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Building environment design — Indoor air quality — Methods of expressing the quality of indoor air for human occupancy

Conception de l'environnement des bâtiments — Qualité de l'air intérieur — Méthodes d'expression de la qualité de l'air intérieur pour une occupation humaine

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16814 was prepared by Technical Committee ISO/TC 205, *Building environment design*.

Introduction

This document is one of a series of International Standards intended for use in the design of buildings and heating, ventilation and air conditioning systems. This series of International Standards specifies the methods of deriving design criteria for new buildings and systems and the retrofit of existing buildings for acceptable indoor environment. The indoor environment includes thermal, acoustic and lighting conditions, and indoor air quality (IAQ).

This International Standard covers methods of expressing IAQ and incorporating the goal of achieving good IAQ into the design process.

This International Standard recognizes that local laws, directives and regulations always apply and this document allows a compliance path which is consistent with such requirements.

The framework is established by the general principle documents.

This document does not prescribe a specific method but rather refers to existing methods in published standards and guidance, as referenced in this document. The referenced methods can be used to specify ventilation rates and other design requirements. The methods have in common the fact that they are based on a consideration of human health and/or comfort requirements. Therefore, the aim of the methods is to control indoor air pollutants to concentration levels below which, under the prevailing hygro-thermal conditions, the pollutants do not have the potential to

— cause a significant risk of adverse health effects,

— adversely affect the comfort of the majority of occupants.

The pollutants considered include human bioeffluents, which have often been the principal consideration for IAQ and ventilation, but also all groups and sources of pollutants that can reasonably be anticipated to occur in the building being designed. The pollutants to be considered can, depending on the sources present, include

— volatile organic compounds (VOCs) and other organics, such as formaldehyde,

— environmental tobacco smoke (ETS),

— radon,

— other inorganic gases, such as ozone, carbon monoxide and oxides of nitrogen,

— viable particles, including viruses, bacteria and fungal spores,

— non-viable biological pollutants, such as particles of mites or fungi and their metabolic products,

— non-viable particles, such as dusts and fibres.

In addition, carbon may be considered as an indicator of the ventilation rate rather than as a health risk in its own right.

Depending on the method selected, the designer can apply a range of approaches to achieve a good IAQ. In addition to the provision of ventilation, some consideration is given to sources of pollution and their control. When specific contaminant sources are present, it is necessary to consider alternative or additional control measures, such as air cleaning or local exhaust ventilation.

Again, depending on the method selected, the designer has the option of setting different target levels of IAQ. Furthermore, different methods can lead to different decisions in relation to, for example, ventilation rate. It is also true that different designers can reach different decisions, even when using the same method, where the method requires the designer to make assumptions or interpretations. Nevertheless, following a rational and documented process is expected to (a) enhance the design and (b) make it easier to address any problems that do arise and incorporate experience gained into future designs.

NOTE See Reference [44] for WHO recommendations on smoking areas in buildings.

Building environment design — Indoor air quality — Methods of expressing the quality of indoor air for human occupancy

1 Scope

This International Standard is intended

— to specify methods to express the quality of indoor air suitable for human occupancy,

— to allow several acceptable target levels of IAQ, depending on local requirements, constraints and expectations.

This International Standard applies to

— the design of new buildings and their systems and the retrofit of existing buildings and systems,

— indoor environments where the major concern is that of human occupants,

— buildings having any combination of mechanical and natural ventilation,

— commercial and institutional buildings.

This International Standard does not apply to residential buildings, industrial buildings and hospitals although those parts of such buildings that are similar to commercial buildings are covered.

The requirements of this International Standard might not achieve acceptable IAQ for all people in all buildings, due to one or more of the following sources of uncertainty.

— The outdoor air brought into the building can be unacceptable or might not be adequately cleaned.

— Indoor air has a wide diversity of sources and contaminants.

— There are many factors that affect occupant perception and acceptance of IAQ, such as air temperature, humidity, noise, odours, lighting and psychological stress.

— There is a range of susceptibility and preference in the population.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16813, *Building environment design — Indoor environment — General principles*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
acceptable IAQ
air in an occupied space toward which a substantial majority of occupants express no dissatisfaction and that is not likely to contain contaminants at concentrations leading to exposures that pose a significant health risk

3.2
acceptable perceived IAQ
air in an occupied space toward which a substantial majority of occupants express no dissatisfaction on the basis of odour and sensory irritation

NOTE Acceptable perceived IAQ is necessary, but not sufficient, to meet acceptable IAQ.

3.3
adapted person
occupant
person who has occupied a space for a sufficient period of time to become adapted to the odours in a space

3.4
air change effectiveness
measure of the effectiveness of outdoor air distribution to the breathing level within the ventilated space

3.5
air change rate
air flow rate to a space, expressed as volume per unit time, divided by the volume of the space in consistent units

NOTE Air change rate is often expressed as air changes per hour.

3.6
air cleaning
process that removes or controls particulate (chemical or microbial) or gaseous contaminants in the air, usually carried out by equipment

3.7
airflow rate

3.7.1
mass airflow rate
q_{m}
flow of air, expressed in units of mass, passing a given plane divided by time

3.7.2
volume airflow rate
q_{V}
flow of air, expressed in units of volume, passing a given plane divided by time

3.8
biological contaminant
biocontaminant
any micro-organism or part of a living organism or substance of biological origin capable of producing an adverse effect on human health or discomfort or damage to human property

NOTE Biological contaminants do include microbial contaminants and other substances, such as insects or dander.

3.9
design documents
drawing, specification, project manual, and other volumes used to document construction requirements and basis of design

3.10
dilution index
DI
ratio of the removal of a contaminant from an enclosure to the rate of its generation

NOTE An enclosure with a higher dilution index represents a less contaminated enclosure. Dilution indices are calculated for each contaminant generated within the enclosure and the lowest DI value applied.

3.11
emission
⟨building environment design⟩
release of contaminant(s) from indoor source(s) into indoor air

3.12
emission factor
ratio of the rate at which an air pollutant is entitled as a result of some activity, to the rate of that activity

NOTE 1 Adapted from ISO 4225:1994 [46].

NOTE 2 The point or area from which the discharge takes place is called the “source”. The term is used to describe the discharge and the rate of discharge. The term can also be applied to noise, heat, etc.

3.13
emission rate
mass (or other physical quality) of pollutant transferred into the atmosphere per unit time

[ISO 4225:1994 [46]]

3.14
enclosure
individual room, space or part thereof

3.15
environmental tobacco smoke
ETS
particulate and vapour-phase contaminants emitted to the atmosphere during the smoking of tobacco products, including side-stream smoke and exhaled mainstream smoke, also known as second-hand smoke (SHS)

3.16
exhaust air
air, other than recirculated air, removed from an enclosure and discharged to the atmosphere

3.17
guideline value
concentration of a pollutant in the air, below which the risk for occurrence of adverse health effects is negligibly low

NOTE It is linked to a time-averaged value.

3.18
HVAC system
system that provides heating, ventilation or air conditioning for buildings

3.19
indoor air
air within an enclosed space, e.g. dwelling or public building

[ISO 4225:1994 [46]]

3.20
infiltration air
uncontrolled passage of air into a space through leakage paths in the building envelope

3.21
local exhaust
extraction of objectionable or hazardous contaminants close to the source and discharged safely to the external atmosphere

3.22
mechanical ventilation
ventilation provided by mechanically powered equipment

3.23
microbial contaminant
fungal, bacterial, or viral organisms, toxins they produce, or particles bearing such organisms or toxins that are airborne or deposited on indoor surfaces and that can cause disease, irritation, allergic reaction, discomfort or damage to human property

3.24
natural ventilation
ventilation through leakage paths (infiltration) and intentional openings (ventilation) in the building envelope or room enclosure, which relies on pressure differences without the aid of powered air-moving components

3.25
occupancy density
number of persons in a space, per unit of net occupiable area

NOTE Expressed in units of persons per square metre or persons per cubic metre.

3.26
occupational exposure limit
occupational exposure standard value
OEL
values set by competent national authorities or other relevant national institutions as limits for concentrations of hazardous compounds in workplace air to prevent adverse health effects on healthy adult workers

3.27
occupational exposure time-weighted average values
ES-TWA
airborne concentration standard values set by competent national authorities as limits for time-weighted average (TWA) concentration of hazardous compounds over an 8/h working day, for a 5/day working week

3.28
occupied zone
area designed for occupancy that is dependent on the geometry and the use of the room and specified case by case

NOTE Usually used only for areas designed for human occupancy and defined as a volume of air that is confined by horizontal and vertical planes. The vertical planes are usually parallel with the walls of the room.

3.29
odour
quality of a substance that stimulates the sense of smell

NOTE Adapted from ISO 4225:1994 [46].

3.30
outdoor air intake
any opening through which outdoor air is admitted

3.31
outdoor air
air entering the system, or opening from outdoors before any air treatment

3.32
particulate matter
solid or liquid particles in air, typically in the size range 0,01 µm to 100 µm in diameter

NOTE PM_{10} is particulate matter smaller than 10 µm in aerodynamic diameter.

3.33
perceived air quality
PAQ
quality of the air perceived by the occupants and expressed by the percentage of persons that perceive the air quality as unacceptable (percent dissatisfied)

3.34
relative humidity
mass of water vapour in the air by volume divided by mass of water vapour by volume at saturation at the same temperature

3.35
recirculated air
air removed from a space and reused as supplied air

3.36
respirable particle
particle that can penetrate into, and be deposited in, the nonciliated portion of the lung

3.37
sensory pollution load
pollution load caused by those pollution sources that have an impact on the perceived air quality

NOTE The load is often expressed by a sensory unit, the olf.

3.38
sink
object on which contaminants are deposited and remain, either permanently or temporarily

NOTE Sinks can become sources when they release deposited contaminants.

3.39
source
persons, materials or processes (activities) from which indoor air contaminants are released

NOTE A source can also be a route of entry of contaminants from outdoor (e.g. air, soil, clothes).

3.40
source control
source management
manner of controlling IAQ by preventing or reducing the emission of air contaminants or entry of air contaminants into an occupied space

3.41
supply air
air introduced into an enclosure by mechanical or natural means

3.42
total organic vapours
total volatile organic compounds
TVOC
sum of organic vapours in air measured by an appropriate sampling and analysis procedure

3.43
unadapted person
visitor
person entering a space from another area with acceptable perceived IAQ whose sensory perception has yet to become desensitized to some air constituents (such as body odours) in the space

3.44
ventilation
process of supplying or removing air by natural means or mechanical means to or from a space for the purpose of controlling air contaminant levels, humidity, odours or temperature within the space

3.45
ventilation rate
airflow rate at which outdoor air enters a building or enclosed space

3.46
ventilation effectiveness
ε_V
measure of the relationship between the pollutant concentration in the exhaust air and the pollutant concentration in the breathing zone

4 Methods of expressing indoor air quality (IAQ)

4.1 General

IAQ may be expressed as the extent to which human requirements are met. Humans have two basic requirements for IAQ: the risk of any adverse health effects of breathing the air should be low and the air should be perceived as acceptable in relation to comfort. These two requirements should be met whenever it is practicable to do so. Corresponding to these two requirements, there are two direct methods of expressing IAQ. A third alternative is an indirect method based on the ventilation rate. Each of these three methods is summarized below. The various guidelines and standards use one or more of these methods to express IAQ, as detailed in Annex B of this document.

4.2 Method based on health

Exposure to pollutants in the air can cause some risk of adverse health effects. Such effects can be short-term, distinct and acute (e.g. eye irritation) or develop over an extended period (e.g. cancer). To limit the health risk, maximum permissible concentrations and corresponding exposure times for individual chemicals are available. Annex C contains recommended guideline values for common pollutants found in indoor and outdoor air. It is based on guidelines published by the World Health Organization. The relation between the actual concentration and the guideline value for a given chemical expresses IAQ as regards the health effect of that particular chemical. Depending on the nature of the health effect, it might not be reasonable to set a guideline concentration below which no significant health effect is expected. This would generally be the case for carcinogens. For some such pollutants, it is possible to estimate the magnitude of risk associated with a given concentration level.

4.3 Method based on perceived air quality

People vary widely in their sensitivity to air pollutants and the discomfort that they experience. Some are very sensitive and difficult to satisfy, while others are less sensitive and are easier to satisfy. To cope with these individual differences, the perceived IAQ can be expressed by the percentage of persons who perceive the air quality as unacceptable (percent dissatisfied). If there are few dissatisfied, the IAQ is high; if there are many dissatisfied, the IAQ is low.

4.4 Method based on the ventilation rate

An indirect method of expressing IAQ is to determine a certain minimum ventilation rate estimated to meet requirements for perceived air quality and/or health in the occupied zone. The relation between the actual and the minimum ventilation rate provides an expression for the IAQ.

5 Conformance

A building, including any ventilation or air-conditioning system, should be designed to provide the required IAQ under specified conditions. The designer shall document the conditions and any assumptions made, including the IAQ requirements that the system is designed to meet. In order to claim that the design process on a specific project complies with the requirements of this document, the following documentation requirements shall be met:

a) project information, including

  — application and flexibility of the space, including a specification of the occupied zone,

  — typical, best and worst outdoor air quality conditions, e.g. corresponding to a certain percentage of a normal year;

b) design criteria and requirements for the project, including

  — whether the design should be for adapted or unadapted persons,

  — pollution load caused by materials applied in the building, including carpets and furnishings,

  — physical properties of the materials used in the building (e.g. adsorption/desorption of chemicals, thermal insulation);

c) building-use assumptions, including

  — number of occupants present (per square metre floor area and per zone) and their estimated activity and clothing preferences,

  — total area of all the zones,

  — percentage of smokers, if smoking is permitted,

  — possibility of opening the windows;

d) cost constraints;

e) initial design alternatives considered;

f) basis for selection of final design;

g) local regulations and requirements considered;

h) method selected to express IAQ and, where applicable, the target level of IAQ selected within that method;

i) calculations carried out using the selected method;

j) documentation of minimum operation and maintenance requirements, including

  — proper commissioning and maintenance of the ventilation or air-conditioning system,

— proper system balancing,

— proper cleaning of the spaces,

— proper use of the ventilation or air-conditioning system;

k) any other design decision processes resulting from following the guidance in Clause 6.

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 environmental criteria for which the system is designed can be achieved only if these conditions are met. Owners and users of the building shall be warned that changes to the application of spaces or pollution load can result in the inability of the system to meet the indoor environmental requirements for which it was designed.

6 Design process

Creating a building that has good IAQ is not just a matter of working to certain design targets. The whole process that the designer goes through has an important impact on the final product. Therefore, this clause outlines the approach that should be adopted. It is cross-referenced to subsequent chapters, which provide detail on issues relevant to this International Standard. In order to achieve good IAQ, HVAC equipment shall be designed, installed and operated properly.

The flowchart in Figure 1 provides a summary of the process, with cross-references to other clauses and subclauses. It illustrates the different steps that the designer should take in order to choose a design method that takes into account the objectives of the building. The end point of the flow chart shows the different methods that are used to express the IAQ, one of which shall be used by the designer. Tables B.1 and B.2 list various factors that are considered by different methods. These factors should be taken into account in order to determine the method to be used in a specific project. Depending on the method chosen, the outcome is unique for each project; this is why it is important that all assumptions be well documented as required in Clause 5. While the order in which the activities depicted in the flowchart are carried out may vary to some extent, all the activities are essential.

Step 1. Define the constraints placed on the design by the client, the location, site conditions, and by local codes/regulations, etc.; see 7.2. These constraints shall be considered in discussion of the brief and decisions documented. If the outdoor air quality is judged to be unacceptable, pretreatment to remove pollutants from the outdoor air shall be considered.

Step 2. Combine the information from step 1 with the detailed design objectives, such as the expected/specified number of occupants and the activities that are likely to be carried out in the building; see 7.2. The system shall be designed so as to facilitate easy cleaning, maintenance and service operation; see EN 12097 [5] for guidance. Information shall be given to the owner about the maintenance required (primarily for filters). The systems requirements for balancing shall be specified.

Step 3. Define the IAQ criteria that will guide the process of selecting an IAQ target level. This includes whether the design takes into consideration the health or comfort of adapted or unadapted persons. It is also necessary to consider at this point the times and locations to which the criteria apply; see 7.3. The designer shall be explicit about which criteria and method will be applied in designing for good IAQ.

Step 4. Identify the pollution sources taken into account; see Annex A.

Step 5. Evaluate options to reduce the concentration levels of pollutants; see Annex A. Air shall not be recirculated or transferred from an enclosure in which smoking is permitted to another enclosure in which it is prohibited. If filtration is used, the filters shall be designed to achieve required levels of cleanliness under all conditions during which the system is running, i.e. variations in pressure differential, etc.

Step 6. Check whether there are special requirements that should be followed, such as local requirements (laws, directives, regulations, guidance, calculation methods, rating methods), which can impose minimum values (or special considerations that influence the choice of a method) or special pollutants to be taken in account. If there is a local requirement, determine whether the intention is for IAQ to exceed that requirement; see Annex B.

Step 7. Choose and apply a method to express IAQ; examples of methods of expression of IAQ are given in Annex B.

The flowchart as expressed in Figure 1 fulfils the project definition for IAQ and states the stages of design, in accordance with ISO 16813. IAQ criteria obtained are considered as input at the different stages of the design building process, from conceptual design to detailed design and final design. If target criteria are not matched, assumptions for IAQ shall be revised.

7 Design brief parameters and assumptions

7.1 Objectives

When designing a building (including the building services), it is important that the designer and the client recognize that the IAQ in a building is the result of several factors, not only ventilation rate. Consideration shall be given to all the relevant elements in the early stages of the design process. The client shall normally provide the designer with a brief, which specifies certain required characteristics of the building, site, indoor environment or occupancy. The designer and client shall work together to define as clearly as possible their objectives concerning the IAQ design. Buildings are designed for a variety of uses: the more detailed the brief is, the more the designer can tailor the building to the client's needs.

Cultural differences, economic parameters and the intended use of the building should be considered when designing a building. The designer should obtain this information from the client, building owner or other expected occupants so that appropriate levels of IAQ can be targeted, using methods that are compatible with the way in which the building is likely to be used. Although the client and designer may discuss and agree, at some point in time the brief comes to represent a set of constraints on the design. In 7.2 are detailed some of the more important constraints that can emerge from the brief, some of them based on assumptions that the designer should clarify with the client (or with other parties as appropriate). The brief sometimes makes statements about the required quality of the indoor environment. Criteria are discussed in 7.3. In addition to all the technical issues and user requirements, budgetary constraints are a major consideration in designing a building and its systems. Although first cost is generally a determining factor, life-cycle costing should be used to support the case for superior design. The growing emphasis on environmental impact and energy savings should result in increased use of life-cycle costs as a preferred method. Recent studies have shown a direct relationship between productivity improvements and improved IAQ; see 7.3.4. The expected economic benefits of such productivity improvements should be quantified when practicable. The designer is encouraged to propose both types of economic analysis to the building owner so that he/she can make an informed decision.

7.2 Constraints

7.2.1 Constraints due to the location of the building

7.2.1.1 Climate

The climate where a building is located can have a major impact on the IAQ of the building. For example, if the climate is cold and dry, the ventilation air has a tendency to lower the humidity level in the building. Conversely, in climates where the outdoor air is humid, the system designer shall consider appropriate dehumidification of the ventilation air. Some degree of dehumidification is often associated with refrigerated cooling. Where humidity levels are intentionally or unintentionally altered because of comfort considerations, adequate attention shall be given to the possible effects on microbiological growth in the ventilation system or inside the building.