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Indoor air —

Part 24:
Performance test for evaluating the reduction of volatile organic compound (except formaldehyde) concentrations by sorptive building materials

Air intérieur —

Partie 24: Essai de performance pour l'évaluation de la réduction des concentrations en composés organiques volatils (sauf formaldéhyde) par des matériaux de construction sorptifs

Reference number
ISO 16000-24:2009(E)

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 16000-24 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 and 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 18: Detection and enumeration of moulds — Sampling by impaction*
- *Part 23: Performance test for evaluating the reduction of formaldehyde concentrations by sorptive building materials*
- *Part 24: Performance test for evaluating the reduction of volatile organic compounds (except formaldehyde) concentrations by sorptive building materials*
- *Part 25: Determination of the emission of semi-volatile organic compounds by building products — Micro-chamber method*

The following parts are under preparation:

- *Part 19: Sampling strategy for moulds*
- *Part 26: Measurement strategy for carbon dioxide (CO_2)*
- *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*
- *Part 27: Standard method for the quantitative analysis of asbestos fibres in settled dust*
- *Part 30: Sensory testing of indoor air*

Furthermore:

- ISO 12219-1, *Indoor air — Road vehicles — Part 1: Whole vehicle test chamber — Specification and method for the determination of volatile organic compounds in car interiors* [planned document]
- 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*

focus on volatile organic compound (VOC) measurements.

Introduction

Sorptive building materials have been marketed in the form of sheet and board products for removing airborne pollutants via physical sorption or chemical reaction.

Harmonized test methods for evaluating sorptive effects are important for comparative assessment of the performance of sorptive building materials that are used for reducing levels of indoor air contaminants.

This part of ISO 16000 specifies a test method for evaluating the performance of sorptive building materials for reducing indoor air volatile organic compound (VOC) (except formaldehyde) concentrations over time.

The performance of sorptive building materials is evaluated by sorption flux and saturation mass per area and is affected by a number of factors. Specific test conditions are therefore defined in this part of ISO 16000.

This part of ISO 16000 can be applied to most sorptive building materials used indoors and for VOCs (excluding formaldehyde).

This part of ISO 16000 is based on and is complementary to the test chamber method specified in ISO 16000-9.

Indoor air —

Part 24:
Performance test for evaluating the reduction of volatile organic compound (except formaldehyde) concentrations by sorptive building materials

1 Scope

This part of ISO 16000 specifies a general laboratory test method for evaluating the reduction in concentration of volatile organic compounds (VOCs) (except formaldehyde) by sorptive building materials. This method applies to boards, wallpapers, carpets, paint products, and other building materials. The sorption of VOCs (except formaldehyde) can be brought about by adsorption, absorption and chemisorption. The performance of the material, with respect to its ability to reduce the concentration of VOCs (except formaldehyde) in indoor air, is evaluated by measuring sorption flux and saturation mass per area. The former directly indicates material performance with respect to VOC reduction at a point in time; the latter relates to the ability to maintain that performance.

Formaldehyde has been excluded from this part of ISO 16000 because it is difficult to obtain as a stable standard in air.

This part of ISO 16000 is based on the test chamber method specified in ISO 16000-9. Sampling, transport and storage of materials to be tested, and preparation of test specimens are described in ISO 16000-11. Air sampling and analytical methods for the determination of carbonyl compounds (except formaldehyde) are described in ISO 16000-3, and those of VOCs are described in ISO 16000-6 and ISO 16017-1.

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 554, *Standard atmospheres for conditioning and/or testing — Specifications*

ISO 6353-3, *Reagents for chemical analysis — Part 3: Specifications — Second series*

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method*

ISO 16000-6, *Indoor air — 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*

ISO 16000-9:2006, *Indoor air — Part 9: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test chamber method*

ISO 16000-11, *Indoor air — Part 11: Determination of the emission of volatile organic compounds from building products and furnishing — Sampling, storage of samples and preparation of test specimens*

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*

3 Terms and definitions

For the purpose of this part of ISO 16000, the following terms and definitions apply.

3.1

breakthrough time

t_b

⟨indoor air⟩ time at which the volatile organic compound concentration in the air eluting from the sample tube reaches 0,5 % of the concentration in the supply air

3.2

degradation coefficient

⟨indoor air⟩ ratio of the mass of volatile organic compounds and carbonyl compounds removed by the initial performance divided by the mass of the same compounds lost by deterioration

3.3

elapsed time

t_e

⟨indoor air⟩ time from start of test to the start of air sampling

NOTE Elapsed time is expressed in days.

3.4

equivalent ventilation rate per area

$F_{V,\,\mathrm{eq}}$

⟨indoor air⟩ increased clean air ventilation rate giving the same reduction in volatile organic compound concentration as the building material

3.5

guideline concentration

⟨indoor air⟩ guideline indoor air concentration for a target chemical compound as specified by the WHO or an appropriate national standards body

3.6

half-lifetime

⟨indoor air⟩ time elapsed from the start of the test until the volatile organic compound concentration decreases to one-half of the initial concentration

3.7

lifetime

t_lt

⟨indoor air⟩ time period over which the product continues to reduce volatile organic compound concentrations

NOTE 1 The lifetime is given in days or years.

NOTE 2 The lifetime is estimated from the sorption flux and sorption capacity measured by the sample tube test.

3.8

mass transfer coefficient

k_a

⟨indoor air⟩ coefficient arising from the concentration difference between the test specimen and ambient air over its surface

NOTE Mass transfer coefficient is expressed in meters per hour.

3.9
recovery

⟨indoor air⟩ measured mass of volatile organic compounds (except formaldehyde) in the air leaving the test chamber with no sample present conditioned over a given time period divided by the mass of volatile organic compounds (except formaldehyde) added to the test chamber in the same time period

NOTE 1 The recovery is expressed as a percentage and provides information about the performance of the entire method.

NOTE 2 Adapted from ISO 16000-9:2006, 3.9.

3.10
saturation mass per area

ρ_{Aa}

theoretical maximum mass of volatile organic compounds (except formaldehyde) that could be removed per area of the sorptive material

NOTE Saturation mass per area is expressed in micrograms per square metre. It corresponds to the total mass per area of sorption at the half-lifetime, or is extrapolated from the sorption capacity derived from the test specified in Annex A.

3.11
sorption capacity

w_{s}

total mass of volatile organic compounds (except formaldehyde) sorbed at breakthrough time per mass of sorbent

NOTE Sorption capacity is expressed in micrograms per gram and is measured using the test specified in Annex A.

3.12
sorption flux

F_m

mass of volatile organic compounds (except formaldehyde) sorbed per time per area at the specified elapsed time from the test start

3.13
supply air concentration

ρ_{s}

mass concentration of volatile organic compounds (except formaldehyde) in the air for supply to the test chamber

3.14
test chamber concentration

⟨indoor air⟩ concentration of volatile organic compounds (except formaldehyde) measured at the outlet of a test chamber, derived by dividing the mass of the volatile organic compounds (except formaldehyde) sampled at the outlet of the chamber by the volume of sampled air

3.15
total mass per area of sorption

integral over time of sorptive flux from the start of the test to the specified elapsed time measured with the test chamber

NOTE Total mass per area of sorption is expressed in micrograms per square metre.

3.16
vapour sampling period

⟨indoor air⟩ period of time during which air is sampled from the outlet of the test chamber using sampling tubes or other devices

4 Symbols

Symbol	Meaning	Unit
ρ_A	mass of sorptive material per area (surface density)	grams per square metre
$\rho_{A\mathrm{a}}$	saturation mass per area	micrograms per square metre
$\rho_{A\mathrm{c}}$	total mass per area of sorption measured by chamber test	micrograms per square metre
$\rho_{\mathrm{in},\,t}$	concentration of target compound at test chamber inlet at elapsed time t	micrograms per cubic metre
$\rho_{\mathrm{out},\,t}$	test chamber concentration at elapsed time t	micrograms per cubic metre
ρ_{s}	supply air concentration in sample tube	micrograms per cubic metre
A	surface area of test specimen	square metres
F_m	sorption flux per time per area	micrograms per square metre per hour
$F_{V,\,\mathrm{a}}$	air flow rate per area	cubic metres per square metre per hour
$F_{V,\,\mathrm{eq}}$	equivalent ventilation rate per area	cubic metres per square metre per hour
k_{a}	mass transfer coefficient determined using water vapor	metres per hour
L	product loading factor	square metres per cubic metre
m	actual mass of test specimen in sample tube	grams
n	air change rate	changes per hour
q_{c}	air flow rate of test chamber	cubic metres per hour
q_{s}	air flow rate of sample tube	litres per minute
t_{b}	breakthrough time	minutes
t_{e}	elapsed time	hours or days
t_{lt}	lifetime of the pollutant-removing performance	hours or days or years
V	air volume of test chamber	cubic metres
w_{s}	sorption capacity measured by sample tube	micrograms per gram

5 Principle

The performance of a building material, the test material, with respect to its ability to reduce the concentration of target VOCs (except formaldehyde) is evaluated by monitoring the reduction of the vapour concentration inside a test chamber containing a test specimen of that material. The test includes an assessment of both the initial performance of the material and how long that performance is maintained. Target compounds are VOCs (except formaldehyde) detected in the test chamber inlet and outlet air.

In this test method, target compounds are spiked into the air of a test chamber containing the material under test. The spiked air should be prepared approximately at the WHO guideline level for target compounds in indoor air. Reference to national standards is possible if this is clearly highlighted in the test report and certificate.

Performance is determined by monitoring the difference of the inlet and outlet concentration of the test chamber. Testing should be continued for the half-lifetime, i.e. until the concentration of target compounds decreases to one-half of the initial concentration under constant ventilation conditions. With this test, sorption flux, F_m, and total mass per area of sorption, $\rho_{A\mathrm{c}}$, at the half-lifetime are determined. The measured $\rho_{A\mathrm{c}}$ at the half-lifetime is defined as the saturation mass per area, $\rho_{A\mathrm{a}}$.

If a test material has a long-lasting target compound reduction performance (e.g. more than 28 days) and it might take too long a time for the test, alternative methods specified in Annex A for determining $\rho_{A\mathrm{a}}$ may be applied.

The performance of sorptive building materials is mainly determined by the concentration of target compounds, the mass transfer coefficient of target compounds to the surface, and the sorption characteristics of the building materials themselves (adsorption isotherm, diffusion resistance, and so on). Therefore, the performance test method shall specify both the concentration of target compounds and the mass transfer coefficient associated with the sorptive building materials.

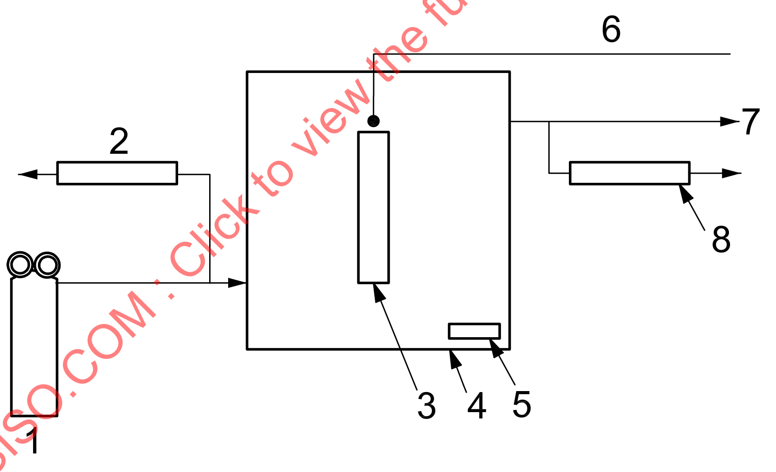
This method does not apply to materials capable of decomposing VOCs (except formaldehyde) by catalytic reaction in the presence of ultraviolet and visible rays.

NOTE The long-term target compound reduction performance is represented by the saturation mass per area, $\rho_{A\mathrm{a}}$, and, if necessary, the lifetime of the pollutant-removing performance, t_{lt}, as the subsidiary index.

6 Apparatus and materials

Usual laboratory equipment, and in particular the following.

6.1 Test chamber, complying with with relevant specifications and requirements of ISO 16000-9 (see Figure 1). No air shall be allowed to circulate from the outlet back to the inlet.



Key

1 target compound(s) in spiked air
2 sampling device
3 test specimen
4 test chamber
5 device to circulate air and control air velocity
6 temperature/humidity monitoring apparatus
7 test chamber outlet
8 sampling device

Figure 1 — Outline of the chamber system

6.2 Sealing material for test specimens, such as **aluminium foil** or a **tape covered with aluminium foil**, to cover the edges and the back of the test specimen, if only the surface normally directly exposed to the indoor environment under the intended conditions of use is the subject of the test.

6.3 Air purifier or **cylinder of clean air**. The purifier shall ensure the supply air before being spiked with target compounds is as clean as possible, i.e. it shall not contain any contaminants at levels greater than the chamber background requirements. In order to prevent a rise in background concentration, an air purifier shall be provided or a cylinder of clean air shall be used.

6.4 Supply air spiked with target compound(s). Apply a standard gas (with known target compound concentrations) or a stable source like a target compound solution as specified in ISO 6353-3 to generate spiked air for supply of the test chamber, at a constant concentration. The stability of the spiked concentration(s) shall be monitored.

The spiked concentration(s) should be determined at least twice (at the beginning and end of the test).

6.5 Temperature and humidity control. Temperature shall be maintained either by installing a test chamber in a place maintained at a required temperature, such as a constant-temperature climate chamber, or by maintaining a required temperature in the chamber. Relative humidity shall be maintained at the required humidity of the supply air.

6.6 Air flow meter, installed at the inlet or the outlet of the test chamber to measure the air flow rate through the chamber.

6.7 Air sampling devices. Use the inlet and outlet air of the test chamber for sampling. When a separate sampling port is used, sample directly from the inlet or outlet of the chamber.

If a duct or tube is used, it shall be as short as possible and maintained at the same air temperature as that in the test chamber. Such a duct or tube shall be made of a material with a very low sorption capacity, e.g. polytetrafluoroethylene.

The sum of sampling air flow rates shall be smaller than the air flow rate into the chamber. Sampling devices shall comply with the specifications of ISO 16000-3 and ISO 16000-6, respectively. When the air is sampled from the inlet, ensure the supply air flow rate remains constant.

A multiport sampling manifold may be used to provide flexibility for duplicate air sampling. A mixing chamber between the test chamber and the manifold or between the air inlet and the test chamber can be included to permit addition and mixing of internal standard gases with the test chamber air stream.

The exhaust from the test chamber should be ducted into a fume hood, ensuring any chemicals emitted from the test material are isolated from the laboratory environment.

6.8 Analytical instrument. For determination of VOCs, a gas chromatograph (GC) shall be used as specified in ISO 16000-6 and ISO 16017-1. For determination of carbonyl compounds, a high performance liquid chromatograph (HPLC) shall also be used as specified in ISO 16000-3. Alternative devices with an equal or better accuracy may be used.

7 Test conditions

7.1 General

The test conditions shall comply with 7.2 and 7.3. This test shall be conducted under atmospheric pressure conditions.

7.2 Test conditions for concentration reduction performance determination

7.2.1 Temperature and relative humidity

Building materials for use in Europe and America shall be tested in accordance with ISO 554 at a temperature of 23 °C ± 2 °C and relative humidity 50 % ± 5 % during the test.

Building materials for use in Japan shall be tested at a temperature of 28 °C ± 1 °C and relative humidity 50 % ± 5 % during the test.

For building materials with applications under other climatic conditions, alternative temperature and air humidity conditions may be used, preferably as specified in ISO 554. State the conditions in the test report.

To check the test material for temperature dependence of reduction performance, measurements under other climatic conditions may be applied.

Initial variations can be observed in the test chamber climate after opening the test chamber door and loading a test specimen. These variations should be recorded.

NOTE Temperature and relative humidity can affect sorption flux and re-desorption from the test material.

7.2.2 Supply air quality and background concentration

The background concentration of the supply air for the test chamber and the air prior to spiking with target compounds shall be low enough not to interfere with the test. The total VOC background concentration shall be lower than 20 µg/m^3. The background concentration of each VOC shall be lower than 2 µg/m^3. Purified water used for humidification shall not contain interfering VOCs that may affect the test.

7.2.3 Mass transfer coefficient

The mass transfer coefficient in terms of ambient air velocity over the surface of the test specimen inside the chamber shall be in the range 15 m/h ± 3 m/h (equivalent to 0,25 m/s ± 0,05 m/s) when determined using water vapour. To check the dependence of the mass transfer coefficient on material performance, take measurements under conditions that influence in an appropriate manner, the mass transfer coefficient.

NOTE 1 The mass transfer coefficient is analogous to the convective heat transfer coefficient where geometry and boundary conditions are similar. The mass transfer coefficient can be estimated with a formulation that relates the mass transfer flux (sorption flux) to a surface to the concentration differences across the boundary layer. For details concerning the mass transfer coefficient and its measurement method, see Reference [5].

NOTE 2 Reduction performance depends on the mass transfer coefficient. The mass transfer coefficient depends on the indoor concentration of the substance, air flow, and the surface area of the test specimen.

7.2.4 Area specific ventilation rate and air change rate

The air change rate shall be kept constant at 0,50 /h ± 0,05 /h. The product-loading factor shall comply with ISO 16000-9:2006, Annex B, or be derived from the geometry and volume of an appropriate model room.

NOTE The selection of air flow rate per area, $F_{V,\mathrm{a}}$, affects the steady-state concentration of target VOCs in the chamber air.

For comparison of results from different test chambers, the air exchange rate, n, and the product-loading factor, L, shall be the same for each chamber. The air change rate, n, and the product-loading factor, L, may affect the sorption flux, F_m.

7.2.5 Supply air concentration

The concentration of target compound(s) in spiked air in the test chamber shall be approximately equal to the WHO guideline concentration(s).

Other concentrations may be applied if relevant for the purpose of the test. This shall be stated explicitly in the report.

It is possible to execute the test using mixed gas that includes two or more target compound(s). In that case, it is necessary to consider the influence of interference.

7.3 Factors affecting the concentration reduction performance

7.3.1 General

For evaluation of the effect of temperature, humidity, and contaminants in air on the target compound concentration reduction performance, modify each of these factors separately.

7.3.2 Effects of temperature and humidity

The temperature in the test chamber should be set to 18 °C ± 2 °C, 23 °C ± 2 °C and 28 °C ± 1 °C, with the relative humidity in the chamber as specified in 7.2.1 and the supply air concentration in the chamber set as specified in 7.2.5.

The relative humidity in the test chamber should be set to 25 % ± 5 %, 50 % ± 5 % and 75 % ± 5 %, with the temperature in the chamber as specified in 7.2.1 and the supply air concentration in the chamber set as specified in 7.2.5.

7.3.3 Effect of concentration of target compound(s) in spiked air

The concentration of target compound(s) in spiked air should be set to twice the guideline concentration specified in 7.2.5, and then to one-half of the guideline concentration, with the chamber temperature and relative humidity set as specified in 7.2.1.

7.3.4 Effects of interfering gases

Various interfering gases are expected to exist in indoor environments. It is possible to measure their effect on the performance of test materials in reducing target compound(s) by measuring such performance while varying the concentration of each interfering gas.

8 Verification of test conditions

8.1 Monitoring of test conditions

Temperature, relative humidity and air flow rate shall be monitored and recorded continuously with instruments meeting the following accuracy specifications:

— temperature:	± 1 °C
— relative humidity:	± 3 %
— air flow rate:	± 3 %

Temperature and relative humidity of air may be measured in the outlet of the chamber if the point of measurement is constructed in a manner that ensures values identical to those inside the test chamber.

8.2 Air-tightness of test chamber

Air-tightness of the test chamber should be checked regularly as specified in ISO 16000-9, either by pressure drop measurements, by comparison of simultaneous measurement of flow rates at the inlet and the outlet ports, or by measuring tracer gas dilution.

8.3 Air change rate in test chamber

The air change rate shall be regularly checked as specified in ISO 16000-9.

NOTE If the test is carried out in the outlet with an air flow meter that is not permanently installed, note that the back pressure introduced by the instrument can lower the flow rate through the chamber.

8.4 Efficiency of the internal test chamber air mixing

Determine the efficiency of the air mixing as specified in ISO 16000-9.

8.5 Recovery

Recovery tests shall be performed in the test chamber by introducing supply air with the same target compound concentrations as to be used in the performance test and then comparing air measurement results at the outlet and inlet of the test chamber. The mean recovery shall be greater than 80 % for the target compound. The results of the recovery test shall be reported (expected concentration versus measured concentration).

NOTE Sink effect, leakage or poor calibration can cause difficulties in meeting minimum requirements for the test.

9 Preparation of test chamber

The test chamber shall be cleaned in order to fulfil the requirements of 7.2. Cleaning can be done by washing the inner surfaces of the test chamber with a detergent followed by two separate rinsings with freshly distilled water. The test chamber is then dried and purged under test conditions. The test chamber can also be cleaned by thermal desorption.

The adsorption of volatile compounds by the chamber itself shall be monitored by performing a test as described in 11.1 but without any test specimen. The adsorption capacity of the chamber itself shall be subtracted from the measured adsorption capacity.

For cleaning of the chamber, an oven may be used to volatilize any aldehydes or VOCs on the internal walls of the test chamber. Alternative methods can be used instead of an oven.

10 Preparation of test specimens

After completing test preparations, supply air spiked with the target compounds to the test chamber. Take a sample of the material to be tested from its package. The sample shall be a part or piece that is representative of a building material. Prepare a test specimen from the sample as specified in ISO 16000-11.

For the measurement of target compound sorption by only one surface of a test specimen, seal the cut edges and the back of the specimen with aluminium foil or other sealing material, or place two test specimens back-to-back with sealed edges.

11 Test methods

11.1 Background concentration and spiked supply air

Prior to beginning a test, ventilate the test chamber for 1 day by running empty, and then measure and determine the background target compound concentrations of the empty test chamber.

The background concentration shall be low enough not to affect the test.

Then start flushing the test chamber with air spiked with target compounds. Allow at least five air exchanges before introducing the test specimen.

11.2 Placing the test specimen in the test chamber

Place the test specimen in the middle of the test chamber to ensure that air may uniformly flow over the sorbing surface of the test specimen. Close the chamber. Take this time as the start of the test.

Place the test specimen in the test chamber as quickly as possible.

11.3 Time intervals for measurement of chamber concentration

11.3.1 Test for concentration reduction performance

After the start of the test, sample air from the chamber inlet and the chamber outlet in accordance with 11.4 at predefined elapsed times.

Measure the quantity of target compounds removed from the test chamber air per area of the test specimen exposed to the chamber air under the measuring conditions specified in 7.2.

Check the total air flow through the test chamber and ensure that there is no air leakage from it. Then, ensure that the outlet air flow rate during air sampling is equal to the inlet air flow rate minus the sum of the sampling air flow rates. The remaining outlet airflow rate shall be at least 20 % of the total sampling air flow rates. Air samples shall be taken 24 h ± 2 h, 72 h ± 6 h, 168 h ± 14 h, 14 days ± 1 day, and 28 days ± 2 days after the start of the test. Additional air samples may be collected. Duplicate sampling is recommended.

Other time intervals may be selected according to the purpose of the test. If data on long-term performance of the test material are required, air sampling shall be done over 28 days after the test start. When the reduction performance decreases to one-half of the initial value, terminate the test.

A subsequent test of re-emission is recommended by subsequently supplying clean air to the test chamber. It is preferable to undertake re-emission tests routinely as part of the reduction performance test. Air samples should be taken 24 h (and other times if required) after the start of the re-emission test. In cases where significant sorption of VOCs to chamber surfaces occurs, it is necessary to understand the relative contribution of the sample and the chamber walls to the total emission. This may be achieved by appropriate control tests without material samples.

If VOCs and other organic vapours are emitted from the material sample, measure their emission rates as described in ISO 16000-3, ISO 16000-6 and ISO 16000-9.

11.3.2 Test for long-term reduction performance

Measure the time at which the reduction performance described in 11.3.1 falls to one-half of its initial value (reduction performance at 24 h after test start), and then measure the total mass per area of sorption, $\rho_{A\mathrm{c}}$, of VOCs and the elapsed time, t_e.

11.3.3 Factors affecting the reduction performance

The effect of each environmental factor may be measured by varying the value of only one factor at a time against those conditions used for the measurement of the reduction performance in 11.3.1. The measuring conditions shall be as specified in 7.2.

11.4 Air sampling

Tenax TA®1) (2,6-diphenyl-*p*-phenylene-oxide polymer resin) or another appropriate sorbent tube as specified in ISO 16000-6 and ISO 16017-1 shall be used for air sampling for the determination of VOC concentration. A

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1) Tenax TA® is the trade name of a product manufactured by Supelco, Inc. This information is given for the convenience of users of this International Standard 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.

2,4-dinitrophenylhydrazine (DNPH) sorbent tube as specified in ISO 16000-3 shall be also used in air sampling for the determination of carbonyl compound concentrations.

12 Determination of target compounds

Elute the DNPH derivatives of carbonyl compounds from the DNPH tubes and analyse as specified in ISO 16000-3. The analysis method of target VOCs shall be as specified in ISO 16000-6 and ISO 16017-1.

13 Expression of results

13.1 Calculation of sorption flux

Calculate the sorption flux per time per area, F_m, using Equation (1):

$$F_m = \frac{\left(\rho_{\mathrm{in},\, t_\mathrm{e}} - \rho_{\mathrm{out},\, t_\mathrm{e}}\right) q_\mathrm{c}}{A} \tag{1}$$

where

$\rho_{\mathrm{in},\, t_\mathrm{e}}$ is the concentration of target compound at test chamber inlet at elapsed time, t_e;

$\rho_{\mathrm{out},\, t_\mathrm{e}}$ is the test chamber concentration at elapsed time, t_e;

q_c is the air flow rate in the test chamber;

A is the surface area of test specimen.

13.2 Calculation of equivalent ventilation rate per area

Assuming that the concentration falls due to increasing air flow rate of clean air, calculate the equivalent ventilation rate per area, $F_{V,\,\mathrm{eq}}$:

$$F_{V,\,\mathrm{eq}} = \frac{\left(\dfrac{\rho_{\mathrm{in},\, t}}{\rho_{\mathrm{out},\, t}} - 1\right) q_\mathrm{c}}{A} \tag{2}$$

13.3 Calculation of total mass per area of sorption and saturation mass per area

Calculate the total mass per area of sorption, $\rho_{A\mathrm{c}}$, at the half-lifetime:

$$\rho_{A\mathrm{c}} = \sum_i \left(F_{m,\,i} \times \Delta t_{\mathrm{e},\,i}\right),\ \Delta t_{\mathrm{e},\,i} = t_{\mathrm{e},\,i} - t_{\mathrm{e},\,i-1} \tag{3}$$

where t_e is elapsed time.

The saturation mass per area, $\rho_{A\mathrm{a}}$, is given by the Identity:

$$\rho_{A\mathrm{a}} \equiv \rho_{A\mathrm{c}} \tag{4}$$

14 Test report

The test report shall include at least the following information:

a) test laboratory:

   1) name and address of the test laboratory,

   2) name of the responsible person;

b) sample description:

   1) type of building material (and brand name, if appropriate),

   2) sample selection process (e. g. random),

   3) product history (date of production, batch number, date of arrival at the test laboratory, date and time of unpacking, date and time of preparation of test specimen, etc.);

c) test results:

   1) sorption flux of target compounds, total mass per area of sorption, the equivalent ventilation rate per area at the specified elapsed time,

   2) the saturation mass per area and the reduction performance in the presence of interfering gases,

   3) details of the method used, with reference to this part of ISO 16000;

d) test conditions:

   1) test chamber conditions [temperature, relative humidity, air change rate, mass transfer coefficient, concentration of target compound(s) in spiked air],

   2) surface area of the test specimen and loading factor,

   3) whether the test specimen was sealed (and how),

   4) information on air sampling (sampling tube used, volume of air sampled, air sampling period from the test start, the number of air samplings, etc.),

   5) test conditions for long-term performance test [temperature, concentration of target compound(s) in spiked air];

e) devices: information on the equipment and procedure (test chamber, sealing material or sealing box, method of spiking the supply air, air purifier, temperature and humidity controls, air flow meter, climate chamber, air sampling devices, analytical instrument, etc.);

f) quality control/quality assurance:

   1) background concentration of target compounds,

   2) recovery data of target compounds,

   3) number of measurements,

   4) result of each analysis of air sampled, if duplicate sampling was undertaken,

   5) accuracy of temperature, relative humidity and air change rate,

   6) quality assurance report;

g) additional details for test materials such as paints, coatings, or plastering materials:

   1) number of test specimens,

   2) mass per area,

   3) thickness,

   4) other observations that may influence the test results (drying conditions, storage, preservation, moisture content, surface treatment),

   5) applied mass per area, in grams per square metre,

   6) applied area,

   7) applied method.

Annex A
(normative)

Sample tube test for long-term reduction performance

A.1 Principle

A.1.1 General

If a test material has a reduction performance greater than, say, 28 days, meaning that a chamber test would take too long, a sample tube test for determining $\rho_{A\mathrm{a}}$ may be applied, based on the physical sorption, chemisorption, and decomposition reaction.

The sample tube test for long-term target compound reduction performance is the method to estimate the sorption capacity, w_s.

NOTE In many cases, the value of $\rho_{A\mathrm{c}}$ is less than w_s. Therefore, $\rho_{A\mathrm{a}}$ estimated by the routine chamber test is less than the value of $\rho_{A\mathrm{a}}$ estimated by the sample tube test.

A.1.2 Target compound reduction by physical sorption

The saturation mass per area, $\rho_{A\mathrm{a}}$, shall be calculated from the sorption capacity, w_s, which is measured by passing air containing target compounds through a glass sample tube filled with a small mass of finely ground (2 mm diameter or less) test specimen at breakthrough time.

A.1.3 Target compound reduction by chemisorption and/or decomposition reaction

The saturation mass per area, $\rho_{A\mathrm{a}}$, shall be calculated from the sorption capacity, w_s, which shall be measured as specified in A.1.2.

It is possible to calculate chemisorption and/or decomposition when the chemical reaction scheme is widely known.

The composition of the chemical substance needs to be known in this case, because the molar concentration of the sorption agent employed is used in the calculation. Therefore, this method is not applicable to natural materials with unknown composition.

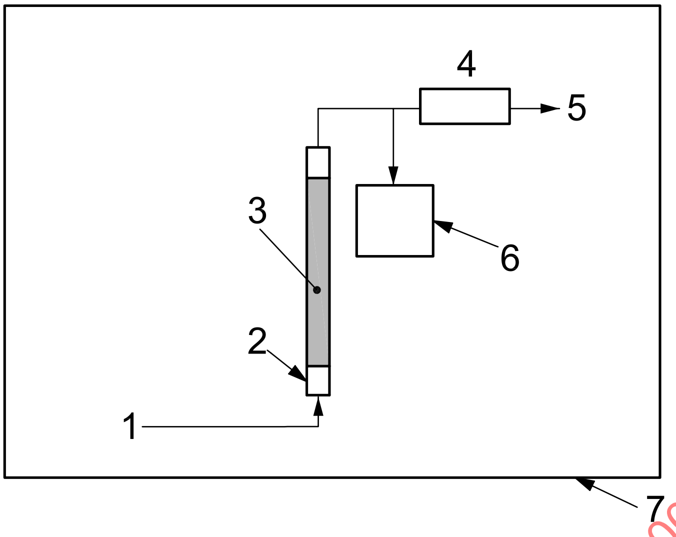
Confirmation is recommended of any calculation of long-term reduction performance by experimental data (testing).

Alternatively, evaluation by calculation of chemical reaction between sorption agent and target compounds may be performed.

A.2 Apparatus and materials

Usual laboratory equipment, and in particular the following.

See Figure A.1 for a typical setup.



Key

1	inlet air
2	sample tube
3	ground test specimen
4	air flow meter
5	outlet air
6	target compound detector
7	climate chamber

Figure A.1 — Example of apparatus for concentration reduction performance evaluation

A.2.1 Sample tube, that fits the testing system and which can accommodate the test specimen. The sample tube is installed so that its length is vertical.

A.2.2 Supply air spiked with target compounds, complying with 6.4.

A.2.3 Temperature control, complying with 6.5.

A.2.4 Air flow meter, installed before the sample tube or behind the air sampling pump for measuring the target compound air flow. Other devices may be used if they have equal or better performance.

A.2.5 Target compound detector, installed at the outlet of the sample tube. It should be able to detect the target compound at 0,5 % of the concentration in the supply air. For example, thermal conductivity detectors or mass spectrometry may be used. Target compound detectors may be applied only after calibration of their response. DNPH or Tenax TA® tubes may also be installed at the outlet of the sample tube to collect air samples at appropriate time intervals.

A.2.6 Climate chamber, in which the sample tube shall be contained. The climate chamber shall be capable of maintaining the test temperature to within ± 2,0 °C.

A.3 Test conditions

A.3.1 Supply air concentration

The total concentration of target compounds spiked into the supply air in the sample tube should be approximately equal to the WHO guideline concentration.

If that is not possible, perform this determination at relatively high VOC concentrations of the order of 10 times the guideline value.

A.3.2 Temperature and relative humidity

The supply air should be dry.

Building materials for use in Europe and America shall be tested at a temperature of 23 °C ± 2 °C during the test (ISO 554).

Building materials for use in Japan shall be tested at a temperature of 28 °C ± 1 °C during the test.

The humidity tends to affect the result. The humidity of the supply air shall be controlled at 50 % ± 5 % during the test and recorded if the test is not conducted with dry air.

Performance in reducing total target compound concentration by physical sorption depends on temperature. Therefore, measurement at three temperatures as specified in 7.3.2 is recommended.

A.4 Test methods

A.4.1 Sampling and pretreatment of test specimen

Grind the test specimen to form fragments that can be fitted in the sample tube, while maintaining secondary structure. Fine particles should be removed prior to the test. The test specimen shall be vacuum dried.

The secondary structure which works effectively to absorb VOCs is maintained as long as the particle radius is approximately 10 times that of the pore.

When dry air is supplied to a sample tube, the test specimen may be vacuum dried after grinding for homogeneity and reproducibility reasons. In this case, absolute dryness may be assumed to be fundamental. If moist (humid) air is used for this test, the specimen may be controlled at the equilibrium condition at the target humidity level.

This procedure shall not be applied to material of inhomogeneous structure.

A.4.2 Preparation of sample tubes

Weigh the ground test specimen and put it into a sample tube. Use glass wool to hold the test specimen in position in the sample tube.

When the tube diameter is large, a perforated support should be installed into the inlet side in order to support the sample and to enhance diffusion of the gas. If a perforated support is not installed, non-uniform diffusion is observed in the sample tube.

A.4.3 Monitoring the concentration of target compound(s) in spiked air

Prior to connecting the sample tube to the system, connect an air sampling tube or detector and determine the concentration of target compound(s) in spiked air as specified.

A.4.4 Test for the breakthrough time of target compounds

Connect the sample tube to the system and start the target compound air flow. Continue the target compound air flow until the outlet air contains 0,5 % of supply air concentration, and then determine the sorption capacity, w_s, (saturated target compound mass per mass of sorbent) at that concentration. Consider this time as the breakthrough time, t_b.