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Indoor air —

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

Air intérieur —

Partie 5: Stratégie d'échantillonnage pour les composés organiques volatils (COV)

Reference number
ISO 16000-5:2007(E)

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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 16000-5 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 6, *Indoor air* and by Technical Committee CEN/TC 264, *Air quality* in collaboration.

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 and polychlorinated dibenzo-p-dioxins/dibenzofurans — Collection on sorbent-backed filters*

— *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*

The following parts are under preparation:

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

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

Furthermore, ISO 16017-1 and ISO 16017-2 deal with VOC measurements.

Introduction

In ISO 16000-1, general requirements relating to the measurement of indoor air pollutants and the important conditions to be observed before or during the sampling of individual pollutants or groups of pollutants are described.

This part of ISO 16000 describes basic aspects to be considered when working out a sampling strategy for the measurements of volatile organic compounds (VOCs) in indoor air. It is intended to be a link between

— ISO 16000-1, *Indoor air, General aspects of sampling strategy*,

— the analytical procedures described in ISO 16000-6, *Indoor air, Determination of volatile organic compounds in indoor air and test chamber air by active sampling on Tenax TA® sorbent, thermal desorption and gas chromatography using MS/FID*, and

— the more generic ISO 16017-1, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling and* ISO 16017-2, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 2: Diffusive sampling*.

This part of ISO 16000 presupposes knowledge of ISO 16000-1.

The sampling strategy procedure described in this part of ISO 16000 is based on Guideline VDI 4300 Part 6 [1].

Indoor air —

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

1 Scope

This part of ISO 16000 is intended as an aid to planning volatile organic compound (VOC) indoor pollution measurements. In the case of indoor air measurements, the careful planning of sampling and the entire measurement strategy are of particular significance since the result of the measurement may have far-reaching consequences, for example, with regard to the need for remedial action or the success of such an action.

An inappropriate measurement strategy may contribute to the complete uncertainty of the measurement result in a larger extent than the measurement procedure itself.

This part of ISO 16000 uses the definition for indoor environment defined in ISO 16000-1.

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 16000-1:2004, *Indoor air — General aspects of sampling strategy*

ISO 16000-6, *Indoor air — Part 6: Determination of volatile organic compounds in indoor air and test chamber air by active sampling on Tenax TA® sorbent, thermal desorption and gas chromatography using MS/FID*

ISO 16000-8, *Indoor air — Part 8: Determination of local mean ages of air in buildings for characterizing ventilation conditions*

ISO 16017-1, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling*

ISO 16017-2, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 2: Diffusive sampling*

3 Definition of volatile organic compounds (VOCs)

Numerous organic compounds are present in indoor environments. Depending on volatility, these are present in the gas phase or are bound to suspended particulate matter or deposited dust. A working group of the World Health Organization WHO [2] classified organic compounds based on boiling point (see Table 1).

Table 1 — Classification of organic pollutants of indoor air [2]

Description	Abbreviation [a]	Boiling point range		Saturation vapour pressures	Examples of sampling media [a]
		from °C	to °C	kPa	
Very volatile organic compounds	VVOC	< 0	50 to 100	> 15	Activated carbon, cooled sampling media, molecular sieves, canister method
Volatile organic compounds	VOC	50 to 100	240 to 260	$> 10^{-2}$	Tenax® 1), graphitized carbon or activated carbon
Semi-volatile organic compounds	SVOC	240 to 260	380 to 400	10^{-2} to 10^{-8}	PUF [b] or XAD-2® 1)
Particulate organic matter	POM	> 380			Filters

[a] The WHO information has been supplemented.

[b] Polyurethane foam.

This classification, based primarily on the boiling point, takes into account aspects of the analysis, especially gas chromatography. Since the transition points are fluid here, it is not useful to specify sharp limits for the boiling point ranges and the sampling media to be selected.

NOTE 1 Boiling points of some compounds are difficult or impossible to determine because they decompose before they boil at atmospheric pressure. Vapour pressure is another criterion for classification of compound volatility that may be used for classification of organic chemicals [3].

NOTE 2 TVOC (total volatile organic compounds) is defined in ISO 16000-6.

4 Sources and occurrence

Several hundred VOCs have been detected in indoor air, stemming from various sources. These sources may be present in the room continuously or intermittently. The most important continuous sources are all kinds of building products, furniture, and room textiles. Intermittent sources include household products and products for renovation, as well as the occupants and a number of their activities, such as smoking and hobby work. Ambient air shall also be considered as a source although its contribution to indoor air pollution by VOCs is generally less important.

The various types of sources mentioned in the preceding paragraph emit a wide range of different VOCs into the indoor air. They also have different emission profiles. As the goal of most indoor air analyses is to provide as representative information as possible on the air pollution status of a room, taking into account the emission characteristics, it is important to develop a sound measurement strategy. In addition, it shall be considered that VOC concentrations in indoor air vary from room to room and are also subject to change over time.

It is difficult to establish a comprehensive list of which VOCs are emitted from which sources because of the ongoing variation in the production of products and the resulting change in the composition of the mixture of VOCs emitted. The VOCs listed in Annex A represent an overview of VOCs that are frequently found in indoor

1) The sorbents listed in Table 1 and elsewhere in this International Standard are those known to perform as specified under this part of ISO 16000. Each sorbent or product that is identified by a trademarked name is unique and has a sole manufacturer; however, they are widely available from many different suppliers. This information is given for the convenience of users of this part of ISO 16000 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.

air. A good overview of the VOC concentrations in indoor air of many countries are given in Reference [4]. The compounds mostly belong to one of the following chemical classes: aliphatic hydrocarbons such as alkanes and cycloalkanes, aromatic hydrocarbons, terpenes, aldehydes, ketones, alcohols, alkoxyalcohols, esters, ethers, and halocarbons.

This listing does not include a number of groups of compounds such as carboxylic acids, isocyanates or amines. Although these VOC may be present in the air of a room they will not readily be detected with the analytical methods routinely applied for VOC. Correct determination of these “special” VOCs, which may also include a number of polar compounds, requires more complex analytical work.

NOTE Sampling and analysis method for formaldehyde and other low boiling aldehydes are given in ISO 16000-3 [5] and ISO 16000-4 [6].

5 Measurement technique

5.1 General

The methods for determining VOCs in indoor air may be divided into short-term and long-term measurement methods, herewith assuming that determination of individual VOCs is considered. The basics of sampling and analysis methods used for VOC analysis are described in ISO 16017-1 and ISO 16017-2. When using active sampling for VOCs from indoor air, ISO 16000-6 shall be used. (A protocol for recording activities and boundary conditions during sampling is given in Annex B.)

5.2 Short-term measurements

Short-term measurements are generally understood to involve a sampling period from less than one hour to a few hours depending on the purpose of the measurement.

The VOCs are concentrated in the sampling medium by air being drawn through the sorbent using suction pumps (active sampling).

The sampling flow rate and the final sampling volume shall be selected as a function of the breakthrough volumes of single VOCs (see ISO 16017-1).

5.3 Long-term measurements

Although it is possible to perform long-term measurements using active sampling with low air flow rate, for this application, sampling using diffusive samplers is the method of choice [7] to [18]. Passive samplers, from here on called “diffusive samplers”, predominantly work according to the diffusion principle and give an integrated measurement value as a mean over the selected exposure period (usually from a few days to several days or weeks). In this method, short-term peak concentrations contribute towards the longer-term mean value given by ISO 16017-2.

6 Sampling and measurement planning

6.1 General

When carrying out indoor air analysis, the procedure depends on the measurement purpose and the emission characteristics of possible sources. Since sources that emit continuously and over long periods are typically the most important, the following subclauses specifically target these types of sources.

6.2 Measurement objective and environmental conditions

6.2.1 General

Before indoor air measurements are carried out, the objective of such measurements shall be clearly defined. Also, independently of the objectives listed below, it shall be made clear in advance whether it is wished to determine the concentration of a single organic compound, or a relatively small number of predetermined VOCs or to record and evaluate the entire VOC profile. If necessary, the measurement strategy shall be orientated accordingly.

Depending on the objective, different environmental conditions shall be maintained or recorded before and during measurements. These environmental conditions principally relate to the ventilation condition, the room temperature and the relative humidity.

6.2.2 Clarification of the reasons for complaints from room occupants, possibly in association with checking compliance of guideline values for indoor air using short-term measurements

6.2.2.1 General

In many cases, indoor air analyses are initiated by various types of complaints expressed by the room occupants. Complaints of this type can range, e.g. from the perception of unknown and frequently unpleasant odours, to headaches, nausea or irritation of the nose, throat or eyes. If VOC guideline values exist and these are time-related, the measuring or sampling period shall correspond to the specified time interval. VOC measurement is carried out under the conditions described below.

6.2.2.2 Naturally ventilated rooms (rooms without mechanical ventilation)

After intensive ventilation for 15 min, doors and windows of naturally ventilated rooms are kept closed for about 8 h (optimally overnight) prior to measurement, without additional sealing measures such as taping over window and door gaps. Sampling is then performed (see ISO 16000-6) with the room still closed off.

To obtain information on the effectiveness of hourly intensive ventilation, the room is ventilated intensively after sampling by opening doors and windows for 5 min. Doors and windows are reclosed and after a waiting time of 1 h a further sample is taken.

6.2.2.3 Rooms with mechanical ventilation

When rooms which are ventilated by mechanical ventilation or air conditioning (VAC) systems are investigated, the system shall be operated according to the building codes or other normative guidelines and the required ventilation shall be in operation at least for 3 h before the sampling is started.

The functioning of the ventilation system should be recorded or measured (see ISO 16000-8).

Rooms operated according to specified ventilation instructions (for example, schools and kindergartens where windows have to be opened after specified time periods), one complete and typical operating cycle has to be carried out prior to measurement.

If room occupants make complaints during unusual conditions, for clarification, measurements should also be performed under these conditions. The functioning of the ventilation system shall be recorded or measured (see ISO 16000-8).

The investigated spaces should preferably be operated according to the building codes or design guidelines and especially in complaint cases any deviation shall be the reported.

The VOC concentration level depends, if conditions are otherwise constant, on the indoor air temperature to a large extent, and possibly also on the relative humidity. To obtain meaningful indoor air VOC concentrations, it is therefore essential to perform the measurement under the climate conditions under which the room being investigated is usually used. If these conditions are outside the comfort zone, then it shall be indicated that complying with these conditions should take precedence over other measures for reducing the VOC concentration.

6.2.3 Determination of the average concentration over a relatively long time period (exposure studies)

To carry out long-term measurements, diffusive samplers are generally used. In these cases, the room does not need to be prepared if the measurement period exceeds 24 h. Usually the sampling period does not exceed one month. In each case, the decisive factor is the performance of the sampler used with respect to stability of the sampling medium and the VOC collected.

In the case of long-term monitoring, the room occupants should continue their usual ventilation behaviour and other activities. The common activities shall be clarified and documented before the examination. It is of particular importance here to obtain knowledge of the activity of intermittent sources. If deviations therefrom occur during the sampling period, these shall also be documented.

NOTE Annex D of ISO 16000-1:2004 gives guidelines for information to be recorded during indoor air measurement.

6.2.4 Determination of the concentration occurring under special conditions

In some cases, it can also be of interest to obtain information on the level of VOC concentrations under special conditions. Such special conditions may occur, firstly, if a room is used under unfavourable climatic conditions, for example, at temperatures or relative humidity outside the comfort region without the room occupants being able to alter this. Secondly, the emission of VOCs from sources which emit temporarily, for example, when a solvent is used, can also be an unusual situation of this type. Accordingly, a short-term measurement is performed under the conditions which are expected to give rise to elevated VOC concentrations.

NOTE The conditions for thermal comfort of temperate climate are described in ISO 7730 [19]. In the case of extreme climatic conditions, ISO 7243 [20], ISO 7933 [21] or ISO/TR 11079 [22] are available.

6.2.5 Identification of sources

If unusual concentrations of VOCs occur, it is of interest to identify the source. The potential sources, such as building materials, interior furnishings, office materials or cleaning agents often have typical emissions reflected in the indoor air. Therefore, it is important to know the emission characteristics of materials and products. The following procedures are suitable for tracing of material sources:

— odour;

— comparison between the results of air measurements in the centre of the room and in the vicinity of the potential source;

— in building-related sources, the emission is measured directly from the suspected structure using a transportable emission test cell, which can be set up on flat surfaces (see ISO 16000-10 [23] and Reference [24]). Alternatively, in some cases samples of materials may be removed for laboratory testing.

Source identification measurements are performed using short-term sampling (ISO 16000-6).

If continuous sources are to be monitored in isolation of other sources, the influence of intermittent sources shall be excluded or minimized (see Table 2).

6.2.6 Checking the success of remedial activities

Measurements are made before and after completion of remedial activities. The indoor air conditions shall be selected here to ensure comparability with the initial measurements. Attention shall be paid as to whether new substances have been introduced into the interior as a result of the remediation measures chosen.

NOTE When new materials such as flooring materials are introduced into an interior space, the indoor air VOC concentrations are high during the first two to twelve months depending of the ventilation efficiency of the space.

6.3 Time of sampling

The sampling time is determined by the measurement purpose. When the results of measurement are interpreted, one shall take into account the concentration variations that occur during relatively large time periods. For example, changes in concentration may occur due to seasonal variations and short-term effects such as changes in source strength and ventilation. *Cigarette smoking or the use of chemicals (e.g. for cleaning) shall be forbidden during air sampling, if there is no intention to take these pollutants into account for the evaluation of the measurement results.* Table 2 gives an overview of important VOC sources and their emission characteristics.

When the change in VOC concentration with time is being considered, two categories of sources may be differentiated: continuous sources which are active over relatively long time periods (months, years) and intermittent sources which are only active over shorter periods (days, hours). More detailed consideration of the emission profile results in further differentiation: each of the two main categories may be subdivided into two groups, those in which the pattern is constant and those in which it is variable with time.

6.4 Duration of sampling and frequency of measurement

The sampling duration is determined first by the measurement purpose and second by the characteristics of the analytical method chosen, for example by the detection limit and the breakthrough volume expected in association with the sorbent chosen.

Particular attention shall be paid to the sampling duration in measurement planning if complaints are the reason for the measurements. Thus, for example, it shall be taken into account that short-term measurements only rarely permit conclusions to be drawn with respect to a mean value valid for longer time periods. On the other hand, long-term sampling leads to a loss of information with respect to the variation with time of the VOC concentrations and particularly with respect to the frequency of the occurrence and the magnitude of peak concentrations.

The frequency of measurements shall be incorporated into the measurement plan in accordance with the measurement purpose and should also be based on the measurement uncertainty.

Table 2 — Emission characteristics of VOC sources

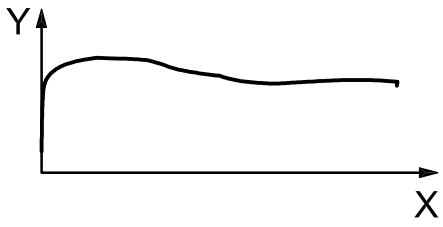
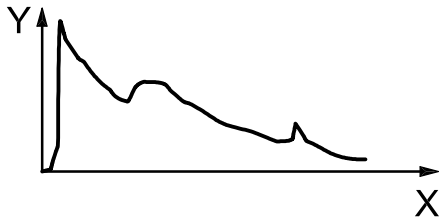
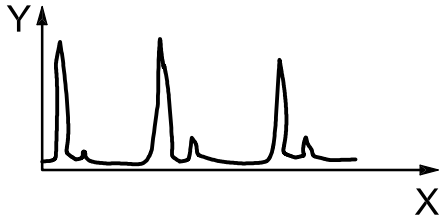
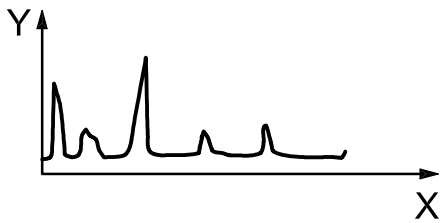
Emission characteristics and indoor air concentration	Example of source	Example of emitting VOCs
Continuous	Building products	
– active over a long period		
– uniform, short term changes in emission rates are low	– PVC	plasticizers, viscosity modifiers, solvent residues, antioxidants, stabilizers
	– linoleum	linseed oil and oxidation products as process residues
	– cork	binders, thermal degradation products
	– parquets and wooden furniture	wood extractives, solvent from varnishes, surface treatment oils and waxes
X time Y concentration		

Table 2 (*continued*)

Emission characteristics and indoor air concentration	Example of source	Example of emitting VOCs
Continuous – irregular, decaying  X time Y concentration	Paints, adhesives	Organic solvents, coalescing solvents, film forming reaction products, film degradation products
Intermittent – active in the short term – uniform – periodic time pattern  X time Y concentration	Cooking Smoking	combustion products, fats and oils, VOCs from spices hundreds of VOCs typical for incomplete combustion
Intermittent – irregular – variable time pattern  X time Y concentration	Cleaning and maintenance agents Hobby products	wood oils, essential oils, fragrants, co-solvents solvents, plasticizers
Ambient sources Indoor concentrations depend on ventilation, distance from the source, building characteristics and meteorological conditions	Traffic, industrial sources, contaminated sites	Large variety of source-dependent VOCs

6.5 Sampling location

It is generally not necessary to investigate every room in a large building or apartment complex. Prior to initiating the monitoring program, appropriate rooms shall be identified for VOC sampling. The criteria for selection are typically the room usage or the occurrence of complaints. Rooms that are occupied for long periods such as living rooms and bedrooms, classrooms and kindergartens, and offices, may be of particular interest.

The sampling location within a room can also influence the result of the measurement. Frequently, higher concentrations are observed in the immediate vicinity of an emission source than anywhere else in the room.

To identify source(s), the measurements can be performed close to the suspected source(s) and at a further distance from those source(s) within a room.

When the compliance with a guideline value is being checked, a procedure should be followed such that sampling is performed at a minimum distance from the walls of 1 m to 2 m and at about the same height above the ground as the sampling point in the room. In that case, one sampling point per room is generally sufficient.

For particular purposes, it can be useful to determine the ambient air concentration for comparison with the indoor air. The ambient air should, if possible, be measured at least 2 m from the building wall at about the same height above ground as the sampling point in the room.

NOTE Sometimes, depending on the pressure differences between spaces, it is possible that pollutants from neighbouring spaces such as stair cases are transported to room investigated.

In the case of buildings fitted with air-conditioning, the ambient air measurement shall be carried out in the vicinity of the ambient air supply inlet.

6.6 Presentation of results and measurement uncertainty

6.6.1 Presentation of results for individual VOC components and TVOC concentration

During measurement planning, the relevant parameters shall be specified. The used parameters shall be notified in the report and the measurement uncertainty shall be specified.

The results of a determination including gas chromatographic separation of VOCs are reported in the form of the concentrations of the individual compounds.

When passive samplers are used, the conversion formulae used to calculate the result, including the diffusion coefficients or absorption rates, shall be specified.

To assess the overall situation, frequently a single concentration value is used as a basis, which is intended to characterize the total VOC concentration (TVOC concentration).

It shall be stated that not all of the VOCs present in the indoor air are included in a TVOC concentration determined in this manner. Low-molecular-mass aldehydes, amines and highly polar VOCs, especially, may not be determined meaningfully using a method which is currently common for gas chromatographic determination of VOCs in air, and shall be determined separately using suitable methods.

6.6.2 Measurement uncertainties

Measurement uncertainties are unavoidable. The overall uncertainty of the measurement is determined by the number of measurements made and by the individual uncertainties in the sampling and analytical methods used. An example of the effect of the number of samples on the uncertainty of the reported result is given in ISO 16000-2:2004[29], Annex D. The representative nature of the result of each single measurement is influenced, in addition, by concentration changes in time and space.

The measurement report shall include, in addition to a reference to the analytical method used, a description of the performance characteristics valid at the time the measurements are made, especially the limits of detection and determination.

In the measurement results, the numerical data are usually reported so that the last decimal place (significant place) represents the order of magnitude of the measurement uncertainty at the same time.

6.7 Quality assurance

The measurement plan shall specify what measures to be taken to meet the quality requirements specified by the client.

It is advisable to carry out replicate sampling. One or more of the samples may be archived for later analysis if desired. The recovery rates shall be documented.

The criteria for selection of a contractor or laboratory to perform VOC measurements should include the following criteria:

— Does the contractor (laboratory) have a documented quality assurance system?

— What calibration methods will be carried out, with what frequency and to what extent?

— Which methods will be used to identify the VOCs

— Are duplicate measurements or comparative measurements (for example, with other laboratories) to be carried out?

— How will the measurement uncertainties be determined?

— In which interlaboratory tests has the contractor (laboratory) participated, and with what results?

Annex A
(informative)

Examples of organic chemicals detected in indoor air

Table A.1 — Examples of some organic chemicals [25] that may be measurable by ISO 16000-6

Chemical compound	CAS number	Boiling point °C [a]	Vapour pressure kPa (25 °C)
Aromatic hydrocarbons			
Benzene	71-43-2	80	10,1
Toluene	108-88-3	110	2,9
Ethylbenzene	100-41-4	136	0,93
m/p-Xylene	108-38-3 / 106-42-3	139 / 138	0,67 to 0,87
o-Xylene	95-47-6	144	0,7
n-Propylbenzene	103-65-1	159	0,3
1,2,4-Trimethylbenzene 1,3,5-Trimethylbenzene	95-63-6 108-67-8	169 165	0,15 to 0,2
2-Ethyltoluene	611-14-3	165	0,4
Styrene	100-42-5	145	0,88
Naphthalene	91-20-3	218	0,01
4-Phenylcyclohexene	31017-40-0	251	
Aliphatic hydrocarbons			
***n*-C_6 to *n*-C_{16}**			
n-Hexane	110-54-3	69	20,1
n-Heptane	142-82-5	98	4,7
n-Octane *n*-Nonane	111-65-9 111-84-2	126 151	1,4 0,5
n-Decane *n*-Undecane	124-18-5 1120-21-4	174 196	0,13 0,14
n-Dodecane	112-40-3	216	0,04
n-Tridecane *n*-Tetradecane	629-50-5 629-59-4	235 253	0,003 4 0,001 3
n-Pentadecane	629-62-9	270	
n-Hexadecane 2-Methylpentane	544-76-3 107-83-5	287 60	0,000 9 [26] 16
3-Methylpentane	96-14-0	63	Ca.16
1-Octene	111-66-0	121	2,3 [27]
1-Decene	872-05-9	170	0,22 [27]
Isobutene	115-11-7	−7	257 (20 °C)
Cycloalkanes			
Methylcyclopentane	96-37-7		18,3
Cyclohexane	110-82-7	81	12,7 (20 °C)
Methylcyclohexane	108-87-2	101	5,73
Terpenes			
3-Carene	13466-78-9	167	
α-Pinene	80-56-8	156	5 [27]
β-Pinene	18172-67-3	164	< 5
Limonene	138-86-3	170	0,19

Table A.1 (*continued*)

Chemical compound	CAS number	Boiling point °C [a]	Vapour pressure kPa (25 °C)
Alcohols			
2-Propanol	67-63-0	82	32 (20 °C) [27]
1-Butanol	71-36-3	118	4,4 [27]
2-Ethyl-1-hexanol	104-76-7	182	0,11 (20 °C) [27]
Benzyl alcohol	100-51-6	205	0,3 (20 °C) [27]
Glycols / Glycol ethers			
2-Methoxyethanol	109-86-4	124 to 125	0,8
2-Ethoxyethanol	110-80-5	135	0,51
2-Butoxyethanol	111-76-2	171	0,1
1-Methoxy-2-propanol	107-98-2	118	1,2 (20 °C)
2-Butoxyethoxyethanol	112-34-5	231	0,003 (20 °C)
2-Phenoxyethanol	122-99-6	245	0,001 (20 °C)
Aldehydes			
Butanal	123-72-8	76	12,2 (20 °C)
Pentanal	110-62-3	103	3,4 (20 °C)
Hexanal	66-25-1	129	3,5 (20 °C)
Nonanal	124-19-6	190 to 192	0,048
Benzaldehyde	100-52-7	179	0,13 (20 °C)
Ketones			
Methylethylketone	78-93-3	80	10,3
Methylisobutylketone	108-10-1	117	0,8
Cyclohexanone	108-94-1	156	0,45
Acetophenone	98-86-2	202	0,13 (15 °C)
Halocarbons			
Trichloroethene	79-01-6	87	2,7
Tetrachloroethene	127-18-4	121	1,87
1,1,1-Trichloroethane	71-55-6	74	2,7
1,4-Dichlorobenzene	106-46-7	173	1,2
Esters			
Ethyl acetate	141-78-6	77	9,7
Butyl acetate	123-86-4	126	1,9
Isopropyl acetate	108-21-4	85	6,3
Methoxypropyl acetate	108-65-6	145 to 146	
2-Ethoxyethyl acetate	111-15-9	156	0,16
Dimethyl phthalate	131-11-3	284	0,001 3 [28]
2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate	25265-77-4	244	
2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	6846-50-0	280	
Other			
2-Pentylfuran	3777-69-3	> 120	
THF (Tetrahydrofuran)	109-99-9	67	19,3 (20 °C)

[a] Depending on the literature used, the boiling points reported may vary by a few degrees Celsius for some compounds.

Annex B
(informative)

Protocol for recording activities and boundary conditions during sampling

During typical use of rooms, temporary emissions may occur owing to activities or behaviour of the occupants. In order to interpret the analytical results, the activities of the occupants, the ventilation conditions and the climatic conditions during sampling shall be determined and documented. During long-term measurements, the participation of the occupants is also necessary. The measurement institute should inform the occupants that activities deviating from customary use can affect the measurement result. For this reason, all activities deviating from customary use should be noted in a protocol. Since many rooms are only used at specific times or are used by different groups of people, in practice, it has proved to be helpful if the activities and boundary conditions are recorded by occupants at the end of a period of use or at the end of a day. The protocols can be collected and be made available to the measurement institute for evaluation at the end of the sampling period.

The final version of the protocol should be established during the appropriate measurement planning. General guidelines concerning information to be recorded during indoor air measurement are given in ISO 16000-1:2004, Annex D.

In the case of long-term sampling, it is advisable, in addition to the information to be obtained in indoor air studies, to record other information listed in Annex D of ISO 16000-1:2004.

When diffusive samplers are used for long-term sampling, the way in which the samplers are attached and the position and height of attachment of the passive samplers in the room shall be documented, if necessary, using a sketch.

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