to 16:00 h during weekdays. Occasionally the building is also occupied during evenings and weekends. The environmental design criteria should be met during the occupied hours of a design day in winter and in summer. 80 % of the occupied hours during the annual opening hours will be less severe than the design days.

b) The spaces in the kindergarten are used inside this occupied zone: a distance larger than 0,6 m from walls and heating and air terminal devices, and up to a height of 1,8 m above the floor.

c) The occupancy is 0,5 persons/(m^2 floor).

d) The activity of the occupants is mainly sedentary/standing/playing, 1,4 met and the clothing insulation is 0,5 clo in summer and 1,0 clo in winter.

e) The window area is 50 % of the exterior wall area with a shading factor of 0,6 and a heat transmission coefficient of 3 W/m^2 × °C.

Walls, ceilings and floors have a heat transmission coefficient of 0,4 W/m^2 × °C.

f) The air temperature is equal to the operative temperature.

g) A mixing ventilation system (supply and return in the ceiling) is applied with a ventilation effectiveness of 1,0 and a turbulence intensity of 40 % in the occupied zone.

h) The cooling load caused by occupants, illumination, solar radiation etc. is 60 W/(m^2 floor).

i) Low-polluting building materials and furnishing are systematically selected, providing a pollution load of 0,1 olf/(m^2 floor).

j) No smoking.

k) The building is situated in an area with excellent outdoor air quality (0 dp) and the levels of outdoor air pollutants are of no health concern.

C.7.3 *Thermal design criteria*

	Summer		*Winter*
Operative temperature (Figure A.2):		*Operative temperature (Figure A.2):*	
Category A:	23.5 °C ± 1.0 °C	Category A:	20,0 °C ± 1,0 °C
Category B:	23,5 °C ± 2,0 °C	Category B:	20,0 °C ± 2,5 °C
Category C:	23.5 °C ± 2,5 °C	Category C:	20,0 °C ± 3,5 °C
Mean air velocity (Figure A.3):		*Mean air velocity (Figure A.3):*	
Category A:	0.16 m/s	Category A:	0,13 m/s
Category B:	0.20 m/s	Category B:	0,16 m/s
Category C:	0.24 m/s	Category C:	0,19 m/s

C.7.4 *Air quality design criteria*

Alternative 1

Sensory pollution load (Table A.6 and Table A.8):

Occupants:	1,2 × 0,5 =	0,6 olf/(m^2 floor)
Building:		0,1 olf/(m^2 floor)
Total sensory pollution load:		0,7 olf/(m^2 floor)

Required ventilation rate for comfort (Equation (A.2) and Table A.5):

Category A: $Q_c = 10 \times 0{,}7/(1{,}0\text{-}0) \times 1/1 = 7{,}0$ l/s (m^2 floor)
Category B: $Q_c = 10 \times 0{,}7/(1{,}4\text{-}0) \times 1/1 = 5{,}0$ l/s (m^2 floor)
Category C: $Q_c = 10 \times 0{,}7/(2{,}5\text{-}0) \times 1/1 = 2{,}8$ l/s (m^2 floor)

Alternative 2

Based on CO_2, ignoring the building as a pollution source:

Required ventilation (Equation (A.3), Table A.6, Figure A.8)

Category A: $Q_c = 0{,}5 \times 18/3\,600 \times 460 \times 10^{-6} = 6{,}0$ l/s (m^2 floor)
Category B: $Q_c = 0{,}5 \times 18/3\,600 \times 660 \times 10^{-6} = 4{,}2$ l/s (m^2 floor)
Category C: $Q_c = 0{,}5 \times 18/3\,600 \times 1\,190 \times 10^{-6} = 2{,}4$ l/s (m^2 floor)

Required supply-air flow rate for thermal design:

If an all-air system is used with a supply-air temperature of 14 °C and the cooling load is 60 W/(m^2 floor), the required supply-air flow rate for Category A for the thermal design is 5 l/s (m^2 floor) during summer conditions.

C.7.5 *Acoustic design criteria*

Sound pressure (Table A.10):

Category A: 30 dB(A)
Category B: 40 dB(A)
Category C: 45 dB(A)

C.8 Department store

C.8.1 *General*

The sales area of a department store is planned to be air-conditioned. The environmental design criteria specified below should be met under the following assumptions:

C.8.2 *Design assumptions*

a) The building is occupied from 08:00 h to 18:00 h during weekdays. The environmental design criteria should be met during the occupied hours of a design day. 99 % of the occupied hours will be less severe than the design day.

b) The spaces in the department store are used inside this occupied zone: a distance larger than 1,0 m from walls and heating and air terminal devices, and up to a height of 1,8 m above the floor.

c) The occupancy is 0,15 persons/(m^2 floor).

d) The activity of the occupants is mainly standing work, 1,6 met and the clothing insulation is assumed to be 0,5 clo in summer and 1,0 clo in winter.

e) The window area is 50 % of the exterior wall area with a shading factor of 0,6 and a heat transmission coefficient of 3 W/m^2 × °C.

Walls, ceilings and floors have a heat transmission coefficient of 0,4 W/m^2 × °C.

f) The air temperature is equal to the operative temperature.

g) A mixing ventilation system (supply and return in the ceiling) is applied with a ventilation effectiveness of 1,0 and a turbulence intensity of 40 % in the occupied zone.

h) The cooling load caused by occupants, illumination, solar radiation etc. is 60 W/(m^2 floor).

i) Low-polluting building materials and furnishing are systematically selected. The total pollution load from building and merchandise is 0,2 olf/(m^2 floor).

j) Smoking is not permitted.

k) The building is situated in an area with excellent outdoor air quality (0 dp) and the levels of outdoor air pollutants are of no health concern.

C.8.3 *Thermal design criteria*

	Summer		***Winter***
Operative temperature (Figure A.2):		*Operative temperature (Figure A.2):*	
Category A:	23,0 °C ± 1,0 °C	Category A:	19,0 °C ± 1,5 °C
Category B:	23,0 °C ± 2,0 °C	Category B:	19,0 °C ± 3,0 °C
Category C:	23,0 °C ± 3,0 °C	Category C:	19,0 °C ± 4,0 °C
Mean air velocity (Figure A.3):		*Mean air velocity (Figure A.3):*	
Category A:	0,16 m/s	Category A:	0,13 m/s
Category B:	0,20 m/s	Category B:	0,15 m/s
Category C:	0,23 m/s	Category C:	0,18 m/s

C.8.4 *Air quality design criteria*

Alternative 1

Sensory pollution load (Table A.6 and Table A.8):

Occupants:	1,5 × 1 × 0,15 =	0,22 olf/(m^2 floor)
Building:		0,2 olf/(m^2 floor)
Total sensory pollution load:		0,42 olf/(m^2 floor)

Required ventilation rate for comfort (Equation A.2 and Table A.5):

Category A: $Q_c = 10 \times 0{,}42/(1{,}0\text{-}0) \times 1/1 = 4{,}2$ l/s (m^2 floor)
Category B: $Q_c = 10 \times 0{,}42/(1{,}4\text{-}0) \times 1/1 = 3{,}0$ l/s (m^2 floor)
Category C: $Q_c = 10 \times 0{,}42/(2{,}5\text{-}0) \times 1/1 = 1{,}6$ l/s (m^2 floor)

Alternative 2

Based on CO_2, ignoring the building as a pollution source:

Required ventilation (Equation A.3, Table A.6, Figure A.8)

Category A: $Q_c = 0{,}15 \times 1{,}5 \times 19/3\,600 \times 460 \times 10^{-6} = 2{,}1$ l/s (m^2 floor)
Category B: $Q_c = 0{,}15 \times 1{,}5 \times 19/3\,600 \times 660 \times 10^{-6} = 1{,}5$ l/s (m^2 floor)
Category C: $Q_c = 0{,}15 \times 1{,}5 \times 19/3\,600 \times 1\,190 \times 10^{-6} = 0{,}9$ l/s (m^2 floor)

Required supply-air flow rate for thermal design:

If an all-air air-conditioning system is used with a supply-air temperature of 14 °C and the cooling load is 60 W/(m^2 floor), the required supply-air flow rate for Category A for the thermal design is 5 l/s (m^2 floor) during summer conditions.

C.8.5 *Acoustic design criteria*

Sound pressure (Table A.10):

Category A: 40 dB(A)
Category B: 45 dB(A)
Category C: 50 dB(A)

Annex D (informative)

Thermal data

D.1 Metabolic rate

Metabolic rates for different activities are given in Table D.1.

Further information on metabolic rates is given in ISO 8996.

Table D.1 — Metabolic rates of different activities

Activity	Metabolic rate	
	W/m^2	met
Reclining	46	0,8
Seated, relaxed	58	1,0
Sedentary activity (office, dwelling, school, laboratory)	70	1,2
Standing, light activity (shopping, laboratory, light industry)	93	1,6
Standing, medium activity (shop assistant, domestic work, machine work)	116	20
Walking on the level: 2 km/h 3 km/h 4 km/h 5 km/h	 110 140 165 200	 1,9 2,4 2,8 3,4

D.2 Clothing insulation

The clothing insulation (I_{cl}) can be estimated directly from the data presented in Table D.2 for typical combinations of garments, or indirectly, by summation of the partial insulation values for each item of clothing (Table D.3). For sedentary persons, who spend a lot of time sitting, the chair may contribute an additional insulation of 0-0,4 clo. Further information is given in ISO 9920. Also listed in Table D.3 are the changes of optimum operative temperature necessary to maintain a thermal sensation at neutral when various garments are added (or removed) at light mainly sedentary activity (1,2 met).

Table D.2 — Thermal insulation for typical combinations of garments

Work clothing	I_{cl}		Daily wear clothing	I_{cl}	
	clo	$m^2\,°C/W$		clo	$m^2\,°C/W$
Underpants, boiler suit, socks, shoes	0,7	0,11	Panties, T-shirt, shorts, light socks, sandals	0,3	0,05
Underpants, shirt, trousers, socks, shoes	0,75	0,115	Panties, petticoat, stockings, light dress with sleeves, sandals	0,45	0,07
Underpants, shirt, boiler suit, socks, shoes	0,8	0,125	Underpants, shirt with short sleeves, light trousers, light socks, shoes	0,5	0,08
Underpants, shirt, trousers, jacket, socks, shoes	0,85	0,135	Panties, stockings, shirt with short sleeves, skirt, sandals	0,55	0,085
Underpants. shirt, trousers, smock, socks, shoes	0,9	0,14	Underpants, shirt, light-weight trousers, socks, shoes	0,6	0,095
Underwear with short sleeves and legs, shirt, trousers, jacket, socks, shoes	1	0,155	Panties, petticoat, stockings, dress, shoes	0,7	0,105
Underwear with short legs and sleeves, shirt, trousers, boiler suit, socks, shoes	1,1	0,17	Underwear, shirt, trousers, socks, shoes	0,7	0,11
Underwear with long legs and sleeves, thermojacket, socks, shoes	1,2	0,185	Underwear, track suit (sweater and trousers), long socks, runners	0,75	0,115
Underwear with short sleeves and legs, shirt, trousers, jacket, thermojacket, socks, shoes	1,25	0,19	Panties, petticoat, shirt, skirt, thick knee-socks, shoes	0,8	0,12
Underwear with short sleeves and legs, boiler suit,thermojacket and trousers, socks, shoes	1,4	0,22	Panties, shirt, skirt, roundneck sweater, thick knee-socks, shoes	0,9	0,14
Underwear with short sleeves and legs, shirt, trousers, jacket, thermojacket and trousers, socks, shoes	1,55	0,225	Underpants, singlet with short sleeves, shirt, trousers, V-neck sweater, socks, shoes	0,95	0,145
Underwear with short sleeves and legs, shirt, trousers, jacket, heavy quilted outer jacket and overalls, socks, shoes	1,85	0,285	Panties, shirt, trousers, jacket, socks, shoes	1	0,155
Underwear with short sleeves and legs, shirt, trousers, jacket, heavy quilted outer jacket and overalls, socks, shoes, cap, gloves	2	0,31	Panties, stockings, shirt, skirt, vest, jacket	1	0,155
Underwear with long sleeves and legs, thermojacket and trousers, outer thermojacket and trousers, socks, shoes	2,2	0,34	Panties, stockings, blouse, long skirt, jacket, shoes	1,1	0,17

Table D.2 — Thermal insulation for typical combinations of garments (*continued*)

Work clothing	I_{cl}		Daily wear clothing	I_{cl}	
	clo	m² °C/W		clo	m² °C/W
Underwear with long sleeves and legs, thermojacket and trousers, parka with heavy quilting, overalls with heavy quilting, socks, shoes, cap, gloves	2,55	0,395	Underwear, singlet with short sleeves, shirt, trousers, jacket, socks, shoes	1,1	0,17
—	—	—	Underwear, singlet with short sleeves, shirt trousers, vest, jacket, socks, shoes	1,15	0,18
—	—	—	Underwear with long sleeves and legs, shirt, trousers, V-neck sweater, jacket, socks, shoes	1,3	0,2
—	—	—	Underwear with short sleeves and legs, shirt, trousers, vest, jacket, coat, socks, shoes	1,5	0,23

Table D.3 — Thermal insulation for individual garments

Garment description	Thermal insulation clo	Change of optimum operative temperature °C
Underwear		
Panties	0,03	0,2
Underpants with long legs	0,10	0,6
Singlet	0,04	0,3
T-shirt	0,09	0,6
Shirt with long sleeves	0,12	0,8
Panties and bra	0,03	0,2
Shirts and blouses		
Short sleeves	0,15	0,9
Light-weight, long sleeves	0,20	1,3
Normal, long sleeves	0,25	1,6
Flannel shirt, long sleeves	0,30	1,9
Light-weight blouse, long sleeves	0,15	0,9
Trousers		
Shorts	0,06	0,4
Light-weight	0,20	1,3
Normal	0,25	1,6
Flannel	0,28	1,7
Dresses and skirts		
Light skirts (summer)	0,15	0,9
Heavy skirt (winter)	0,25	1,6
Light dress, short sleeves	0,20	1,3
Winter dress, long sleeves	0,40	2,5
Boiler suit	0,55	3,4
Sweaters		
Sleeveless vest	0,12	0,8
Thin sweater	0,20	1,3
Sweater	0,28	1,7
Thick sweater	0,35	2,2
Jackets		
Light, summer jacket	0,25	1,6
Jacket	0,35	2,2
Smock	0,30	1,9
High-insulative, fibre-pelt		
Boiler suit	0,90	5,6
Trousers	0,35	2,2
Jacket	0,40	2,5
Vest	0,20	1,3
Outdoor clothing		
Coat	0,60	3,7
Down jacket	0,55	3,4
Parka	0,70	4,3
Fibre-pelt overalls	0,55	3,4
Sundries		
Socks	0,02	0,1
Thick, ankle socks	0,05	0,3
Thick, long socks	0,10	0,6
Nylon stockings	0,03	0,2
Shoes (thin soled)	0,02	0,1
Shoes (thick soled)	0,04	0,3
Boots	0,10	0,6
Gloves	0,05	0,3
Simple chair	0,10	0,6
Upholstered office chair	0,20	1,3
Upholstered chair with back and sides	0,30	1,9

Annex E (informative)

Extract from "World Health Organization Regional Publication: Air quality guidelines for Europe"[1)]

Summary of the guidelines

The term "guidelines" in the context of this book implies not only numerical values (guideline values), but also any kind of guidance given. Accordingly, for some substances the guidelines encompass recommendations of a more general nature that will help to reduce human exposure to harmful levels of air pollutants. For some pollutants no guideline values are recommended, but risk estimates are indicated instead. Table 1 summarizes the different endpoints on which guideline values and carcinogenic risk estimates have been based for organic and inorganic substances, showing that all relevant biological effects (endpoints) were evaluated and sometimes more than one endpoint was considered for guideline recommendations.

The numerical guideline values and the risk estimates for carcinogens (Tables 2 to 5) should be regarded as the shortest possible summary of a complex scientific evaluation process. Scientific results are an abstraction of real life situations, and this is even more true for numerical values and estimates based on such results. Numerical guideline values, therefore, are not to be regarded as separating the acceptable from the unacceptable, but rather as indications. They are proposed in order to help avoid major discrepancies in reaching the goal of effective protection against recognized hazards. Moreover, numerical guidelines for different substances are not directly comparable. Variations in the quality and extent of the scientific information and in the nature of critical effects result in guideline values which are only comparable between pollutants to a limited extent.

Owing to the different bases for evaluation, the numerical values for the various air pollutants should be considered in the context of the accompanying scientific documentation giving the derivation and scientific considerations. Any *isolated* interpretation of numerical data should therefore be avoided and guideline values should be used and interpreted in conjunction with the information contained in the appropriate sections.

It is important to note that guidelines are for individual chemicals. Pollutant mixtures can yield differing toxicities, but data are at present insufficient for guidelines relating to mixtures (except that of sulfur dioxide and suspended particulates) to be laid down.

Guideline values based on effects other than cancer

The guideline values for individual substances based on effects other than cancer and odour are given in Table 2. Guideline values for combined exposure to sulfur dioxide and particulate matter are indicated in Table 3.

[1)] The extract in Annex E is quoted from WHO Regional Publications, European Series No. 23. 1987.

The emphasis in the guidelines is placed on exposure, since this is the element that can be controlled to lessen dose and hence lessen response. As stated earlier, the starting point for the derivation of guideline values was to define the lowest concentration at which adverse effects are observed. On the basis of the body of scientific evidence and judgements of protection (safety) factors, the guideline values were established.

However, compliance with the guideline values does not guarantee the absolute exclusion of undesired effects at levels below the guideline values. It means only that guideline values have been established in the light of current knowledge and that protection factors based on the best scientific judgements have been incorporated, though some uncertainty cannot be avoided.

For some of the substances, a direct relationship between concentrations in air and possible toxic effects is very difficult to establish. This is especially true of those metals for which a greater body burden results from ingestion than from inhalation. For instance, available data show that the food chain is, for most people, the critical route of non-occupational exposure to lead and cadmium. On the other hand, airborne lead and cadmium may contribute significantly to the contamination of food by these metals. Complications of this kind were taken into consideration and an attempt was made to develop air quality guidelines which would also prevent those toxic effects of air pollutants that resulted from uptake through both ingestion and inhalation.

For certain compounds, such as organic solvents, the proposed health-related guidelines are orders of magnitude higher than current ambient levels. The fact that existing environmental levels for some substances are much lower than the guideline levels by no means implies that pollutant burdens may be increased up to the guideline values. Any level of air pollution is a matter of concern, and the existence of guideline values never means a licence to pollute.

The approach taken in the preparation of the air quality guidelines was to use expert panels to evaluate data on the health effects of individual compounds. As part of this approach, each chemical is considered in isolation. Inevitably, there is little emphasis on such factors as interaction between pollutants that might lead to additive or synergistic effects and on the environmental fate of pollutants (e.g. the role of solvents in atmospheric photochemical processes leading to the formation or degradation of ozone the formation of acid rain and the propensity of metals and trace elements to accumulate in environmental niches). These factors militate strongly against allowing a rise in ambient pollutant levels. Many uncertainties still remain, particularly regarding the ecological effects of pollutants, and therefore efforts should be continued to maintain air quality at the best possible level.

Unfortunately, the situation with regard to actual environmental levels and proposed guideline values for some substances is just the opposite, i.e. guideline values are below the existing levels in some parts of Europe. For instance, the guideline values recommended for major urban air pollutants such as nitrogen oxides, ozone and sulfur oxides point to the need for a significant reduction of emissions in some areas.

Table 1. Established guideline values and risk estimates

Substance	IARC Group classification	Risk estimate based on carcinogenic endpoint	Guideline value(s) based on:		
			toxicological endpoint	sensory effects or annoyance reaction	ecological effects
Organic substances					
Acrylonitrile	2A	x			
Benzene	1	x			
Carbon disulfide	–		x	x	
1,2-Dichloroethane	–[a]		x		
Dichloromethane	–[a]		x		
Formaldehyde	2B		x		
Polynuclear aromatic hydrocarbons (Benzo[*a*]pyrene)	–[b]	x			
Styrene	3		x	x	
Tetrachloroethylene	3		x	x	
Toluene	–		x	x	
Trichloroethylene	3		x		
Vinyl chloride	1	x			

Table1. Established guideline values and risk estimates (continued)

Substance	IARC Group classification	Risk estimate based on carcinogenic endpoint	Guideline value(s) based on:		
			toxicological endpoint	sensory effects or annoyance reaction	ecological effects
Inorganic substances					
Arsenic	1	x			
Asbestos	1	x			
Cadmium	2B		x		
Carbon monoxide	–		x		
Chromium (VI)	1	x			
Hydrogen sulfide	–		x	x	
Lead	3		x		
Manganese	–		x		
Mercury	–		x		
Nickel	2A[c]	x			
Nitrogen dioxide	–		x		x
Ozone/photochemical oxidants	–		x		x
Radon	-	x			
Sulfur dioxide and particulate matter	-		x		x
Vanadium	-		x		

[a] Not classified, but sufficient evidence of carcinogenicity in experimental animals.
[b] Not classified, but sufficient evidence of carcinogenicity of PAH in humans in some occupational exposures (*IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans*, Vol. 34). Sufficient evidence of carcinogenicity for benzo[*a*]pyrene in animal studies. Benzo[*a*]pyrene is present as a component of the total content of polycyclic aromatic hydrocarbons in the environment (*IARC Monographs on the Evaluation of the* Carcinogenic *Risk of Chemicals to Humans* Vol. 32).
[c] Exposures from nickel refineries are classified in Group 1.

Table 2. Guideline values for individual substances based on effects other than cancer or odour/annoyance[a]

Substance	Time-weighted average	Averaging time	Chapter
Cadmium	1–5 ng/m^3	1 year (rural areas)	19
	10–20 ng/m^3	1 year (urban areas)	
Carbon disulfide	100 µg/m^3 [b]	24 hours	7
Carbon monoxide	100 mg/m^3 [b]	15 minutes	20
	60 mg/m^3 [b]	30 minutes	
	30 mg/m^3 [b]	1 hour	
	10 mg/m^3	8 hours	
1.2-Dichloroethane	0.7 mg/m^3	24 hours	8
Dichloromethane (Methylene chloride)	3 mg/m^3	24 hours	9
Formaldehyde	100 µg/m^3	30 minutes	10
Hydrogen sulfide	150 µg/m^3	24 hours	22
Lead	0.5–1.0 µg/m^3	1 year	23
Manganese	1 µg/m^3	1 year [c]	24
Mercury	1 µg/m^3 [d]	1 year	25
	(indoor air)		
Nitrogen dioxide	400 µg/m^3	1 hour	27
	150 µg/m^3	24 hours	
Ozone	150–200 µg/ m^3	1 hour	28
	100–120 µg/ m^3	8 hours	
Styrene	800 µg/ m^3	24 hours	12
Sulfur dioxide	500 µg/ m^3	10 minutes	30
	350 µg/ m^3	1 hour	
Sulfuric acid	– [e]	–	30
Tetrachloroethylene	5 mg/ m^3	24 hours	13
Toluene	8 mg/ m^3	24 hours	14
Trichloroethylene	1 mg/ m^3	24 hours	15
Vanadium	1 µg/ m^3	24 hours	31

a Information from this table should not be used without reference to the rationale given in the chapters indicated.
b Exposure at these concentrations should be for no longer than the indicated times and should not be repeated within 8 hours.
c Due to respiratory irritancy it would be desirable to have a short term guideline, but the present data base does not permit such estimations.
d The guideline value is given only for indoor pollution: no guidance is given on outdoor concentrations (via deposition and entry into the food chain) that might be of indirect relevance.
e See Chapter 30.

Note. When air levels in the general environment are orders of magnitude lower than the guideline values, present exposures are unlikely to present a health concern. Guideline values in those cases are directed only to specific release episodes or specific indoor pollution problems

Table 3. Guideline values for combined exposure to sulfur dioxide and particulate matter[a)]

	Averaging time	Sulfur dioxide ($\mu g/m^3$)	Reflectance assessment: black smoke[b] ($\mu g/m^3$)	Gravimetric assessment: Total suspended particulates (TSP)[c] ($\mu g/m^3$)	Gravimetric assessment: Thoracic particles (TP)[d] ($\mu g/m^3$)
Short term	24 hours	125	125	120[e]	70[e]
Long term	1 year	50	50	–	–

[a] No direct comparisons can be made between values for particulate matter in the right- and left-hand sections of this table, since both the health indicators and the measurement methods differ. While numerically TSP/TP values are generally greater than those of black smoke there is no consistent relationship between them, the ratio of one to the other varying widely from time to time and place to place, depending on the nature of the sources.

[b] Nominal $\mu g/m^3$ units, assessed by reflectance. Application of the black smoke value is recommended only in areas where coal smoke from domestic fires is the dominant component of the particulates. It does not necessarily apply where diesel smoke is an important contributor.

[c] TSP: measurement by high volume sampler, without any size selection.

[d] TP: equivalent values as for a sampler with ISO–TP characteristics (having 50 % cut-off point at 10 µm); estimated from TSP values using site-specific TSP/ISO–TP ratios.

[e] Values to be regarded as tentative at this stage, being based on a single study (involving sulfur dioxide exposure also).

For substances with malodorous properties at concentrations below those where toxic effects occur, guideline values likely to protect the public from odour nuisance were established; these were based on data provided by expert panels and field studies (Table 4). In contrast to other air pollutants, odorous substances in ambient air often cannot be determined easily and systematically by analytical methods because the concentration is usually very low. Furthermore, odours in the ambient air frequently result from a complex mixture of substances and it is difficult to identify individual ones; future work may have to concentrate on odours as perceived by individuals rather than on separate odorous substances.

Table 4. Rationale and guideline values based on sensory effects or annoyance reactions using an averaging time of 30 minutes

Substance	Detection threshold	Recognition threshold	Guideline value
Carbon disulfide in viscose emissions			20 µg/m³
Hydrogen sulfide	0.2-2.0 µg/m³	0,6 - 6,0 µg/m³	7 µg/m³
Styrene	70 µg/m³	210-280 µg/m³	70 µg/m³
Tetrachloroethylene	8 mg/m³	24-32 mg/m³	8 mg/m³
Toluene	1 mg/m³	10 mg/m³	1 mg/m³

Guidelines based on carcinogenic effects

In establishing criteria upon which guidelines could be based, it became apparent that carcinogens and non-carcinogens would require different approaches. These are determined by theories of carcinogenesis which postulate that there is no threshold for effects (i.e. that there is no safe level). Therefore, risk managers are faced with two decisions: either to prohibit a chemical or to regulate it at levels that result in an acceptable degree of risk. Indicative figures for risk and exposure assist the risk manager to reach the latter decision. Therefore, air quality guidelines are indicated in terms of incremental unit risks in respect of those carcinogens for which at least limited evidence of carcinogenicity in humans exists (Table 5).

Table 5. Carcinogenic risk estimates based on human studies[a]

Substance	IARC Group classification	Unit risk[b]	Site of tumour
Acrylonitrile	2A	2×10^{-5}	lung
Arsenic	1	4×10^{-3}	lung
Benzene	1	4×10^{-6}	blood (leukaemia)
Chromium (VI)	1	4×10^{-2}	lung
Nickel	2A	4×10^{-4}	lung
Polynuclear aromatic hydrocarbons (carcinogenic fraction)[c]		9×10^{-2}	lung
Vinyl chloride	1	1×10^{-6}	liver and other sites

[a] Calculated with average relative risk model.
[b] Cancer risk estimates for lifetime exposure to a concentration of 1 μg/m^3.
[c] Expressed as benzo[*a*]pyrene (based on benzo[*a*]pyrene concentration of 1 μg/m^3 in air as a component of benzene-soluble coke-oven emissions).

Separate consideration is given to risk estimates for asbestos (Table 6) and radon daughters (Table 7) because they refer to different physical units and are indicated in the form of ranges.

Unfortunately, the recent reclassification of dichloromethane by IARC has not allowed sufficient time to publish a detailed risk estimate which takes into account important information on the metabolism of the compound. The risk estimate for cancer from the animal bioassay is not used for this reason in the guidelines.

Table 6. Risk estimates for asbestos[a]

Concentration	Range of lifetime risk estimates	
500 F* /m^3 (0.0005 F/ml)	10^{-6}–10^{-5}	(lung cancer in a population where 30% are smokers)
	10^{-5}–10^{-4}	(mesothelioma)

[a] See Chapter 18 for an explanation of these figures.

Note. F* = fibres measured by optical methods.

Table 7. Risk estimates and recommended action level[a] for radon daughters

Exposure	Lung cancer excess lifetime risk estimate	Recommended level for remedial action in buildings
1 Bq/m^3 EER	(0.7×10^{-4}) - (2.1×10^{-4})	≥100 Bq/m^3 EER (annual average)

[a] See Chapter 29 for an explanation of these figures and for further information.

Formaldehyde represents a chemical for which cancer bioassays in rats have resulted in non-linear exposure response curves. The non-linearity of the tumour incidence with exposure concentrations led Starr & Buck to introduce the "delivered dose" (amount of formaldehyde covalently bound to respiratory mucosal DNA) as the measure of exposure into several low-dose extrapolation models. Results showed considerable differences in the ratio between risk estimates based on the administered dose and those based on the delivered dose, with a great variance of ratios between models. Since estimates vary because of the inherent differences in approach, cancer risk estimates are referred to but not used for the guidelines. In addition, such estimates should be compared with human epidemiological data when an informed judgement has to be made.

The evidence for carcinogenicity of 1,2-dichloroethane in experimental animals is sufficient, being based on ingestion data. No positive inhalation bioassays are available. Consequently, an extrapolation from the ingestion route to the inhalation

[a] Starr, T. B. & Buck, R. D. The importance of delivered dose in estimating low-dose cancer risk from inhalation exposure to formaldehyde. *Fundamental and applied laxicology*, 4: *740-753 (1984).*

route is needed to provide a cancer risk estimate from the bioassay data. Such extrapolations are best conducted when detailed information is available on the kinetics of metabolism, distribution and excretion. Two estimates calculated from data on oral studies are provided for the risk of cancer through inhalation of 1,2-dichloroethane, but they lack detailed data for the route-to-route extrapolation and are not used in the guidelines.

It is important to note that quantitative risk estimates may give an impression of accuracy which in fact they do not have. An excess of cancer in a population is a biological effect and not a mathematical function, and uncertainties of risk estimation are caused not only by inadequate exposure data but also, for instance, by the fact that specific metabolic properties of agents are not reflected in the models. Therefore, the guidelines do not indicate that a specified lifetime risk is virtually safe or acceptable.

Table 8. Guideline values for individual substances based on effects on terrestrial vegetation

Substance	Guideline value	Averaging time	Remarks
Nitrogen dioxide	95 μg/m³ 30μg/m³	4 hours 1 year	In the presence of SO_2 and O_3 levels which are not higher than 30μg/m³ (arithmetic annual average) and 60 μg/m³ (average during growing season) respectively
Total nitrogen deposition	3 g/m²	1 year	Sensitive ecosystems are endangered above this level
Sulfur dioxide	30μg/m³ 100μg/m³	1 year 24 hours	Insufficient protection in the case of extreme climatic and topographic conditions
Ozone	200μg/m³ 65μg/m³ 60μg/m³	1 hour 24 hours averaged over growing season	
Peroxyacetylnitrate	300μg/m³ 80μg/m³	1 hour 8 hours	

The decision on the acceptability of a certain risk should be taken by the national authorities in the context of a broader risk management process. Risk estimate figures should not be applied in isolation when regulatory decisions are being made; combined with data on exposure levels and individuals exposed, they may be a useful contribution to risk assessment. Risk assessment can then be used together with technological, economic and other considerations in the risk management process.

Guidelines based on ecological effects on vegetation

Although the main objective of the air quality guidelines is the direct protection of human health, it was decided that ecological effects of air pollutants on vegetation should also be considered. The effects of air pollutants on the natural environment are of special concern when they occur at concentrations lower than those that damage human health. In such cases, air quality guidelines based only on effects on human health would allow for environmental damage that might indirectly affect human well-being.

It should be understood that the pollutants selected (SO_x, NO_x and ozone/photochemical oxidants) (Table 8) are only a few of a larger category of air pollutants that may adversely affect the ecosystem. Furthermore, the effects which were considered are only part of the spectrum of ecological effects. Effects on aquatic ecosystems were not evaluated, nor were effects on animals taken into account. Nevertheless, the available information indicates the importance of these pollutants and of their effects on terrestrial vegetation in the context of the European Region.

Annex F (informative)

Ventilation effectiveness

To estimate the ventilation effectiveness, it is often useful to divide a space into two zones: one is the air supply zone and the other is the rest of the room. In mixing ventilation the supply zone is usually above the breathing zone. The best conditions are achieved when the mixing is so efficient that the two zones are transformed into one. In displacement ventilation there is a supply zone, occupied by people, and an exhaust zone above. The best conditions are achieved when there is minimal mixing between exhaust and supply zone.

The values in Table F.1 consider the impact of air distribution and supply-air temperature but not of the location of the pollution sources in the space. The pollution sources are assumed to be evenly distributed throughout the ventilated space. If the effectiveness of a given displacement ventilation system is unknown, an effectiveness of one can be assumed.

For a low-polluting building (Table 1, Table A.8, and Table C.1), dominating surface materials should be from Category M1 and no significant area should be from Category M3. A certain amount of materials may be from Category M2 (Finnish guidelines allow 20 %). Only office machines with an insignificant pollution load should be used.

A building that does not fulfil the above requirements is not a low-polluting building (Table C.1).

Further guidelines on the design, maintenance and operation of HVAC systems and on construction and cleanliness in low-polluting buildings is given in the 1995 FiSIAQ [5]classification.

Further guidance on emissions from materials in low-polluting buildings is provided in the 1991 SCANVAC guidelines and specifications [4].

Annex H (informative)

Bibliography

[1] World Health Organization. *Air quality guidelines for Europe*. Copenhagen: 1987, p.22.

[2] Commission of EC. "Indoor air quality and its impact on man". *In: Guidelines for ventilation requirements in buildings. European concerted action*. EC Report No. 11. Brussels: 1992.

[3] European Audit Project to optimize Indoor Air Quality and Energy Consumption in Office Buildings, Delft: 1992-1995.

[4] SCANVAC. *Classified indoor climate systems. Guidelines and specifications*. Stockholm: 1991.

[5] FiSIAQ. *Classification of indoor climate, construction, and finishing materials*. Helsinki: 1995.

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