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Air quality — Determination of time-averaged mass emissions and emission factors — General approach

Qualité de l'air — Détermination de la moyenne temporelle des émissions massiques et des facteurs d'émission — Approche générale

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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 11771 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 264, *Air quality*, in collaboration with Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 4, *General aspects*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Introduction

This Intenational Standard describes the measurement procedures necessary to determine the mass emission of substances from stationary sources. Empirically generated data are necessary to determine the uncertainty that can be associated with a stated result and to enable the verification of emission measurement reports.

This Intenational Standard also describes the measurement procedures necessary to determine emission factors. An emission factor is a value that relates the quantity of a pollutant released with an activity associated with the release of that pollutant. Emission factors are useful when the operational conditions and time period for which they are representative is known.

Emission factors are used to calculate and report mass emissions for both emission inventory and non-inventory uses. Inventory uses can include:

— emission trading;

— compiling polluting release and transfer registers;

— air quality modelling;

— air quality management;

— compliance with national emission limits.

Non-inventory uses can include:

— developing site-specific emission estimates;

— developing control strategies;

— risk assessments;

— deciding appropriate permit limits.

The most commonly used methodology for compiling an emission inventory is to combine information on the extent to which an activity takes place (quantified by activity data a) with representative values of the emissions or removals per unit activity, called emission factor F. The basic equation providing the emission as a mass emission rate $\dot{m}$ is given by

$$\dot{m} = aF$$

The basic equation can be modified in some circumstances to include, for instance, emission reduction efficiency (abatement) factors.

NOTE 1 Countries compiling inventories for reporting emissions under international agreements use methodologies agreed upon by convention {e.g. UN FCCC, UN ECE Long-range Transboundary Air Pollution (Reference [31]), or the UN ECE Aarhus Convention}. A common feature of all these conventions is a requirement to use good practice methodologies when estimating and reporting emissions. This is particularly important when providing emission estimates for base year emission inventories used in policy instruments. Good practice is usually taken to mean the use of procedures that ensure inventories are accurate (i.e. without bias) in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that uncertainties are reduced so far as possible. Good practice guidance does not usually specify how to establish emission factors or what information should be reported and be available to allow broad application of emission factors. It is the goal of this International Standard to close this gap, to increase the quality of emission inventories and to improve efficiency.

Emission factors published in most compilations typically are:

- arithmetic averages of available source emission measurement data;
- based on a limited number of emission measurements;
- representative of a restricted period of process operating time;
- representative of a limited range of process operating conditions;
- representative of a limited sample of process units commonly used.

Emission factors are numerical estimates with uncertainties that can include systematic and random components, e.g. measurement uncertainty, fluctuations in pollutant emission control efficiency, and variability in process operation. The numerical uncertainty associated with a particular emission factor, for a single source, can be estimated provided that there is sufficient, high quality, source test data to estimate statistically the underlying variability of the more important influencing factors. Uncertainty also arises from the use of an emission factor applicable to one activity, process, technology or installation being used to represent a situation for which it is unsuitable. In many cases, it is not possible to quantify the uncertainty introduced through inappropriate use of emission factors, and this situation is discouraged.

Emission factors should be used with caution. Alternative means exist for estimating emissions that can be more appropriate under some circumstances.

A material balance can provide an adequate quantification of emissions in situations where a high percentage of material is lost to the atmosphere (e.g. carbon and sulfur in fuel, solvent loss in an uncontrolled coating process). Material or mass balance determinations can also account for fugitive emissions not easily measured otherwise. In contrast, material balances may be inappropriate where material is consumed or chemically combined in the process, or where losses to the atmosphere are a small portion of the total process throughput.

Data from frequent and representative source-specific emissions measurements or continuous emission monitoring systems can provide measures of actual pollutant emissions from a source.

Site-specific measurement data from a limited number of emissions measurements, while improving the certainty of the emission data, represent only the conditions existing at the time of the testing or monitoring. To improve the estimate of longer-term (e.g. daily, monthly, yearly) emissions, conditions under which tests occur should be representative of the source's expected range of operations.

NOTE 2 Even in the absence of representative source-specific data, emission information from process control technique and abatement system vendors, particularly emission performance guarantees or emission measurement data from similar equipment can still be a better source of information than source-category emission factors.

This International Standard requires the use of supporting standards not all of which are yet available.

Air quality — Determination of time-averaged mass emissions and emission factors — General approach

1 Scope

This International Standard specifies a generic method for the determination and the reporting of time-averaged mass emissions from a specific installation or of a family of installations (or common source type), using data collected by measurements, and by establishing:

- mass emission rates by the simultaneous measurement of concentration and gas flow, using standardized manual or automatic methods, and also the estimation of the uncertainty of the measurements;
- time-averaged mass emission rates using time series of mass emission rate values, their uncertainty characteristics, and also the determination of the expanded uncertainty of the average;
- time-averaged emission factors for a specific installation or of a family of installations and their associated uncertainty characteristics;
- a quality management system to assist the process of inventory quality assurance and verification.

This International Standard is applicable to the determination of emission factors for stationary sources including emissions from industrial processes where calculation from fuel and raw material is not practical, for greenhouse gases, and air pollutants including fine particulate material. This International Standard does not address compliance monitoring in the context of emission control regulations.

This International Standard requires the use of measurement-based methods and calculation-based methods that use measurement data. It covers the planning and execution of the measurement programme to collect data, selection of sampling methods, calculation of results, estimation of uncertainty, determination of emission factors, and the reporting of information in a form that enables users to apply them. This International Standard specifies how to:

- generate time-averaged mass emission rate data of a known quality, for a defined period of time, and a documented set of operational conditions;
- generate complete data sets representative of a known time period (i.e. a calendar year) by filling gaps in mass emission rate data series and combining data sets numerically;

NOTE 1 Time series data can be available for only a limited elapsed period (i.e. weeks, months, or years) and can be available only for a discrete process whereas inventories can be necessary which average over a different period (i.e. for a calendar year).

- calculate emission factors for a known time period;
- calculate time-averaged emission factors of a known quality for a known source type.

The measurement of emissions from vehicular, area or fugitive sources is not specifically covered. However, this International Standard can be used for quantification of emission factors for those sources provided that measurements of emissions are available.

NOTE 2 Emission fluxes from fugitive and area sources can be directly measured using optical open-path techniques. The results from these measurements can be treated in an analogous way to the measurements described in this International Standard to determine time-averaged emissions and emission factors.

This International Standard does not explicitly include measurement procedures that are fully described in the referenced standards. Neither does it provide advice on the generation of activity statistics.

This International Standard is compatible with ISO 14064-1[5] and ISO 14064-3[6].

2 Terms and definitions

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

2.1
emission factor
ratio of the rate at which an air pollutant is emitted as a result of some activity, to the rate of that activity

NOTE 1 Adapted from ISO 4225:1994[2], 3.31.

EXAMPLE The mass, in kilograms, of particulate emitted per tonne of coal burned, the mass, in kilograms, of NO_x per tonne of clinker produced in a country per year, or the mass, in tonnes, of CO_2 emitted per megajoule of energy produced.

NOTE 2 Since data are usually derived for a limited range of operating conditions or periods, the conditions or periods over which an emission factor can be considered typical or applicable are needed (see 5.2.2).

NOTE 3 Emissions refer to the set of individual substances that are emitted.

NOTE 4 An emission factor differs from a mass emission rate, the latter has specific dimensions of mass divided by time.

2.2
good practice
set of procedures intended to ensure that reported emissions are accurate (i.e. without bias) in the sense that they are systematically neither over- nor underestimates as far as can be judged, and that uncertainties are reduced as far as possible

2.3
measurand
particular quantity subject to measurement

[ISO 9169:2006[3], 2.1.11]

2.4
measurement system
complete set of measurement instrumentation and associated equipment used for the determination of a specified measurand

2.5
measurement plan
document describing the data collection methodology to be used for a particular installation, the type and quantity of data to be collected, the data processing, the quality system to be adopted, and the processes to be used to estimate measurement uncertainty

NOTE The measurement plan describes any provisions specific either to periodic determinations of mass emissions or emission factors by a test laboratory or to continuous mass flow measurements made by the operator of an installation.

2.6
test
technical operation that consists of the determination of one or more characteristics of a given product, process or service in accordance with a procedure

NOTE 1 For emission measurements, a test consists of series of measurements of one measurand or of combined measurements of several measurands.

NOTE 2 A valid test is often specified as a number of measurements (usually not less than three) that is indicative of the process emission under observation.

3 Symbols and abbreviated terms

AMS automated measuring system

A cross-sectional area of the sampling plane

a activity data

$e(\overline{a})$ sensitivity coefficient of the time-averaged activity rate

$e(\overline{\dot{m}})$ sensitivity coefficient of the time-averaged mass emission rate

F emission factor

$\dot{m}$ mass emission rate

p confidence level

$U_p(y)$ expanded uncertainty of a measurand y at confidence level p

$u(\overline{a})$ uncertainty of the time-averaged activity rate

$u(\overline{\dot{m}})$ uncertainty of the time-averaged mass emission rate

$u(y)$ standard uncertainty of a measurand y

$\dot{V}$ volume flow rate

v flue gas velocity

y measurand

γ_m mass concentration

4 Principle

The mass emission rate, $\dot{m}$, is calculated by multiplying a measured (or calculated) mass concentration, γ_m, by a measured (or calculated on the basis of measurements) volume flow rate, $\dot{V}$, of the flue gas, with both being representative of the same period of time and calculated for the same reference conditions (temperature, pressure, water vapour and oxygen content), by Equation (1):

$$\dot{m} = \gamma_\mathrm{m} \dot{V} \tag{1}$$

The time-averaged emission factor, F, of a measured component is generated by dividing the mass emission rate, $\dot{m}$, of the activity by a measure of the activity associated with the release (activity data a), with both the mass emission rate and the activity data being representative of the same period of time. The basic equation used is given by Equation (2):

$$F = \frac{\dot{m}}{a} \tag{2}$$

Time-averaged emission factors are calculated by dividing suitably averaged mass emission rates by a measure of the activity rate representative of the same time period. Time-averaged mass emission rates and emission factors are quoted with the associated relevant information that describes the operational conditions and time period for which they are representative.

The determination of the relevant measured input quantities for the calculation requires a documented measurement plan.

The uncertainty of the mass emission rate and emission factors is determined by estimating the uncertainty of both the measurement and the activity data.

NOTE Annex B provides additional information on the principles fundamental to ensuring that mass emission data reported for inventory purposes give a true and fair account.

5 Determination of mass emission rates

5.1 Planning

5.1.1 General

Before data collection commences, prepare a measurement plan that specifies the minimum data quality requirements. The measurement plan shall also include:

a) measurement objectives including data quality objectives;

b) data collection and measurement methods to be used;

c) type, quality, and quantity of data to be collected;

d) data-processing procedures to be used to determine the time-averaged mass emission, emission factors and associated uncertainties;

e) quality management system requirements;

f) any associated procedures that can be required to ensure that data quality meets the specified data quality objectives;

g) reporting procedures.

The details that shall be included in the measurement plan are listed in Annex A.

NOTE General guidance on the measurement plan is available, e.g. in EN 15259[12].

5.1.2 Type and quantity of data to be collected

Emission data and activity data, if required, shall be collected over the time period specified in the measurement objective. The data shall conform to the uncertainty requirements, the other data quality requirements specified in the quality management system, and the data-processing procedures to be used, as specified in the measurement plan.

NOTE 1 The time period for mass emissions is typically 6 months or a year. The time period over which emission factors are determined can depend on the time period of available activity data.

Take measurements for a known time period when the installation is operating within the known operational bounds set in the measurement plan.

The measurements should be made at measurement sites where the data are representative of the normal variation of the installation or process emission. The documentation accompanying the monitoring plan should indicate how the minimum number of sampling points to be used for each parameter measured is to be decided and how these are to be selected.

When determining the concentration of a measured component for a known time interval (i.e. by periodic measurement), also measure the volume flow rate or any associated measurands necessary to compute the mass emission rate.

NOTE 2 The time interval can be regular (e.g. once per month) or irregular. Measurands can include the amount, quantity or physical property of an emission. Measurements for less than 24 h are usually made using portable equipment.

When employing an automatic measurement method for the measurand, the flue gas velocity or any associated measurements should also be made using an automated measurement system. The uncertainty, data capture rate, and minimum time coverage shall conform to the data quality requirements of the measurement plan.

5.1.3 Source description data

Information shall be collected describing the operational conditions and the time period, for which the emission rate is representative. This shall be clearly documented (see A.3).

5.2 Measurements

5.2.1 General

Perform the required measurements of the components used for the determination of mass flow rate using national or International Standards that enable the determination of the uncertainty that can be associated with a stated result and to enable the verification of emission reports. If this requires the use of supporting standards that are not yet available, 5.2.2 and 5.2.4 should be regarded as informative.

Clear and unambiguous instructions shall be provided for measurement personnel.

5.2.2 Determination of the mass concentration

Determine the mass concentration, γ_m, of the measured component in the flue gas over the sampling duration specified in the measurement plan.

NOTE 1 The measurement plan can specify periodic or continuous measurements. Typical sampling durations are 30 min or 1 h. Continuous measurements can require averaging of the measured signals over the sampling duration specified in the measurement plan.

Sampling shall be representative of the specified sampling duration taking into account the likely variability of the process.

The measurement methods used shall have known performance characteristics.

A sufficient number of samples shall be taken to ensure that the mass concentration, γ_m, meets the data quality objective.

NOTE 2 The performance characteristics of the method necessary to estimate the measurement uncertainty of the result include repeatability, reproducibility, detection limit, measurement range, and cross-sensitivity. Suitable measurement methods have been field tested to determine their performance characteristics and the expanded uncertainty to be expected with their use — typically at the 95 % confidence level. Some International Standards, European Standards or suitable validated national standards can meet these criteria. A selection of International Standard reference methods for the automated measurement of common pollutants is listed in the bibliography.

Automated measurement systems (AMS) should be operated under a quality system that assures they are installed to measure emissions to air and are capable of meeting the uncertainty requirements of measured values specified in the measurement plan.

NOTE 3 The capability of meeting uncertainty requirements can be demonstrated by application of ISO 14956[7].

NOTE 4 EN 14181[11] describes the calibration of AMS.

Express the result as an average of the concentration over the sampling duration specified in the measurement plan.

5.2.3 Determination of temperature, pressure, humidity, and oxygen

Determine temperature, pressure, humidity (moisture) and oxygen, if required, using standardized measurement methods. Sampling shall be in the same sampling plane and in close proximity to, but not interfering with, that used for the determination of the mass concentration and gas velocity. The measurements shall be representative of the time period of the mass concentration measurement.

NOTE Suitable standardized determinations of temperature, pressure, humidity, and oxygen are listed in the Bibliography.

5.2.4 Measurement of the volume flow rate

Determine the volume flow rate, $\dot{V}$, by use of a standardized measurement method or by a validated calculation procedure based on fuel composition, measured fuel amount, and measured oxygen concentration.

The volume flow rate shall be determined for the sampling plane used for the determination of the mass concentration.

NOTE 1 This can be achieved by measuring the flue gas velocity, v, or oxygen concentration in the same sampling plane and in close proximity to, but not interfering with, that used for the determination of the mass concentration.

The velocity or oxygen measurement shall be representative of the time period of the mass concentration measurement.

NOTE 2 EPA Methods 2[28], 2G[28], 2F[28], 2H[28], and Conditional Test Method-041[29] are applicable methods for gas velocity measurement. These methods can be used to measure unadjusted velocity, yaw-adjusted velocity, yaw and pitch angle-adjusted velocity, wall effects in circular stacks or ducts, and wall effects in rectangular stacks or ducts, respectively. Combination methods, e.g. 2GH or 2FH can also be used. For discontinuous methods, type L Pitot tubes, as described in ISO 3966:2008[1], Annex A can be used. Alternatively, other measurement devices (e.g. type S Pitot tube) can also be used, provided that they are calibrated against standardized Pitot tubes.

The cross-sectional area, A, of the sampling plane shall be determined with known uncertainty.

The volume flow rate is the product of the flue gas velocity and the cross sectional area, A, of the sampling plane at its point of measurement as given by Equation (3):

$$\dot{V} = vA \qquad (3)$$

5.3 Calculation of mass emission rates

Calculate the mass concentration, γ_m, of the measured component in the flue gas and the volume flow rate, $\dot{V}$, at the same conditions of temperature, pressure, and humidity.

If required by the measurement plan, the mass concentration and the volume flow rate shall be corrected to the same reference conditions for the oxygen or carbon dioxide content specified.

NOTE 1 The use of common standardized conditions enables the volume-based concentration values and corresponding volume flow rates to be multiplied together without the introduction of bias.

The results shall be expressed in SI units.

Calculate the mass emission rate by multiplying the mass concentration of the measured component in the flue gas by the associated volume flow rate of the flue gas according to Equation (4):

$$\dot{m} = \gamma_\mathrm{m} \dot{V} \qquad (4)$$

NOTE 2 Mass emission rates related to the sampling duration of the mass concentration measurement are called “short-term averages” in the following.

NOTE 3 When, in the course of periodic or manual measurement, a series of tests has been made under similar process operating conditions, as specified in the measurement plan, the results can be averaged and the result can be taken to be representative of the time period of the measurement sequence as a whole.

When using automated continuous measurement, the mass emission rate shall be generated continuously and recorded as a time series of fixed period averages. The time series may be averaged and the result taken to be representative of the time period of the measurement sequence as a whole.

NOTE 4 For most processes, hourly or half hourly averaging is suitable.

5.4 Determination of time-averaged mass emission rates

Average the mass emission rates over the averaging period specified in the measurement plan.

NOTE 1 Mass emission rates averaged over the averaging period specified in the measurement plan are called "long-term averages" in the following.

When using periodic or manual measurement, a number of tests may be averaged over a longer time period provided that they conform to 5.2 and the uncertainty criteria as specified in the measurement plan are met. When using an automated continuous measurement system, the time-averaged mass emission rate is the simple arithmetic average of the time resolved mass emission rates (e.g. half hourly) for the periods when the process was within the operational criteria specified in the measurement plan.

Record the installation process conditions for which the derived value is applicable and document the proportion of time during the averaging period for which the installation was operating outside the criteria specified in the measurement plan (see 5.1.2 and Annex A).

Record the derived value of the averaged mass emission rate in SI units. The value may, in addition to SI units, be reported in superseded units, provided it is made clear that the superseded units are given for information only.

NOTE 2 The mass emission rate data can be 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 arising from missing data. ISO 11222[4] can be used to calculate the additional uncertainty, due to incomplete time coverage, of the mean value of a mass emission rate obtained from a series of measurements. ISO 11222[4] is applicable only when the time series data used are representative of the temporal structure of the emission as a whole.

5.5 Uncertainty estimation

5.5.1 General

The uncertainty of the mass emission rate of a measured component shall be determined in accordance with the general principles of ISO/IEC Guide 98-3:2008[10].

The determination of the uncertainty of short-term averages of the mass emission rate requires:

- establishment of a suitable model equation describing the whole measurement process and the relationship between the input quantities used to calculate the mass emission rate;
- determination of the variance equation describing the combination of the uncertainty contributions of the individual input quantities by application of the law of uncertainty propagation to the model equation;
- determination of the uncertainty of the input quantities;
- calculation of the standard uncertainty of the mass emission rate;
- determination of a coverage factor taking into account the number of degrees of freedom associated with the individual uncertainty contributions and the level of confidence;
- calculation of the expanded uncertainty of the mass emission rate.

The standard uncertainty and the associated number of degrees of freedom shall be available for the measured input quantities used to calculate the mass emission rate by use of the model equation. Suitable standard measurement methods for the input quantities have known uncertainties, which are often expressed as repeatability and reproducibility in the field. If the mass emission rate is calculated from data collected using non-standard methods, this information is often missing. The user shall determine the uncertainty of the measurement methods used to measure the input quantities and shall verify the uncertainty by comparison with documented values obtained e.g. during the validation of the measurement method. ISO 20988[9] provides guidance on the estimation of the uncertainty of air quality measurements, such as concentration and volume flow measurements, and the associated number of degrees of freedom.

The estimation of the uncertainty of long-term averages of the mass emission rate shall be based on a model equation, which includes the measurement induced uncertainty of the short-term averages and the additional uncertainty due to incomplete coverage of the time period of the long-term average. ISO 11222[4] provides guidance on the determination of the uncertainty of time averages of air quality measurements.

The model equation should address the time period of the long-term average, particularly with respect to the calibration frequency of emission measuring equipment. For example, if continuous monitoring equipment is calibrated following EN 14181[11], then calibration is carried out with up to a 3 year time period, with annual calibration checks, against a standard reference method. This calibration regime leads to a number of uncertainty sources which can be considered systematic over a yearly emissions reporting period.

5.5.2 Standard uncertainty

The standard uncertainty of short-term averages of the mass emission rate of a measured component shall be calculated as the square root of the variance of the mass emission rate, which is given as the sum of the variance contributions of the individual input quantities.

The standard uncertainty of long-term averages of the mass emission rate of a measured component shall include the measurement-induced uncertainty and the uncertainty due to incomplete coverage of the averaging period of the emission rate data.

NOTE 1 The mass emission rate data can be 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 arising from missing data.

The random and systematic uncertainty components of the short-term averages have to be taken into account when calculating the measurement-induced uncertainty of long-term averages (see e.g. ISO 11222[4]).

NOTE 2 The uncertainty of the long-term average can not be calculated by summing the uncertainties of shorter time periods divided by the square root of the number of these shorter time periods as this requires completely random uncertainties.

NOTE 3 The uncertainty estimation for the long-term average requires the establishment of a model equation, which allows the correct handling of random and systematic uncertainties.

For a time series of short-term averages of measured mass emission rates, the measurement induced uncertainty of the long-term average may be taken to be the same as the uncertainty of the individual mass emissions rates. This is equivalent to assuming that all uncertainty sources are systematic, which provides a safe estimate of the measurement-induced uncertainty of the long-term average.

NOTE 4 The assumption that all uncertainties are systematic can be considered as a worst case scenario.

ISO 11222[4] can be used to calculate the additional uncertainty, due to incomplete time coverage, of the average of a mass emission rate obtained from a series of measurements.

5.5.3 Expanded uncertainty

The expanded uncertainty of the mass emission rate, which is the dispersion of the range of values that could reasonably be expected in practical situations, shall be determined by multiplying the standard uncertainty of the mass emission rate by the coverage factor.

The coverage factor shall be determined as the value of the t-distribution for the effective number of degrees of freedom of the standard uncertainty and the statistical confidence level specified in the measurement plan.

NOTE The level of confidence is typically 95 %.

The effective number of degrees of freedom of a standard uncertainty is calculated from the Welch-Satterthwaite solution specified in ISO/IEC Guide 98-3:2008[10]. ISO 20988[9] and ISO 11222[4] provide guidance on the calculation of the effective number of degrees of freedom.

For long-term averages, a coverage factor of two may be used provided that the average is calculated from at least 30 short-term averages and the systematic part of the measurement-induced uncertainty is small compared to the random part.

6 Activity data

6.1 Collection of activity data

Activity data to be determined in accordance with the specification in the measurement plan shall be selected such that it complements the measured emission data. It should match as closely as possible the factors prescribed in A.3.

When using measurement to generate activity rates, any flow meters, weighing equipment, counting devices etc. that are used shall have known performance characteristics and be calibrated, maintained, and inspected on a regular basis.

NOTE Activity data can include fuel use, raw material feed, or production data (area of surface coated, etc.).

Where the collection of additional information is specified in the measurement plan, such as for chemical analysis, calorific value of fuels, raw materials or products being metered, this should be based on representative sampling and analyses carried out by accredited laboratories.

Measurement equipment used to determine activity data should be subject to maintenance, calibration, and inspection in accordance with operational procedures described in the quality system. Laboratories that are accredited according to ISO/IEC 17025[8] for such activities should perform the test work. The guidance given in 5.2.1 can be used for the measurement of activity data also.

When activity data are collected on a continuous basis, the proportion of time shall be recorded during which metering equipment is operating outside the equipment performance criteria specified in the measurement plan or when the data capture rate is reduced.

The measurement plan shall indicate how moisture and other measurements are to be taken if the fuel or raw materials are not dry or if there are contaminants that could adversely affect the measurement process.

The measurement plan should also specify, for any process, the specific conversion and oxidation factors to be determined and any other measurements necessary for that purpose (see e.g. Reference [34]). For example, if the fuel or raw materials used are not dry, a moisture analysis may be necessary to determine the dry fuel equivalence. Related measurements should be made simultaneously, or in such a way that ensures the correct functional relationship between the variables being sampled, otherwise integrated flows or emissions derived from the measurements are likely to be incorrect.

6.2 Activity data uncertainty

Determine the standard uncertainty of the activity data collected by measurement by combining the measurement uncertainties of the individual measurements made.

Determine the expanded uncertainty of activity data derived from measurements, made according to 5.2, by multiplying the standard uncertainty of the activity data by the coverage factor. The coverage factor shall be determined as the value of the t-distribution for the effective number of degrees of freedom of the standard uncertainty and the statistical confidence level specified in the measurement plan.

When activity data have not been calculated from measured data, the uncertainty should be estimated via a process of expert judgment and the assumptions made should be fully documented.

7 Determination of time-averaged mass emission factors

7.1 General

Determine emission factors over a time period that is typical or applicable to the installation or process emissions pertaining to the period covered by the available activity statistics or for the time period specified in the measurement plan. Record and report the process operating conditions and time period over which an emission factor can be considered typical.

NOTE 1 Many uses require emission factors to be representative of emissions over a calendar year.

NOTE 2 Mass emission rate data can be aggregated to create time series matching the time constant of the available activity data provided that measurements have been taken under process operating conditions that conform to the data quality requirements of the monitoring plan. Time series can be incomplete if, for either mass emission or activity data, a manual or periodic method has been used or if data has been lost from continuous emission measurement (see C.1).

NOTE 3 Emission factors can be constructed that are representative of a generic group of installations when several potential datasets are available that refer to the same quantity and were collected in a manner conforming to Clause 5 (see C.2).

7.2 Calculating the time-averaged emission factor

Calculate the time-averaged emission factor, $\overline{F}$, by dividing a suitably time-averaged mass emission rate, $\overline{\dot{m}}$, by a measure of the activity rate, $\overline{a}$, averaged over a similar time period according to Equation (5):

$$\overline{F} = \frac{\overline{\dot{m}}}{\overline{a}} \quad (5)$$

The emission factors shall be quoted with associated text that describes the operational conditions and time period for which they are representative.

NOTE Emission reduction efficiency factors may be calculated from the difference of the mass emission rates determined upstream and downstream (either simultaneously and sequentially) of any abatement equipment used.

7.3 Uncertainty of the time-averaged emission factor

Determine the standard uncertainty of the time-averaged emission factor by taking the positive square root of the sum of the variance contributions of the mass emission rate and the activity data according to Equation (6):

$$u(\overline{F}) = \sqrt{e^2(\overline{\dot{m}})\, u^2(\overline{\dot{m}}) + e^2(\overline{a})\, u^2(\overline{a})} \quad (6)$$

where

$e(\overline{\dot{m}})$ is the sensitivity coefficient of the time-averaged mass emission rate;

$u(\overline{\dot{m}})$ is the uncertainty of the time-averaged mass emission rate;

$e(\overline{a})$ is the sensitivity coefficient of the time-averaged activity rate;

$u(\overline{a})$ is the uncertainty of the time-averaged activity rate.

Determine the expanded uncertainty of time-averaged emission factor by multiplying the standard uncertainty of the time-averaged emission factor by the coverage factor. The coverage factor shall be determined as the value of the *t*-distribution for the effective number of degrees of freedom of the standard uncertainty and the statistical confidence level specified in the measurement plan.

7.4 Aggregating emission factors

Calculate aggregate emission factors, if required by the measurement plan and its associated reporting requirements (see Annex A), by aggregating time-averaged emission factors that, within the specification of the measurement plan, form a common source type (see e.g. Reference [30]), including:

- production process;
- production steps;
- seasonal or ambient changes that have not been resolved by adjusting the averaging period;
- age, type, and condition of installation or process;
- variability of fuel or raw materials;
- load;
- time period.

NOTE Reporting to different source type categories, such as UN FCCC CRF categories (Reference [30]) and UN ECE NFR codes (Reference [31]), can require the aggregation of data with variations in operating conditions at an installation, differences in process details at similar facilities, differences in test procedures among tests, or differences in test quality and associated uncertainties.

Significant differences in emissions attributable to identifiable and quantifiable process, feedstock or control measure variable, shall be minimized by complete documentation in the measurement reports.

7.5 Uncertainty estimation of aggregates of emission factors

Estimate the standard uncertainty of aggregates of emission factors pooling independently determined estimates to create a hypothetical population that can subsequently be re-sampled to determine the mean, standard deviation, and associated coverage factors.

NOTE A description of the use of a Monte Carlo methodology for simulating a population from a probability density function constructed from limited data sets is given in Reference [32].

8 Quality management system requirements

Employ a quality management system to verify that the quality assurance and quality control procedures are sufficient to meet the user needs and data quality requirements specified in the measurement plan. The quality management system shall cover the measurement planning, the performance of the measurements and the assessment of data.

NOTE 1 The precision and trueness or the uncertainty of the time-averaged emission factors can be managed and verified by way of a quality system that controls and assures the integrity, correctness, and completeness of: the data, information relating to the operational status of the emitting source, the time period for which the emission factor is representative, assumptions made, activity data, and any conversion factors used.

NOTE 2 In this context, quality control is the system of routine technical activities used by measurement personnel to check that the data acquisition and processing conforms to measurement and data quality requirements. Quality assurance is the system of review procedures used by personnel, independent of the monitoring staff, intended to demonstrate conformance with measurement and data quality objectives have been met.

NOTE 3 ISO/IEC 17025[8] contains general requirements that, if met, enable testing laboratories that demonstrate their ability to operate a quality system, technical competence and ability to generate valid results. CEN/TS 15675[13] provides an application of ISO/IEC 17025:2005[8] to periodic emission measurements.

9 Reporting

9.1 General

Present mass emission rate and emission factor data, together with information that describes their derivation, in sufficient detail that a user can assess the applicability of the emission factors.

9.2 Test report

The test report shall include the measurement plan and describe, directly or by reference, the:

— details of the data collection and measurement methodologies used;

NOTE 1 EN 15259[12] and Reference [32] illustrate the information typically listed in test reports.

— data collected and used to determine time-averaged mass emission rate and emission factors;

— time-averaged mass emission rates and/or emission factors together with estimates of their associated uncertainty;

— methodology to estimate the uncertainties;

— quality management system employed;

— additional evidence to demonstrate that data quality meets any specified minimum requirements or data quality objectives (e.g. source test, equipment tested, conditions under which the test was performed, etc.).

Reporting shall be in sufficient detail to allow an independent recalculation.

The results shall be expressed in SI units.

NOTE 2 ISO/IEC 17025[8] provides additional guidance on the preparation of test reports.

Annex A
(normative)

Minimum requirements for the measurement plan

A.1 General

The measurement plan shall specify clear instructions in sufficient detail to enable the determination of time-averaged mass emissions and emission factors with known uncertainty characteristics by measurement personnel.

Measurements shall be documented in sufficient detail that a verifier can reproduce the determination.

The measurement plan should specify:

— identification and location of source to be measured;

NOTE The location data can include information relating to the region and regional conditions at the time of data acquisition.

— the data to be collected and data quality objectives;

— measurement sites and sections, sampling strategy and other relevant items as specified, e.g. in EN 15259[12];

— the measurement methodologies to be used;

— the type and quantity of data to be collected;

— the information to be collected relating to the installation and process conditions pertaining at the time of testing;

— the data processing to be undertaken;

— the quality management system;

— any additional processes necessary to demonstrate that the mass emission is systematically neither over nor under the true emission.

A.2 Data collection and measurement methodologies

The data collection and measurement methodologies used for both the mass emission rate and activity data shall be suitable for use on the installation and the process under investigation. Typically they should specify the:

— measurands and any associated reference measurements;

— procedures to ensure the representativeness of the measurements;

— standard reference methods to be used;

— analytical equipment needed and its operational requirements;

— the data quality objectives to be achieved including any accuracy, precision, uncertainty requirements, or data capture requirements;

NOTE Data capture objectives commonly include specifications for the uncertainty, minimum data capture and minimum time coverage.

— the types of an activity comprising the common source type for which the emission factor is representative;

— the quality system to be followed.

A.3 Type and quantity of data to be collected

The general information to be documented specifying the operational conditions and the time period for which the emission rate is representative shall include

— reporting arrangements and conventions adopted;

— any additional installation or process related information collected to enable data processing or interpretation of the results;

— conditions (or range of conditions) of the process (or for industrial installations the capacity, load, fuel or feedstock) pertaining during the measurements;

— personnel responsible for the measurements and others involved.

The information specific to the installation or process and the measurements taken, shall include:

— installation or process name or description;

— process feedstock or fuel type;

— plant capacity (net or total capacity, input or output orientated, operating rate, and throughput during the test etc.);

— abatement systems and their operating parameters;

— age of the facility and the abatement systems;

— dates of last maintenance performed on abatement systems;

— description of last maintenance performed on abatement systems;

— any process control technique or abatement system malfunctions during the test;

— pollutants tested for and the test methods used;

— number of individual measurements to be made and the conditions comprising a valid test;

— any temperature, pressure, humidity, and any other associated measurements necessary;

— number of data to be collected to calculate the uncertainty associated with the test;

— any deficiencies or deviations in the test procedures;

— the number and duration of test runs;

— any additional documentation required by the quality management system;

— the identification of the testing laboratories and personnel used.

NOTE 1 The list is drawn from EN 15259[12] and the other material referenced in the Bibliography.

NOTE 2 All emissions of a component from the installation should be represented in the mass emissions or emission factor, not only those emissions that could easily be measured.

A.4 Data processing and reporting

Data processing requirements and the specification for the format of the results to be quoted shall specify the:

— calculations to be done and the way that they should be computed;

— documentation requirements to enable the results to be traced back through the calculations to the collected basic data and process operating conditions;

— units of the result;

— reporting procedures that form an account of the measurements, the description of the measurement objectives, and the measurement plan.

The documentation relating to the installation conditions that the data are representative of shall include measurement dates and periods of the measurement campaign.

Annex B
(informative)

Example of uncertainty estimation

B.1 General

This annex provides an example of the uncertainty calculation. It is based on the approach used in the Netherlands for the determination of dinitrogen oxide (nitrous oxide) emissions.

B.2 Dinitrogen oxide emissions from nitric acid production plant

B.2.1 Description of the measurement

Nitric acid production involves the oxidation of ammonia using oxygen from ambient air. Dinitrogen oxide is produced as a by-product and can be emitted to air in the tail gas from the process plant if suitable abatement is not in place. It is not possible to determine the emitted dinitrogen oxide from a simple mass balance calculation based on input material to the process. The determination of the mass emission of dinitrogen oxide is therefore based on direct measurement of its concentration in the emissions stream and on the determination of the flow rate. The flow rate is determined from a balance calculation using measurements of the oxygen concentration in the emissions stream and metering the input process gas streams. The flow calculation is based on the metered input air, adjusting the volume flow in the exhaust stream by measuring the oxygen removed from the gas during the process. There are three input ambient air gas streams which are combined to provide the total input process gas (known as $\dot{V}_\text{p}$, $\dot{V}_\text{s}$ and $\dot{V}_\text{a}$). The dinitrogen oxide concentration in the exhaust gas is measured continuously using an automated measuring system, providing a time series of measurements. Data are recorded every hour, to produce monthly mass emission figures. This annex provides an example of the calculation of the uncertainty of a monthly mass emission figure.

NOTE This example of a mass emissions rate calculation for dinitrogen oxide described here is based on the material provided by the Dutch Emissions Authority.

In accordance with this International Standard, the calculation of mass flow is based on a time series of measurements providing hourly values (though they are derived from shorter period data).

The measurement model equation for the hourly mass emission rate is given by Equation (B.1):

$$\dot{m} = \left(\dot{V}_\text{p} + \dot{V}_\text{s} + \dot{V}_\text{a}\right) \cdot \left(\frac{1 - 0{,}209\,5}{1 - \varphi_{\text{O}_2}}\right) \gamma_{\text{N}_2\text{O}} \tag{B.1}$$

where

$\dot{V}_\text{p}$ is the primary measured flow rate, e.g. in cubic metres per hour, of air under standard conditions;

$\dot{V}_\text{s}$ is the secondary measured flow rate, e.g. in cubic metres per hour, of air under standard conditions;

$\dot{V}_\text{a}$ is a term describing an additional constant air input flow, e.g. in cubic metres per hour, under standard conditions;

φ_{O_2} is the measured oxygen volume fraction, expressed as a percentage;

$\gamma_{\text{N}_2\text{O}}$ is the measured dinitrogen oxide mass concentration, e.g. in milligrams per cubic metre, at standard conditions.

The monthly average emission rate is the average of all $\dot{m}$ (for which the plant was operating correctly) over the month. The uncertainty of the time average is determined in accordance with ISO 11222[4], which provides a method to determine the uncertainty of the time average, taking into account the uncertainty due to the determination of the hourly emissions data and the effect of missing values.

The data set used for this example is based on a period of 29 days (February in a leap year) and is missing a period of data of 86 h (3,5 days) in one single period within the month. The time coverage of the available data is 88 %, which is acceptable.

B.2.2 Standard uncertainty of the hourly emission rate

The standard uncertainty of the mass emission rate is determined by the propagation of uncertainty in accordance with the principles of ISO/IEC Guide 98-3:2008[10].

NOTE ISO/IEC Guide 98-3 is identical to ENV 13005[14].

The uncertainties of the flow meters which provide the $\dot{V}_{\mathrm{p}}$ and $\dot{V}_{\mathrm{s}}$ values are reported to be 3 % of value with a level of confidence of 95 % ($k = 2$). This is derived from the certification of the meters. No information is provided about the components of these uncertainties which are random or systematic. Under standard conditions, $\dot{V}_{\mathrm{a}}$ is an assumed constant flow of 700 m^3/h, which has an assumed uncertainty of 25 %.

The continuous emission measurements of dinitrogen oxide and oxygen are made with instruments which are calibrated in accordance with EN 14181[11]. The regulatory requirement is that the uncertainty of the measurements made with these analysers is 5 % of value with a level of confidence of 95 %. The QAL1 assessment according to EN 14181[11] is reported to have demonstrated that the analysers meet this requirement. The QAL3 according to EN 14181[11] is designed to ensure that the analysers stay within control. Because of the infrequent calibration of the analysers, it may be assumed that the dominant uncertainty terms are systematic.

The combined standard uncertainty of the mass emission rate, $\dot{m}$, is given by Equation (B.2):

$$u^2(\dot{m}) = \sum_{i=1}^{N} \left[\left(\frac{\partial \dot{m}}{\partial X_i} \right)^2 u^2(X_i) \right] \tag{B.2}$$

where $\left[\left(\frac{\partial \dot{m}}{\partial X_i} \right) u(X_i) \right]$ is the partial uncertainty due to the ith term in the measurement model equation.

For the measurement model given by Equation (B.1), the combined standard uncertainty is given by Equation (B.3):

$$\begin{aligned} u^2(\dot{m}) = {} & \left(\frac{\partial \dot{m}}{\partial \dot{V}_{\mathrm{p}}} \right)^2 u^2(\dot{V}_{\mathrm{p}}) + \left(\frac{\partial \dot{m}}{\partial \dot{V}_{\mathrm{s}}} \right)^2 u^2(\dot{V}_{\mathrm{s}}) + \left(\frac{\partial \dot{m}}{\partial \dot{V}_{\mathrm{a}}} \right)^2 u^2(\dot{V}_{\mathrm{a}}) + \\ & \left(\frac{\partial \dot{m}}{\partial \varphi_{\mathrm{O_2}}} \right)^2 u^2(\varphi_{\mathrm{O_2}}) + \left(\frac{\partial \dot{m}}{\partial \gamma_{\mathrm{N_2O}}} \right)^2 u^2(\gamma_{\mathrm{N_2O}}) \end{aligned} \tag{B.3}$$

The volume flow rates $\dot{V}_{\mathrm{p}}$, $\dot{V}_{\mathrm{s}}$ and $\dot{V}_{\mathrm{a}}$ each have the same sensitivity coefficient given by Equation (B.4):

$$\frac{\partial \dot{m}}{\partial \dot{V}} = \frac{(1 - 0{,}209\,5)\,\gamma_{\mathrm{N_2O}}}{1 - \varphi_{\mathrm{O_2}}} \tag{B.4}$$

The sensitivity coefficient for oxygen is given by Equation (B.5):

$$\frac{\partial \dot{m}}{\partial \varphi_{\mathrm{O_2}}} = \frac{(1 - 0{,}209\,5)\,\gamma_{\mathrm{N_2O}} \left(\dot{V}_{\mathrm{p}} + \dot{V}_{\mathrm{s}} + \dot{V}_{\mathrm{a}} \right)}{\left(1 - \varphi_{\mathrm{O_2}} \right)^2} \tag{B.5}$$

The sensitivity coefficient for dinitrogen oxide is given by Equation (B.6):

$$\frac{\partial \dot{m}}{\partial \gamma_{N_2O}} = \frac{(1 - 0{,}209\ 5)\ \left(\dot{V}_p + \dot{V}_s + \dot{V}_a\right)}{1 - \varphi_{O_2}} \tag{B.6}$$

Table B.1 gives the results of a conventional uncertainty evaluation for this measurement model using typical values for the input quantities and their associated uncertainties. Rows 2 to 6 contain information about the input quantities in the model, which are the values (column 2), associated relative standard uncertainties (column 3), absolute standard uncertainties (column 4), sensitivity coefficients (column 5) and the contribution to the combined standard uncertainty (column 6).

Table B.1 — Conventional uncertainty evaluation for an example of the calculation of mass emissions rate

Quantity	Value	Relative standard uncertainty %	Absolute standard uncertainty	Sensitivity coefficient	Uncertainty contribution $u(X_i)$ kg/h
$\dot{V}_p$	72 567,76 m^3/h	1,5	1 088,5 m^3/h	141,5 × 10^{-6} kg/m^3	0,154
$\dot{V}_s$	10 898,03 m^3/h	1,5	163,5 m^3/h	141,5 × 10^{-6} kg/m^3	0,023
$\dot{V}_a$	663,54 m^3/h	12,5	82,9 m^3/h	141,5 × 10^{-6} kg/m^3	0,012
γ_{N_2O}	172,7 mg/m^3	2,5	4,32 mg/m^3	68,97 × 10^3 m^3/h	0,298
φ_{O_2}	3,6 %	2,5	0,1 %	12,36 kg/h	0,011
$\dot{m}$	12 kg/h	2,8	—	—	0,337

For this example, the hourly mass emission rate of 12 kg/h has a combined standard uncertainty of 0,34 kg/h. The corresponding expanded uncertainty at a level of confidence of 95 % ($k = 2$) is given by 0,67 kg/h or 5,6 % of the measured mass emission rate.

B.2.3 Calculation of the uncertainty of the monthly average mass emission rate

Following the approach in ISO 11222[4] the uncertainty in the monthly average mass emission rate is calculated from Equation (B.7):

$$u^2(\bar{\dot{m}}) = u_M^2(\bar{\dot{m}}) + u_S^2(\bar{\dot{m}}) \tag{B.7}$$

where

$u_M^2(\bar{\dot{m}})$ is the mean square uncertainty of the monthly average mass emission rate, $\bar{\dot{m}}$, due to the uncertainty in the determination of the set of measurement results, $\dot{m}$;

$u_S^2(\bar{\dot{m}})$ is the mean square uncertainty of the monthly average mass emission rate, $\bar{\dot{m}}$, due to the incomplete time coverage (i.e. missing values) in the monthly data, $\dot{m}$.

B.2.4 Standard uncertainty due to the measurements of mass emission rate

In accordance with the approach of ISO 11222:2002[4], 6.2 c), where no information is available to differentiate between random and systematic uncertainties over the month period, the uncertainties in the individual reading $\dot{m}$ are assumed to be systematic over the averaging period.

In this case, the individual uncertainties, $u(\dot{m}_i)$, for each hourly mass emission measurement may be calculated using the method described in B.2.2. Assuming all these uncertainties are non-random, the contribution these make to the uncertainty in the monthly average may be determined from the following.

The model equation for the monthly average emission rate is given by Equation (B.8):

$$\bar{m} = \frac{1}{N}\sum_{i=1}^{N}\dot{m}_i \tag{B.8}$$

where N is the number of hourly data points, $\dot{m}$.

From Equation (B.8), the sensitivity coefficient for each uncertainty $u(\dot{m})$ is $1/N$. Assuming the uncertainty terms are caused by systematic effects, the combined standard uncertainty $u_M(\bar{m})$ is therefore given by Equation (B.9):

$$u_M(\bar{m}) = \sum_{i=1}^{N}\frac{1}{N}u(\dot{m}_i) \tag{B.9}$$

For data in which there is little variation in the parameters over the time period of interest, the uncertainty in the monthly average may be calculated by applying the uncertainty calculation described in the preceding for the hourly emission rate, to the monthly average values for the input parameters. This approximation avoids the need to determine the uncertainty on every hourly value.

For the example data set, the average dinitrogen oxide mass emission rate for the month is 13,69 kg/h. The value of $u_M(\bar{m})$ determined by determining the uncertainties for all 610 hourly values and combining them as described above is 0,387 0 kg/h, or 2,83 % of the monthly average.

By comparison, applying the uncertainty calculation to the monthly average values for the input parameters ($\bar{\dot{V}}_p$, $\bar{\dot{V}}_s$, $\bar{\dot{V}}_a$, $\bar{\varphi}_{O_2}$ and $\bar{\gamma}_{N_2O}$) gives a standard uncertainty of 0,387 2 kg/h. The difference between the two approaches in this case is negligible.

NOTE A full uncertainty analysis can be carried out on the measurement process, to assess the random component of the uncertainties. For example the QAL3 zero and span data obtained in accordance with EN 14181[11] can be used to derive a measure of the repeatability of the measurements of oxygen and dinitrogen oxide over the measurement period. The systematic uncertainties can be calculated from the QAL2 calibration procedure specified in EN 14181[11]. In addition, information on the effect of influence quantities obtained during the performance testing of the analysers can also be included. This uncertainty analysis would provide separate information on the random and systematic terms in the uncertainties of the oxygen and dinitrogen oxide data. These uncertainties could then be used within the approach of ISO 11222:2002[4], 6.2 a) to determine the uncertainty of the monthly average. This more involved approach would provide a lower uncertainty — as the random terms would be reduced by a factor of $\sqrt{N}$, where N is the number of data points in the monthly average.

B.2.5 Standard uncertainty due to incomplete time coverage of the monthly mass emission data

The uncertainty due to the incomplete time coverage of the data $u_S(\bar{m})$ can be determined using the procedures given in ISO 11222[4] [see Equation (B.10)]:

$$u_S^2(\bar{m}) = \left(1 - \frac{N}{N_{max}}\right)\frac{1}{N}s^2(\dot{m}) \tag{B.10}$$

where

N is the actual number of recorded data points (in the case of the example $N = 610$);

N_{max} is the total number of possible data points in the time series (in the case of the example the month is 29 days long with 696 potential hourly emission data values);

$s^2(\dot{m})$ is the variance of the available data with $s^2(\dot{m}) = \frac{1}{N-1}\sum_{i=1}^{N}\left(\dot{m}_i - \bar{\dot{m}}\right)^2$.

For the example data, the variance of the available data is given by $s^2(\dot{m}) = 2{,}577\ (\text{kg/h})^2$ and the uncertainty due to the incomplete time coverage by $u_{\text{S}}(\bar{\dot{m}}) = 0{,}023$ kg/h.

As can be seen, the uncertainty due to incomplete time coverage is, as expected, small.

B.2.6 Combined uncertainty of monthly average mass emission rate

The square of the combined uncertainty of monthly average mass emission rate is given by Equation (B.11):

$$u^2(\bar{\dot{m}}) = u_{\text{M}}^2(\bar{\dot{m}}) + u_{\text{S}}^2(\bar{\dot{m}}) = (0{,}3870^2 + 0{,}023^2)\left(\frac{\text{kg}}{\text{h}}\right)^2 \qquad \text{(B.11)}$$

The combined uncertainty of monthly average mass emission rate is given by Equation (B.12):

$$u(\dot{m}) = 0{,}388\ \frac{\text{kg}}{\text{h}} \qquad \text{(B.12)}$$

The expanded uncertainty for a confidence level of 95 % ($k = 2$) is therefore 0,778 kg/h.

The monthly mean dinitrogen oxide mass emission rate can therefore be expressed by Equation (B.13):

$$\bar{\dot{m}} = (13{,}69 \pm 0{,}78)\ \frac{\text{kg}}{\text{h}} \qquad \text{(B.13)}$$

Annex C
(informative)

Data manipulation

C.1 Filling gaps in time series data

Gaps in incomplete data sets can be filled provided that the data collected and the measurements made correspond to a specified location over a defined averaging time period when the installation is operating within acceptable operational bounds.

NOTE 1 Many users require emission factors representative of a period of time different from that over which measurement data were collected. Gaps in the time series of activity statistics exist when data are available at less than annual frequency. Time series data need to be inferred to compile a complete annual estimate for the years between surveys, and for fore- and back-casts (e.g. estimates are needed for 1990 to 2004 when survey data are only available for 1995 and 2000).

A population distribution can be simulated from an incomplete time series data using stochastic techniques.

Splicing techniques can be used to fill gaps and incomplete coverage of time series data from periodic measurement methods.

NOTE 2 A description of the use of the splicing techniques of interpolation and extrapolation to link and extend time series is given in Reference [32], Vol. 1, Chapter 5. It is useful when using these techniques to base any underlying trends on the basis, where possible, of surrogate data known to correlate with the emission of the measured component or the activity rate. In the absence of suitable surrogate data, simple linear extrapolation can be used.

C.2 Combining data sets numerically

Data sets can be combined to form emission factors, representative of a generic group of installations, by pooling the raw data and re-estimating the mean and 95 % confidence limits, provided that they:

— refer to the same measured component;

— were collected in a manner conforming to Clause 5;

— are of the same reporting class specified in the measurement plan.

When data are not homogeneous (e.g. because of the presence of abatement technology at some plant but not others) the data should be stratified (subdivided) so that each stratum is homogeneous and the aggregate total for the source category is the sum of the strata. The uncertainty estimates should then be obtained by treating each stratum in the same way as an individual source category. Inhomogeneity can be identified by specific knowledge of circumstances of individual plant or technology types, or by detailed data analysis, e.g. scatter plots of estimated emissions against activity data.

Bibliography

Standards included by reference

[1] ISO 3966:2008, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes*

[2] ISO 4225:1994, *Air quality — General aspects — Vocabulary*

[3] ISO 9169:2006, *Air quality — Definition and determination of performance characteristics of an automatic measuring system*

[4] ISO 11222:2002, *Air quality — Determination of the uncertainty of the time average of air quality measurements*

[5] ISO 14064-1, *Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*

[6] ISO 14064-3, *Greenhouse gases — Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions*

[7] ISO 14956, *Air quality — Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty*

[8] ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

[9] ISO 20988, *Air quality — Guidelines for estimating measurement uncertainty*

[10] ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement* (*GUM:1995*)

[11] EN 14181, *Stationary source emissions — Quality assurance of automated measuring systems*

[12] EN 15259, *Air quality — Measurement of stationary source emissions — Requirements for measurement sections and sites and for the measurement objective, plan and report*

[13] CEN/TS 15675, *Air quality — Measurement of stationary source emissions — Application of EN ISO/IEC 17025:2005 to periodic measurements*

[14] ENV 13005:1999, *Guide to the expression of uncertainty in measurement (GUM)*

Other standards of relevance

[15] ISO 7935, *Stationary source emissions — Determination of the mass concentration of sulfur dioxide — Performance characteristics of automated measuring methods*

[16] ISO 9096, *Stationary source emissions — Manual determination of mass concentration of particulate matter*

[17] ISO 10396, *Stationary source emissions — Sampling for the automated determination of gas emission concentrations for permanently installed monitoring systems*

[18] ISO 10780, *Stationary source emissions — Measurement of velocity and volume flowrate of gas streams in ducts*

[19] ISO 10849, *Stationary source emissions — Determination of the mass concentration of nitrogen oxides — Performance characteristics of automated measuring systems*

[20] ISO 12039, *Stationary source emissions — Determination of carbon monoxide, carbon dioxide and oxygen — Performance characteristics and calibration of automated measuring systems*

[21] ISO 14164, *Stationary source emissions — Determination of the volume flowrate of gas streams in ducts — Automated method*

[22] EN 13211, *Air quality — Stationary source emissions — Manual method of determination of the concentration of total mercury*

[23] EN 13284-1, *Stationary source emissions — Determination of low range mass concentration of dust — Part 1: Manual gravimetric method*

[24] EN 14789, *Stationary source emissions — Determination of volume concentration of oxygen (O_2) — Reference method — Paramagnetism*

[25] EN 14790, *Stationary source emissions — Determination of the water vapour in ducts*

[26] EN 15267-1, *Air quality — Certification of automated measuring systems — Part 1: General principles*

[27] EN 15267-3, *Air quality — Certification of automated measuring systems — Part 3: Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources*

Other methods included by reference

[28] EPA Method 2, *Determination of stack gas velocity and volumetric flow rate (type S Pitot tube)*; EPA Method 2F, *Determination of stack gas velocity and volumetric flow rate with three-dimensional probes*; EPA Method 2G, *Determination of stack gas velocity and volumetric flow rate with two-dimensional probes*; EPA Method 2H, *Determination of stack gas velocity taking into account velocity decay near the stack wall*

[29] EPA Conditional Test Method 041, *Determination of volumetric gas flow in rectangular duct or stacks taking into account velocity decay near the stack or duct walls*

Other publications included by reference

[30] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *2006 IPCC guidelines for national greenhouse gas inventories*, Vols 1-5, prepared by the National Greenhouse Gas Inventories Programme, EGGLESTON, H.S., BUENDIA, L., MIWA, K., NGARA, T., TANABE, K. editors. Hayama: Institute for Global Environmental Strategies. Available (2010-04-04) at: http://www.ipcc-nggip.iges.or.jp/

[31] UN ECONOMIC COMMISSION FOR EUROPE. *Guidelines for estimating and reporting emissions data under the convention on long-range transboundary air pollution*. Prepared by the Convention's Task Force on Emissions Inventories and Projections and the secretariat. Geneva 2003. (Air Pollution Studies No. 15.)

[32] USEPA. *Clearinghouse for emissions inventories and emissions factors*. Washington, DC: US Environmental Protection Agency. Available (2010-04-04) at: http://www.epa.gov/ttn/chief/

[33] Detailed Procedures For Preparing Emissions Factors (Draft): procedure describing the specific tasks involved in the development of air pollution emissions factors, prepared for USEPA, May 9, 2006, http://www.epa.gov/ttn/chief/efpac/procedures/index.html

Other publications of relevance

[34] 2007/589/EC: Commission Decision of 18 July 2007 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council (notified under document number C(2007) 3416). *Official J*. 2007-08-31, **L 229**(1), pp. 1-85. Available (2010-04-04) at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:229:0001:01:EN:HTML

[35] EUROPEAN ENVIRONMENTAL AGENCY. *EMEP/EEA Emissions inventory guidebook 2009: Technical guidance to prepare national emission inventories*. Luxembourg: Office for Official Publications of the European Communities. (EEA Technical Report No. 9.) Available (2010-04-04) at: http://tfeip-secretariat.org/unece.htm

[36] ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

[37] USEPA. *Emission inventory improvement program technical report series*. Washington, DC: US Environmental Protection Agency. Available (2010-04-04) at: http://www.epa.gov/ttn/chief/eiip/techreport/

[38] USEPA. Quality assurance and quality control . In: *US multi-agency radiation survey and site investigation manual* (*MARSSIM*), Chapter 9. Washington, DC: US Environmental Protection Agency. Available (2010-04-04) at: http://www.epa.gov/radiation/marssim/docs/revision1_August_2002corrections/chapter9.pdf

[39] Assessment of emissions factor uncertainty and default emissions factor adjustments for non-inventory applications (Draft), report prepared for USEPA, OAQPS, August 2006

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