
**Soil quality — Sampling —
Part 204:
Guidance on sampling of soil gas**

Qualité du sol — Échantillonnage —

Partie 204: Lignes directrices pour l'échantillonnage des gaz de 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.

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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 2, *Sampling*.

ISO 18400-204:2017

This first edition of ISO 18400-204 cancels and replaces ISO 10381-7:2005, which has been technically and structurally revised. The ISO 18400 series is based on a modular structure and cannot be compared to ISO 10381-7 clause by clause.

A list of all parts in the ISO 18400 series can be found on the ISO website.

Introduction

This document is one of a group of International Standards to be used in conjunction with each other where necessary. The ISO 18400 series deals with sampling procedures for the various purposes of soil investigation. The roles/positions of the individual standards within the total investigation programme are shown in [Figure 1](#). 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.

Toxic, asphyxiating and explosive soil gases can enter buildings and other built development on and below ground and variously pose potential risks to occupants and users and to the structures themselves.

Such gases might be present in the ground naturally, or be present as a result of contamination of the ground, or arise from buried wastes. In addition to the main components found in air (nitrogen and oxygen), soil gas can contain volatile organic compounds (VOCs), inorganic vapours (e.g. mercury) and a wide range of other gases (e.g. methane, carbon dioxide, carbon monoxide, hydrogen sulfide, ammonia, helium, neon, argon, xenon, radon, etc.).

These gases can have several origins such as: landfilled wastes; contaminated soils on a brownfield site; plume of contaminated groundwater; spill or leakage of chemicals products, leaks of mains gas (natural gas); sewer gas, etc.

In order to complete an assessment of the risks posed by the presence of permanent and other soil gases like VOCs, it is necessary to understand and characterize the potential sources of gas in and around a site.

Guidance on installations for soil gas sampling (equipment and instruments, methods of sampling, requirements of controls, etc.) and other relevant information (e.g. on environmental conditions) are provided in this document.

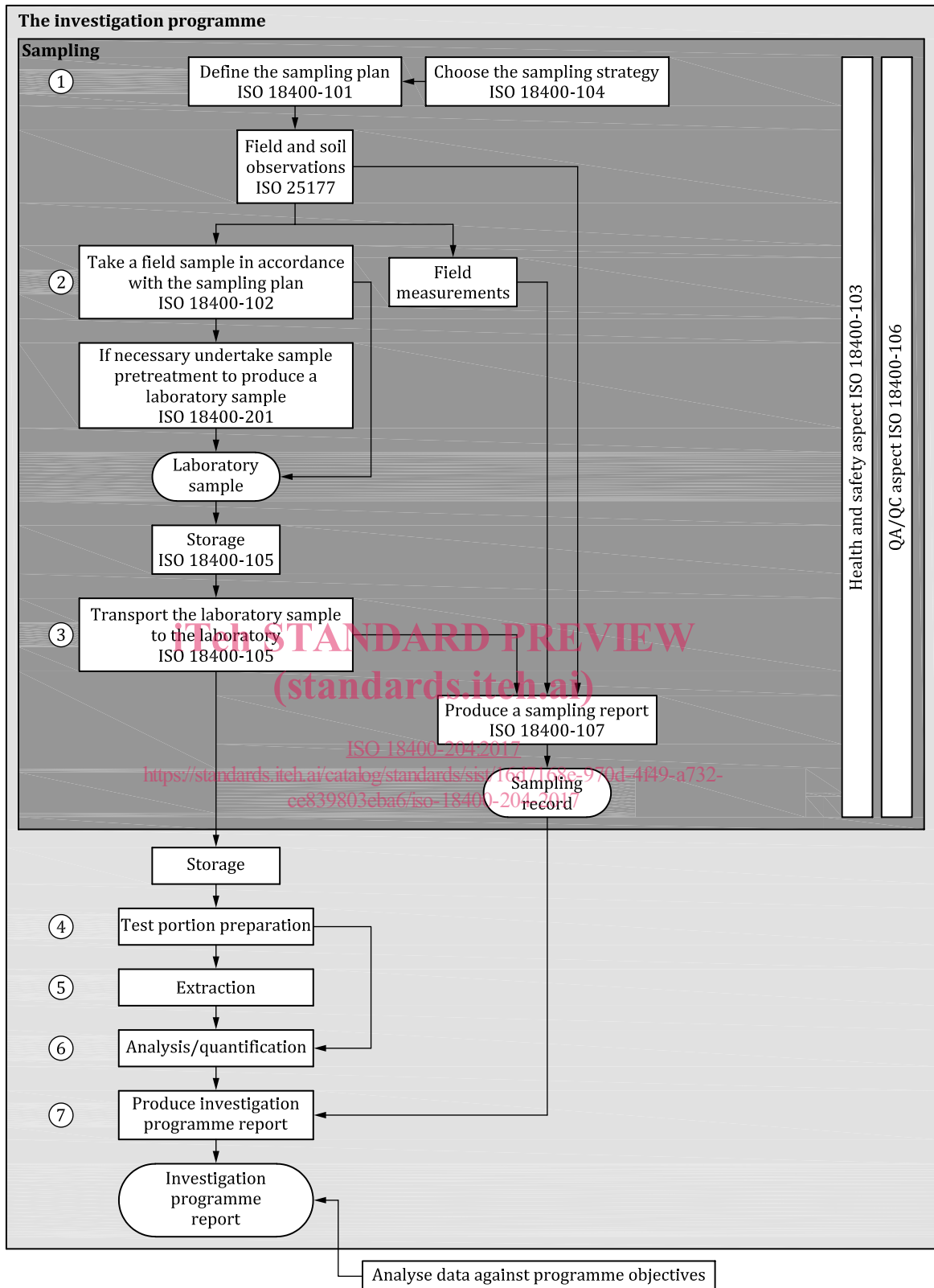


Figure 1 — Links between the essential elements of an investigation programme

NOTE 1 The numbers in circles in Figure 1 define the key elements (1 to 7) of the investigation programme.

NOTE 2 Figure 1 displays a generic process which can be amended when necessary.

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Soil quality — Sampling —

Part 204: Guidance on sampling of soil gas

1 Scope

This document contains guidance on soil gas sampling using

- active sampling (adsorbents, filters, air containers), and
- passive sampling

applied at permanent or temporary monitoring wells or other installations in soils or underneath buildings (sub-slab).

It provides guidance on:

- development of a sampling plan;
- construction of monitoring installations;
- transport, packaging and storage of soil gas samples;
- quality assurance.

This document also gives basic information about

- soil gas dynamics, and
- identification of soil gas sources

relevant to permanent or temporary boreholes in soils or underneath buildings (sub-slab).

The compounds covered by this document are:

- volatile organic compounds (VOCs);
- inorganic volatile compounds (e.g. mercury, HCN);
- permanent gases (i.e. CO₂, N₂, O₂, CH₄).

This document does not give guidance on:

- risk evaluation and characterization;
- selection and design of protective measures;
- the verification of protective measures, although the site investigation methodologies described can be used when appropriate;
- the sampling of atmospheric or indoor gases;
- the measurement of gases from the soil entering into the atmosphere;
- monitoring and sampling for radon.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 11074, *Soil quality — Vocabulary*

ISO 18400-107, *Soil quality — Sampling — Part 107: Recording and reporting*

3 Terms and definitions

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

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 active soil gas sampling

sampling by extracting a certain volume of soil gas

3.2 breakthrough

detection of an adsorbent control section of one or more compounds having a mass greater than 5 % of the mass quantified on the measuring section

3.3 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 adsorption tube

3.4 dense non aqueous phase liquid DNAPL

liquid of a group of organic substances which is relatively insoluble in the water and denser than the water

3.5 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

3.6 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 1 to entry: It is important that attention be paid to cross-sensitivities.

3.7 gas migration

movement of gas from the source through the ground to the adjoining strata or to emit to atmosphere

Note 1 to entry: Examples of sources include e.g. wastes within a landfill or spill of hydrocarbons.

3.8**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* (3.7)

3.9**gas sampling**

collection of a volume of soil gas contained in the pore space of the soil

3.10**landfill**

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

3.11**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 1 to entry: It can also include a large number of VOCs (trace components).

3.12.1**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

3.12.2**upper explosive limit****UEL**

uppermost 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

3.13**light non aqueous phase liquid****LNAPL**

liquid of a group of organic substances which is relatively insoluble in the water and less dense than the water

3.14**method by adsorption**

method in which substances to be determined are concentrated adsorptively on an adsorbent, subsequently desorbed and analysed

Note 1 to entry: The adsorbent can be e.g. activated charcoal or XAD-4 resin.

3.15**monitoring installation**

permanent or temporary device used for soil gas sampling

EXAMPLE Sub-slab, soil gas probe.

3.16**non aqueous phase liquid****NAPL**

liquid of a group of organic substances which is relatively insoluble in the water

3.17**one-stage soil gas sampling**

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

3.18

passive soil gas sampling

sampling based on the adsorption of gases of the ground on an adsorbent placed in the ground, without using artificially reduced pressure

3.19

permanent gas

element or compound that is a gas at all ambient temperatures likely to be encountered on the surface of the earth

EXAMPLE Gas like mine and landfill gases.

Note 1 to entry: Permanent gas can also be defined as “element or compound that is a gas at all ambient temperatures likely to be encountered on the surface of the earth”; see ISO 11074:2015, 3.6.11.

3.20

soil gas

gas and vapour in the pore spaces of soils

3.21

soil gas monitoring device

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

Note 1 to entry: Depending on the type and stability of fitting, a distinction is made between temporary (for single or short-term repeated soil sampling) and stationary and semi-permanent or permanent soil gas monitoring points (for long-term observation)

3.22

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 1 to entry: 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.

3.23

soil gas sample volume

volume of soil gas taken to form the sample

3.24

continuous soil gas sampling

sampling from a monitoring 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

3.25

sub-slab

soil gas sampling location just below the foundation slab of a building, within the unsaturated zone

3.26

subsoil

layer of soil beneath the surface soil and overlying the bedrock (called also “undersoil”)

3.27

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

3.28**volatile organic compound****VOC**

organic compound that is volatile under normal environmental/atmospheric conditions, although it can be found in the ground in the solid, liquid and dissolved phase form as well as in gaseous phase

Note 1 to entry: VOC can also be defined as “organic compound” which is liquid at room temperature (20 °C), which generally has a boiling point below 180 °C”; see ISO 11074:2015, 6.1.24.

Note 2 to entry: Examples include single-ring aromatic hydrocarbons and other low boiling halogenated hydrocarbons, which are used as solvents or fuels, and some degradation products.

4 Preliminary items to be considered

Soil vapour monitoring is a faster and cheaper method to detect contamination of VOCs in soils and/or in groundwater and for mapping the plumes than soil boreholes and/or the installation of groundwater monitoring wells. The method permits establishment of a much denser network of soil gas monitoring points than is usually possible for groundwater monitoring wells and soil boreholes.

The choice of sampling technique should be consistent with the requirements of the investigation (including subsequent analytical procedures, conceptual site model, investigation objectives, etc.). 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 creation of preferential pathways to avoid contamination of underlying aquifers.

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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 18400-102 and ISO 18400-103).

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.

NOTE 1 A preliminary condition for soil gas sampling and monitoring is the prior recording of the geological soil profiles/pedological layers. For some sites, this can be done whilst taking soil samples from borings.

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 measurements results. Water saturation (total or partial) of unsaturated layer (e.g. after rainfall) can significantly reduce the soil gas emission rates, limit soil gas mobility, and lead to high levels of humidity can severely reduce the adsorption capacity of some sorbents.

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 should be taken from greater depths (but compatible with investigation objectives).

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

NOTE 2 Causes of differential pressure effects include the rise of warm air within buildings and the operation of air-conditioning systems. Gas can enter through:

- cracks and openings in concrete ground slabs such as cracks due to shrinkage;
- construction joints/openings, e.g. at wall/foundation interface with ground slab;
- cracks in walls below ground level present due for example to shrinkage or movement;
- gaps and openings in suspended concrete or timber floors;

- gaps around service pipes and ducts;
- cavity walls;
- staircases, elevator shaft.

Gas migration into other structures also needs to be considered, especially below ground structures such as manholes, culverts, lift pits, mine shafts, access to underground services, etc.

This document specifically deals with the sampling of soil gas. Related exhaust or interference sources in ambient air (industrial or more generally anthropogenic activities) are not considered apart from the constitution of a field blank.

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 subsoil can present toxicological risks of varying severity. Due to this possibility, personnel should be provided with appropriate gas detection equipment and should be equipped, according to the potential toxicity (assumed or measured), with suitable personnel protective equipment (PPE).

Certain organic fumes (as well as methane, for example) 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 18400-103).

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5 Basic principles

5.1 Physical and chemical principles

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5.1.1 Permanent gases

Potentially hazardous permanent gases (see [3.19](#)) such as methane and carbon dioxide occur most commonly in “landfill gas” and “mine gases”.

Wherever biodegradable material is present in landfill sites or within the soil matrix of the ground beneath a brownfield site, microbial activity will produce methane and/or carbon dioxide. These gases can similarly be produced in alluvial deposits and by degrading natural organic material. 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.

Mine gas, also called coal mine methane (CMM), is a set of various vapours produced during mine operations. It is a mix of methane (essentially, more than 90 %) and carbon dioxide (nearly 10 %). Some minor gases are also present: carbon monoxide (product of incomplete combustion of carbon), hydrogen sulfide and nitrogen.

Abandoned mine methane (AMM) refers to mine gas after exploitation, which is trapped in the former galleries, boosted and propelled to the surface throughout the flooding of the mine. It usually contains less methane and more air than CMM (50 % to 60 % of methane, depending on the sealing of the mining voids and former works).

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 [5.4](#).

Methane is explosive at concentrations of between 5 % and 15 % (volume fraction) in air; below 5 % [the lower explosive limit (LEL)] there is insufficient gas to support combustion and above 15 % [the

upper explosive limit (UEL)] there is insufficient oxygen to support combustion. These both explosive limits are changed by the presence of other gases (e.g. carbon dioxide).

Carbon dioxide is an asphyxiant and also toxic. It can cause adverse health effects in concentrations greater than about 0,5 % (volume fraction).

The LEL of a mixture of explosive gas is equal to the lowest LEL among the components of the gaseous mixture. In the same way, the UEL of a mixture of explosive gas is equal to the highest UEL among the components of the gaseous mixture. Thus, other alkanes concentration (ethane, notably) should be considered in the calculation of LEL/UEL.

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 subsurface is dependent on the gas generation rate, the atmospheric pressure, the permeability of the waste mass and the surrounding strata, changes in the level of leachate or groundwater within the site and the temperature.

Depending upon site engineering and local geology, gas can migrate considerable distances and can present a hazard to nearby developments.

In the particular case of mine gas, the cessation of water pumping leads to a rise in water table levels which increases the gas pressure in mine voids, and consequently increases the probability of surface gas emissions, through the ground or former mine works. 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. Usually, decompression boreholes are drilled to avoid this phenomenon. They are good monitoring and sampling points to monitor mine gas composition, pressure, flow and water level.

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5.1.2 Volatile organic compounds

Depending on the pressure and temperature conditions, VOCs enter into soil pore space as either a liquid or a gaseous phase. They are present in soil as gaseous and liquid phases, dissolved in soil water, adsorbed on solid (organic and inorganic) soil particles or enclosed in capillary cavities.

Dynamic distribution equilibriums are established according to the prevailing conditions and bound forms of the pollutants. Owing to the diversity of the possible substance distributions and the time-dependent effects on the equilibrium, each determination of the contaminant concentration can provide only a "point-in-time" description of the status. Every interference, with the soil and/or groundwater, affects the distribution equilibrium in a different way, which is difficult to assess.

A saturation equilibrium between the liquid and gaseous phases is established in the contaminated zone independent of the amount of substance present. A soil gas saturation concentration of a VOC develops in the immediate surroundings of the polluted area, irrespective of whether it is a very small drop of the substance or a large deposit. The concentrations measured in the soil gas should not be used as an index of the actual amount of substance present in the soil. VOCs disperse in soil gas by convection (i.e. in the direction of the pressure gradient) and diffusively (i.e. in the direction of the concentration gradient). VOCs in the soil can be transported as flowing non-aqueous-phase liquids (NAPLs and/or DNAPLs), or together with another flowing liquid phase (e.g. groundwater, or dissolved in mineral oil), from which they can be transferred back into the soil gas.

5.2 Environmental conditions

It is important that atmospheric conditions, before and during the sampling, be recorded. It will generally be sufficient to record the conditions about a week prior to sampling, but rainfall up to a couple of weeks before may affect soil gas sampling, depending on, e.g. temperature, soil type and