SLOVENSKI STANDARD
kSIST-TS FprCEN/TS 17660-2:2024

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Kakovost zraka - Vrednotenje lastnosti senzorskih sistemov za kakovost zraka - 2. del: Delci v zunanjem zraku

Air quality - Performance evaluation of air quality sensor systems - Part 2: Particulate matter in ambient air

Luftbeschaffenheit - Leistungsbewertung von Luftqualitätssensorsystemen - Teil 2: Partikelförmige Stoffe in der Außenluft

Qualité de l'air - Évaluation des performances des systèmes capteurs de la qualité de l'air - Partie 2 : Particules dans l'air ambiant

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This draft Technical Specification is submitted to CEN members for Vote. It has been drawn up by the Technical Committee CEN/TC 264.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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European foreword

This document (TC 264 WI 00264208) has been prepared by Technical Committee CEN/TC 264 "Air quality", the secretariat of which is held by DIN.

This document is currently submitted to the Vote on TS.

This document is Part 2 of a series of documents published under the general title Air quality — Performance evaluation of air quality sensor systems.

Part 1 covers the performance evaluation of air quality sensor systems for gaseous pollutants in ambient air.

Part 2 covers the performance evaluation of air quality sensor systems for particulate matter in ambient air.

Introduction

Sensor systems are generally seen as emerging measuring devices for the monitoring of air quality. Sensor systems provide a fast and low-cost complement to the reference and equivalent measurement methods as defined in Directive 2008/50/EC on ambient air quality and cleaner air for Europe [1]. Sensor systems could allow for air pollution monitoring at a lower cost and with a higher spatial density than with the reference and equivalent measurement methods. They also allow for new air pollution applications including monitoring in complex topographies, at traffic junctions, in street canyons, at remote sites, on mobile platforms (pedestrians, cyclists, vehicles, trams) and for citizen science studies, e.g. monitoring around areas of local concern, schools, or parks.

Sensor systems use one or more low-cost sensors that are based on several technologies. However, sensor systems share two common features, portability and low-cost, compared with traditional reference or equivalent measurement methods. Typically, sensor systems can continuously monitor air pollution with fast response times ranging from a few tens of seconds to a few minutes.

Currently, the use of sensor systems for air quality monitoring is limited by the low accuracy of measurements that they can achieve. Additionally, there was no unambiguous protocol for evaluating sensor systems with a structured metrological approach, ensuring traceability from sensor system measurements to national and international standards. A protocol will enable exhaustive and transparent evaluation of sensor systems that can be an important step towards including sensor system measurements into the monitoring of air quality for regulatory and non-regulatory purposes.

The protocol in this document applies to sensor systems and supports the requirements of Directive 2008/50/EC. This procedure evaluates whether the measurement uncertainty of the sensor system meets the data quality objectives defined in Directive 2008/50/EC for indicative measurements. This protocol also allows for a less demanding evaluation of the performance of sensor systems for non-regulatory measurements.

This document defines common procedures and requirements for the evaluation of the performance of sensor systems to facilitate mutual recognition by the relevant bodies or stakeholders and thereby minimise both administrative and cost burdens on manufacturers. It does not describe the roles and responsibilities of manufacturers, test laboratories and relevant bodies under these procedures.

1 Scope

This document specifies the general principles, including testing procedures and requirements, for the classification of performance of low-cost sensor systems for the monitoring of particulate matter in ambient air at fixed sites. The classification of sensor systems includes tests that are performed under prescribed conditions. It does not guarantee performance in locations that are different from the tests, variations in meteorological climate from the test programme or account for stability over time, which can only be assessed under ongoing quality control strategies.

The described procedure is applicable to the determination of the mass concentration of particulate matter. The pollutants that are considered in this document are PM_{10} and $PM_{2,5}$ in the range of concentrations expected in ambient air.

This document provides a classification that is consistent with the requirements for indicative measurements and objective estimation defined in Directive 2008/50/EC. In addition, it provides a classification for applications (non-regulatory measurements) that require more relaxed performance criteria.

This document applies to sensor systems used as individual systems. It does not apply to sensor systems as part of a sensor network. However, for some applications (e.g. in cities) sensor systems are deployed as part of a sensor network. Annex A provides information on the use of sensor systems as nodes in a sensor network.

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 16450, *Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2,5)*

EN 15267-1, *Air quality - Assessment of air quality monitoring equipment - Part 1: General principles of certification*

EN 15267-2, *Air quality - Assessment of air quality monitoring equipment - Part 2: Initial assessment of the manufacturer's quality management system and post certification surveillance for the manufacturing process*

3 Terms and definitions

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

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

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

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

3.1
ambient air
outdoor air in the troposphere where provisions concerning health and safety at work apply and to which members of the public do not have regular access

Note 1 to entry: This does not include workplaces as defined by Directive 89/654/EC [2].

[SOURCE: Directive 2008/50/EC] [1]

3.2
averaging period

period of time for which a limit value is associated

Note 1 to entry: For this document, the averaging period is defaulted to 24 h unless otherwise specified (more information can be found in Directive 2008/50/EC).

3.3
calibration

operation that, 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] [3]

Note 1 to entry: A calibration can be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it can consist of an additive or multiplicative correction of the indication with associated measurement uncertainty. Calibration should not be confused with adjustment of a measuring system, often mistakenly called “self-calibration”, nor with verification of calibration.

Note 2 to entry: This document does not describe the process of calibration of sensor systems.

3.4
Class 1 sensor system

measuring device delivering data that are at minimum consistent with the data quality objectives of indicative measurements

Note 1 to entry: The term “indicative measurement” does not refer to the performance of the sensor system.

3.5
Class 2 sensor system

measuring device delivering data that are at minimum consistent with the data quality objectives of objective estimations

Note 1 to entry: The term “objective estimation” does not refer to the performance of the sensor system.

3.6
Class 3 sensor system

measuring device delivering data that comply with a relaxed target measurement uncertainty, but are not formally associated with any mandatory data quality objective

Note 1 to entry: Relaxed target measurement uncertainties are given in Table 2.

3.7
combined standard measurement uncertainty

standard measurement uncertainty that is obtained using the individual standard measurement uncertainties associated with the input quantities in a measurement model

[SOURCE: JCGM 200:2012, 2.31] [3]

3.8
coverage factor

number greater than one by which a combined standard measurement uncertainty is multiplied to obtain an expanded measurement uncertainty

Note 1 to entry: A coverage factor symbol is usually termed *k*.

[SOURCE: JCGM 200:2012, 2.38] [3]

3.9
drift

continuous or incremental change over time in measurement, due to changes in properties of a sensor system

Note 1 to entry: Drift is not related either to a change in a quantity being measured or to a change of any recognized influencing quantity.

3.10
expanded measurement uncertainty
expanded uncertainty

product of a combined standard measurement uncertainty and the coverage factor

Note 1 to entry: The factor depends upon the type of probability distribution of the output quantity in a measurement model and on the selected coverage probability. The term "factor" in this definition refers to a coverage factor.

Note 2 to entry: Expanded measurement uncertainty is termed "overall uncertainty" in paragraph 5 of Recommendation INC-1 (1980) (see the GUM) and simply "uncertainty" in IEC documents.

Note 3 to entry: Expanded measurement uncertainty is also referred to as "uncertainty" in this document.

[SOURCE: JCGM 200:2012, 2.35] [3]

3.11
equivalent method

method for the measurement of the concentration of particulate matter (PM10; PM2,5) meeting the data quality objectives for fixed measurements and tested according to EN 16450

3.12
exposure chamber
test chamber

volume that can be sealed with controlled conditions of temperature, humidity and test aerosol, used for testing the sensor system

3.13
fixed measurements

measurements taken at fixed sites, either continuously or by random sampling, to determine the levels in accordance with the relevant data quality objectives

Note 1 to entry: The data quality objectives are listed in Table 2 (more information can be found in Directive 2008/50/EC).

3.14
independent measurement

measurement that is not influenced by a previous individual measurement, by separating two individual measurements by at least four response times

3.15
indicative measurements

measurements which meet data quality objectives that are less strict than those required for fixed measurements

Note 1 to entry: The data quality objectives are listed in Table 2 (more information can be found in Directive 2008/50/EC).

3.16
$PM_{10-2,5}$

difference between reported PM_{10} and reported $PM_{2,5}$ concentrations, also termed coarse particles

3.17
PMx

particulate matter suspended in air which passes through a size-selective inlet at a constant flow with a 50 % efficiency cut-off at x µm aerodynamic diameter

Note 1 to entry: By convention, the size-selective standard inlet designs prescribed in EN 12341 — used at the prescribed flow rates – possess the required characteristics to sample the relevant PM fraction suspended in ambient air.

Note 2 to entry: The efficiency of the size selectiveness of other inlets used could have a significant effect on the fraction of PM surrounding the cut-off, and, consequently on the mass concentration of PM_x determined.

[SOURCE: EN 12341:2023] [4]

3.18
measurement repeatability
repeatability

measurement precision under a set of repeatability conditions of measurement

[SOURCE: JCGM 200:2012, 2.21] [3]

3.19
objective estimation

measurements which meet data quality objectives that are less strict than those required for indicative measurements

Note 1 to entry: The data quality objectives are listed in Table 2 (more information can be found in Directive 2008/50/EC).

3.20
reference method

standard gravimetric measurement method for the determination of the PM10 or PM2,5 mass concentration of particulate matter according to EN 12341[4]

3.21
repeatability condition of measurement

conditions that include the same measurement procedure, same operators, same measuring system, same operating conditions and same location, and replicate measurements on the same or similar objects over a short period of time

Note 1 to entry: A condition of measurement is a repeatability condition only with respect to a specified set of repeatability conditions.

Note 2 to entry: In chemistry, the term "intra-serial precision condition of measurement" is sometimes used to designate this concept.

[SOURCE: JCGM 200:2012, 2.20] [3]

3.22
sensor
individual sensor

physical unit that produces a signal related to the concentration of particulate matter in air

3.23
sensor system

single integrated set of hardware that uses one or more sensors to produce a signal related to the concentration of particulate matter in air that can supply real time measurements

Note 1 to entry: The term "instrument" has a very similar definition, but many researchers are typically referring to a reference or equivalent grade device when using the word "instrument".

Note 2 to entry: All the tests that are intended in this document are designed for sensor systems only.

Note 3 to entry: Sensor systems contain many common components in addition to the basic sensing or analytical element that is used for detection. Common core components and functions can include:

— sensing detector (the actual sensor);

— sampling capability (generally active sampling for PM);power systems, which may include batteries;

— analogue to digital conversion;

— signal processing;

— local data storage;

— data transmission;

— enclosure.

3.24
standard measurement uncertainty
standard uncertainty

measurement uncertainty expressed as a standard deviation

[SOURCE: JCGM 200:2012, 2.30] [3]

3.25
uncertainty of measurement
measurement uncertainty

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

Note 1 to entry: Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for, but instead, associated measurement uncertainty components are incorporated.

Note 2 to entry: The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Note 3 to entry: Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

Note 4 to entry: In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

[SOURCE: JCGM 200:2012, 2.26] [3]

4 Symbols and abbreviations

4.1 Symbols

For the purposes of this document, the following symbols apply.

NOTE In the following list, all symbols related to the measurement uncertainty of source contributions are indicated as standard uncertainty, e. g. $u(X)$. However, in the text expanded uncertainties of the same source contributions can be used, e. g. $U(X)$.

a	intercept of the regression line
b	slope of the regression line
c	intercept of the corrected dataset
d	slope of the corrected dataset
$F\left(\frac{FINE}{COARSE}\right)$	factor of the sensor response change from fine to coarse conditions
k	coverage factor
L	LV, UAT or LAT currently being assessed
$Mdn(sensorratio)_{30-60\%}$	median of $Sensorratio$ with hourly RH% between 30 % and 60 %;
$Mdn(sensorratio)_{85-95\%}$	median of $Sensorratio$ with hourly RH% between 85 % and 95 %.
n	is the number of measurement periods where all sensor systems are providing valid data (with identical n_s)
n_s	number of replicate sensor systems
$PM_{10-2.5}$	PM coarse, difference between reported PM_{10} and reported $PM_{2,5}$ concentrations
r	measurement repeatability; repeatability
R	value of the residual sum of squares resulting from the linear regression
R_2	Coefficient of determination
RH_{factor}	Factor that expresses the change in sensor response (compared to the equivalent method) when RH changes from low (30-60%) to high (85 to 95%)
$PM_{2,5}$(sen, FINE)	$PM_{2,5}$ sensor response (µg/m^3), averaged over the duration of the test with fine PM fraction
$PM_{2,5}$(eq, FINE)	$PM_{2,5}$ measured by equivalent method (µg/m^3), averaged over the duration of the test with fine PM fraction
$PM_{10-2,5}$(sen, COARSE)	$PM_{10-2,5}$ sensor response (µg/m^3), averaged over the duration of the test with coarse PM fraction
$PM_{10-2,5}$(eq, COARSE)	$PM_{10-2,5}$ measured by equivalent method (µg/m^3), averaged over the duration of the test with coarse PM fraction
$R_{PM_{2,5}(FINE)}$	ratio of sensor to reference method measurements for $PM_{2,5}$ during the test with fine PM fraction

$R_{PM_{10-2,5}(COARSE)}$	ratio of sensor to reference method measurements for $PM_{10-2,5}$ during the test the test with coarse PM fraction
$Sensor\ ratio$	ratio of hourly average of the sensor PM measurement to the hourly average of the PM measurements of the equivalent method for $PM_{2,5}$ or PM_{10}
y_{sen}	hourly average of sensor measurement
y_{eq}	hourly average of equivalent method
$u(a)$	standard uncertainty of the intercept of a regression line
$u(b)$	standard uncertainty of the slope of a regression line
$u(\mathrm{bs, RM})$	between reference method standard uncertainty
$u(\mathrm{bs, s})$	between sensor systems standard uncertainty
$U_{\mathrm{field},L}$	expanded uncertainty of the field measurements of the sensor system at the value of ‘L =’ LV, UAT or LAT currently being assessed, in units of mass concentrations
$U_{\mathrm{field,corr},L}$	expanded uncertainty of the corrected sensor system at the value of ‘L =’ LV, UAT or LAT currently being assessed, in units of mass concentrations
x	value of the reference measurement
x_i	i^{th} x-value (reference measurement)
$\bar{x}$	average of the values x_i
y	value of the sensor system response
y_i	i^{th} y-value (sensor system response)
$y_{i,j}$	value of the sensor system response for period i of sensor system j
$\bar{y}$	average of the values y_i
$\bar{y}_i$	average for period i of the n_{s} replicate sensor systems;

4.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

AQMS	air quality monitoring station (more information on the measurement methods can be found in Directive 2008/50/EC)
DQO	data quality objective
GPS	global positioning system
LAT	lower assessment threshold
LV	limit value
OLS	ordinary least squares
R^2	coefficient of determination
RH	relative humidity
RSS	residual sum of squares resulting from the linear regression