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Indoor air —

Part 41: Assessment and classification

Air intérieur —

Partie 41: Évaluation et classification

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 6, *Indoor air*.

A list of all parts in the ISO 16000 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In our society, privately and professionally, people stay indoors most of the day. Therefore, the quality of the indoor air is very decisive for the quality of life and health. This especially applies to small children, sick people and other vulnerable groups of persons.

Numerous scientific studies verify the positive effects of good indoor air on the overall performance during learning (e.g. in kindergartens and schools) and working. A consequence of improved indoor air quality can be, for example, reduced sickness rates and absenteeism.

The entitlement to high-quality indoor air does not contradict economical aspects of energy- and cost-efficiency. Improvements in the quality of indoor air are achievable with simple measures, for example, change of behaviour patterns.

This document describes a procedure to classify the air quality of indoor spaces using quality classes. These quality classes enable the allocation of the room air to a high, medium or low quality. The quality classes are based on criteria for physical, chemical and biological parameters according to the state of science and research. These criteria can be both concentration values in the room air (e.g. with formaldehyde) as well as sensory and other findings in the room itself (e.g. with mould). The basis for classifying a measured value of a parameter in a quality class is the definition of class boundaries for quality classes A to C by national institutions, using guide values from national guidelines, European and international publications and trade literature.

The most frequent pollutant sources indoors are human activities (e.g. domestic-, hobby- and cleaning activities, tobacco smoke), combustion processes as well as building materials, furnishings and interior design materials. The exception is the radioactive inert gas radon, which mostly originates from the geological subsoil and enters the interior spaces via leaks in the building envelope.

A variety of substances can emit into the indoor air from the most diverse pollution sources. For this reason, the single analysis of a source or pollutant cannot be used as a substitute for an overall assessment of the indoor air. A meaningful assessment of the indoor air is only achievable by an overall assessment of all pollutant sources and substances.

This document is intended for specialists who deal with the assessment of indoor air in the course of planning, construction, operation and use of buildings (e.g. indoor-experts, architects, specialist planners of trades, building owners, building developers and contracting authorities, maintenance engineers, lessors). Also included are producers and distributors of products, that are installed and/or operated indoors (e.g. building products), and possible users.

Indoor air —

Part 41: Assessment and classification

1 Scope

This document specifies a procedure for the assessment of the indoor air quality that is valid for all interior rooms in residential and non-residential buildings with natural or mechanical ventilation, in which people do not only stay temporarily.

This document is applicable to indoor environments as defined in ISO 16000-1.

The assessment of working materials in workrooms or workplaces in buildings, that are subject to statutory occupational safety specifications, are excluded from this document. In these rooms, only air constituents that do not originate from working materials can be assessed according to this document.

It is not possible to define classes with exact values for the individual pollutants, as the corresponding limit and guide values differ in individual countries. In addition, the values relate to different observation periods.

Aspects concerning electromagnetic fields, noise and vibrations and their effect on the indoor air quality are not the object of this document. The classification of further consequences and measures, such as organisational steps, structural engineering measures, renovation proposals, further human medicine appraisals and the like, are not the object of this document.

NOTE This document applies to of all types of indoor environments occupied by all kinds of persons, including regular users, clients and workers.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 11665-8, *Measurement of radioactivity in the environment — Air: radon-222 — Part 8: Methodologies for initial and additional investigations in buildings*

ISO 16000 (all parts), *Indoor air*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
building product
product or building kit, that is manufactured or brought into circulation, to be installed permanently in buildings or parts of buildings and whose performance affects the performance of the building with regard to the basic requirements on buildings

[SOURCE: EU-BauPVO, Article 2 (1)[23]]

3.2
assessment value
value obtained from an assessment

Note 1 to entry: The assessment value can be an individual measured value, the arithmetic mean of individual measured values or the result of a continuous measurement over a particular time period. In the case of carbon dioxide (CO_2), the assessment value is a statistical evaluation of the individual measured values.

3.3
assessment period
period during which the investigation of the indoor air takes place

Note 1 to entry: The assessment period is adapted to the parameter to be assessed and the measuring task and linked to certain usage conditions.

3.4
emission
release of chemicals, vibration and radiation to the environment

Note 1 to entry: The emission of air constituents can be specified as mass flow. In relation to *building products* (3.1), the mass flow can be related to area, length, mass, volume or component.

Note 2 to entry: The terms “emission” and “release” basically have the same meaning.

3.5
main parameter
parameter which, during an overall assessment, is taken into consideration without fail

3.6
secondary parameter
parameter that is also taken into consideration for the overall assessment, if references to its relevance exist in the preliminary survey

3.7
guide value
default value that serves as a comparative value for the assessment

Note 1 to entry: Specific guide values for interior rooms are defined, for example, by the WHO and national/professional institutions.

4 General

4.1 Procedure

The procedure for the assessment of the indoor air quality consists of the following steps:

a) preliminary survey;

b) investigation plan;

c) investigation;

d) documentation;

e) expert opinion.

When this document is applied, it should be taken into consideration that the concentrations of substances in the room air can fluctuate greatly: spatially, time-related and usage-specific. This is particularly dependent on ventilation, the building services and the individual user behaviour.

Individual results of certain parameters cannot sufficiently characterize the indoor air, therefore the overall assessment described in this document is necessary in order to obtain a comprehensive and differentiated picture of the room air situation.

An investigation of buildings for pollutants shall be carried out in accordance with ISO 16000-32.

4.2 Parameters

Chemical, biological and physical parameters play a role in the assessment of the indoor air.

— chemical parameters and particles: gases, volatile and hardly volatile organic and inorganic compounds, fibres, dusts, dust constituents and odours;

— biological parameters: fungi, bacteria, viruses, pollen and other allergens (e.g. animal epithelia, insects/insect compounds, mites, mite excrement, plant parts/fibres);

— physical parameters: room air and environment surface temperatures, operative temperature, air humidity, air velocity, lighting, sounds and noise, electromagnetic fields and charged particles.

In the context of this document, only selected chemical and biological parameters are dealt with. The room air temperature and the humidity should be regarded as supplementary physical parameters.

NOTE Physical parameters are dealt with in, for example, ISO 7730.

5 Indoor air quality

For the assessment of the indoor air according to this document, a classification of the room air quality into three quality classes A (high), B (medium) and C (low) is performed based on prescribed main parameters (see 7.2). In addition, further secondary parameters (see 7.3) should be taken into consideration, if necessary.

The class limits of the quality classes are defined by:

— guide values in the sense of maximum permissible concentrations in the room air (e.g. with formaldehyde) or distributions of measured values (e.g. with carbon dioxide CO_2),

— sensory findings in the room itself (e.g. with mould, odours).

The use of a questionnaire can also contribute to the assessment of a room.

6 Quality classes

Table 1 provides an overview of the quality classes and describes the requirements on the room air quality on which these classes are based. The designations and descriptions of the requirements according to Table 1 are only partly applicable for the parameter “Mould – microbial infestation”.

Table 1 — Indoor air quality classes

Quality class	Designation	Description
A	High room air quality	Room air with low substance concentrations
B	Medium room air quality	Room air with average substance concentrations
C	Low room air quality	Room air with above-average substance concentrations
Lowest air quality class not fulfilled		Substance concentrations above the class limits of quality class C

If any main criteria do not permanently fulfil even quality class C, the indoor air shall not be classified but is considered to be “outside all quality classes”.

During the course of an assessment, the need for different quality classes can arise for a specific interior, depending on which parameter is considered.

For the assessment, it shall be taken into consideration that many building products show a significant decrease of their emissions, especially in the first days and weeks after their manufacturing. A meaningful holistic assessment of the room air condition in the sense of this document is only possible in an actual usage stage.

7 Criteria for the definition of the quality classes

7.1 General

The basis for classifying a measured value of a parameter in a quality class is the definition of class boundaries for quality classes A to C. The limits of the quality classes can be defined on the basis of guide values from national guidelines and European and international, publications and trade literature. For the parameter "Mould – Microbial Infestation", in addition the condition of the room with regard to mould infestation is adjudged.

7.2 Main parameters

Parameters most frequently giving rise for complaints due to the quality of indoor air are defined as main parameters in this document.

In the framework of the overall assessment, the expert shall assess all these main parameters, however a measurement of every parameter is not always necessary (see 8.4.4).

Table 2 lists the main parameters as well as the corresponding clauses in annexes of this document.

Table 2 — Main parameters

Parameter	Clause
Formaldehyde	A.2
Volatile organic compounds (VOC)	A.3
Radon	A.4
Carbon dioxide	A.5
Mould - microbial infestation	A.6
Odour	A.7
Fine dust (PM1, PM2.5, PM10), ultrafine particles (UFP)	—

The criteria for the parameter carbon dioxide were derived from considerations of comfort as well as the users´ cognitive performance. Carbon dioxide levels are also used as an indicator for the concentration of emissions of the user or animals by breathing and body effluence into indoor air.

The appearance of mould is usually associated with the presence of filamentous fungi and yeast. Often bacteria are also present. In the case of air measurements, only the concentration of mould and bacteria is usually recorded.

The physical parameters “room air temperature” and “relative humidity” shall be recorded separately in the representation of the measurement results, because they influence the concentrations of pollutants in the room air and are frequently associated by users with an inadequate indoor air quality.

7.3 Secondary parameters

Secondary parameters are used, when there are indications of an occurrence of substance concentrations with a negative impact on the indoor air quality. In these cases, the investigation program shall be complemented with these secondary parameters. The consideration of secondary parameters shall be identified and justified accordingly in the overall assessment.

No quality classes are defined in this document for secondary parameters. That does not mean that quality classes cannot be defined. For some of the compounds, no effectiveness threshold or concentration can be specified, under which no health-related effects are to be expected.

The evaluation of secondary parameters is at the discretion of the expert.

In summary, secondary parameters include factors such as

— ammonia and heavy metals (e.g. mercury),

— asbestos,

— carbon monoxide,

— biocides (e.g. PCP, lindane),

— CMR substances in general,

— synthetic mineral fibres,

— nicotine,

— polychlorinated biphenyls (PCB),

— polychlorinated dioxins and furans (PCDD/PCDF),

— polycyclic aromatic hydrocarbons (PAH),

— sulfur dioxide,

— nitrogen oxides,

— other organic compounds besides VOC (VVOC, SVOC, MVOC), and

— parameters: fungi, bacteria, viruses, pollen and other allergens (e.g. animal epithelia, insects/insect compounds, mites, mite excrement, plant parts/fibres).

ISO 16000-1:2004, Annex C contains a list of sources of air impurities in interior rooms and the substances or substance groups emitted from them, that shall be used as a basis for the determination, investigation and assessment of secondary parameters.

Before the implementation of measurements of identified hazardous substances in the room, the investigation of possible sources in buildings is recommended.

8 Assessment plan

8.1 Overview

The overall assessment of the indoor air of an individual room or a building with multiple rooms shall take the individual steps of the assessment procedure into account, as listed in Table 3.

Table 3 — Phases of an overall assessment

Phase 1: Finding	
Preliminary survey	Compilation of the information and documents required for the planning of an investigation (e.g. previous test results, medical findings, data sheets)
Investigation plan	Decision, whether the sampling or investigation is to be carried out on-site; definition of the parameters to be considered in the planning of an investigation
Investigation	Implementation of the planned investigation or sampling and evaluation of the samples
Documentation	Documentation of the measurement procedure, measuring results and framework conditions of the investigation
Phase 2: Assessment	
Classification in quality classes	Assessment of the room air quality based on the quality classes according to this document

Figure 1 shows the individual steps of Table 3 and the documents resulting therefrom.

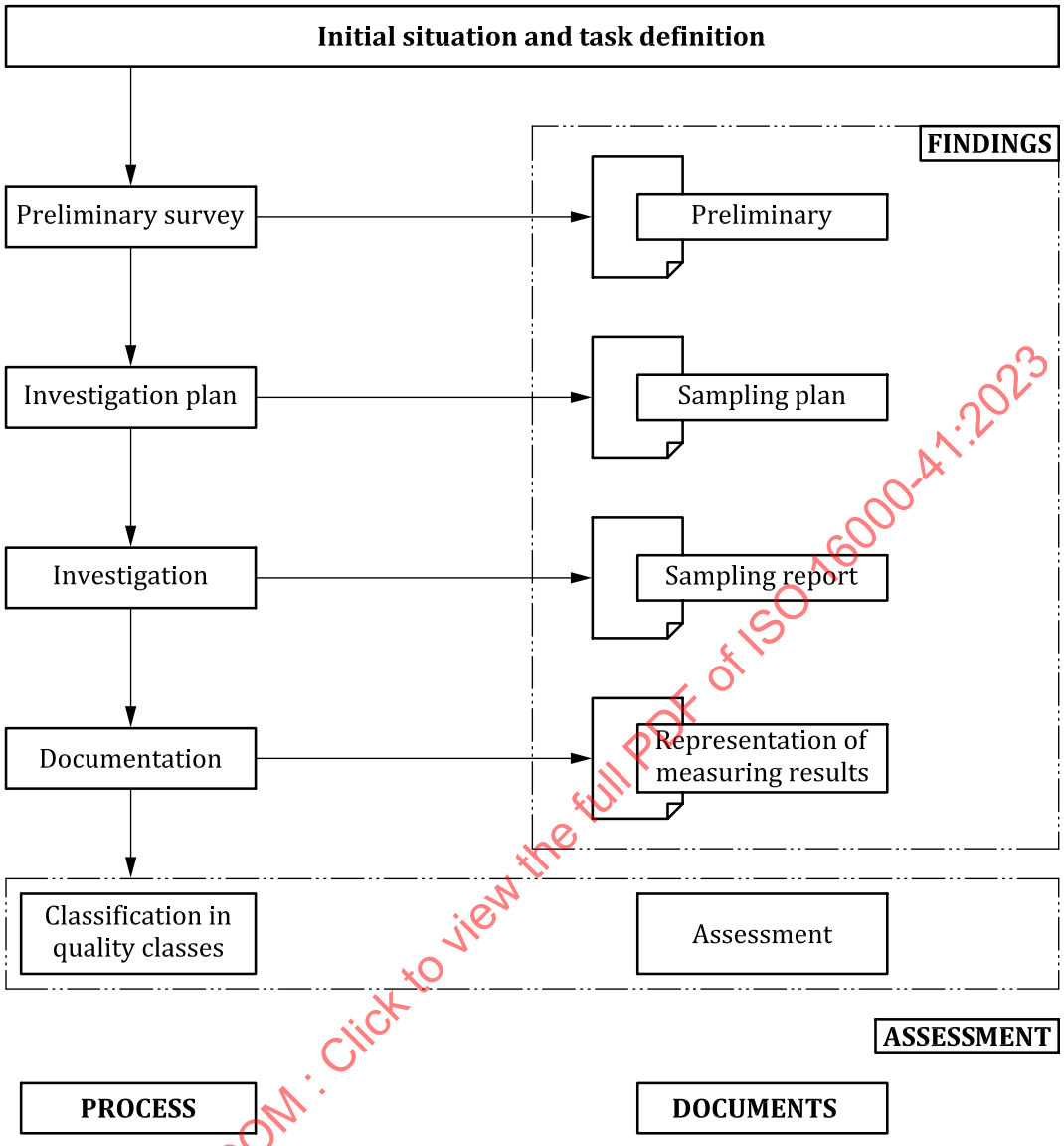

Figure 1 — Procedure and steps of an assessment of the indoor air

8.2 Documentation and reports

The documentation shall include the findings and the assessment.

The introduction of the documentation shall include the aims and objectives of the indoor air assessment and the reason why the assessment is performed. Subsequently every individual step shall be documented separately in the report according to Figure 1 (preliminary survey, investigation plan, sampling report and representation of the measurement results).

The conclusions from the results of the findings and the classification in quality classes shall be documented in the form of a report.

8.3 Purpose of measurements

8.3.1 Possible reasons

An assessment of the room air of interior rooms can be triggered for numerous reasons. Possible reasons are, for example:

a) Adherence to predetermined values: The adherence to predetermined values is verified. This can, for example, be in connection with the certification of building performance or assessments of the reasonableness of odours.

b) Acquisition of information through measurements: The background concentration, or a concentration before, during and after a renovation measure is checked, based on e.g. control-, work-accompanying- and release measurements. Likewise, such measurements can be performed in the course of research studies, for which the parameters are usually predetermined.

c) Insufficient quality of the indoor air: There are general complaints by room users concerning a room air quality perceived as poor. These complaints can be, for example, in connection with an unpleasant smell.

d) Impairment of the health of room users: There are indications for an impairment of the health of room users due to pollutants or physical parameters in the indoor air. These indications can be, for example, specific symptoms in the respiratory tract of room users.

These various reasons can exist individually or also jointly and in each case result in different methods of procedure of the respective competent specialist.

8.3.2 Concretisation of assessment

With cases 8.3.1 a) and b), a further concretization of the assessment plan is advisable, but not necessary. In these two cases, a sampling strategy can be defined without further surveys.

In situations covered by 8.3.1 c) and d), a concretisation of the symptoms of the room users is required. This concretisation should be carried out, for example, through systematic questioning of those affected as well as other persons involved (e.g. locally knowledgeable, medical expert).

To record the subjective evaluation by those affected, for example, questionnaires can be used for the perceived air quality.

8.4 Preliminary survey

8.4.1 General

A preliminary survey consists of a basic investigation and a local inspection, which together represent the result of the preliminary survey.

In the course of the preliminary survey, initial technical or organisational measures can already be recommended (e.g. elimination of obvious pollutant sources, change of the room utilization). Furthermore, in this case, the need to consult other specialists can already arise (doctors, hygienists, air-conditioning technicians, structural engineers and the like).

The preliminary survey forms the basis for the investigation plan. The results of the preliminary survey shall be documented as part of the findings with regard to the type and scope of the surveys performed.

It should be taken into consideration that besides the chemical, biological and physical parameters, psychological factors can also play a role. In the course of the preliminary survey, among other things the following aspects are to be observed:

— symptoms of those affected by health problems or about the limitations of comfort;

— the type of use of the rooms;

— the building products used;

— the objects of equipment used and materials of the interior design;

— the ventilation (ventilation via windows/doors and/or mechanical ventilation) and the equipment of the air purification (design and maintenance);

— sources in the vicinity of the room or the building (e.g. in adjacent rooms and the entry with the outside air);

— events in the past, that can have an influence on the room air quality (e.g. fires).

The information gained in the course of the preliminary survey shall be considered holistically and enables the definition of the next procedure.

Annex B provides a compilation of documents that may be used in the course of a preliminary survey.

8.4.2 Basic investigation

During a preliminary survey, the first step is an investigation with the aim of compiling already existing documentation. For these details about the location, the building and the utilization shall be recorded.

The investigation records can include, for example:

— documentation of the radon potential of the subsurface,

— details from potentially registered contaminated sites,

— plans and sections of the room or building,

— official documents,

— already existing expert assessments,

— details about the building materials used,

— heating, sewage and ventilation systems,

— maintenance, renovation and conversion measures,

— former uses, and

— special events (e.g. accidents, water damage and fires).

8.4.3 Local inspections

An on-site visit is part of the assessment, during which the respective rooms are visually inspected. The results of this inspection shall be documented in writing. If applicable, the writing shall be complemented with additional mapped and pictorial representations. For a systematic representation, technical building descriptions and building plans can be used. If mapped out documents are missing, it is advisable to produce sketches true to scale. If areas cannot be inspected, these shall be listed and the reason for not inspecting them shall be given.

Under certain circumstances, an initial identification of substances or substance classes is feasible by means of sensory perception. In this case, the initial identification of said substances shall be used to pre-determine main and secondary parameters for the assessment.

NOTE For a local inspection, it can be useful to bring tools such as lamp, mirror, tape measure, ladder, camera and the like on site.

8.4.4 Conditions for the omission of the measurement of parameters

The measurement of main parameters can be omitted under the following conditions, whereby in any case the assessment of these shall be carried out by an expert.

— A secured presence of quality class A with regard to a particular main parameter shall be determined (e.g. if no sources for this substance are present). In this case, the assessment of this parameter contains a comprehensive justification for the omission of the measurement.

— If there are investigation results present, which were performed according to the state of technology and according to the methods and framework conditions (e.g. type of usage) defined in this document, then these can also be included in the overall assessment.

— For the main parameter mould (microbial infestation, see Clause A.6), a classification into quality classes, based solely on the inspection, is possible under certain circumstances. In this case, the assessment of this parameter contains a comprehensible justification for the omission of the measurement, based on the local inspection. It should be considered that hidden mould damage is not covered in this case. To cover hidden mould damage, further investigation is needed.

If measurements are not carried out, the reasons shall be justified and documented comprehensively by the expert. Otherwise, no overall assessment is possible in the sense of this document.

8.5 Investigation plan

8.5.1 General

Based on the results of the preliminary survey, the sampling strategy of the room air shall be defined, which in turn determines the investigation plan. The investigation plan is based on the specific reason for the investigation and documents its planned boundary conditions and the objective.

The investigation plan shall be documented as part of the findings with regard to the type and scope of the measures to be performed.

The following aspects should be considered for the definition of the sampling strategy:

— main parameters to be investigated (see Table 2), consisting of the respective chemical, biological and physical measurement parameters;

— secondary parameters to be investigated;

— parameters that cannot be acquired analytically;

— sampling methodology;

— times of the samplings;

— locations of the samplings;

— frequency of the samplings;

— duration of the measurements;

— use of the room (e.g. occupancy rate, activities).

8.5.2 Normative specifications

For the design of the investigation plan, the respective parts of the ISO 16000 series shall be considered, in which the individual aspects of the sampling strategy are described.

ISO 16000-1 describes general aspects for planning indoor measurements that apply for all substances or substance groups. Based on this, the other parts of the ISO 16000 series contain specifications that shall be observed during the sampling planning for the respective substance or substance groups.

Annex B provides a list of the documents that can be used in the course of the investigation.

8.5.3 Determination of sampling points

The minimum number of sampling points per room shall be calculated in accordance with Formula (1):

$$P = 0,1 * \sqrt{A} \quad (1)$$

where

P is the number of sampling points;

A is the area of the room or part of the building, in m^2.

The results shall be rounded up to the next whole number. For smaller rooms ($P < 1$), one sampling point per room shall be set. For a building with multiple rooms, in which a similar room air quality can be assumed, or for rooms that are connected, the sum of the areas of these rooms is used in the formula.

If a similar indoor air quality can be assumed in multiple rooms of the same building, the investigation of all individual rooms may not be necessary. In these cases, the sampling can be performed in representative and permanently occupied rooms. These rooms should comprise at least 10 % of the occupied space. The selection of the respective rooms shall be justified by the expert.

In rooms with high occupancy and poor ventilation, additional measurements should be considered.

If the same room is equipped with multiple air conditioning systems, it is necessary to determine the number of measurement points for each air conditioning system or zone of air conditioning units.

8.5.4 Utilization of the interior room

For the sampling planning, the actual use of the interior room should be considered. There are three types of measurements that can be performed:

a) Measurements during normal usage: The normal usage can require the presence of persons and under certain circumstances the implementation of particular activities. Such measurements can enable identification of a background load.

b) Measurements during special used zones: Special uses can cause concentrations in the room air deviating from the normal use. Simulations of the special usage are permitted.

c) Unoccupied zones: For some substances measurements under equilibrium conditions are required (e.g. formaldehyde or VOCs).

EXAMPLE 1 Lower concentrations of some pollutants as CO_2 during the absence of users.

EXAMPLE 2 Increased concentrations during the implementation of maintenance or renovation work.

8.5.5 Seasonal fluctuations and ventilation

In rooms, seasonally different conditions can exist. Such different conditions, for example caused by the heating period (cold season/winter) can have an influence on the air quality. In this case, an overall assessment for the whole year is not possible, and the assessment shall be subdivided seasonally, if appropriate.

As a rule, measurements should be taken with the windows closed, unless the measurement task requires a different approach. The specifications for ventilation (e.g. how long the windows have to remain closed before the measurement) can be found in the ISO 16000 series or other methods, proven to be equivalent to the respective part of the ISO 16000 series.

8.5.6 Complementary outside air measurements

Due to infiltration and ventilation, an exchange between indoor and outdoor air always takes place. Therefore, in some cases, the need arises to complement indoor air measurements with outdoor air measurements. These outdoor air measurements are required in cases in which it is expected that the concentration of pollutants in the interior room is decisively influenced by the concentration of outside air.

An outside air measurement or reference measurement in an uncontaminated area is always required for measurements of mould.

8.6 Investigation

The implementation of the investigation plan shall take place through sampling.

The investigation shall be carried out by sampling with subsequent analysis and evaluation. Sampling and analysis shall be carried out in accordance with the requirements of the ISO 16000 series or other methods proven to be equivalent to the respective part of the ISO 16000 series.

8.7 Report

In all cases the sampling report shall contain the following details:

— indication of which rooms are representative of others and which have been classified only on the basis of measurement of other rooms,

— chemical and biological measurement parameters (parameter scope),

— room air temperature and the relative humidity,

— sampling technique,

— times of the samplings,

— sampling points including room identification,

— sampling frequencies,

— duration of the measurements,

— type of use of the room, and

— reproducible justification for the omission of measurements of certain main parameters.

The measurement results shall be specified room by room, broken down according to parameter.

The representation of the measurement results shall be documented as part of the findings. For the assessment, relevant boundary conditions and information, that are not regulated in the relevant International Standards (e.g. the presence of persons for CO_2 measurements), shall be specified.

8.8 Division in quality classes

The division of indoor air into quality classes with respect to a particular parameter is produced through a comparison of the assessment values determined with the respective class limits of the quality classes as well as through the results of the on-site findings of the expert. An example classification for CO_2 and other supporting information is provided in Clause A.5.

The quality classes shall be identified separately for each parameter. For the assessment of a room, different quality classes can result for individual parameters. These quality classes need to be identified for each room that was investigated.

The reduction of the classification of multiple parameters of rooms or buildings to one single quality class is not permitted.

Annex A
(informative)

Quality classes for main parameters

A.1 General

This annex lists measurement methods for each main parameter. Indications for the determination of the assessment value are also listed. The basis for classifying a measured value of a parameter in a quality class is the definition of class boundaries for the quality classes by national institutions.

Based on existing specifications, three quality classes are defined for each main parameter (see Table 1). The allocation of a room into the respective quality class results from the measurements. In cases of mould, a perpetration, including a visual assessment by an expert shall be used for the classification.

The sampling of indoor air in general shall be carried out in accordance with the ISO 16000 series. If a ventilation system exists, it should be operated at a realistic ventilation stage during the assessment.

A.2 Formaldehyde

A.2.1 General

Formaldehyde is a flammable, colourless, very reactive, pungent smelling gas with the chemical formula HCHO. The aqueous solution is also called "Formaline" (CAS Registry Number®[1] 50-00-0).

Formaldehyde is one of the most well-known air pollutants in indoor spaces. It is used widespread as constituent of products in everyday use. It is emitted from wood materials, building materials, smoking and furnishing objects. In the past, formaldehyde frequently led to contamination of indoor air. Even today, unfavourable boundary conditions like low air exchange rate, high temperature or moisture can lead to increased concentrations.

A.2.2 Measurements

The sampling strategy for formaldehyde is described in ISO 16000-2.

The description for sampling of formaldehyde as well as the evaluation of the samples shall be in accordance with ISO 16000-3. Other standardized methods are also suitable for the specific characterization of formaldehyde. The sampling time should be adjusted according to the method used.

If possible, the measurements should be performed at different times. Over time, indoor air measurements for formaldehyde can result in fluctuating values, even under constant usage. Parallel measurements at different time points increase the significance of the results. Individual measurements are only of limited use for an assessment.

The assessment period for formaldehyde usually spans over half an hour. The determination of the half hour average shall be performed under conditions described in ISO 16000-2:

— the room shall be ventilated over a period of 15 min and afterwards, it shall not be ventilated for at least 8 h before sampling;

— if a ventilated system is present, it shall be in use at least 3 h before and during the sampling;

1) Chemical Abstracts Service (CAS) Registry Number® is a trademark of the American Chemical Society (ACS). This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

— the ventilation system shall be run in the typical mode for the sampled room.

A.2.3 Classification in quality classes

The assessment value for formaldehyde is produced from the arithmetic mean of the individually measured values and two significant figures reported. This assessment values shall be used for the determination of the quality class.

A.3 Volatile organic compounds

A.3.1 General

VOCs describe, according to ISO 16000-6, a group of organic compounds, eluting between and including n-hexane and n-hexadecane on a gas chromatographic column specified as a 5 % phenyl 95 % methyl polysiloxane phase capillary gas chromatographic column.

Substances from the group of VOC belong to the most frequent air pollutants occurring in indoor spaces. As constituent of numerous products, they are widespread and are used as solvents, auxiliary materials and reactants. Apart from this, VOC are also emitted from numerous everyday products. This includes wood materials, building materials and furnishing objects. VOC are also emitted to indoor air from natural materials. Even today, VOCs often lead to severe indoor air contamination.

NOTE From controlled effects studies with VOC mixtures of defined composition it can be concluded, that the probability for the occurrence of irritant effects and odour perceptions increases as the total concentration of the mixture rises, expressed as total VOC concentration (TVOC). However, due to the variability of the composition of the VOC spectrum and the resulting variety of possible effect end points, no ensured dose-effect relationships can be specified. In some cases, however, the parameter can contribute to an assessment of the indoor air.

A.3.2 Measurements

The sampling strategy with regard to VOC is described in ISO 16000-5. The analysis is carried out by means of thermodesorption according to ISO 16000-6.

If possible, the measurements should be performed at different times since indoor air VOC contents are highly variable, even in constant usage conditions. Parallel measurements at different measuring points in the room increase the significance of the results. Individual measurements are only of very limited use for an assessment.

The assessment period for VOCs often extends over half an hour and in certain cases a longer period is set for sampling. In the case of very long sampling times, ISO 16017-2 can be used. The determination of the half hour average shall be performed under conditions described in ISO 16000-5:

— the room shall be ventilated over a period of 15 min and afterwards, it shall not be ventilated for at least 8 h before sampling (equilibrium conditions);

— if a ventilated system is present, it shall be in use at least 3 h before and during the sampling;

— the ventilation system shall be run in the typical mode for the sampled room.

For the determination of the weekly average, measurements shall be carried out under normal usage conditions (see ISO 16017-2 for VOCs). Ventilation phases to a normal extent (for instance, three times a day in apartments, every two hours in offices) should be assumed as part of the assessment period. The measurement is accompanied by continuous recording of the temperature and the relative humidity.

A.3.3 Classification in quality classes

The assessment values for VOCs are produced from the arithmetic mean of the total values measured in parallel and/or at different times.

Individual and total values of VOC (if needed) shall be assessed separately. Substances and substance groups for which no guide values from recognized institutions exist cannot be assessed according to this document. However, the concentrations of these substances represent a part of the TVOC as a screening parameter and can be assessed using this parameter. TVOC emission values are not reliable indicators of the impact of products of emissions or indoor air quality with respect to human health.

A.4 Radon

A.4.1 General

The naturally occurring, inert gas radon occurs through the radioactive decay of uranium and is radioactive itself. Since uranium occurs in almost all grounds, radon is also formed everywhere. As a gas, radon can mix with indoor air via the soil air migrating through gaps and cracks in the foundation. Radon and its derivatives infiltrate the lungs via inhalation. Radon is quickly exhaled; however, radon derivatives remain stuck in moist respiratory tracts. The upper cell layers of lung tissue become damaged by the alpha radiation released by these derivatives with a subsequent impact on the occupants' health.

A.4.2 Measurements

The measurement of radon in the room air shall be carried out in accordance with ISO 11665-8. The measuring devices shall be set up for at least two months. At least half of the measurement period shall be in winter and the other half shall be in summer as a measurement of radon activity concentration over several weeks in summer can lead to different results than a measurement taken over several weeks in winter.

A.4.3 Classification in quality classes

The assessment values for radon are produced from the arithmetic mean of the total values measured in a certain period.

A.5 Carbon dioxide

A.5.1 General

On one hand, carbon dioxide is used as an indicator for volatile substances and odorous substances emitted by humans, but it also has physiological effects, above all on the occupants' performance, even in low concentrations. An exact separation of the effects of CO_2 as substance itself and the effects of other substances emitted by humans (e.g. very volatile organic compounds (VVOC), odorous substances) is not possible in the context of measurements according to this document.

A.5.2 Measurements

The sampling strategy of the room air with regard to CO_2 shall be carried out in accordance with ISO 16000-26. The measuring method applied shall be suitable to supply individual values regarded as representative for an interval of maximum 1 min.

During the measurement period, a realistic maximum usage of the rooms should be striven for (e.g. two persons in a bedroom, a full school class).

The assessment period in which the measurements takes place should be adapted to the aim of the measurement for CO_2. This assessment period should be representative for the normal usage of the room. With indoor rooms, this normal usage is characterized, among other things, by:

— the occupancy of persons;

— the intensity of the usage;

— the typical activity and ventilation rate.

EXAMPLE If a room, for example, a school room or classroom, is used by a different number of persons, the assessment period is restricted to the time of the most intensive, still common usage, whereby either the duration of the break before or after is also included as part of the assessment period.

The assessment period shall be covered by the samplings, whereby the CO_2 concentrations shall be measured at regular intervals. Recorded in all cases are typical phases, such as periods of maximum occupancy or ventilation periods. The sampling periods can only be limited with constant concentrations or regular recurring phases.

Table A.1 shows examples for the assessment periods for CO_2 measurements.

Table A.1 — Examples for the assessment periods for CO_2 measurements

Interior space	Period of interest	Typical assessment periods h
School classes	Lesson time of a school day from the beginning of instruction to the end of instruction	6 to 8
	Lesson time of a school hour from the beginning of instruction to the end of instruction	1 to 2
Workplaces, offices	Working time from the start of work to the end of work	8
Auditoriums, event rooms, theatres	Duration of the event including breaks	2 to 6
Apartments	Night situation in the bedroom	8
	Overall situation, e.g. in the living room	24

For measurements in school classes, the assessment period can be the duration of the lessons in an average day, but also in a single school hour.

For offices, the assessment period is normally an average working day, from the beginning of work to the end of work. For apartments, the period of continuous usage can be relevant, in the bedroom, the hours at night. The measurements shall be carried out during a normal usage or a simulated usage with realistic ventilation phases.

For bedrooms, the assessment period is defined as the duration during which people in the bedroom are asleep. During the actual sleep phase, the windows and doors shall remain closed.

A.5.3 Classification in quality classes

The assessment value for CO_2 is derived from the arithmetic mean of the results of the measurement interval.

Table A.2 shows an example of quality classes for the assessment value for the main parameter CO_2 during the assessment period.

Table A.2 — Example of quality classes for CO_2

Quality class	Arithmetic mean for class limits for CO_2 ppm absolute	Description of the quality classes
A	≤1 000	Requirements for indoor rooms for the continuous stay of persons in which intellectual activities are carried out or which are used for regeneration
B	1 001 to 1 400	General requirements for indoor rooms for the continuous stay of persons
C	1 401 to 5 000	Requirements for indoor rooms with brief use by persons
Outside the quality classes	>5 000	Not acceptable for use by persons

A.6 Mould — Microbial infestation

A.6.1 General

The appearance of mould is usually associated with the presence of filamentous fungi, yeast and often bacteria are also present. The load of a room due to mould and bacteria can manifest itself in the form of a concealed or visible microbial infestation ("mould") and/or contamination of the premises by mould constituents or microbial metabolites from other sources. Mould and bacteria can also play a role in material studies.

A mould infestation is not always associated with an increased concentration of mould components or metabolic products in the indoor air, as mould fungi and bacteria have different flight capabilities, and microbial infestation can be located in hidden areas.

Elevated concentrations of mould components or metabolites indicate an origin in the room, as it can also result from mould and bacteria concentrations indoors, as they can also originate from the outside air or other parts of the building.

A.6.2 Measurements

The condition of the investigated room shall be recorded by means of an on-site inspection. During the inspection, building physics measurements (e.g. moisture measurements on surfaces / in components, thermal imaging camera) are carried out as well as components and casings can be opened, in order to obtain sample material.

The sampling strategy of the room air with regard to mould spores shall, if necessary, be carried out in accordance with ISO 16000-19. The air investigation of the mould spore concentration shall be carried out in accordance with ISO 16000-16, ISO 16000-17 and ISO 16000-18. Air sampling by means of sedimentation samples or investigation of sedimented dust is not sufficient. Sampling of moulds should always take place before opening the construction or the inspection of components and casings.

NOTE The mould and bacteria concentration in indoor air are just one of the parameters that can indicate microbial contamination. Others are mould-typical odours, discoloration on the walls or damp spots on the material. The concentration of mould and bacteria in indoor air can be low, especially if the infestation is hidden, even though there is a massive infestation.

Due to increased spore concentrations in outdoor air during the warm season, the total concentration of the outdoor air reference sample can be higher than the total concentration in the indoor air despite an infestation indoors. Special attention should be drawn to the differences in species composition between indoor and outdoor air, and in particular, to the presence of humidity indicators.

The assessment period for mould and bacteria measurements spans several minutes. Measurements should always be carried out in multiple determinations (see ISO 16000-19). The determination of the concentration of mould and bacteria shall be performed under conditions described in ISO 16000-19:

— the room shall be ventilated over a period of 15 min and afterwards, it shall not be ventilated for at least 8 h before sampling;

— if a ventilated system is present that cannot be switched, it shall be in use at least 3 h before and during the sampling;

— the ventilation system shall be run in the typical mode for the sampled room.

Reference measurements of mould and bacteria in outside air or in building control areas can be carried out in order to be able to assess the results of indoor air measurements. If possible, the organisms obtained from measurements should be identified at the level of genus and species.

A.6.3 Classification in quality classes

For the concentration of mould and its microbial components, no toxicologically derived, absolute reference values can be specified.

The criteria for the division into quality classes are:

— results of the mould spore measurements, and

— on-site findings of a potential mould infestation.

The results of the air measurements can give an indication of whether a mould source is likely.

For the assessment and division of a room into a quality class, non-visible areas, such as, for example, footfall sound insulation or the cavities in lightweight construction walls, shall also be included. For this purpose, microbiological investigations of surfaces or materials as well as mould sniffing dogs can also be helpful.

If there is no visible hidden microbial infestation present and there are no indications of mould infestation (e.g. known water damage, health indications, odours mould indicating damp/mould damage), further examinations can be waived and the room can be classified to be of quality class A. In the case of any suspicion of hidden mould infestation, further examinations shall be carried out.

If different assessments results arise from the aforementioned investigation measures, the room shall be allocated to the poorer quality class.

A.7 Odours

A.7.1 General

The relationship between measured odour thresholds and the occurrence of an odour nuisance is very complex. It is largely influenced by atmospheric processes, which determine the propagation of the odorous substances, by the quality of the odour (hedonic effect) and ultimately by the receptor properties of the people exposed to the odour. These properties do not only differ greatly from person to person, but change over the course of time even for the same person.

A.7.2 Measurements

The recording and assessment of the odours with regard to the intensity and type of the odours is carried out according to ISO 16000-30. Other parameters such as hedonic tone or acceptance are also helpful for classification into quality classes. The assessments should be performed by a group of trained personnel (see ISO 16000-30).