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Indoor air —

Part 8:
Determination of local mean ages of air in buildings for characterizing ventilation conditions

Air intérieur —

Partie 8: Détermination des âges moyens locaux de l'air dans des bâtiments pour caractériser les conditions de ventilation

Reference number
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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 16000-8 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 6, *Indoor air*.

ISO 16000 consists of the following parts, under the general title *Indoor air* :

— *Part 1: General aspects of sampling strategy*

— *Part 2: Sampling strategy for formaldehyde*

— *Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method*

— *Part 4: Determination of formaldehyde — Diffusive sampling method*

— *Part 5: Sampling strategy for volatile organic compounds (VOCs)*

— *Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA® sorbent, thermal desorption and gas chromatography using MS/FID*

— *Part 7: Sampling strategy for determination of airborne asbestos fibre concentrations*

— *Part 8: Determination of local mean ages of air in buildings for characterizing ventilation conditions*

— *Part 9: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test chamber method*

— *Part 10: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test cell method*

— *Part 11: Determination of the emission of volatile organic compounds from building products and furnishing — Sampling, storage of samples and preparation of test specimens*

— *Part 12: Sampling strategy for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (PAHs)*

— *Part 13: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) — Collection on sorbent-backed filters*

— *Part 14: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) — Extraction, clean-up and analysis by high-resolution gas chromatography/mass spectrometry*

— *Part 15: Sampling strategy for nitrogen dioxide (NO_2)*

— *Part 16: Detection and enumeration of moulds — Sampling by filtration*

— *Part 17: Detection and enumeration of moulds — Culture-based method*

— *Part 23: Performance test for evaluating the reduction of formaldehyde concentrations by sorptive building materials*

The following parts are under preparation:

— *Part 18: Detection and enumeration of moulds — Sampling of moulds by impaction*

— *Part 24: Performance test for evaluating the reduction of the concentrations of volatile organic compounds and carbonyl compounds (except formaldehyde) by sorptive building materials*

— *Part 25: Determination of the emission of semi-volatile organic compounds by building products — Micro-chamber method*

Furthermore, the two International Standards, ISO 16017-1 on pumped sampling and ISO 16017-2 on diffusive sampling, focus on volatile organic compound (VOC) measurements.

This corrected version of ISO 16000-8:2007 incorporates the following corrections:

— Equation (D.2) (and the line of text immediately preceding this equation), Equation (D.5) and Equation (D.11) have been corrected.

— In Clause 2, the reference to the ISO/IEC Guide 98 was changed and footnote 1) was added.

— In 7.1.5, 7.2.5, 7.3.4, C.1.1 and D.1, the reference to ISO/IEC Guide 98:1995 was changed to GUM:1995.

— In B.3, footnote 1) was renumbered as footnote 2).

Introduction

An adequate air change is of fundamental importance for indoor air quality. Proper ventilation of all buildings is necessary for the health and comfort of the occupants as well as to protect against damage (e.g. due to excessive atmospheric humidity). However, the present-day use of tightly sealed windows, for example in residential and office buildings, can lead to insufficient ventilation. This situation in turn may lead to an increase in the concentration of substances emitted indoors. Manual ventilation by the occupants or the use of mechanical ventilation systems is thus required. However, excessive ventilation can lead to discomfort and increased energy consumption.

Building regulations make provision for ventilation to control moisture and other pollutants. Measurements of the ventilation conditions allow confirmation of whether these requirements are met in practice. Knowledge of the ventilation conditions is important in order to be able to analyse the possible causes of poor indoor air quality. Thus, ideally, sampling and analysis of contaminants indoors should be accompanied by ventilation measurement, making it possible to estimate the strengths of contaminant sources.

This part of ISO 16000 describes the use of single tracer gas for determining the age of air in a building which is naturally or mechanically ventilated. The age of air is an important factor in assessing the adequacy of ventilation. The concept local mean age of air (and its inverse the local effective air change rate) is used for assessing the ventilation conditions in the building. The mean age of air in a building zone indicates the average time the air in a zone has spent in the building accumulating contaminants. It is closely connected to the time it takes to exchange the air within a zone. The concentration of a contaminant released from continuous indoor sources increases with the length of time the air has spent indoors. The lower the age of air in a space, the lower the concentration. Normally, the ventilation air is supplied at selected parts of the building envelope, and seeks its way to the different building spaces. Thus, before the ventilation air reaches a specific room, a significant portion of the air may have spent time in other rooms, accumulating contaminants. Therefore, the local mean age of air, which describes how long the air in a particular space has spent indoors, needs to be considered in relation to air quality.

The purpose of this part of ISO 16000 is to describe the use of ventilation measurement techniques suitable for air quality studies. For this purpose, the ventilation rate and the air distribution patterns in the building should be measured for representative conditions of interest.

ISO 12569 describes the use of tracer gas dilution for determining the air change rate in a single zone. The procedures for tracer gas dilution include concentration decay, constant injection and constant concentration. ISO 12569 should be used when studying the thermal performance of buildings.

In the case where a zone exchanges air only with the outside (i.e. has no inflow of air from other parts of the building), the tracer gas concentration within the zone can be characterized with a single value, and the ventilation conditions are constant over the measurement period; this part of ISO 16000 and ISO 12569 should, in theory, provide identical results. The methods described in this part of ISO 16000 can, however, be used beyond these conditions, for example in spaces with several zones, which may exchange air with each other, and in cases where the ventilation conditions vary during the measurement period.

Indoor air —

Part 8: **Determination of local mean ages of air in buildings for characterizing ventilation conditions**

1 Scope

This part of ISO 16000 describes the use of single tracer gas for determining the local mean age of air as an indicator of ventilation conditions in a building. The procedures include concentration decay and homogeneous constant emission.

The described methods are intended for air quality studies and can be used for

a) checking whether the building ventilation requirements are met,

b) estimating the adequacy of ventilation in buildings with indoor air quality problems, and

c) characterizing the strength and distribution of indoor emission sources.

In principle, the methods can be applied to all indoor spaces, regardless of the type of ventilation used and the state of mixing of air between zones. The prevailing ventilation conditions need not be disturbed by the measurement.

This part of ISO 16000 does not address the details of the analytical methods for tracer gases. The availability of such analysis services should be checked before planning actual field measurements.

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 12569, *Thermal performance of buildings — Determination of air change in buildings — Tracer gas dilution method*

Guide to the expression of uncertainty in measurement (GUM), BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1993 [1)]

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12569 and the following apply.

1) Corrected and reprinted in 1995. To be republished as ISO/IEC Guide 98-3.

3.1
homogeneous emission
strategy to inject tracer gas in such a way that the injection rate per unit volume is equal in all parts of ventilated system

3.2
local mean age of air
ventilation parameter, which describes the length of time the air at a specific location has on average spent within the building

NOTE See A.1 for a further explanation of this term.

3.3
ventilated system
the building space, which can exchange air directly or indirectly with the space of interest

NOTE At the border of the ventilated system, there is no other inflow of air than outdoor air.

3.4
zone
space within the building where air mixing is sufficient to create an essentially uniform concentration of a tracer gas released anywhere within that space

NOTE 1 To be considered a zone, the space should not exhibit concentration differences larger than 20 % of the mean.

NOTE 2 A zone can be part of a room, an entire room or even include several rooms.

3.5
zone mean age of air
ventilation parameter, which describes the length of time the air in a zone has on average spent within the building

NOTE In the case of complete mixing within a zone, this is equal to the local mean age of air at any point within the zone.

4 Principles of tracer gas measurements for determining of ventilation conditions

4.1 General principles

Tracer gas techniques for measuring ventilation rely on the possibility of differentiating between air that is already within a space of interest and new air coming into that space. This means that it shall be able either to mark the air already in the space and follow how the marked air is replaced by new ventilation air or, alternatively, to mark the incoming air and measure how this marked ventilation air is distributed through the space.

It should be observed that air flowing into a specified zone from other zones that have a lower or higher concentration of tracer gas would influence the result of the measurement. Therefore, it is important to keep to the prescribed boundary conditions that are different for different tracer gas methods.

If the ventilation condition is to be determined in a zone, which has no inflow of air from other parts of the building (single isolated zone), it is not necessary to inject tracer gas or mark the air in other parts of the building in order to obtain correct results. However, if the zone can exchange air with other parts of the building, which is usually the case, special strategies for tracer gas injection in those connected zones shall be followed in order to avoid ambiguous results. It should also be noted that the closing of doors to a room does not necessarily lead to zero inflow of air from other parts of the building. Such means of restricting a normally occurring airflow will also change the ventilation of a room from that which would otherwise prevail.

4.2 Selected tracer gas methods

4.2.1 General

This part of ISO 16000 describes the strategies for tracer gas injection and measurement in spaces that cannot be regarded as single isolated zones. ISO 12569 presents the tracer gas dilution methods for spaces that can be characterized as a single zone. If the ventilation conditions are constant over the measurement period, and the space of interest can be regarded as a single isolated zone, the methods presented in this part of ISO 16000 and ISO 12569 are, in theory, identical. Under these conditions, the local mean age of air would be the same as the inverse of the air change rate determined using ISO 12569.

4.2.2 Decay method

The principle of the decay method is to mark the air in the ventilated system with tracer gas and determine the rate at which the marked air is replaced with unmarked air.

The zone to be measured and all other zones in the building with which the zone of interest can exchange air directly or indirectly shall be marked with a common initial tracer gas concentration. Such a strategy will prevent air coming from other parts of the building from being regarded as “clean ventilation air” to a greater extent than its actual delivered ventilation power.

The concentration history is recorded as a function of time. The local mean age of air is obtained from the quotient of the integral of the concentration versus time and the initial concentration.

The decay method can generally be used without problems up to air change rate $n = 10\ h^{-1}$.

4.2.3 Active homogeneous emission method

In the active homogeneous emission method, tracer gas is fed at measured constant rates into the zones by a suitable adjustable flow injection device. The injection rates shall be proportional to the zone volumes. The steady state tracer gas concentration of room air is measured using a suitable gas analyser. The local mean age of air is obtained from the quotient of the steady state concentration and the injection rate per unit volume.

The zone to be measured and all other zones in the building with which the pertinent zone can exchange air directly or indirectly shall be equipped with constant homogenous emission of tracer gas.

4.2.4 Passive homogeneous emission method

In the passive homogeneous emission method, tracer gas is emitted at known constant rates into the zones using diffusion sources. The emission rates shall be proportional to the zone volumes. The steady state tracer gas concentration of room air is measured by collecting an integrating sample in a sorbent tube (actively using an air sampling pump or passively using diffusion sampling) and analysing this sample afterwards in an especially equipped laboratory. The local mean age of air is obtained from the quotient of the steady state concentration and the emission rate per unit volume.

The zone to be measured and all other zones in the building with which the zone of interest can exchange air directly or indirectly shall be equipped with constant homogenous emission of tracer gas.

The use of this method requires a special analysis service able to analyse the sample from the sorbent tube in order to determine the amount of the tracer gas in the sample.

5 Measurement planning

5.1 General

Before measurement of the local mean ages of air in a building space, the purpose of the measurement shall be clearly defined. Also, knowledge of the type of building and the particular characteristics of that part of the building that is to be investigated are essential for the choice of tracer gas technique and the detailed planning of the test.

The ventilation rate and the air distribution patterns in the building should be measured at representative conditions of interest. These conditions should not be disturbed by the measurement, unless it is the purpose of experiment to test the effect of different conditions, of for example door opening, window opening, etc.

The homogenous emission method using sampling on adsorbent tubes is especially suitable for determining the ventilation conditions in the context of air quality studies. Depending on the requirement, short-term (pumped sampling of a few litres of air) or long-term measurements (passive sampling during days to several weeks) can be carried out. In the investigation of indoor air quality (IAQ) problems, the ventilation measurements usually accompany the actual measurement of pollutant. An advantage of this measurement method is the possibility to simultaneously determine the local mean ages of air and the pollutant concentration.

In determination of “air change” (“airflow rate” or “air change rate”), for example using the methods described in ISO 12569, only the total airflow rate to the ventilated system is of concern. Such measurements are therefore restricted to buildings or other enclosures that can be treated as a single zone. In those methods, it shall therefore be ensured that there is complete mixing of air between all spaces within the ventilated system during the measurement.

5.2 Identification of the ventilated system

In planning the test, the “ventilated system” to which the space of interest belongs shall first be identified, because all spaces within the ventilated system shall be tagged with tracer gas. The ventilated system is defined as the building space, which can exchange air directly or indirectly with the space of interest. At the border of the ventilated system, there shall not be any inflow of air other than outdoor air. Thus, a part of a building should only be considered a ventilated system if it has negligible inflow of air from other parts of the building (for example via doorways, air leakage or return air ducts). The location of pollutant sources should also be taken into account to ensure that polluted air is not misinterpreted as outdoor air. In practice, this means, for example that

— for a single family house, all rooms including the cellar (unless there is an airtight door) should be included in the ventilated system, and

— for a flat in an apartment building, all rooms in the studied apartment (and in some cases also the staircase) should be included in the ventilated system.

5.3 Identification of zones

A zone is a space within the ventilated system where it can be assumed that the air mixing is sufficient to ensure a uniform concentration of air tracer gas. Within the ventilated system, there may be several spaces that can be regarded as zones. All such zones should be identified and their volumes measured. The zone-volumes are needed in order to calculate the amount of tracer gas to be injected in the different zones. Small closed spaces with only extract air (e.g. bathrooms), or without any supply of outdoor air (e.g. closets) do not need any tracer gas injection. The volume of small closed spaces, which may receive some supply of outside air should be added to the volume of any connected zone. Large rooms and long corridors may be subdivided into two or more zones.

5.4 Choice of measurement method

5.4.1 General

The choice of the measurement method depends on the type and size of the building, the intended measurement time, the purpose of the measurement, and the availability of equipment and analysis service.

5.4.2 Type of building

5.4.2.1 Simple buildings (e.g. small to moderate-sized dwellings that can be characterized with one to four zones)

When the number of zones is small, it is relatively easy to achieve an initial homogeneous tracer gas concentration within the whole ventilated system. For short-term measurements, the decay method is therefore best suited.

5.4.2.2 Complex buildings (e.g. office buildings and other structures in which the ventilated system comprises several zones)

In this case, it may be very difficult to achieve the necessary condition for the decay method of equal initial tracer gas concentration in all zones. The homogeneous emission method may therefore be better suited than the decay method in this case.

5.4.3 Measurement period

5.4.3.1 Short-term conditions of interest

The decay method is the most practical method to monitor short-term ventilation conditions in simple buildings, while the passive homogeneous emission method with pumped sampling is better suited for complex buildings.

5.4.3.2 Long-term time variation of interest

Though repeated use of the decay method is feasible in buildings with few zones, the most appropriate choice for long-term measurement in all types of buildings is the homogeneous emission method. The purpose may be to monitor the change of ventilation conditions as a function of time, for example in order to investigate the effect of weather conditions or to test the effect of different ventilation strategies. This requires active air sampling using continuous monitoring of tracer gas concentration or repeated sampling using syringes, bags, evacuated gas tubes or pumped collection tubes. The active homogeneous emission method is suitable for measuring time-varying conditions in simple buildings, while passive homogeneous emission with active sampling is better suited for complex buildings.

5.4.3.3 Long-term average conditions of interest

The purpose may be to investigate only the time average of the mean ages of air in different parts of a building. Advantages of this monitoring strategy are that short-term variations in ventilation are levelled out and that the result is directly coupled to the average exposure to contaminants (or dose) generated indoors. The most appropriate choice for monitoring average conditions is the passive homogeneous emission method using passive sampling or integrating sampling using pumps.

5.5 Determination of measurement points

The suitable number and distribution of measurement points are determined from the purpose of the measurement. Air sampling is necessary only in those zones where it is of interest to determine the local mean age of air. If the purpose is to map the distribution patterns of ventilation air within the building, measurements should be performed in several zones, while sampling in only one or a few zones is necessary to get information on local ventilation conditions. Sampling shall be performed at places which are thought to be representative of the zones. It shall not be attempted close to the tracer gas sources (minimum 1 m distance) or close to an air supply terminal. Irrespective of the purpose of the measurement, at minimum of three measurement points should be used in order to gain information of the range of variation. When performing a manual sampling, the sample can advantageously be taken at different positions in the zone. If the purpose is to gain information on the total ventilation flow rate or air exchange efficiency in the building (see E.2), sampling should also be performed close to identifiable air exhaust points.

6 Tracer gases and equipment for determining ventilation conditions

6.1 Choice of tracer gas

Apart from being able to analyse at low concentration with available measurement equipment, tracer gases shall be harmless to health and should fulfil other requirements.

Annex B (informative) provides information on choosing tracer gases based on accepted practice.

6.2 Tracer gas concentration standard

The tracer gas should be used within safe limits for concentration. If the source is pure tracer gas, avoid gas volumes that could create inadvertent hazards. An extremely large pressurized cylinder of pure gas, for example, could momentarily create unsafe concentrations in a small room. Avoid conditions where the amount of tracer gas that may be absorbed onto surfaces and into subordinate enclosures is significant.

Avoid the use of radioactive tracer gases.

The required amount of tracer gas depends on the sensitivity of the detection method, the ventilation rate and the size of the rooms.

6.3 Equipment for feeding the tracer gas

6.3.1 Decay technique

The purpose of tracer gas feeding for the decay technique is to achieve a uniform concentration of tracer gas throughout the ventilated system.

Choose one of the following apparatus for injecting tracer gas.

— **Graduated syringe**, or other container of known volume with a means for controlled release of its content.

— **Compressed tracer gas supply**, with a flow rate measurement and control device.

Choose a technique for creating a uniform initial concentration in the ventilated system from one or more of the following.

a) **Fans** that permit good mixing within and between zones.

b) **Injection lines** that dispense tracer gas via manifolds or switches. All parts of the injection lines shall be clearly labelled “Tracer Gas Only” and shall be keyed to the location that receives the tracer gas.

c) **Swinging doors**. After tracer gas injection in all zones, the doors between zones may be swung back and forth to increase interzonal mixing.

Injection lines should be purged to ensure delivery of known tracer gas volume to a given zone.

All artificial mixing shall be turned off and doors reset to their desired state (open/closed) at the moment of the start of the decay measurement.

NOTE Leaks in injection lines can release tracer gas at unwanted locations and in uncontrolled unwanted concentrations.

6.3.2 Active homogeneous emission technique

The purpose of feeding the tracer gas is to achieve a homogeneous emission rate of the tracer gas within the ventilated system. This means that the constant tracer gas injection rate in each zone of the ventilated system shall be proportional to the zone volume. The following steps are necessary for this:

a) metering the tracer gas emission rate in each zone (This can be performed directly using a pressurized cylinder that is brought into the zone and controlling the gas emission rate via pressure regulator and flow meter, or by using injection lines connecting a remotely located tracer gas source to the zone.);

b) ensuring complete mixing within zones may be necessary in large zones. (This can be achieved by operating one or more fans or by distributing the injection to several points throughout the zone.)

6.3.3 Passive homogeneous emission technique

The purpose of feeding the tracer gas is to achieve a homogeneous emission rate of the tracer gas within the ventilated system. This means that the constant tracer gas injection rate in each zone of the ventilated system is proportional to the zone volume. The following steps are necessary for this:

a) emitting the tracer gas in each zone using diffusion sources with known emission rates;

b) ensuring complete mixing within zones may be necessary in large zones. (This can be achieved by using one or more fans. Multiple diffusion vials with known emission rates may be required for larger zones.)

The fact that the tracer gas emission rate from diffusion sources is strongly temperature dependant, shall be taken into consideration when distributing passive tracer gas sources. The temperature should also be logged at representative locations throughout the measurement period.

6.4 Sampling the tracer gas

6.4.1 Sampling methods

The sampling methods described below are suitable for both decay and homogeneous emission methods, depending on the analytical method used for the tracer gas.

Sampling should be carried out at representative points, and should never be located close to air supplies and windows.

6.4.2 Continuous automatic sampling

The gas analyser is usually connected to the measurement points by one or more inert gas sample tubes through which air is drawn with a pump to the gas analyser. When sampling from several locations, the sampling locations can be chosen via automatically or manually operated multi-port valves. It is important that a sampling tube is flushed with new sample just before introduction into the analysing instrument.

6.4.3 Manual sample collection

With manual sample collection methods, a sample is first collected using a suitable container (syringe, bag or evacuated gas container). The sample is then analysed in the laboratory.

Materials used in manual sample collectors shall be non-absorbent, non-reactive and impermeable for the tracer gas in use. Depending on the tracer gas, the list of suitable materials may include, for example, glass, copper, stainless steel, polypropylene, polyethylene and polyamide.

Care should be taken when collecting manual samples in rooms with a normally closed door. Opening the door and entering the room may introduce a large unwanted amount of air exchange between the two connected zones. An easy and often used practice is to install a tube from the room to the adjacent room through the keyhole, draw one or two syringe samples for purging the tube and take the next sample for analysis.

6.4.4 Solid sorbent samplers

In the active solid sorbent sampling method, room air is drawn (continuously or intermittently) through a solid sorbent suited to the tracer gas in use for the sampling period. After sampling, which shall be performed using a calibrated sampling pump, the loaded samplers are desorbed (using thermal desorption or solvent extraction) to determine the sorbed amount of tracer gas and hence the tracer gas concentration in the sampled air. Pumped sampling using solid sorbent tubes is appropriate for continuous sampling periods of up to a few hours and for intermittent sampling for several days. When using intermittent pumped sampling,