# INTERNATIONAL STANDARD

# ISO 11222

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## Air quality — Determination of the uncertainty of the time average of air quality measurements

*Qualité de l'air — Détermination de l'incertitude de mesure de la moyenne temporelle de mesurages de la qualité de l'air*



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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.ch
Web www.iso.ch

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## Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11222 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 4, *General aspects*.

Annex A of this International Standard is for information only.



 

# Introduction

Measurands in the field of air quality monitoring can be highly varying functions of time. Special considerations are-required when estimating measurement uncertainties of time averages of air quality monitoring data. The approach [3], using the standard deviation of the recorded measurement results divided by the square root of the number of measurement, is applicable only to measurands that do not change with time and to measuring systems that do not exhibit systematic uncertainties.

The statistical treatment of random and systematic deviations of measurement results has been harmonized by the concept of measurement uncertainty introduced by the *Guide to the expression of uncertainty in measurement* in 1993 (GUM). This approach is based on the general application of the rule of uncertainty propagation. Although not addressed explicitly by the GUM, the concept of uncertainty propagation and measurement uncertainty can also be applied to measurands exhibiting distinct time structure.

Standard uncertainty may be required as a measure of data quality to be provided when reporting a time average of air quality monitoring data. If appropriate, data quality objectives can be defined separately for:

a) the uncertainty of the time average induced by the measuring system,

b) the uncertainty of the time average induced by incomplete time coverage of the monitoring data,

c) the uncertainty of the time average due to limited spatial coverage of monitoring data.



These influences make up independent contributions to the mean square uncertainty of a time average. In this International Standard, a time average of measured air quality data is intended to describe the air quality at a specified location or within a specified stack within a given time period. The uncertainty of the time average due to spatial coverage of monitoring data is not considered.



 

# Air quality — Determination of the uncertainty of the time average of air quality measurements

## 1 Scope

This International Standard provides a method for the quantification of the uncertainty of a time average of a set of air quality data obtained at a specified location over a defined averaging time period. The method is applicable to air quality data obtained by continuous or intermittent monitoring by means of a specified measuring system. The uncertainty of the time average depends on both the uncertainty of the measurement results and the uncertainty due to incomplete time coverage of the data set.

This International Standard is only applicable if:

a) the set of air quality data used to calculate the time average is representative of the temporal structure of the measurand over the defined time period,

b) appropriate information on the uncertainty of the measurement results is available, and

c) the measurement results have all been obtained at the same location.



This International Standard implements recommendations of the *Guide to the expression of uncertainty in measurement* (GUM).



## 2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

GUM:1995, *Guide to the expression of uncertainty in measurement*, First edition, BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML

## 3 Terms and definitions

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

**3.1**
**arithmetic mean**
**average**
sum of values divided by the number of values

[ISO 3534-1:1993, 2.26]

**3.2**
**combined standard uncertainty**
standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variances and covariances of these quantities weighted according to how the measurement result varies with changes in these quantities

[GUM:1995, 2.3.4]

NOTE The (combined) standard uncertainty of the result of a measurement is the positive square root of its mean square uncertainty.

**3.3**
**covariance**
measure of the statistical dependence of two observable quantities which may be considered as random variables

NOTE Two observable quantities have a non-zero covariance if they are correlated, i.e. a change in one quantity results in a change in the other quantity.

**3.4**
**coverage factor**
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

[GUM:1995, 2.3.6]

**3.5**
**expanded uncertainty**
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

[GUM:1995, 2.3.5]



NOTE If the expanded uncertainty of a result $X$ of measurement on the level of confidence $p$ is given by $U_p(X)$, the unknown true value of $X$ is expected with probability $p$ to be located within the interval $[X - U_p(X); X + U_p(X)]$.

**3.6**
**influence quantity**
quantity that is not the measurand but that affects the result of the measurement

[GUM:1995, B.2.10]

**3.7**
**mean square uncertainty**
⟨of a result of measurement⟩ square of the combined standard uncertainty of a measurement result

NOTE The mean square uncertainty of a measurement result may also be estimated by the mean square deviation of the measurement result from material measures of the “true” value.

**3.8**
**measurand**
particular quantity subject to measurement

[VIM:1993, 2.6]

NOTE In the field of air quality monitoring, the measurand can be a highly varying function of time.

**3.9**
**measuring system**
complete set of measuring instruments and other equipment with operating procedures for carrying out specified air quality measurements

 

NOTE The operating procedure includes or refers to a specification of the calibration routine, if calibration of the measuring system is needed for its proper operation.

**3.10**
**model equation**
mathematical model of the measurement that transforms the set of (repeated) observations performed into the measurement result

**3.11**
**number of degrees of freedom**
in general, the number of terms in a sum minus the number of constraints on the terms of the sum

[GUM:1995, C.2.31]

**3.12**
**random variable**
a variable that may take any of the values of a specified set of values and with which is associated a probability distribution

[GUM:1995, C.2.2]

**3.13**
**reference material**
material or substance one or more of whose property values are sufficiently homogeneous and well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials

[VIM:1993, 6.13]



**3.14**
**reference standard**
standard, generally having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived

[VIM:1993, 6.6]

**3.15**
**result of a measurement**
value attributed to a measurand, obtained by measurement

[VIM:1993, 3.1]

**3.16**
**standard**
material measure, measuring instrument, reference material or measuring system intended to define, realize, conserve or reproduce a unit or one or more values of a quantity to serve as a reference

[VIM:1993, 6.1]

**3.17**
**standard deviation**
positive square root of the variance of the random variable considered

NOTE Adapted from the GUM:1993, C.2.12.

**3.18**
**standard uncertainty**
uncertainty of the result of a measurement expressed as a standard deviation

[GUM:1995, 2.3.1]

**3.19**
**time average**
mean value of a set of measurement results (air quality data) recorded within a defined time period

**3.20**
**uncertainty**
parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand

[VIM:1993, 3.9]

NOTE The uncertainty of a result of a measurement may be described by the (combined) standard uncertainty or by an expanded uncertainty on a stated level of confidence.

**3.21**
**variance**
⟨of a random variable or of a probability distribution⟩ central moment of order 2

NOTE The variance of a random variable may be defined equivalently as the expected value of the quadratic deviation of the random variable about its expected value.

## 4 Symbols and abbreviated terms

$C_i$ individual measurement result recorded in the time period $T$



$\bar{C}_T$ time average of air quality monitoring data $C_i$

$f$ number of degrees of freedom



$f_{\text{eff}}$ effective number of degrees of freedom

$f_{\text{M}}$ number of degrees of freedom assigned to the standard uncertainty $u_{\text{M}}(\bar{C}_T)$ induced by the measuring system applied

$f_{\text{S}}$ number of degrees of freedom assigned to the standard uncertainty $u_{\text{S}}(\bar{C}_T)$ due to incomplete time coverage

$f\left(u(j)\right)$ number of degrees of freedom when assessing the standard uncertainty $u(j)$

$f\left(u_{\text{r}}(j)\right)$ number of degrees of freedom when assessing the standard uncertainty $u_{\text{r}}(j)$

$f\left(u_{\text{nr}}(j)\right)$ number of degrees of freedom when assessing the standard uncertainty $u_{\text{nr}}(j)$

$f\left(u_{\text{nr}}\right)$ number of of degrees of freedom when assessing the standard uncertainty $u_{\text{nr}}$

$f\left(u_{\text{r}}(C_i)\right)$ number of of degrees of freedom when assessing the standard uncertainty $u_{\text{r}}(C_i)$

$k_p(f)$ coverage factor for confidence level $p$ and number of degrees of freedom $f$

$M$ number of time intervals $T(j)$ covering the time period $T$

Max maximum of set of values

$N$ number of measurement results $C_i$ recorded in the time period $T$

$N_{\text{max}}$ number of measurement results $C_i$ necessary for complete coverage of the time period $T$

$n(j)$ number of observed measurement results in time interval $T(j)$

 

| | |
|---|---|
| $s(C_i)$ | standard deviation of the set of $N$ individual measurement results $C_i$ used to calculate the time average $\bar{C}_T$ |
| $T$ | time period allocated to the time average $\bar{C}_T$ |
| $T_s$ | time period allocated to an individual measurement result $C_i$ |
| $T(j)$ | sub-interval of time period $T$ |
| $u(C_i)$ | standard uncertainty of $C_i$ |
| $u_r(C_i)$ | random part of the standard uncertainty of $C_i$ |
| $u_r$ | constant random part of the standard uncertainty of $C_i$ |
| $u_{nr}$ | non-random part of the standard uncertainty of $C_i$ |
| $u(j)$ | standard uncertainty of $C_i$ in time interval $T(j)$ |
| $u_r(j)$ | random part of the standard uncertainty of $C_i$ in time interval $T(j)$ |
| $u_{nr}(j)$ | non-random part of the standard uncertainty of $C_i$ in time interval $T(j)$ |
| $u(\bar{C}_T)$ | (combined) standard uncertainty of the time average $\bar{C}_T$ |
| $u_M(\bar{C}_T)$ | standard uncertainty of the time average $\bar{C}_T$ induced by the measuring system |
| $u_S(\bar{C}_T)$ | standard uncertainty of the time average $\bar{C}_T$ due to incomplete coverage of the time period $T$ by the data set used to calculate the time average |
| $u_r(\bar{C}_T)$ | random part of $u_M(\bar{C}_T)$ |
| $u_{nr}(\bar{C}_T)$ | non-random part of $u_M(\bar{C}_T)$ |
| $U_p(\bar{C}_T)$ | expanded uncertainty of $\bar{C}_T$ on the stated level of confidence $p$ |
| $v_r$ | constant relative standard uncertainty of $C_i$ |



## 5 Requirements on the input data

### 5.1 General

This International Standard provides methods to estimate the uncertainty of the time average of a set of scalar measurement results quantifying a time series of an air quality measurand within a defined time period. The measurand may exhibit significant time structure. The approach [3], using the standard deviation of the measurement results divided by the square root of the number of available measurement results, is applicable only to measurands not exhibiting significant temporal structure and to measuring systems that are only influenced by random uncertainties. In the field of air quality monitoring, measurands often exhibit significant temporal structure and distinct non-random uncertainties. Therefore, a different approach is needed to quantify the uncertainty of time averages in the field of air quality monitoring.

The set of $N$ measurement results $C_i$ of air quality recorded within a defined averaging time period $T$ used to calculate the time average $\bar{C}_T$ is given by formula (1):

$$\{C_i: \quad i = 1 \text{ to } N\} \tag{1}$$