
**Soil quality — Sampling —
Part 7:
Guidance on sampling of soil gas**

Qualité du sol — Échantillonnage —

Partie 7: Lignes directrices pour l'échantillonnage des gaz du sol

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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 10381-7 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 2, *Sampling*.

ISO 10381 consists of the following parts, under the general title *Soil quality — Sampling*:

- *Part 1: Guidance on the design of sampling programmes*
- *Part 2: Guidance on sampling techniques*
- *Part 3: Guidance on safety*
- *Part 4: Guidance on the procedure for investigation of natural, near-natural and cultivated sites*
- *Part 5: Guidance on the procedure for the investigation of urban and industrial sites with regard to soil contamination*
- *Part 6: Guidance on the collection, handling and storage of soil for the assessment of aerobic microbial processes in the laboratory*
- *Part 7: Guidance on sampling of soil gas*
- *Part 8: Guidance on sampling of stockpiles*

Introduction

ISO 10381-7 is one of a group of International Standards to be used in conjunction with each other where necessary. ISO 10381 (all parts) deals with sampling procedures for the various purposes of soil investigation. The stated soil-gas and landfill-gas measurements do not give any quantitative statement of the total quantity of material detected in soil gas or soil. The measurement results can be influenced by, e.g. temperature, humidity, air pressure, minimum extraction depth, etc.

The general terminology used is in accordance with that established in ISO/TC 190 and, more particularly, with the vocabulary given in ISO 11074-2.

In addition to the main components (nitrogen, oxygen, carbon dioxide), soil gas can contain other gases (methane, carbon monoxide, mercaptans, hydrogen sulfide, ammonia, helium, neon, argon, xenon, radon, etc.). It can also contain highly volatile organic compounds or inorganic vapours (mercury) which are of special interest within the framework of investigating soil and groundwater contamination.

Due to the different physical properties and ranges of concentrations of gases in soil and landfills as well as the wide variety of objectives for soil-gas sampling, this part of ISO 10381, after the general clauses 1 to 4, is subdivided into two sections:

- a) permanent gases of soil gas and landfill gas (Clause 5); and
- b) volatile organic compounds (VOCs) (Clause 6)

Thus it is inevitable that some details are repeated in both clauses in order to make the guidance comprehensive.

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Soil quality — Sampling —

Part 7: Guidance on sampling of soil gas

WARNING — This part of ISO 10381 concerns on-site soil and sub-soil gas analysis requiring particular health and personal safety precautions.

1 Scope

This part of ISO 10381 contains guidance on the sampling of soil gas.

This part of ISO 10381 is not applicable to the measurement of gases from the soil entering into the atmosphere, the sampling of atmospheric gases, or passive sampling procedures.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10381-1, *Soil quality — Sampling — Part 1: Guidance on the design of sampling programmes*

ISO 10381-2, *Soil quality — Sampling — Part 2: Guidance on sampling techniques*

ISO 10381-3, *Soil quality — Sampling — Part 3: Guidance on safety*

ISO 11074-1, *Soil quality — Vocabulary — Part 1: Terms and definitions relating to the protection and pollution of the soil*

ISO 11074-2, *Soil quality — Vocabulary — Part 2: Terms and definitions relating to sampling*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11074-1 and ISO 11074-2 and the following apply.

3.1

active soil-gas sampling

sampling by extracting a certain volume of soil gas

3.2

biodegradation

the physical and chemical breakdown of a substance by living organisms, mainly bacteria and/or fungi

3.3 borehole
hole formed into soil or landfilled material into which may be installed a standpipe to enable gas monitoring to be carried out

NOTE A borehole is also used as a means of venting or withdrawing gas.

3.4 concentration/adsorption method
method in which substances to be determined are concentrated adsorptively on an adsorbent (e.g. activated charcoal or XAD-4 resin), subsequently desorbed and analysed

3.5 dead volume
volume which is present between the suction opening of the soil-gas probe and the sampling vial, including the volume of the sampling vial or of the absorption tube

3.6 direct method
direct measuring method
method of analysis where the soil-gas sample (aliquot) is directly introduced into a suitable equipment without first being concentrated and subjected to analysis

3.7 direct-reading detecting tube
glass tube filled with reagents which, after drawing through certain gaseous compounds, show concentration-dependent chromophoric reactions and which are thus used for qualitative and semi-quantitative analyses as well

NOTE It is important that attention be paid to cross-sensitivities.

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3.8 gas migration
movement of gas and vapour from the wastes within a landfill or through the ground to the adjoining strata, or emission to the atmosphere

3.9 gas monitoring well
standpipe suitably installed inside a borehole from which gas samples can be taken to measure soil-gas concentrations and to monitor changes in composition of soil gas or soil-gas migration

3.10 gas sampling
collection of a proportion of material for testing such that the material taken is representative of the gas in the pore space of the location of sampling

3.11 landfill
deposition of waste into or onto the land as a means of disposal

NOTE It can eventually provide land which may be used for another purpose.

3.12 landfill gas
mixture of permanent gases (main components), dominated by methane and carbon dioxide, formed by the decomposition of degradable wastes within landfill sites

NOTE It can also include a large number of VOCs (trace components).

3.13**lower explosive limit****LEL**

lowest percentage (volume fraction) of a mixture of flammable gas with air which will propagate an explosion in a confined space at 25 °C and atmospheric pressure

3.14**one-stage soil-gas sampling**

sampling of soil gas directly from a soil-gas probe placed in soil, without pre-drilling

3.15**passive soil-gas sampling**

sampling based on the adsorption of soil gas on an absorbent placed in soil, without employing negative pressure

3.16**permanent gas**

element or compound with boiling point below – 60 °C at atmospheric pressure

3.17**sample volume**

volume of soil from which the soil-gas sample is taken

3.18**soil gas**

gas and vapour in the pore spaces of soils

3.19**soil-gas monitoring device**

borehole finished with suitable material for stabilisation of the borehole wall and/or for limiting the sampling area.

NOTE Depending on the type and stability of fitting, a difference is made between temporary (for single or short-term repeated soil sampling) and stationary (for long-term observations) soil-gas measuring points.

3.20**soil-gas probe****soil-gas sampling probe**

probe, generally a tube, which is installed directly into soil (one-stage soil-gas sampling), or in a borehole (two-stage soil-gas sampling) to take soil-gas samples.

NOTE By applying a negative pressure to the upper end of the soil-gas probe (head), the soil gas at the lower end (tip) is drawn through the suction opening(s) and transferred to a gas collecting equipment and online measurement equipment (direct measuring method) or to an absorbent (concentration method), which are installed either in or at the head of the soil-gas probe or subsequently used.

3.21**soil-gas suction test**

continuous soil-gas sampling from a borehole well over a controlled longer period of time (mostly several hours up to days) to observe the variations over time of the gas concentrations and of the pressure distribution in the soil

3.22**two-stage soil-gas sampling**

sampling done firstly through installation of a borehole with the aid of a drilling instrument or by small boring, and secondly by sampling of soil gas from a soil-gas probe installed in the borehole

3.23
volatile organic compound
VOC

compound which is liquid at room temperature (20 °C) and which generally has a boiling point below 180 °C

EXAMPLES single-ring aromatic hydrocarbons and other low boiling halogenated hydrocarbons, which are used as solvents or fuels, and some degradation products.

4 Preliminary points to be considered

The choice of sampling technique shall be consistent with the requirements of the investigation (including subsequent analytical procedures). Consideration should also be given to the nature of ground under investigation, as well as the nature and distribution of contamination, the geology and the hydrogeology. Every effort should be made to avoid cross-contamination and at no point should underlying aquifers be put at risk.

Before intrusive works begin, a comprehensive check should be made of the ground to ensure that no services or structures are at risk and no hazards are present. (For more information on sampling techniques and safety, see ISO 10381-2 and ISO 10381-3.)

When sampling soil gas close to the surface, the effect of ambient air penetration needs to be considered. The sampling depth is determined by the presence of impermeable cover over the ground surface, the soil type (porosity, clay content, etc.) and the depth of bedrock. It is considered unlikely that useful samples can be collected at depth less than 0,5 m. For routine monitoring of soil gas, a minimum depth of 1 m is recommended.

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Circumstances in cold conditions make soil-gas sampling difficult in many ways. Ground frost greatly limits the mobility of gas in soil and should be considered in planning and carrying out sampling as well as in interpreting the measuring results. Similarly water saturated ground can limit mobility.

The main problem with soil-gas sampling below the frozen ground is the loss of air-filled porosity due to the high moisture content in the zone between frozen and unfrozen parts of the ground. Consequently the samples shall be taken from greater depths.

All buildings constructed on unfrozen ground act as pathways or barriers for upwards soil-gas migration. Underpressure and differences in concentration in the buildings can also assist gases to penetrate the basements of buildings.

Pressure effects caused by the rise of warm air within buildings can assist the entry of gases into buildings.

Some organic pollutants in the gas phase in soil and sub-soil can present toxicological risks of varying severity. Due to this possibility, personnel should be equipped, according to the potential toxicity (assumed or measured), with suitable protective material.

Certain organic fumes can form explosive mixtures with air. (Explosivity limits and self-ignition temperatures should be taken into account.). It is therefore appropriate to use electrical equipment and tools which are suitable for use in explosive atmospheres.

Health and safety issues should be considered at all times. Training should be given to ensure that personnel understand the necessary precautions. (For more information on safety, see ISO 10381-3.)

5 Permanent gases

5.1 Investigation objectives

5.1.1 Soil gas

The objectives of the investigation for permanent soil gases are

- analysis of soil-gas composition, and
- determination of the difference of concentration on a site.

5.1.2 Landfill gas

The objective of the investigation for landfill gases is

- analysis of landfill gas composition.

5.1.3 Further objectives

Further objectives may be

- assessment of possible reasons for plant growth inhibition,
- optimization or control of sealings or gas collecting installations,
- rough estimate of gas production potential and duration of gas production,
- detection of underground combustion,
- design of gas protection measures for buildings.

5.2 Basic principles

5.2.1 Physical and chemical principles

Wherever biodegradable material is present in landfill sites or within the soil matrix of the made ground beneath a brownfield site, microbial activity will produce landfill gas. Similar gas can also be produced in alluvial deposits and degrading natural organic material (see Annex B). Landfill gas consists primarily of methane and carbon dioxide (at a ratio of approximately 60:40). Depending on microbial activity, this ratio can change. A number of additional trace gases can be present.

Permanent gases can also originate from coal deposits, peat, natural deposits (e.g. chalk and alluvial deposits), from leaks of mains gas (natural gas) and from sewer gas. Information on techniques for identifying the origin of gas can be found in 5.2.3.

Methane is explosive at concentrations of between 5 % and 15 % (volume fraction) in air; below 5 % there is insufficient gas to support combustion and above 15 % (volume fraction) there is insufficient oxygen to support combustion. Carbon dioxide is an asphyxiant and can cause adverse health effects in concentrations greater than 0,5 % (volume fraction).

Landfill gas is usually saturated with moisture and is corrosive. It can cause vegetation to die back due to the elimination of oxygen from the plant's root zone or to the presence of phytotoxic compounds. Its density depends upon the ratio of carbon dioxide to methane: the higher the ratio of carbon dioxide the greater the density.

Gas pressure within the sub-surface is dependent on the gas generation rate, the permeability of the waste mass and the surrounding strata, and changes in the level of leachate or groundwater within the site. Other important factors are temperature and atmospheric pressure.

Depending upon site engineering and local geology, gas can migrate considerable distances and can present a hazard to nearby developments. In the case of mine gas, the cessation of water pumping can lead to a rise in water table levels which can increase the gas pressure, and consequently increase surface gas emissions. It is therefore important to gain an understanding of gas concentrations and flow rates to establish the potential for gas migration off-site or atmospheric emissions.

5.2.2 Ambient conditions

It is important during the monitoring of a site, that atmospheric conditions, for 3 to 4 days before and during the sampling, be recorded. Local climatic conditions at the time of monitoring should also be recorded. This information can help in the interpretation of the data. The most important parameters to record are

- atmospheric pressure, and
- rainfall.

Other useful parameters are

- temperature (ambient air and soil gas),
- wind speed/direction, and
- water table depth.

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During dry periods the ground can crack, especially if clay is used to cover sites. This will lead to an increase in gas emissions at the surface. In periods of wet weather, the clay will become wet and swell, and cracks will be sealed. This will reduce surface gas emissions and can lead to increased gas concentrations and increased lateral migration. A measurement of soil permeability and moisture content can be helpful in assessing these effects.

A rising water table, caused by rainfall for example, can put the gas under pressure and force it to the surface; however, it can also block migration pathways. The saturation of superficial soils can restrict the venting of landfill gas to atmosphere. This can result in variations in gas pressure and concentrations.

Falling atmospheric pressure can increase emission rates. Rising atmospheric pressure can have the opposite effect. The magnitude of this effect depends upon the soil permeability and the rate at which the pressure changes.

In general, however, it can be difficult to establish the cause of changes in concentrations and emissions since they may be due to a combination of the above factors.

5.2.3 Identifying the source of gas

Identifying the origin of the gas is important when making decisions regarding its monitoring and control. The composition of a gas may help identify the source. Examples are given below.

- Gas from a geological source may have a higher proportion of methane than landfill gas.
- Geologically-derived gas generally contains up to 15 % ethane and higher hydrocarbons, while biogenic methane contains only trace amounts.
- It may be possible to distinguish mains gas from other gases if the exact composition of the local mains gas is known. Mains gas may have odour compounds such as sulfides and mercaptans added to give the gas a distinctive odour; it may also contain long chain hydrocarbons such as octane and nonane. Helium is often removed from mains gas.

Landfill gas may also contain higher than normal concentrations of higher hydrocarbons if the waste contains substances that generate or release such gases and vapours.

Identification of different components may, however, be limited as the components may be affected by chemical changes occurring in the ground during migration, by solution in groundwater and by adsorption onto clays, etc.

Biogenic (formed by microbiological activity) methane and thermogenic (formed by thermal degradation of organic matter at higher temperatures and pressures) methane have different proportions of carbon isotopes carbon 12 and carbon 13 which can be measured to identify the origin of the gas. The technique, however, requires specialist laboratories.

5.3 General considerations for sampling

The strategy should be site specific and should be based upon the particular conditions of the site in question as well as on the information obtained from the site investigation (see Annex C).

It should be considered that any invasive activity can affect migration patterns and will act as a pathway for the gas.

In addition to gas monitoring, boreholes are also useful for obtaining hydrogeological, geotechnical and contamination information and are therefore a useful multi-purpose tool.

If gas concentration measurements are required at different depths the use of multi-level boreholes is undesirable and multiple well installations are to be preferred.

When results shall be compared to others and especially when monitoring from standpipes, the technique used should be consistent to ensure comparable results between different operators, techniques and over different monitoring periods. To achieve this, quality assurance measures as given in 5.10 need to be followed.

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Gas concentration measurements may be taken using portable equipment (see Table E.1) or samples may be taken for off-site laboratory analysis. It is advisable to collect gas samples, to be submitted for confirmatory analysis in a laboratory, in order to verify the on-site monitoring results.

5.4 Sampling requirements

5.4.1 Sampling options

Gas may be monitored using a range of different sampling techniques (see Table 1).

Although each technique has its uses, in situations where a detailed, long-term understanding of the site is required, monitoring wells installed in boreholes tend to be the most favourable option.

5.4.2 Borehole construction

During drilling of the borehole, the borehole atmosphere should be monitored with on-site equipment at 1 m intervals. Where ground water is encountered, useful information on the content of gas in the underlying ground can be obtained by measuring the gas concentrations immediately above the water level at 1 m intervals as the drilling progresses.

5.4.3 Location of sampling

The location and design of monitoring wells or other chosen technique should be planned well in advance, in accordance with the aims of the site investigation, the conceptual site model and considerations including health and safety, location of underground services, etc. (see Tables A.1 through A.5). A plan should be drawn up in detail and adhered to. Any changes to this plan should be noted.