BS ISO 20951:2019

BSI Standards Publication

# Soil Quality — Guidance on methods for measuring greenhouse gases ($CO_2$, $N_2O$, $CH_4$) and ammonia ($NH_3$) fluxes between soils and the atmosphere

Documents
Document Sharing Hub

Full document details: BS ISO 20951:2019

# National foreword

This British Standard is the UK implementation of ISO 20951:2019.

The UK participation in its preparation was entrusted to Technical Committee EH/4, Soil quality.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2019
Published by BSI Standards Limited 2019

ISBN 978 0 580 97884 5

ICS 13.020.40; 13.080.01

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2019.

**Amendments/corrigenda issued since publication**

| Date | Text affected |
|---|---|

Documents
Document Sharing Hub

Full document details: BS ISO 20951:2019

INTERNATIONAL STANDARD

# ISO 20951

First edition
2019-06

# Soil Quality — Guidance on methods for measuring greenhouse gases ($CO_2$, $N_2O$, $CH_4$) and ammonia ($NH_3$) fluxes between soils and the atmosphere

*Qualité du sol — Recommandations sur les méthodes de mesure des gaz à effet de serre ($CO_2$, $N_2O$, $CH_4$) et des flux d'ammoniac ($NH_3$) entre les sols et l'atmosphère*

Reference number
ISO 20951:2019(E)

Documents
Document Sharing Hub

© ISO 2019

Full document details: BS ISO 20951:2019

**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2019

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

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

Published in Switzerland



© ISO 2019 – All rights reserved

Documents
Document Sharing Hub

Full document details: BS ISO 20951:2019

# Contents

Page

**Foreword** ..... **iv**
**Introduction** ..... **v**
**1 Scope** ..... **1**
**2 Normative references** ..... **1**
**3 Terms and definitions** ..... **1**
**4 Methods for measuring GHGs and ammonia fluxes between soil and the atmosphere** ..... **2**
**5 Concentration measurements and air sampling** ..... **5**
5.1 General ..... 5
5.2 Concentration measurement methods ..... 5
5.3 Air sampling ..... 7
**6 Selection of the appropriate methods** ..... **9**
**7 Minimum requirement for reporting** ..... **10**
**Annex A** (informative) **Description of the flux measurement methods** ..... **11**
**Annex B** (informative) **Description of the concentration measurement methods** ..... **24**
**Annex C** (informative) **Description of the air sampling methods** ..... **29**
**Bibliography** ..... **33**

© ISO 2019 – All rights reserved


Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019

# Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

This document was prepared by Technical Committee ISO/190, *Soil quality*.

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


© ISO 2019 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019

# Introduction

Greenhouse gas (GHG) emissions from soils have become a major environmental concern. Global and national emission inventories have identified soils, in particular agricultural soils, as being a major contributor to these emissions, in particular nitrous oxide ($N_2O$), methane ($CH_4$) and carbon dioxide ($CO_2$) related to loss of soil organic matter. Agricultural soils are also major emitters of ammonia ($NH_3$), which is a precursor of $N_2O$. Changes in soil management should take account of these emissions as part of efforts to mitigate climate change.

GHGs and ammonia fluxes from soil are complex to measure. They are variable and heterogeneous as they are governed by weather/meteorological conditions (e.g. temperature and moisture regimes), soil characteristics (e.g. soil parental material, pH, clay content, cation exchange capacity) and for managed soils by the agricultural or forestry practices (e.g. crop and wood residues management, soil tillage or no-tillage, inputs of soil conditioner and fertilizers, irrigation). These factors generally interact and their effects on GHG emissions are still poorly quantified. It results in large uncertainties for the inventories of national and global agricultural emissions. For example, Freibauer (2008)[1] has estimated an uncertainty at 80 % for European (EU27) agricultural $N_2O$ emissions. With the reinforcement of international and regional climate policies, comparable and reliable information is needed to report on GHG emissions but also to adopt and verify mitigation options.

No standard covers the measurement of GHGs and ammonia emissions from soils. However, several measurement methods have been developed. This document provides guidance on the main methods available to quantify the exchanges of greenhouse gases ($CO_2$, $N_2O$, $CH_4$) and ammonia ($NH_3$) between soils and the atmosphere. It is intended to help users to select the measurement method or methods most suited to their purposes by setting out information on the application domain and the main advantages and limitations of each methods.

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019

Documents
Document Sharing Hub

# Soil Quality — Guidance on methods for measuring greenhouse gases ($CO_2$, $N_2O$, $CH_4$) and ammonia ($NH_3$) fluxes between soils and the atmosphere

## 1 Scope

This document gives an overview and provides guidance on the main methods available to quantify the exchanges of greenhouse gases ($CO_2$, $N_2O$, $CH_4$) and ammonia ($NH_3$) between soils and the atmosphere.

It is intended to help users to select the measurement method or methods most suited to their purposes by setting out information on the application domain and the main advantages and limitations of each methods.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

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

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

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

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

**3.1**
**intrusive method**
measuring method that can influence the emitting processes

**3.2**
**mass balance approach**
method based on a mass balance consisting of measuring the flux of compounds entering and leaving a volume of air above the soil surface being studied

**3.3**
**micrometeorological method**
method using analyses of the atmospheric concentration of the gas and meteorological measurements such as wind speed, wet and dry-bulb air temperatures, net radiation, and heat fluxes.

Note 1 to entry: These techniques are used for determining field-scale fluxes, and include eddy covariance, energy balance, aerodynamic and mass balance technique. They do not disturb the environmental conditions.

**3.4**
**oasis effect**
effect arising from the local environment of the field being studied and affecting emissions from a particular field depending on whether it is in an environment with a high level of emissions or a low level of emissions

Note 1 to entry: the oasis effect will only affect compounds whose fluxes result from a thermodynamical equilibrium between the surface and the atmosphere ($NH_3$).

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019

## 4 Methods for measuring GHGs and ammonia fluxes between soil and the atmosphere

There are methods for measuring ammonia and GHG fluxes between soil and the atmosphere for a diversity of conditions and spatio-temporal resolutions (from less than an hour up to several days, from the soil sample up to several square kilometres) (this section). The main methods generally involve air sampling and determination of the concentration of the gas(es) of interest. Several concentration measurement and air sampling methods are compatible with a given flux measurement strategy (see Clause 5). The methods used and their combination depend on the purpose for which the measurements will be used, the operators' qualifications and the financial resources available (see Clause 6).

Two main strategies can be used:

a) chamber methods measuring the fluxes at source, and

b) atmospheric method used to estimate the fluxes at a distance from the source.

NOTE 1 Chamber methods are intrusive methods based on using static or dynamic flux chambers. Static and dynamic flux chambers can only quantify emissions for a small area of the source. Fluxes generally vary in time (variations in the parameters for weather and season) and in space (different soils and climatic conditions). For spatial extrapolation at field-scale, a sampling strategy using several chambers is required to reflect the variations in emissions over the area. Flux spatial structure could be determined by exploratory measurements prior to monitoring, or by assuming that flux will vary according to soil properties (e.g.: texture, organic matter content) or landscape features (e.g.: position in a slope). These methods can also be applied under laboratory conditions to determine the emissions of gases from soil samples, but hard to scale-up to field scale.

NOTE 2 Atmospheric methods are non-disruptive. The net exchange is estimated by measuring concentrations at a distance from the source together with micrometeorological measurements (e.g.: wind, air temperature). The fluxes are then estimated on the basis of these measurements, with a mass-balance approach or with models. Some of these methods are fairly difficult to implement and are highly dependent on weather conditions. Some knowledge of micrometeorology is generally required. They can be used to characterize global fluxes from heterogeneous, diffuse sources within a given area, without being able to distinguish the contribution of each particular source. In particular, atmospheric methods measure both soil and vegetation contributions, if there is active vegetation.

Table 1 presents the different methods and their main advantages and limitations.


© ISO 2019 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019

**Table 1 — The different methods and their main advantages and limitations**

| | Application domain | Main advantages | Main limitations |
|---|---|---|---|
| **Chambers methods** | | | |
| Static flux chambers | — Applicable to low fluxes<br>— Mainly used for comparison of treatments<br>— Applicable in field and in laboratory<br>— Small area (~$m^2$)<br>— Can be automated for monitoring dynamics over short periods<br>— Non-reactive gases ($CO_2$, $CH_4$, $N_2O$) | — Easy to implement<br>— High sensitivity even with low instrumental precision<br>— Evaluation of spatial variability with several chambers<br>— Most common flux measurement methods with many methodological references | — Intrusive method modifying emissions conditions. Chambers may alternate between locations (provide multiple chamber bases) to limit the impact of the chamber on the soil environment and hence emissions.<br>— Spatial extrapolation of measurements requires a sampling strategy using several chambers with spatial and temporal extrapolation models. |
| Dynamic flux chambers and wind tunnels | — Comparison of treatments<br>— Applicable in field and in laboratory<br>— Small area (~$m^2$) | — Possible control of wind speed<br>— Preferred for reactive gas such as $NH_3$ | — Intrusive method modifying emissions conditions<br>— Very difficult to extrapolate results to representative field emissions<br>— The oasis effect can increase or decrease the apparent flux |

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019

**Table 1** *(continued)*

| | Application domain | Main advantages | Main limitations |
|---|---|---|---|
| **Atmospheric methods** | | | |
| Mass-balance methods | — Continuous monitoring<br>— Real conditions<br>— Comparison of treatment | — Easy to implement and not expensive<br>— Non-intrusive method<br>— Can be used for small areas (few tens of square metres) | — Need a large number of measurement points<br>— Background concentration should be measured accurately |
| Inverse modelling | | — Easy to implement and not expensive<br>— Non-intrusive method<br>— Small numbers of measurement points<br>— Can be used to estimate emissions from several sources simultaneously, if there is a sufficient number of sensors (n+1 where n is the number of sources). | — Suitable for uniform, major emissions sources with low and fairly constant background concentrations<br>— Not suitable for areas with hedges or scattered trees or with significant changes in surface roughness<br>— Deployment over extended periods with changes in wind direction requires multiple measurement points to cover all wind directions. |
| Aerodynamic gradient | — Continuous monitoring<br>— Real conditions<br>— Allows measuring atmospheric deposition | — Non-intrusive method<br>— Measures the flux from the surface directly<br>— Can be used to monitor multiple sources | — Difficult to implement and expensive<br>— Assumes a large uniform emitting surface |
| Eddy-covariance | | — Applicable to large areas (>1 ha)<br>— Non-intrusive method | — Very difficult to implement and expensive<br>— Assumes a uniform emitting surface. Methodologies are in development to distinguish different emitting surfaces through flux footprint analysis (see for example Cowan et al. 2016[2]; Bureau et al. 2017[3]).<br>— Requires high speed sensors for wind and gas concentrations, but method derived from eddy-covariance such as disjunct eddy-covariance (DEC) have been developed for measuring fluxes without high speed analysers<br>— In development, for reactive gases such as $NH_3$<br>— Flux underestimation when turbulence is low, particularly during nights. |


© ISO 2019 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019

# 5 Concentration measurements and air sampling

## 5.1 General

Methods for measuring soil-atmosphere exchange of GHGs and ammonia involve the determination of gas concentrations in volumes of air. There are various methods to determine the concentrations, involving air sampling if necessary. They are characterized by the chemical species which they can detect and the associated limits of detection, the acquisition frequency, their precision, their cost and by the ease of use.

## 5.2 Concentration measurement methods

There are two families of concentration measurement methods (Table 2) that can be used for any type of gas targeted:

— Physical methods (absorption spectroscopy). The main characteristics of these methods are their very short response time, their sensitivity and the possibility of monitoring the concentration dynamics in real time (possibly monitoring several gases with different levels of concentration at the same time). Open path technologies exist for measuring integrated gaseous concentrations over a path directly in the atmosphere.

— Chemical methods (gas chromatography, laboratory assays, chemiluminescence). These methods are suitable for ad hoc measurements or for measurements integrated over periods from a few minutes to a few weeks. They are, therefore, less suitable for monitoring concentration dynamics. Furthermore, most of these methods are selective and cannot be used to measure several gases at the same time using the same equipment.

Annex B provides concentration measurement methods.

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019

**Table 2 — Concentration measurement methods**

| Method | Application domain | Advantages | Limitations |
|---|---|---|---|
| **Chemical methods** | | | |
| Gas chromatography | — Gaseous $CO_2$, $CH_4$, $N_2O$, $NH_3$<br>— Suitable with chamber and atmospheric methods, except eddy-covariance | — Technique is well understood, commercial equipment is available<br>— High sensitivity and low limit of detection (of the order of ppm for $CO_2$ and ppb for $N_2O$, $NH_3$ and $CH_4$)<br>— Can be used to quantify several chemical species at the same time<br>— Can be used where there are high concentration fluctuations<br>— Suitable with small sample volumes<br>— Easily automated | — May be used in the field for continuous measurements but has logistical limitations and high operating costs (bottles of carrier gas, reference gases, daily intervention by operators and maintenance of ambient conditions). |
| Chemiluminescence | — Gaseous $NH_3$<br>— Suitable with both dynamic chamber and atmospheric methods | — High sensitivity of a few ppb for $NH_3$<br>— Fast response time (down to 0,1s) with rapid data acquisition<br>— Particularly suitable for use with eddy covariance method | — Frequent calibration<br>— Interference may be problematic for low concentrations in rural areas |
| Laboratory assay of ammonium ($NH_4^+$) in solution<br>-<br>Continuous flow analysers (CFA) | — $NH_4^+$ trapped in solution (passive diffusion sampler, denuders and trapping of ammonia in acid solution) | — High speed analyses (40 to 60 samples per hour)<br>— Robust<br>— Good reproducibility | — Allowance should be made for interference with other gases if the samples are very acidic (e.g.: having been trapped in an acid solution) |
| Laboratory assay of ammonium ($NH_4^+$) in solution<br>-<br>Liquid chromatog-raphy | | — Can be used to assay all the major cations at the same time as ammonium<br>— Reproducible | — Long analysis time (4 samples per hour)<br>— Interference with other gases if the sample contains a large number of cations |
| Laboratory assay of ammonium ($NH_4^+$) in solution<br>-<br>Conductivity | | — Easy to implement<br>— Low cost<br>— Small samples<br>— Wide measurement range and low limit of detection<br>— Good reproducibility | — Long analysis time (5 to 12 samples per hour) |

[a] TDLAS : Tunable Diode Laser Absorption Spectroscopy; OA-ICOS : Off-Axis Integrated Cavity Output Spectroscopy; CRDS : Cavity Ring-Down Spectroscopy.


© ISO 2019 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 20951:2019