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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
$e(\bar{a})$	sensitivity coefficient of the time-averaged activity rate
$e(\bar{\dot{m}})$	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
$u(\bar{a})$	uncertainty of the time-averaged activity rate
$u(\bar{\dot{m}})$	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):

$$\dot{V} = vA \tag{3}$$

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):

$$\dot{m} = \gamma_{\mathrm{m}} \dot{V} \tag{4}$$

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.

