INTERNATIONAL STANDARD

ISO 16000-37

First edition
2019-02

Indoor air —

Part 37: Measurement of $PM_{2,5}$ mass concentration

Air intérieur —

Partie 37: Mesure de la concentration massique en $PM_{2,5}$

Reference number
ISO 16000-37:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

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

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

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

Introduction

Airborne particulate matter (colloquially known as “fine dust”) plays a role not only outdoors, but is also significant in terms of hygiene, especially indoors. People in industrialized countries spend most of the day indoors. Either particles are transported into indoor air from outdoor environments or the particles directly result from indoor sources, such as smoking, residential wood burning and cooking.

$PM_{2,5}$ concentration and composition in indoor environments strongly depend on parameters such as the room size, relative humidity, air exchange rate, airflow conditions and sink effects on surfaces (e.g. walls, ceilings, floor coverings, furnishings). In addition, particles already sedimented are temporarily resuspended to the air through various activities and can be inhaled. All this can result in highly variable levels of indoor $PM_{2,5}$ pollution that are not easily ascertained or assessed in terms of their impacts on health.

This document describes the general strategies for the measurement of indoor $PM_{2,5}$ concentration.

This document was prepared in response to the need for improved comparability of methods for particle measurement.

Indoor air —

Part 37:
Measurement of $PM_{2,5}$ mass concentration

1 Scope

This document specifies the measurement methods and strategies for determining the $PM_{2,5}$ mass concentrations of suspended particulate matter (PM) in indoor air. It can also be used for determining PM_{10} mass concentration.

The reference method principle consists of collecting $PM_{2,5}$ on a filter after separation of the particles by an impaction head and weighing them by means of a balance.

Measurement procedure and main requirements are similar to the conditions specified in EN 12341.

This document also specifies procedures for operating appropriate supplementary high time resolution instruments, which can be used to highlight peak emission, room investigation and as part of the quality control of the reference method.

Quality assurance, determination of the measurement uncertainty and minimal reporting information are also part of this document.

The lower range of application of this document is 2 µg/m^3 of $PM_{2,5}$ (i.e. the limit of detection of the standard measurement method expressed as its uncertainty).

This document does not cover the determination of bioaerosols or the chemical characterization of particles. For the measurement and assessment of dust composition, see the relevant technical rules in the International Standards in the ISO 16000 series.

This document does not cover passenger compartments of vehicles and public transport systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12341, *Ambient air — Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2,5}$ mass concentration of suspensed particulate matter*

3 Terms and definitions

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

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

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

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

3.1
aerodynamic diameter
diameter of a sphere of density 1 g cm^{-3} and the same setting velocity in still air as the particle of interest under prevailing conditions of temperature, pressure and relative humidity

Note 1 to entry: The aerodynamic diameter is calculated using the formula:

$$D_a = D_p \sqrt{\frac{1}{\chi}} \sqrt{\frac{\rho_p}{\rho_0}}$$

where

D_a is the aerodynamic diameter;
D_p is the particle diameter;
ρ_p is the density of the particle;
ρ_0 is the standard density;
χ is the form factor.

Note 2 to entry: The form factor describes by how much the resisting force of an irregular shaped particle is greater than that of a sphere with the same volume[10].

Note 3 to entry: The aerodynamic diameter determines the sedimentation and the separation properties of particles in impactors. It is also of particular importance for penetrative behaviour and the retention of particles in the human body.

Note 4 to entry: Various definitions are used for the particle diameter, depending on the measurement method. These different diameters are only indirectly comparable since different particle properties are being measured, e.g. geometric diameter, diameter according to dielectric mobility, diameter according to light scattering properties.

[SOURCE: ISO 7708:1995, 2.2, modified — "particle" has been removed from the term, the definition has been reworded, and the original Note 1 to entry has been replaced by Notes 1 to 4 to entry.]

3.3
mass concentration
c
ratio of the mass *m* of the measured component and the gas volume *V*, as shown by:

$$c = \frac{m}{V}$$

[SOURCE: EN 15259:2007, 3.26]

3.4
particle
small discrete mass or solid or liquid matter

[SOURCE: ISO 29464:2017, 3.2.111]

3.5
PM_x
particulate matter suspended in air which is small enough to pass through a size-selective inlet with a 50 % efficiency cut-off at x µm aerodynamic diameter

[SOURCE: EN 12341:2014, 3.1.14]

3.6
cut-off diameter
aerodynamic diameter at which the impactor stage has a separation efficiency of 50 %

[SOURCE: ISO 23210:2009, 3.1.2, modified — The definition has been changed from "where the separation efficiency of the impactor stage is 50 %".]

3.7
calibration
operation which, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

[SOURCE: JCGM 200:2012, 2.39, modified — The notes have been removed.]

3.8
uncertainty
<of measurement>parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: JCGM 100:2008, 2.2.3, modified — The notes have been removed.]

3.13
parallel measurement
measurement from a measuring system that takes samples from the same air over the same time period

3.14
reference method
RM
measurement method(ology) which, by convention, gives the accepted reference value of the measurement

4 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

JCGM Joint Committee for Guides in Metrology

PM particulate matter

QA quality assurance

QC quality control

5 Measurement strategy for determing $PM_{2,5}$ indoors

5.1 Location and number of sampling points

The measurement usually takes place in the centre of the room at approximately 1,5 m height (see ISO 16000-1 and ISO 16000-34).

As a minimum, one measurement per investigated room should be performed. If stable conditions cannot be guaranteed for all points in the same room, additional locations should be investigated.

The sampling volume extracted per hour shall not exceed 10 % of the hourly volume of room air exchanged. If this is unknown, the sampling volume extracted per hour shall not exceed 10 % of the room's volume.

The indoor area is usually a quieter space compared to outdoors. Additional isolation of the sampling system or relocating the pump outside the room should be considered to limit noise impact.

5.2 Measurement strategy for source attribution

The indoor sources of PM are diverse. ISO 16000-34 describes the necessary procedure for assigning and evaluating individual indoor sources. The number and place of the sampling points are also specified in this document, taking into account the type of room and expected activity.

In order to classify the relevance of specific sources, indoor measurements under different conditions (examples are given in Annex A) may be necessary. Furthermore, three different operational states are defined.

a) Resting state without activity: This state is characterized by the absence of users and user activities and by switching off all fixed equipment (e.g. ventilation system, gas heating, refrigerators, servers).

b) Resting state with equipment activity: This state is characterized the absence of users and user activities, but with operation of all fixed and/or constantly operated equipment.

c) Active user state: This state is characterized by usage activity of the relevant persons and by the operation of all fixed and/or constantly operated equipment.

5.3 Indoor air condition

Indoor air conditions (e.g. temperature, pressure, humidity) have a direct effect on indoor air measurements. These parameters shall be measured in the investigated room and specified in the report.

Outdoor conditions (e.g. rain, strong wind) can strongly affect the result. Thus, parallel outdoor measurements of $PM_{2,5}$ are always recommended.

The user's normal ventilation arrangements should be maintained. The usage and ventilation conditions can be documented through concurrent measurements of CO_2 concentration.

The impact of door and window openings can be very important. This aspect should be discussed with the client and the situation during the measurement should be documented in the report.

6 Principle of measurement

6.1 General considerations

For source regulatory purposes (i.e. for comparison with an assessment value, for auditing whether it is complied with), only the reference method described in Clauses 6 and 7 can be used.

6.2 Description of the standard measuring principle

The conditions for determining the $PM_{2,5}$ particle mass concentration shall conform to the conditions specified in EN 12341. A specific statement shall be given when deviation from EN 12341 is allowed or mandatory.

Indoor air is passed through a size-selective inlet at a known, constant flow rate. Due to their inertia, large particles are collected on a greased impactor plate. Small particles follow the gas stream and are collected on a backup filter. The sampling head is constructed in such a way that only the particle size fraction with diameters up to the specified cut-off value of 2,5 µm is deposited on the filter. The $PM_{2,5}$ fraction is thus collected on a filter for a known sampled volume. The collected mass of the PM material is then determined by weighing the filter at pre-specified, constant conditions before and after collection.

Key factors that can affect the result of the measurement are addressed by EN 12341 and include:

— the design and construction of the size-selective inlet;

— the sampling flow;

— particle deposition losses in tubing between the inlet and the filter;

— uncontrolled losses in the tubing and on filter due to drying and evaporation losses of semi-volatile PM at any time between collection and weighing;

— changes in the weight of the filters or PM due to, for example, adsorption of water vapour and semi-volatile compounds, or the spurious addition or loss of material, buoyancy or static electricity.

In order to minimize the effects of these factors, EN 12341 gives requirements for a series of parameters that determine the magnitudes of these effects.

7 Equipment and facilities

7.1 Sampling system components

The conditions related to the sampling system and procedure shall conform to the conditions specified in EN 12341.

The following deviations from the requirements in EN 12341 are allowed by this document.

— Indoor temperatures are expected to be quite stable. Therefore, using a conditioning sampler is not mandatory, if a room temperature between 15 °C and 25 °C is continuously observed and if the filter is returned to the weighing room within a maximum of 5 days after particle collection.

— The sampling period could be split (i.e. 2 × 12 h or 3 × 8 h), provided that all samplings are performed on same filter and completed within 3 days for a 24 h overall sampling time. This would allow a focus on a specific period of time where a source of pollution is expected (i.e. office hours only).

— In polluted areas where a 24 h sampling can result in an overload of the impaction head, sampling time can be reduced in a way that a quantity between 5 mg to 10 mg is eventually collected on the filter.

— It is allowed for the purposes of a supplementary method (see Clause 8) to take a minor side flow after the inlet and before the filter holder, as long as the flow is smaller than the allowed averaged error (<2 %) and does not disturb the main flow or gravimetrically collection.

In order to correctly estimate the best procedure for application (e.g. estimation of $PM_{2,5}$ concentration, estimation of the presence of punctual sources, presence of specific cycle), the use of real-time supplementary methods are recommended at any time as part of the QC of the reference method.

7.2 Weighing facilities and procedure

The conditions related to the weighing facilities and procedures shall conform to the conditions specified in EN 12341.

8 Supplementary high time resolution method

8.1 General

For source regulatory purposes, only the reference method described in Clauses 6 and 7 can be used.

Nevertheless, a high time resolution instrument is required for capturing high peak emission or for room investigation. Thus, supplementary methods could be used for exploratory purpose, following recommendations described in this clause.

Supplementary methods can also help QC of the reference method (see 10.2).

8.2 Selection of the supplementary instrument

ISO 16000-34 describes the different supplementary instruments in detail.

Only instruments described in ISO 16000-34:2018, Figure 3 and covering a minimum range between 300 nm and 5 000 nm in particle size should be used.

NOTE Particles below 300 nm are normally negligible in terms of mass and can thus often be neglected when measuring $PM_{2,5}$ mass concentration. Particles below 300 nm, nevertheless, often represent the more important fraction of $PM_{2,5}$ in number and this is thus a useful parameter to monitor, especially in cases of room investigation. Combinations of several instruments are often necessary to take this smallest fraction into account and to characterize a room correctly.

8.3 Supplementary procedure

Representative test dusts for comparison tests are not available. Airborne particles in indoor air are expected to be very case-specific with respect to composition, concentration and size distribution. Due to this high variability in dust composition, proving equivalence for all conditions is impossible. For the same reason, supplementary procedures performed in ambient air (e.g. equivalent according to Reference [7]) do not ensure equivalence of the instrument indoors, as sources are different.

A comparison measurement should therefore be performed in the environment of interest. The supplementary and the reference instrument should run in parallel over a 24-h period in the centre of the environment under investigation. The supplementary instrument may be used alone for further investigation, but only after the comparison has proven to be successful.

Room conditions shall be similar during comparison and investigation. During the investigation step, it is recommended to run an additional measurement with the reference instrument to highlight any potential variation in the condition of the room.

If the supplementary instrument is used in another location of the room (i.e. room investigation), conditions in all locations should be similar. Additional parallel measurements should be considered in case of doubt.

9 Evaluation and reporting the results

For the reference method, the mass concentration is calculated as the difference in mass between the virgin and sampled filter, divided by the sampled volume. Measurement results shall be expressed as $\mu g/m^3$, where the volume of air is that at the conditions near the inlet at the time of indoor sampling.

Results obtained with a supplementary method should be reported in the unit of the basic measurand (i.e. number concentration). Real time data can be reported or averaged depending of the measurement purpose. Nevertheless, a 24-h average of data measured during the parallel measurement with the reference method shall always be calculated and reported.

Recalculation from one metric to another (i.e. from number to mass) is not recommended due to the strong influence of the dust type (e.g. shape, density, charge, colour). Instead, recalculation should be based on the comparison with the reference instrument.

10 Quality assurance and uncertainty evaluation

10.1 Reference method

10.1.1 General

The measurement uncertainties associated with the gravimetric measurement method are on one hand affected by determining the mass through weighing and by sample handling and on the other side by the quality of the sampling volume measurement. EN 12341 lists all the relevant factors affecting the measurement uncertainties.

QA should be performed and uncertainty evaluation calculated in accordance with the technical requirements specified in EN 12341. The uncertainty evaluation of the reference method should be reported.

When supplementary methods are used, real-time data should be used as QC for the gravimetric reference method (i.e. sudden changes in concentration which result from an unwelcome artefact).

10.1.2 Flow control system

The flow control equipment used in sampling shall allow the determination of the flow rate that is necessary for the correct size selection in the sampling head, and also the determination of a known sampling volume for calculating the $PM_{2,5}$ concentration. The input data used by the flow control system should be traceable back to the International System of Units (SI).

Several flowmeters or flow control systems indicate standard flows rather than volumetric flows. The standard flow always refers to standard conditions of the flow sensor ($T_{standard}$, $P_{standard}$), which are not uniformly defined among manufacturers and which may deviate considerably from actual meteorological conditions. The volumetric flow is the actual flow passing through a system at the actual meteorological conditions (T, P).

It shall be carefully checked whether the sample flow indicated by the instrument's flow control system is given as volumetric or standard flow. In the latter case, corrections shall be considered for the calculation of the actual sample volume. The flowmeter manual should be consulted for appropriate corrections.

It is recommended to always refer the sample volume to indoor temperature and air pressure at the sampling site.

In the standard sampling head of the low-volume sampler (LVS), the volume flow should be adjustable to a nominal value of 2,3 m^3/h under indoor conditions. The maximum permitted relative error of the actual flow may not exceed 5 % of the nominal value under indoor conditions.

10.1.3 Weighing system

A climate-controlled system should be used for conditioning and weighing the filter. This system is called a weighing chamber in accordance with EN 12341. It can be either a suitable room or housing. The temperature and the relative humidity should be measured continuously and set to 19 °C to 21 °C and 45 % to 50 %, respectively (both measured as an hourly mean). The balance should be installed and operated in the weighing chamber and should have a resolution of ≤10 µg. The balance should have a valid calibration certificate traceable to the SI.

10.1.4 Checking the equipment's parameters

A performance test of the equipment should be done before each measurement in order to check operation in accordance with the manufacturer's specifications. The instrument's operational capability should be checked for each measurement and documented in the protocol. In case of a malfunction, the instrument may not be used until the instrument's full operational capability has been checked and re-established. If feasible, the instrument's data record should be checked for error warnings

after each measurement. It is advisable to have a record of the meteorological conditions during the measurements and to check the data for large temporal changes that may have an impact on the result.

10.2 Supplementary methods

ISO 16000-34:2018, Figure 3 lists the reference standards related to each available supplementary method. QA should be performed according to technical requirements specified in the listed document. When the document describes how uncertainty can be assessed, expended uncertainty should be reported. If no international method is available, QA should be performed according to technical manual of the instrument.

The supplementary method should be used as QC for the reference method. Sudden changes in concentration should be investigated and reported if they can have an influence on the reference method result. Spatial variation in the room or presence of specific sources should also be addressed in a way to ensure that the location of the reference method is representative of the entire room.

The relation between the reference mass obtained by the reference method and the estimated mass based on accumulation of the real-time signal should always be established, as it can potentially highlight an important sampling problem.

Annex A
(informative)

Examples of particle concentrations encountered during room user activities

This guideline describes the measurement of $PM_{2,5}$ indoors for the purpose of assessing indoor fine dust pollution. In order to complement this description, Table A.1 contains an informative list of empirical values obtained for concentration ranges of the fractions PM_{10} and $PM_{2,5}$ through indoor air measurements of residential premises in Germany[10][11]. It can serve as a benchmark during an appraisal of indoor premises, with which the concentrations of fine particles in (residential) indoor premises during the listed usage types and user activities can be calculated. These values can serve experts and/or measuring institutes during future fine dust measurements in correctly selecting the effective range of the measurement method.

The concentration data shown in Table A.1 should be used as benchmark and not as a valuation standard for assessing air cleanliness.

Where these concentration ranges are exceeded, this does not imply a need for action in terms of mitigation procedures and/or remedial maintenance. The calculated concentration depends on many factors, such as the intensity of the source, the type, nature, intensity and frequency of use, the distance between the source and the measuring equipment and on specific properties of the room, especially the ventilation rate. Moreover, other particle numbers may be obtained by using measuring equipment where the effective range does not correspond to that used in the cited investigations[10][11]. The reference values listed in Table A.1 do not allow conclusions to be reached about hygiene risks associated with the measured particle numbers and mass concentrations. The current literature deals in more detail with, for example, the following user activities: scented oils[12], sprays[13], incense sticks[14][15], cooking[16][17], laser printers[18][19][20], household appliances[21][22][23], various activities[24][25][26].

Table A.1 — Empirical values for particle concentration ranges of the fractions PM_{10}, $PM_{2,5}$ and ultrafine particles[11][25]

Indoor situation	Measured particle fraction	Empirical values of typical concentration ranges in Germany	Concentration depends in particular on
Presence and general activities of persons			
Dwellings	PM_{10}	(30 to 80) µg/m³	Number of persons present in the room and respective activity
	$PM_{2,5}$	(10 to 40) µg/m³	
Schools, day nurseries	PM_{10}	(40 to 150) µg/m³	
	$PM_{2,5}$	(10 to 40) µg/m³	
Offices	PM_{10}	(20 to 60) µg/m³	
	$PM_{2,5}$	(10 to 40) µg/m³	
Specific user activities			
Smoking	PM_{10}	(50 to 500) µg/m³	Number/quantity
	$PM_{2,5}$	(20 to 100) µg/m³	
Using a vacuum cleaner	PM_{10}	(30 to 150) µg/m³	Degree of pollution, filtration performance
	$PM_{2,5}$	(10 to 40) µg/m³	
Cooking/preparing hot water	PM_{10}	(40 to 100) µg/m³	Duration and intensity
Stove/fireplace	PM_{10}	(40 to 200) µg/m³	Fireplace/stove construction, heating material, chimney
	$PM_{2,5}$	(20 to 100) µg/m³	