INTERNATIONAL STANDARD

ISO 16000-12

First edition
2008-04-01

Indoor air —

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

Air intérieur —

Partie 12: Stratégie d'échantillonnage des polychlorobiphényles (PCB), des polychlorodibenzo-p-dioxines (PCDD), des polychlorodibenzofuranes (PCDF) et des hydrocarbures aromatiques polycycliques (HAP)

Reference number
ISO 16000-12:2008(E)

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Published in Switzerland

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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 16000-12 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 by impaction*

— *Part 19: Sampling strategy for moulds*

— *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 for building products — Micro-chamber method*

— *Part 27: Standard method for the quantitative analysis of asbestos fibres in settled dust*

— *Part 28: Sensory evaluation of emissions from building materials and products*

The following parts are planned:

— *Part 20: Detection and enumeration of moulds — Sampling from house dust*

— *Part 21: Detection and enumeration of moulds — Sampling from materials*

— *Part 22: Detection and enumeration of moulds — Molecular methods*

Furthermore, VOC measurements by pumped and diffusive sampling are specified in:

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*

Introduction

ISO 16000 (all parts) specifies general requirements relating to the measurement of indoor air pollutants and the necessary conditions to be observed before or during the sampling of individual pollutants or groups of pollutants as well as the measurement procedures themselves (see Foreword).

Sampling of polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs) also known as polychlorinated oxanthrenes, and polychlorinated dibenzofurans (PCDFs) in indoor air is described in ISO 16000-13 whereas the corresponding extraction, clean-up and analysis by high-resolution gas chromatography/mass spectrometry is specified in ISO 16000-14. For sampling and analysis of PAHs, ISO 12884 may be employed.

Several PCBs, PCDDs/PCDFs, and PAHs are considered to be potential human carcinogens. There are 209 individual PCBs (congeners), 75 PCDDs and 135 PCDFs. The most toxic PCBs are those that are coplanar and structurally similar to PCDDs. The most toxic PCDD is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). The toxicity of PCBs and PCDDs/PCDFs are calculated according to an internationally accepted system (see Annex A and Reference [1]). In 1997 (updated in 2005), a group of experts of the World Health Organization (WHO) fixed toxic equivalent factors (TEFs) for PCDDs/PCDFs and 12 PCBs, known as dioxin-like PCBs (Reference [1]) (see Annex A). These 12 dioxin-like PCBs consist of four non-ortho PCBs and eight mono-ortho PCBs (no or only one chlorine atom in 2-, 2'-, 6- and 6'-position), having a planar or mostly planar structure, see Table A.2.

The principal sources of PCDDs/PCDFs in indoor air are impurities in wood preservatives containing pentachlorophenol (PCP) and emissions from fires involving chlorinated products. PCBs are emitted into the indoor air primarily from concrete sealers, certain paints, or electrical capacitors; their use for these applications has been banned in many countries in recent years. Emissions from nearby landfills and abandoned industrial sites may also contribute PCBs and PCDDs/PCDFs to the indoor environment. The major origin of PAHs indoors is from combustion processes (mostly tobacco smoke and smoke from open fires).

Except for the case where there are direct indoor sources, PCBs and PCDDs/PCDFs enter indoor air from ambient air by ventilation. However, in ambient air these compounds are usually found at extremely low concentrations; e.g. several femtograms per cubic meter for PCDDs/PCDFs and about 10 pg/m^3 to several hundred picograms per cubic meter for total PCBs. The compounds addressed in this part of ISO 16000 are usually distributed between the gas and particle phases in ambient or indoor air, depending on the temperature, humidity, degree of chlorination, their concentration and capacity to associate with suspended particulate matter. Separate analyses of the filter and vapour trap will not reflect the original atmospheric phase distributions at normal ambient temperatures because of volatilization of compounds from the filter and should not be attempted.

Shipping of PCDD/PCDF standard reference materials shall comply with national legal regulations. They shall be transported in special containers that are commercially available. Handling should only be done by trained operators.

The sampling strategy specified in this part of ISO 16000 presupposes familiarity with ISO 16000-1.

This part of ISO 16000 uses the definition of indoor environments given by the Expert Council on Environmental Matters (see ISO 16000-1 and Reference [2]): dwellings — having living rooms, bedrooms, DIY (do-it-yourself) rooms, sports rooms and cellars, kitchens and bathrooms; workrooms or work places — in buildings that are not subject to health and safety inspections in regard to air pollutants (e.g. offices, sales premises); public buildings — e.g. hospitals, schools, kindergartens, sport halls, libraries, restaurants and bars, theaters, cinemas or other function rooms); and the interiors of private and public transport vehicles.

This part of ISO 16000 is based on VDI 4300-2[3].

Indoor air —

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

1 Scope

This part of ISO 16000 specifies the planning of measurements for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs) also known as polychlorinated oxanthrenes, polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (PAHs) in indoor air. 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, e.g. with respect to the need for remedial action or the success of such an action.

An inappropriate measurement strategy may contribute more overall uncertainty to the measurement result than the measurement procedure itself.

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 12884, *Ambient air — Determination of total (gas- and particle-phase) polycyclic aromatic hydrocarbons — Collection on sorbent-backed filters with gas chromatographic/mass spectrometric analyses*

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

ISO 16000-13, *Indoor air — 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*

ISO 16362, *Ambient air — Determination of particle-phase polycyclic aromatic hydrocarbons by high performance liquid chromatography*

3 Sources and incidence of PCBs, PCDDs/PCDFs and PAHs

3.1 General

PCBs, PCDDs/PCDFs and PAHs get into indoor air from a variety of sources as explained in 3.2, 3.3, and 3.4. Owing to sorption effects, the compounds originating from primary sources can be sorbed by various surfaces that may then act as secondary sources.

Not all sources and processes that could result in elevated concentrations of these substances in indoor air are known as yet. Table 1 gives an overview of the highest yielding sources that can all be designated as primary. Depending on the strength and period of action of the individual primary sources, vaporization, diffusion, sorption or sedimentation processes lead to contamination of the surfaces in the room. Even after removal of the primary sources, these contaminated surfaces themselves can act as secondary sources.

Table 1 — Possible sources of PCBs, PCDDs/PCDFs and PAHs in indoor air

Class of substance	Sources
PCBs	PCB-containing jointing materials Defective capacitors, e.g. in lamps Defective transformers Paints and varnishes containing flame retardants Plasticizers used in plastics, e.g. in sealing material for expansion joints in prefabricated concrete construction Forming oil employed in concrete construction Soil tracked in from emissions and polluted sites
PCDDs/PCDFs	Pentachlorophenol-containing materials, e.g. wood preservative paints, leather Fires in the presence of halogenated materials Soil tracked in from emissions and polluted sites
PAHs	Tobacco smoke Smoke from open fires Dyes or products containing tar oil or pitch (e.g. as glue for parquet flooring) Soil tracked in from emissions and polluted sites Cooking

When there are no obligatory criteria of assessment for evaluating the indoor air, an initial evaluation of the results of the indoor air investigation can be carried out by comparison with the concentrations of the relevant substances in the ambient air. Table 2 shows some typical ambient air concentrations for benzo[*a*]pyrene (the guide component for PAHs), PCDDs/PCDFs [as toxic equivalents (TEQ) according to WHO, see Annex A.3] and PCBs [as the sum of the concentrations of six congeners; see footnote a) to Table 2].

Table 2 — Concentration ranges of PCBs, PCDDs/PCDFs and PAHs in the ambient air of urban areas

Class of substance	Ambient air, mean concentration range	
	urban level	high concentration site
PCBs [a]	5 ng/m^3 to 10 ng/m^3	—[b]
PCDDs/PCDFs [c]	0,05 pg/m^3 to 0,15 pg/m^3	0,15 pg/m^3 to 0,5 pg/m^3
PAHs (only benzo[*a*]pyrene)	0,5 ng/m^3 to 1 ng/m^3	1 ng/m^3 to 21 ng/m^3(Reference [7])

[a] Sum of the six PCB congeners (28, 52, 101, 138, 153, 180 according to the Ballschmiter System), multiplied by 5 to calculate the total PCB content.

[b] PCBs are ubiquitous, increased concentrations are encountered only in the immediate vicinity of contaminated buildings.

[c] Toxic equivalents, see Annex A.

3.2 PCBs

In the past, PCBs have been deliberately and openly employed indoors in a number of materials so as to achieve certain material properties. Thus, polymer-based sealing materials containing PCBs as plasticizers have been employed especially in buildings using the open concrete slab method of construction. In addition, lightweight boards treated with PCB-containing emulsion paints have been used for suspended ceilings, and wooden surfaces painted with PCB-containing flame retardants have also been found.

Closed systems are, for example, small PCB-containing capacitors which have found widespread use, among other things, in lamps. Due to government mandates and voluntary restrictions applied by manufacturers, PCBs are no longer used in capacitors, either in lamps or elsewhere.

If there are important sources of emission in the vicinity of the building being examined, the ambient air shall also be considered as a source.

3.3 PCDDs/PCDFs

PCDDs/PCDFs are present as impurities in pentachlorophenol (PCP). They can get into the indoor environment from pentachlorophenol-containing materials used up to the end of the 1970s and to a small extent up to the middle of the 1980s (Reference [4]). PCB-containing jointing compounds can also contain PCDDs/PCDFs and release them into room air.

In the case of fire, chlorine-containing organic materials, e.g. electric cable sheathing, floor coverings, and PVC door and window frames give rise to PCDDs/PCDFs bound to soot and other particles, which deposit on surfaces and, if not cleaned off, are a continual source of pollution in the indoor air. Recommendations for the renovation, evaluation, disposal, and procedures in the case of rooms contaminated in this way have been prepared by the German Federal Health Office (References [5] and [6]).

3.4 PAHs

PAHs are formed in all incomplete-combustion processes. The best known example is cigarette smoking. However, chimneys that do not draw properly or candles burning with a sooty flame can give rise to measurable amounts of PAHs. They can also be released by pitch-containing materials used in interior construction work.

4 Measurement procedure

4.1 General

Most PCBs, PCDDs/PCDFs and PAHs belong to the semi-volatile group of organic compounds. In indoor air, they are encountered both bound to particles (suspended and settled dust) and in the gas phase.

Sampling and analytical procedures for pollution measurement are subject to standardization (see Table 3).

Table 3 — Sampling and analytical procedures

Class of substance	Procedure	Brief description
PCBs	ISO 16000-13	Sampling using either a low volume sampler or a high volume sampler with a polyurethane foam or other suitable adsorbent material preceded by a particle filter.
PCDDs/PCDFs	ISO 16000-13	Sampling using either a low volume sampler or a high volume sampler with a polyurethane foam or other suitable adsorbent material preceded by a particle filter.
PAHs	ISO 12884, ISO 16362, national standards	ISO 12884 and ISO 16362 apply to ambient air and indoor air measurements. In the latter case, the user shall take into consideration that, due to noise, only a low volume sampler should be used (see ISO 16000-13). In this case, some adaptation is necessary.

4.2 PCBs

Sampling should be conducted with a quiet, low-volume sampler (flow rate between 1,2 m^3/h and 2,8 m^3/h), if possible. If required to detect lower concentration levels, a high-volume sampler (flow rate between 6 m^3/h and 16 m^3/h) may be employed with certain limitations. In either case, no more than 10 % of the room air volume shall be sampled per hour. High-volume samplers are typically very noisy and cannot be used in occupied areas. Appropriate samplers and analytical procedures are described in ISO 16000-13.

The PCBs are extracted from the filter and the solid sorbent, and subjected to multistage chromatography to remove the impurities and analysed by gas chromatography/mass spectrometry (GC/MS).

4.3 PCDDs/PCDFs

Sampling should be conducted with a quiet, low-volume sampler (flow rate between 1,2 m^3/h and 2,8 m^3/h) if possible. If required to detect lower concentration levels, a high-volume sampler (flow rate between 6 m^3/h and 16 m^3/h) may be employed with certain limitations. In either case, no more than 10 % of the room air volume shall be sampled per hour. High-volume samplers are typically very noisy and cannot be used in occupied areas. Appropriate samplers and analytical procedures are described in ISO 16000-13.

The PCDDs/PCDFs are extracted from the filter and the solid sorbent, and subjected to multistage chromatography to remove the impurities and analysed by GC/MS.

4.4 PAHs

For total PAH measurements, the same sampling protocol described in 4.1 and 4.2 shall be employed (see ISO 16000-13, ISO 12884 and ISO 16362 for appropriate samplers). A low volume sampler is the first choice. However, if only semi-volatile PAH (with 5 or more rings; vapour pressures less than 10^{-8} kPa or boiling points higher than 475 °C) are of interest, a sampler equipped with a particle filter only (not backed up by a vapour trap) may be employed (see ISO 16362).

For the analysis, the PAHs are extracted, the extracts filtered, and most of the solvent removed. In some cases, it may be necessary to separate off the polar nonaromatic components by means of column chromatography. The concentrates are separated by GC, high performance liquid chromatography or MS and the PAHs are determined using suitable detectors.

5 Measurement planning

5.1 General

Since PCBs, PCDDs/PCDFs and PAHs determinations require complicated and costly analyses, a measurement strategy shall be prepared for the representative determination of these substances. The purchaser and the laboratory shall agree on the sampling strategy which shall be based on this part of ISO 16000.

5.2 Status review before measurement

Before the indoor air measurements are started, carry out general studies relevant to the particular case. Investigate the background to any complaints and determine details of the nature of the building, room furnishings etc. (as specified in ISO 16000-1).

The preliminary work shall also include a status review of possible sources and processes of emission.

In many cases it is useful, by analysing samples of material to be considered as sources and in individual cases wipe samples, to obtain a rough guide as to the extent to which the substances in question actually play a role in the indoor environment being examined. A procedure based on the particular case or on the type of source, as presented briefly in the following examples, has proven appropriate.

The settled house dust and tracked-in soil may be analysed to obtain an indication of the potential exposures of room occupants to PCBs, PCDDs/PCDFs and PAHs. Sampling and boundary conditions to be taken into account for this method are described in Reference [8].

5.2.1 PCBs

As mentioned in Clause 4, PCBs in interior spaces may be attributed to various sources. To obtain a rough estimate of possible PCB pollution in buildings with non-uniform levels of contamination, it is useful to conduct a status review of possible sources.

The procedure for investigating possible PCB pollution in interior rooms is given in Annex B.

5.2.2 PCDDs/PCDFs

PCDD/PCDF measurements are generally not necessary in a room containing wood treated with preservatives containing pentachlorophenol (PCP). If information about PCDD/PCDF concentrations is desired, measurements should only be carried out if the quotient, Q, in reciprocal metres, according to Equation (1) (Reference [9]):

$$Q = \frac{A}{V} \tag{1}$$

where

A is the treated wood area, in metres squared;

V is the room volume, in metres cubed

is $\geqslant 0{,}2\ m^{-1}$ and the PCP mass fraction is more than 50 mg per kilogram of wood.

In the case of fires, PCDD/PCDF measurements are not generally required (Reference [6]). The occurrence of PCDDs/PCDFs in the case of fire and the procedure to be observed are discussed in detail in Annex C.

5.2.3 PAHs

If a composition containing tar oil (e.g. as wood preservative) has been employed in the past, it can be assumed on the basis of the product-specific composition that a potential source of PAHs is present. Valuable indications of possible indoor air pollution by PAHs can be obtained by analysing the benzo[*a*]pyrene content (guide component) of the sample of the suspected source material.

5.3 Measurement objective (and indoor climatic conditions)

Before indoor air measurements are carried out, the measurement objective shall be clearly defined. Conceivable objectives are:

a) information about the average concentration under usual conditions;

b) information about the peak concentration (special conditions);

c) checking compliance to a guide value;

d) information about the ratio of indoor and ambient air concentrations.