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# Soil quality — Sampling —

## Part 301: Sampling and on site semi-quantitative determinations of volatile organic compounds in field investigations

*Qualité du sol — Échantillonnage —*

*Partie 301: Échantillonnage et mesures semi-quantitatives sur site des composés organiques volatils dans le cadre d'investigations sur le terrain*



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# Foreword

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This document was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Impact assessment*.

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

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.

# Introduction

Soil samples, especially those containing volatile organic compounds (VOCs), are subject to change as a result of physical, chemical or biological reactions that can take place between the time of sampling and the start of the analysis. The nature and intensity of these reactions is often such that, if the necessary precautions are not taken during sampling, transport, storage and laboratory preparation, the determined concentrations will be different from what they were at the time of sampling.

VOCs are flammable and typically toxic, carcinogenic, narcotic, or otherwise harmful to humans and other biota and terrestrial and aquatic ecosystems, and can cause degradation of certain artificial materials, including plastics. Human exposure can be by inhalation, ingestion (direct and indirect) and dermal contact.

Volatile organic compounds (VOCs) are organic compounds that are volatile under normal environmental/atmospheric conditions, although they can be found in the ground in the solid, liquid and dissolved phase form as well as in the gaseous phase (ISO 11074:2015/Amd.1:2020[1], 6.1.25 modified).

A knowledge of how VOCs can be present in the ground (organic phase, adsorbed phase, dissolved phase and vapour phase), their distribution between soil matrix (i.e. solid, liquid and gaseous), and how they can behave in soil is important. This is necessary in order to reduce uncertainties and to understand how reliable determinations of concentrations in soil are likely to provide a realistic picture of potential risks in any particular situation but also to better design remediation strategies.

Research and field experience have shown that:

a) depending on the management context, some sampling techniques are giving reliable results while others can lead to underestimating results;

b) if soil samples for VOC analysis are incorrectly collected and handled during field sampling, storage and laboratory preparation, a significant proportion of the volatiles compounds can be lost.

Therefore, it is important that the applied sampling techniques, and procedures for conservation, packaging, transport, delivery to the laboratory and laboratory preparation are well chosen, in relation to the degree of accuracy expected.

The decision maker and project leader in charge of investigations are responsible for choice of a soil sampling method that will provide representative soil samples and reduce uncertainties for subsequent interpretation. The selection of appropriate techniques and procedures depends on the objectives of the investigations, the soil characteristics, the nature of the volatiles compounds being targeted and possible organizational constraints in the field. Such attention and care assists in the collection of representative samples so that the analytical results later provide a reliable basis for estimating potential risks. In general, investigations performed on a sample in the laboratory can provide evidence for the sample only. Whether this can be transferred to the soil or site of interest and how far it can be valid should be considered carefully; however this is not within the scope of this document.

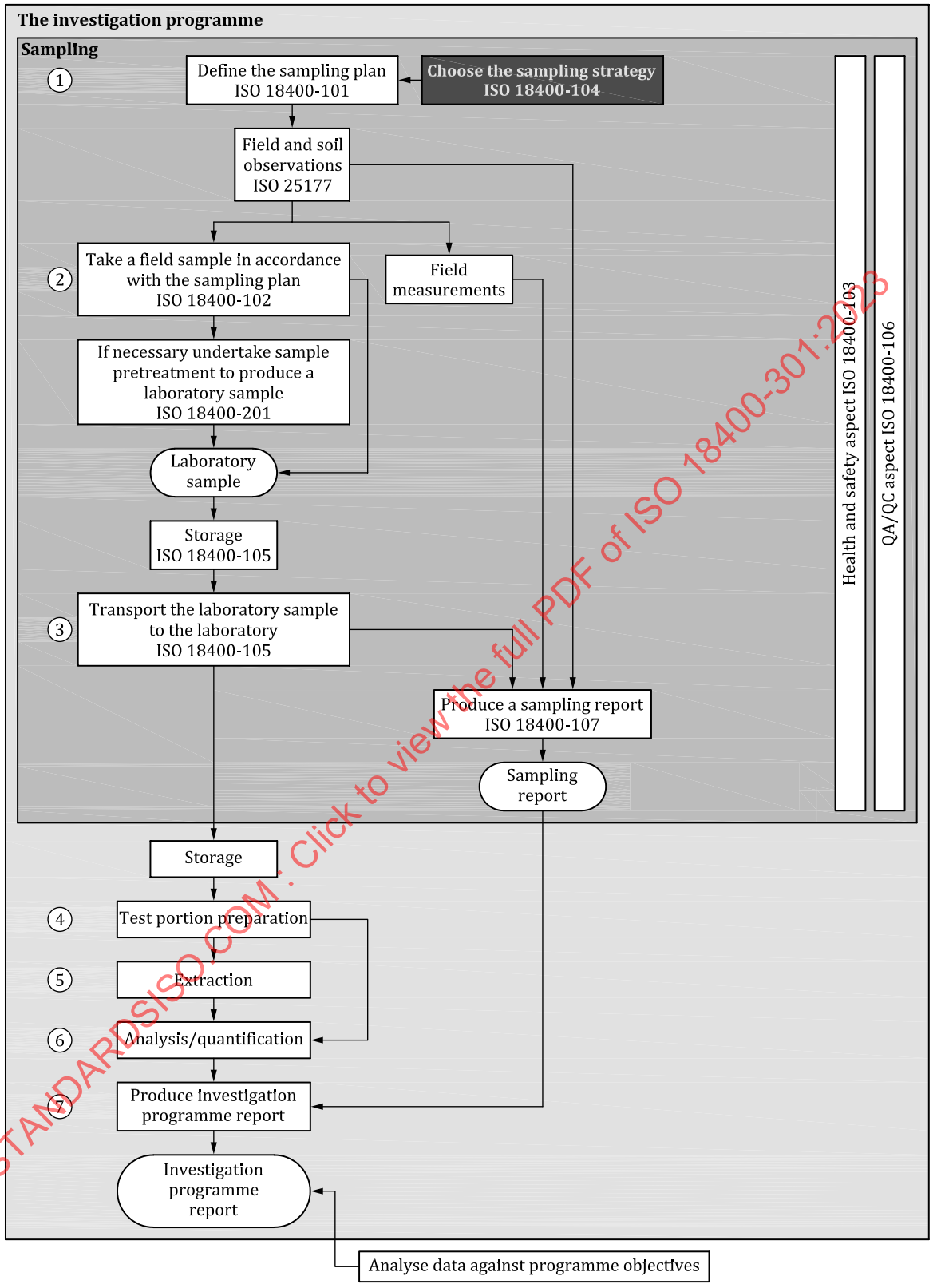
The main objective of this document is to help all stakeholders (technicians, project leaders, owner, authorities and laboratories) carry out adequate determination of VOCs when VOCs are known to be present or suspected in the soil. It provides requirements and guidance on the selection of relevant methods that can be used for taking soil samples, minimizing in the process the possible loss of VOCs before, during and after collection of soil samples. This document distinguishes two main approaches to the collection of soil samples (in-situ sampling methods and ex-situ sub-sampling methods) and clarifies their use, their applicability and limits. The description of each method takes into account the physical, chemical or biological reactions that can occur in soil and how it influences VOCs determination. For example, this document can provide field operators, project leaders and laboratories, an overview of relevant methods for measuring VOCs concentrations in soil, that minimize the possible loss of VOCs before, during and after sample collection.

This document also lists the main measurement instruments for semi-quantitative determination of VOCs during soil sampling (e.g. photoionization detector).

This document can be used when preparing field investigations or to analyse the results of such investigations. In particular, planning the sampling and measurement procedures can require considerable time, resources, competent staff and quality control during their implementation.

This investigation can be part of a broader environmental investigation or can be limited to only VOCs. Laboratories adopt procedures that will yield accurate results for the sample as presented to the laboratory. The sampling methods described are suitable for use in connection with, amongst others, the analytical methods described in ISO 15009,[2] ISO 16558-1[3] and ISO 22155[4].

International Standards within the total investigation program are shown in Figure 1.






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

NOTE 2 This figure displays a generic process which can be amended when necessary.

NOTE 3 The step requiring undertaking a sample pretreatment to produce a laboratory sample (see ISO 18400-201 “Physical pretreatment in the field”) is not applicable in the context of VOC sampling.

NOTE 4 When a vial with methanol is used, preservation of sample is done on site, not in the laboratory.

NOTE 5 Step 5 “extraction” consists of agitating the soil sample with the methanol. It is done once the sample is at the laboratory.

NOTE 6 The role of this document is illustrated in Figure 2.

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

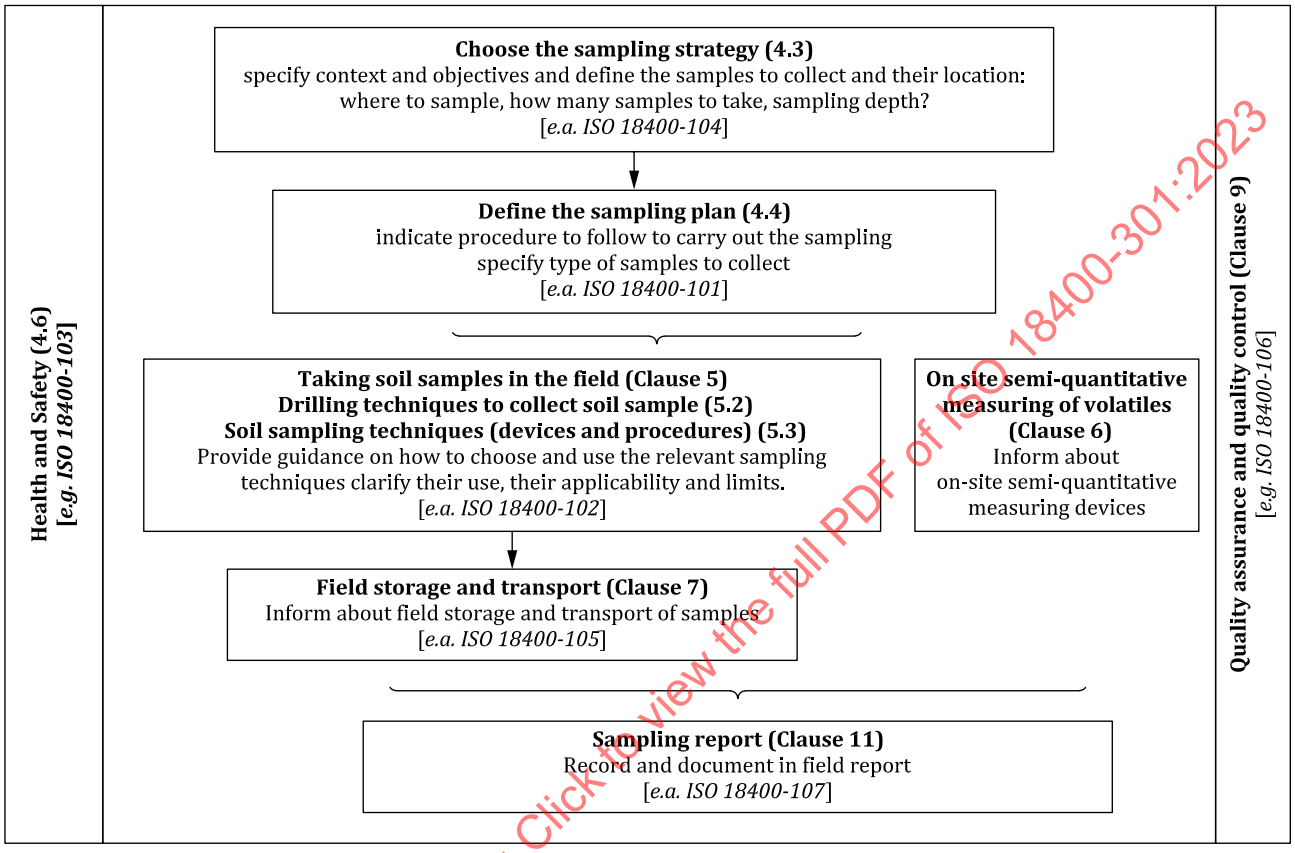



**Figure 2 — Soil sampling process described in this standard in the context of VOCs**

# Soil quality — Sampling —

# Part 301: Sampling and on site semi-quantitative determinations of volatile organic compounds in field investigations

## 1 Scope

This document provides specific requirements and recommendations on soil sampling and semi-quantitative measurements in field investigations for volatile organic compounds (VOCs) that are not explicitly covered in the existing ISO 18400 series. In addition, it provides information on the preparation steps (choosing a sampling strategy, defining a sampling plan); describes sampling techniques (drilling techniques, sampling devices and procedures) and field measurements; and gives advice on conservation, packaging, transport and delivery to the laboratory in the context of VOCs (see soil sampling process described in Figure 2).

VOCs to which this document can be applied include:

— volatile aromatic hydrocarbons such as benzene, toluene, ethylbenzene, naphthalene;

— aliphatic ethers such as methyl tert.-butyl ether (MTBE), ethyl tert.-butyl ether (ETBE) and tert.-amyl methyl ether (TAME);

— volatile halogenated hydrocarbons such as tetrachloroethene and, trichloroethene.

The document does not cover the volatile non-organic compounds. However, some information about these is provided in Annex D.

This document provides requirements and guidance on the selection of drilling and sampling techniques for determining VOCs and how to use them. It clarifies the applicability and limits of the drilling and sampling techniques, taking into account the physical, chemical or biological reactions that can occur in soil.

This document gives requirements and recommendations on the use of instrumental measurement techniques for determination of VOC concentrations in air, firstly in relation to worker safety, and subsequently for semi-quantitative measurements of volatiles during soil sampling.

The following subjects are outside the scope of this document:

— direct quantitative measurement of volatile compounds by field analysis laboratories;

— investigations and evaluation of soil gas quality (these are dealt with ISO 18400 204);

— safety risk assessment; and

— analytical procedures.

## 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*

## 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 terminology databases for use in standardization at the following addresses:

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

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

**3.1**
**small coring device**
instrument used to obtain small cores of soil for analyses

Note 1 to entry: The instrument can either be an apparatus that is used to take metal coring ring (see 5.3.3.2) or a disposable plastic corer (see 5.3.3.3).

**3.2**
**cutting cylinder**
cylindrical device with removable top and base forced into the surface of the ground/exposed soil to obtain an undisturbed sample

Note 1 to entry: Cutting cylinders can be reused if the size and shape is standardized between sampling institutes and laboratories. A commonly used specification is a stainless-steel cutting cylinder that has an internal diameter of 38 mm and a length of 200 mm which yields a sample volume of 226 ml.

[SOURCE: ISO 11074:2015/Amd.1:2020, 4.4.7 modified — the brackets have been removed; a note to entry has been added.]

**3.3**
**sampling technique**
all appropriate procedures and sampling devices to obtain samples in the field for soil description and laboratory testing and analysis

Note 1 to entry: The manner of selection of the sampling technique is to be described in the sampling plan.

[SOURCE: ISO 11074:2015, 4.4.29 modified — "and describe samples of soil or soil material, either in the field or during transportation and in laboratory" has been replaced by "samples in the field for soil description and laboratory testing and analysis".]

## 4 General aspects

### 4.1 Using data from VOCs sampling

Depending on the management context under consideration, the soil sampling strategy shall be chosen to ensure that the samples are representative of the volume of soil concerned and that the resulting data are sufficient in number and quality to meet the intended objective.

Where the aim of the investigation is to assess the health and safety risks from inhalation of vapours, risk assessments are based primarily on concentrations measured in soil gas or in ambient air (e.g. in a confined space), but it is common practice, and sometimes necessary, to also measure VOCs in groundwater and soil.

For soils, the applied sampling technique depends on the objectives of the investigations, the soil characteristics, the nature of the volatiles compounds being targeted and any organisational constraints in the field. This choice should also be based on an understanding and consideration of the factors that can compromise the analytical results by causing loss, or occasionally addition of VOCs.

Research studies have shown that if soil samples for VOC analysis are incorrectly collected and handled during field sampling, storage and laboratory preparation, a significant proportion of the volatile compounds can be lost.

American studies (Hewitt 1996 and 1999) show that loss by volatilisation occurs mostly within minutes to hours, while loss by biodegradation can extend over some days to several weeks. They show losses of 10 % to 15 % in just 5 min of exposure of the soil to air. These losses are greater than 90 % for TCE in less than 40 min.

The application of suitable sampling techniques and procedures for conservation is therefore required to preserve the sample, limit the loss of compounds through volatilisation or biodegradation.

If these aspects are carefully considered in the sampling plan, the collected sample should meet the requirement of representativeness. The analytical results consequently are likely to provide a reliable basis for estimating potential risks.

Results from soil sampling are only valid for the sample taken. They should be transposed to the soil environment or the studied site with caution and with the help of additional information and observations.

The decision maker and project leader in charge of investigations are responsible of the selection of a soil sampling method that will provide representative soil samples and reduce uncertainties for subsequent interpretation.

It is assumed that methanol immersion and use of a small coring device yield equivalent results. Publications of performance studies on the use of these two methods are available. French trials have also made it possible to compare (in order of magnitude) the sampling methods (metal coring ring, glass jar with no field preservation and vial prefilled with methanol).

NOTE For more information, see References [19] to [25].

## 4.2 Behaviour of volatile organic compounds (VOCs)

Before defining a soil sampling strategy, it is necessary to understand the behaviour of volatile compounds in soil. Particular attention to the following characteristics is needed:

a) VOCs are most likely to be present in soil following incidents such as spillages or leaks;

b) VOCs can be present in solution in water, in the vapour phase, sorbed to soil particles, present between particles as a non-aqueous phase liquid (NAPL);

c) VOCs can be preferentially associated with soil organic matter, including plant remains, or preferentially present in soil pore spaces and finer soil fractions;

d) concentrations of VOCs are likely to vary according to the types of soil (e.g. sand, clays), soil properties (e.g. grain size, moisture, organic matter) and in particular in the transition zone between two soil horizons;

e) concentrations of VOCs can vary by orders of magnitude over very short distances (e.g. a few centimetres).

Soil conditions with the highest potential for vapour intrusion (dry granular soil – high vapour permeability) are also the most difficult in which to accurately measure VOC concentrations. Conversely, moist homogenous fine soil (e.g. clay) are the easiest soil types in which to accurately measure concentrations, but typically represent the lowest potential for vapour intrusion due to their low vapour permeability.

Particular attention should be paid to the likely small-scale variations in concentrations and how VOCs can be present. It should be kept in mind, that the results received from the investigation of a sample are valid for the sample only. Transferring them to the soil or the site under investigation should be done with great care and with the aid of additional information and observations.

## 4.3 Sampling strategy

The sampling strategy specifies context, objectives and the samples to collect (e.g. number and type) and where to collect them from (location, depth, etc.).

NOTE For general guidance on sampling strategies, see ISO 18400-104[9].

## 4.4 Sampling plan

Soil samples are subject to modifications as a result of physical, chemical or biological reactions that can take place between the time of sampling and the start of the analysis. Especially when targeting VOCs, these shall be minimised. Therefore, precautions should be taken during the sampling process, transport and storage and laboratory preparation.

The possible observed modifications in the soil sample and losses can be linked mainly to the following factors:

— volatilization during drilling and sampling activities that result in a disturbance of soil structure, or aeration of soil samples and alteration of ambient vapour pressure;

— diffusion through the sample container during storage/shipping;

— biodegradation and chemical degradation during storage/shipping;

— volatilization losses during laboratory operations, for example, sampling methods that involve sample handling or sub-sampling in the laboratory.

These processes can influence sample results by either lowering concentrations or producing detectable biodegradation or chemical degradation products not present in the initial sample.

An important part of the sampling plan is to consider the importance of these changes. The sampling plan should specify, in consultation with the laboratory performing the analysis, procedures for sampling; and for preservation, storage and transport of samples; and any requirements specific to the method (s) of analysis to be employed.

When determining VOCs, single, undisturbed samples are usually collected for laboratory use: these samples are high quality discrete samples that are collected at a specified depth under controlled conditions that limit any physical or chemical disturbance of the sample. Specifically, none of the constituents of the sample should have been altered during the sampling process.

Assessment of a situation usually involves a lot of information about different media. For example, it could involve cross-referencing soil samples with measurements (in situ and/or in the laboratory), soil gas results, visual and field observations (colour, etc.).

All information about type of samples and applied sampling techniques should be described in the sampling plan.

NOTE For general guidance on sampling plans, see ISO 18400-101[6].

## 4.5 Sampling station

Sampling in accordance with this document usually requires good working conditions, as far as possible shielded from the weather (rain, wind, hot sun, etc.) at a designated location (sampling station). It requires dexterity, careful attention to the detailed application of the procedures and careful recording of everything that is done.

The sampling station should provide, a sheltered environment which allows samples to be collected, field measurements to be made, and soil descriptions to be carried out. It should also minimise the potential for cross-contamination, for example, from exhaust fumes, smoking and perfume.

A sampling station should ordinarily be established so that:

a) the material to be sampled can be accessed;

b) equipment can be laid out;

c) equipment can be cleaned if necessary;

d) samples can be transferred to temporary on-site storage;

e) samples can be prepared for transport off site; and

f) all operations and observations can be recorded (see Clause 11).

If a sampling station is not established, the reason should be recorded, and the potential impact on the reliability of sampling noted. When the sampling is carried out from an in-situ surface or disturbed recovered material, the sampling operation should be completed as close to the sampling location as possible once the sample has been taken into the sampling device.

NOTE The arrangements for sampling from a core obtained with windowless sampler or similar require special attention (see 5.2.2).

## 4.6 Health and safety

A health and safety risk assessment shall be undertaken prior to investigation which looks into the risks associated with the sampling techniques that are to be used, as well as other site-specific risks associated with intrusive site investigation, when dealing with soil containing VOCs.

Field operators should have appropriate first aid training.

All necessary measures shall be taken when selecting and applying sampling techniques to protect health and safety of those carrying out the work, anyone entering the site (with or without permission), and the general public (e.g. the occupants of neighbouring properties) and to avoid harm to the environment.

Risks associated with sampling soil containing VOCs which can be associated with direct contact and inhalation of toxic and potentially carcinogenic substances, shall be minimized by:

— appropriate design of the sampling techniques (use of drilling and sampling techniques to limit soil exposure to the atmosphere);

— provision of suitable personal protective equipment (PPE), such as chemical resistant gloves, eye protection and respiratory equipment where necessary;

— ceasing drilling and sealing the bored hole (this may be permanently or temporarily whilst advice is sought) if anything untoward is encountered (e.g. unexpectedly high concentrations of VOCs or positive gas flows) during drilling.

Before carrying out any intrusive sampling, checks for services should be made.

Appropriate training shall be given to ensure that personnel understand the precautions required when sampling soil containing VOCs and when using specific sampling methods, such as sampling into vials containing methanol or jars with no field preservation.

Methanol (toxic and flammable liquid) can present risks for the environment, health and safety. Vials containing methanol should thus be used according to a standard protocol in order to prevent exposure.

When immersion in methanol (toxic and flammable liquid) is chosen as the sample preservation method, then it is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with national regulatory conditions. These include undertaking sampling in

a well-ventilated area, and access to washing and first aid facilities, including the provision of an eye wash. Field operators should have appropriate first aid training.

NOTE 1 For general guidance on safety, see ISO 18400-103[8].

NOTE 2 More information on the potential effects of contaminated soil on human exposure can be found in ISO 15800[5].

NOTE 3 A French trial has also made it possible to assess operator exposure in the field during soil sampling. See Reference [29].

# 5 Taking soil samples in the field

## 5.1 General

The drilling and sampling technique should be chosen taking into account:

— the objectives of the investigation;

— the required analytical data quality objectives which includes detection limits;

— the concentration range of interest if known;

— the soil's characteristics : type of soil (made ground, gravels, compact soil, dry sand, bedrock,...);

— the access conditions;

— the presence of asbestos and other hazardous substances;

— what VOCs are likely to be present based on the conceptual site model and the preliminary investigation.

As highlighted in Figure 3, implementing soil sampling techniques usually consists of two steps:

a) gaining access to the chosen depth at the sampling point using the relevant drilling equipment;

b) taking soil samples with an in-situ sampling method or an ex-situ sub-sampling method.

The following soil sampling techniques can be used in the context of VOCs - soil sample is taken and preserved in:

— a cutting cylinder filled in-situ that is immediately gas-tight sealed and sent to a laboratory;

— a small coring device (metal coring ring or disposable plastic corer), filled ex-situ that is immediately gas-tight sealed and sent to a laboratory;

— a vial pre-filled with methanol (soil extruded ex-situ from a syringe or an appropriate coring tool) sent to a laboratory.

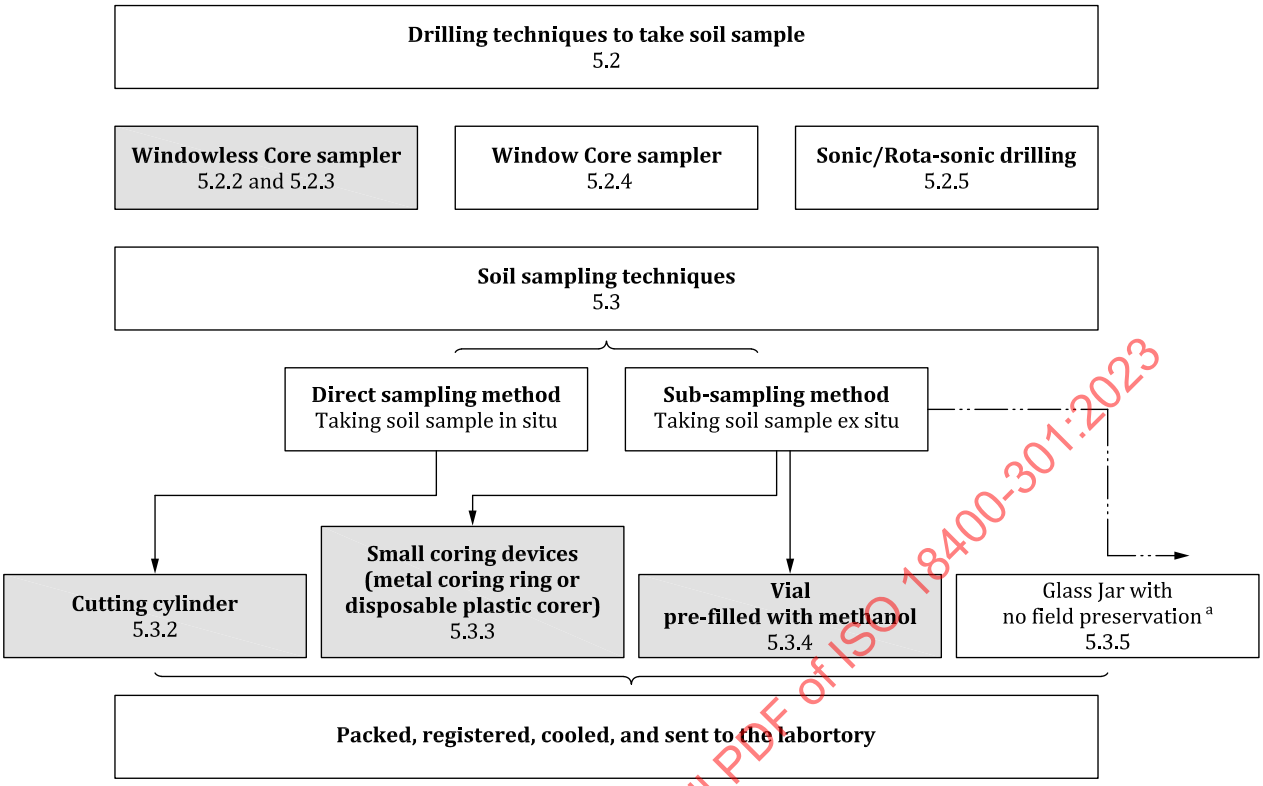
Publications of performance studies on the use of these methods are available (see References [21] to [26]).

Sampling into a glass jar with no preservation is not recommended to determine VOCs but where such a method is necessary, due to the specifics of the soil type or design of the investigation, every effort should be made to minimise as far as practical the loss of volatiles to atmosphere prior to sampling.

NOTE Sampling into a glass jar can lead to a recurrent underestimation of the results (i.e. VOC content in soils). This phenomenon is of varying magnitude according to the nature of the soils, the compounds present such as halogenated VOCs, etc. However, in certain special cases, a glass jar without field preservation can be used, provided that this is justified and the reasons recorded. The conditions of application and limitations of this method are presented in 5.3.1 and 5.3.5.






**Key**

| | |
|---|---|
| | more suitable for VOCs |
| a | Sampling technique used in certain special cases. |

**Figure 3 — Drilling and sampling techniques**

## 5.2 Drilling techniques to take undisturbed soil samples

### 5.2.1 General

This subclause provides specific information on possible drilling techniques to preserve the soil structure and collect undisturbed soil samples in the context of VOCs.

It provides information on how to select the appropriate drilling and sampling equipment when sampling and measuring VOCs. In this context, special attention shall be paid to the preservation of the sample to minimize VOCs losses and ensure the safety and health of the operator and the protection of the environment.

NOTE For more information about drilling techniques, see ISO 18400-102[7].

A key consideration for choosing a drilling technique is the ability to take soil samples representative of in-situ conditions. Samples submitted for laboratory analysis shall be capable of being tested for physical and chemical properties and for this reason the sample shall not be physically altered by the drilling technique.

The drilling techniques recommended in this subclause allow minimal soil disturbance and limit the loss of VOCs. Drilling techniques such as the windowless core sampler are effective for volatiles, as they allow for:

— collection of an undisturbed sample from the extruded core;

— preservation of the integrity of the samples and minimization of losses of VOCs;

— limitation of cross contamination;

— limitation of soil exposure to the atmosphere.

### 5.2.2 Windowless core sampler

Windowless core samplers (see Figure 4) are appropriate for use when VOCs are investigated.

A conventional windowless core sampler, while not generally maintaining the strict integrity of the soil sample (possible loss of solids, water and/or NAPL), is considered the best practical technique for limiting the loss of volatile compounds.

Note that this drilling technique requires more handling and time before sampling (extraction of the core, cutting of the plastic liner), than a window core sampler or other drilling techniques with no plastic liner.

**Figure 4 — Windowless core sampler with a plastic liner**

Strict sample integrity can be provided by a windowless core sampler coupled with cryogenic core sampler (e.g. nitrogen freezing of soils). This technique, which has been the subject of research work, is however rarely used in an operational context of investigation of contaminated sites. As such, it is not described here.

### 5.2.3 Commentary on sampling from a windowless core sampler

As indicated in 5.2.1, windowless sampling is generally preferred when the objective is the determination of VOCs. There should be little, if any, loss of volatiles during drilling and when the material to be sampled is contained within a plastic liner which can be extracted from the metal casing at the designated sampling station prior to the sample being taken. It is (conceptually) possible to cap the ends of the liner temporarily if necessary. Some interaction between the liner and some VOCs cannot be ruled out so sampling needs to be done expeditiously.

The minimum diameter for a plastic liner should be 3 cm. The sending of liners to laboratory should be avoided because of several practical problems in preservation during transport and laboratory sampling, e.g. cooling.

No other samples should be taken from the core and geotechnical examination of the core should only be carried out when all samples required for determination of VOCs have been taken. The geotechnical logging of the core should only be carried out when all samples required for determination of VOCs have been taken. After this operation, other soil samples can be collected from the core (that has been exposed to the atmosphere) but only to determine non-volatile compounds.

If the core is not retained in a plastic liner, no attempt should be made before sampling to screen the exposed surface, for example using a PID (photo ionization detector) device to locate high and low levels of measures, or to describe the material cored, as this will delay sampling and is likely to lead to loss of VOCs.

As the plastic liner is not compatible with halogenated VOCs, the soil core should not be left in contact with the plastic for too long, e.g. core sections from the plastic liner should not be stored and sent to the laboratory for analysis.

However, if the core is retained in the liner, headspace screening can be carried out on the unsampled soil, using a PID that is inserted in holes made in the liner in order to orientate the areas to be sampled (see B.1.2 and Figure B.2).

Whichever practice is used to open the liner, the sample should be taken as soon as possible once the liner has been opened.

NOTE 1 Field screening, such as use of a PID (photo-ionization detector), can be used on the remaining material after samples are collected, to inform the analysis plan. If the sample liner is split open (see NOTE 2), the core is retained in the liner whilst sampling is carried out.

NOTE 2 It is customary to split the liner open along its full length either with a single cut from a blade or with two parallel cuts so that a thin strip of material is exposed. Splitting the liner requires skill and the right tool(s). It can be made easier by having a frame in which the core can sit with the knife(s) held by the frame.

NOTE 3 Splitting the liner along its full length has the disadvantage that VOCs can be lost along the full length whilst sampling is carried out at a specific location along the core. Thus, opening small windows in the liner where sampling is to be carried out immediately prior to sampling is preferable.

NOTE 4 An alternative approach, when the material in the core is suitable, is to saw, taking care to avoid heating, an intact core (including plastic liner) into several sections (e.g. four), and sampling vertically into the cut ends (duplicate samples can be taken from adjacent cut faces). It could be possible to sample the original top and bottom of the core provided these are temporarily sealed and exposed material is first removed to create a fresh surface (e.g. using a bulb-planter or similar). Alternatively, a short section of the core could be removed by sawing to expose a new surface. The task is made easier by use of a supporting frame (saw horse).

NOTE 5 After collecting samples for determination of VOCs, headspace screening can be carried out on the unsampled soil, followed by logging of the core (see 6.1 for a procedure that can be used).

NOTE 6 When selecting a screening method, such as a PID, the capabilities and limitations of the method is clearly understood (for example an 11,7 eV lamp is required to screen for certain chlorinated solvents instead of the standard 10,6 eV lamp) – see B.1.

### 5.2.4 Window core sampler

The window core sampler (see Figure 5) is not the most appropriate technique to obtain samples for testing for volatiles: a part of soil (external soil core) is exposed to the atmosphere just before sampling, which can cause loss of compounds by volatilization.

As this technique is not able to completely preserve the soil structure (compression and following expansion while pushing the sampler into the ground and drawing it back), it should be used only with justification (should be recorded and reported) and with caution for the subsequent sampling in some specific situations. It can be used, for example, when access is difficult for other techniques in a building as it can be in the form of a small and easily transportable tool.

**Figure 5 — Window core sampler**

### 5.2.5 Sonic/Rota-sonic drilling

For particular contexts, sonic or rota-sonic drilling (see Figure 6) can be useful to employ. This technique involves the use of high frequency energy which shears and displaces the soil particles. Rota-sonic combines rotary and sonic drilling capabilities in the same rig.

Rotary-sonic drilling can penetrate all soil types as well as hard rock, concrete and other obstructions (sonic drilling can be subject to refusal).

This technique is suitable for soil sampling for VOCs when used with a casing. It permits recovery of continuous undisturbed samples.

Dry-drilling without flush can result in heat being generated by the drill rod causing loss of volatiles. This loss can be reduced by changing the sonic drilling process.

NOTE Introduction of mechanical energy into the ground generally can mobilize liquid phases, especially high frequency energy. When sampling for VOCs it is important to be able to extract a sufficiently representative sample that is retained in the sampling tube with minimal loss from the end. Therefore, and as for the techniques described in 5.2.2 and 5.2.4, the material requires a degree of cohesiveness. If necessary, a basket can be placed at the end of the casing.

**Figure 6 — Sonic drilling**

Sonic or rotary-sonic drilling can be done with or without a casing depending on the type of soil and the presence of water. For environmental drillings under the groundwater table, a casing shall be used to prevent cross contamination or the risk of spreading contamination during the drilling.

Flexible sheaths (sock-like) are used in sonic drilling. This is specific to the sonic drilling if compared to the other techniques described above where rigid sheaths are used.

### 5.2.6 Filling of boreholes

Boreholes should normally be filled with materials of equal or less permeability than the surrounding ground, e.g. in order to prevent contamination and any connections between aquifers. If there is an influence on future projects, special technical requirements for backfilling should be specified in advance. Voids should not be permitted to occur during the placement of the filling material in the borehole.

The control over the filling of the borehole with bentonite at the level of non- or poorly water-penetrable layers shall be carried out with care and this shall be recorded.

NOTE 1 For general guidance on filling of borehole, see ISO 18400-102.

NOTE 2 This is a general rule for environmental drillings, but especially for the extreme quick drilling method using (rotary-)sonic as this is often a risk.

## 5.3 Soil sampling techniques

### 5.3.1 General

A key consideration for choosing a relevant sampling technique is the ability to minimize in the process the possible loss of VOCs before, during and after to collection of soil samples.

It is up to the project leader to decide and justify which method will be used. Investigation objectives and reduction of uncertainties will lead its choice in order to provide representative soil samples for subsequent interpretation. During the survey, it is up to those on site to decide and justify on a site-specific basis and/or organizational constraints whether a method (drilling techniques and/or sampling technique) is not appropriate and/or must be changed.

NOTE For more information about sampling techniques, see ISO 18400-102.

The following soil sampling techniques can be used in the context of VOCs:

— Iîn-situ sampling techniques: a cutting cylinder filled in-situ, brought to the surface and closed with caps (see 5.3.2);

— ex-situ sampling techniques: soil sample is collected after the implementation of a drilling technique (as described in 5.2) and preserved in:

  — a small coring device (metal coring ring or disposable plastic corer); see 5.3.3;

  — a vial pre-filled with methanol; see 5.3.4.

Sampling in a glass jar with no field preservation is not recommended when looking for the presence of VOC in soils. This method can lead to a recurrent underestimation of the results (i.e. VOC content in soils). This phenomenon is of varying magnitude according to the nature of the soils, the compounds present such as halogenated VOCs, etc. However, in certain special cases, this method can be used, provided that this is justified (this information should be recorded and the reason notified). The conditions of application and limitations of this method are presented in 5.3.5.

All these sampling techniques should be used with a specific protocol to preserve the soil structure and limit VOCs losses. In all cases, samples taken for VOC analysis should be taken immediately after exposure of the soil of interest.

Procedures for application of these soil sampling techniques are described in Annex A.

For small volume sampling devices, an additional separate sample for dry matter content / moisture content should be collected, where each sample for determination of VOCs has been taken.

This sample should be taken from the same material as the sample for determination of VOCs. The sample container should be filled completely with soil to minimize headspace but should not be subject to preservation. The container, once closed, should be further sealed to avoid loss of moisture.

Advantages and limitations of soil sampling techniques are presented Table 1 and Table 2.

### 5.3.2 Cutting cylinder filled in-situ and sealed

This method uses a thin-walled stainless steel cylinder with a connecting head to a rod or similar device that can be used to push or hammer it into the soil. A suitable device for inter-laboratory use that can also make reuse possible is a steel cylinder that has an internal diameter of 38 mm and a length of 200 mm which yields a sample volume of 226 ml. See Figure 7.

The cutting cylinder (or stainless-steel tube) (1) is pushed or hammered into the ground (manually or by a drilling machine) to a desired depth from the surface or at the bottom of a pre-drilled borehole. The pre-drilling can be done with a manual or motorized drilling equipment, provided that the borehole is stable and does not collapse.

NOTE To prevent a borehole collapsing, a casing can be used.

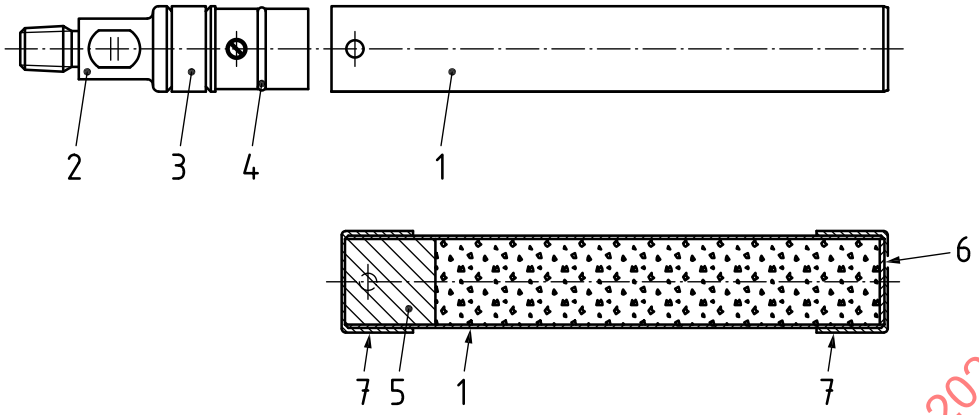
Pre-drilling techniques should not use fluid (air or water) as this can change the composition of the soil to be sampled with the cylinder.

The sample tube is pushed or hammered directly into the original undisturbed soil profile without contact with the atmosphere. The cylinder shall not be used for subsampling or filling by hand. In very loose soil or in a non-cohesive soil, soil can drop out. To prevent this, a stainless-steel sampling tube with a core catcher should be used.

Once filled with the material to be sampled, the coring apparatus is retrieved from the borehole, the tube is disconnected from the coring apparatus and capped on both ends.

Due to the potential for microbial degradation, the contained sample should be shipped promptly to the laboratory for analysis (see Clause 7).

The cutting cylinder (1) is fitted with a sampler head (2), with a valve (3) allowing de-pressurization during sampling, whilst preventing loss of pressure whilst the cylinder is taken out. An O-ring (4) secures the airtight connection between the coring apparatus and the sample tube. A stainless-steel filling block (5) fills up the headspace in the tube after disconnecting the tube from the coring apparatus. The filling block and the stainless-steel insulation plate (6) prevent diffusion between the 2 caps (7) and the sample. The caps close off the sample tube after sampling.




**Key**

1 cutting cylinder (stainless-steel tube)
2 sampler head
3 valve (to release air when hammered into soil)
4 O-ring
5 stainless-steel filling block
6 stainless-steel insulation plate
7 PE cap

**Figure 7 — Description of a cutting cylinder 226 ml**

Figure 8 shows illustration of a suitable device soil coring kit (cutting cylinder 226 ml).

**Figure 8 — Sampling using a cutting cylinder 226 ml**

The cutting cylinder is used following the protocol in A.1.

### 5.3.3 Small coring devices filled ex-situ and sealed (metal coring ring or disposable plastic corer)

#### 5.3.3.1 General

Use of small coring devices as described in this subclause can provide undisturbed samples that are sent sealed to the laboratory. They can provide reliable results when used correctly.

It is important to note that in addition to the sample taken for VOC analysis, another sample is required to determine the dry matter content.

The size of these coring devices does not allow extra analyses for, for example, organic matter; nor does it allow re-analysis. For that reason, extra samples can be appropriate (apart from duplicate-sampling procedures).

NOTE This causes extra sampling material to be disposed off but is in the end reducing the carbon footprint.

A soil core is extruded with a machine (drilling) and taken to ground level. Then, a small portion of soil (sub-sample) is taken with a metal coring ring (e.g. 16 ml) or a disposable plastic corer (3 ml to 15 ml) and the sample is sent promptly to the laboratory.

They have a hermetic seal which limits the losses of volatile compounds. However, due to the potential for microbial degradation, the contained sample should be shipped promptly to the laboratory (see Clause 7). These coring devices are preferably used in cohesive soil (clay, silt, fine sand). They only allow the detection of volatile compounds.

These types of samplers do not require a laboratory sub-sampling step because all of the soil is transferred into a pre-filled vial of methanol. However, during the sample handling steps in the laboratory and the opening of the small sampling devices, volatilization losses can also occur. These losses depend on the extent and duration of exposure to air.

#### 5.3.3.2 Soil sampling using a soil corer containing a metal coring ring 16 ml

As shown in Figure 9 and Figure 10, this soil corer (see equipment described in Figure 9) is fitted with a handle (1), a stainless steel soil corer (2) and a coring ring 16 ml (3) in which the sample is contained. The plunger (4) is only used to clean the soil corer.

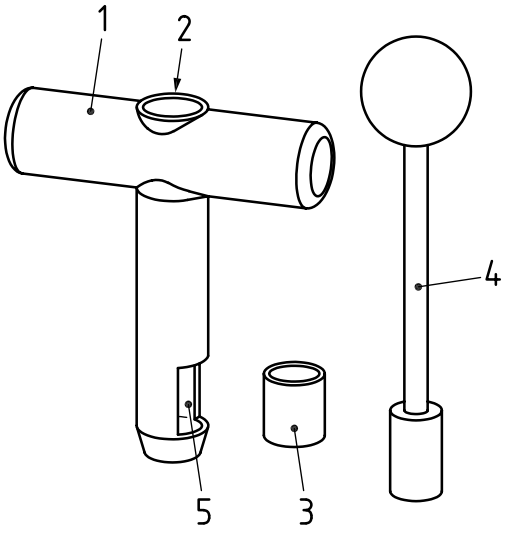
Once filled with the material to be sampled, the coring ring is ejected in its entirety and capped for use as a contained sample in its own right.

The coring ring 16 ml (approximately 25 g) is sealed with caps to protect it from sorption (without synthetic materials), leakage and diffusion, and it is refrigerated or frozen.

Once it arrives at the laboratory the soil core still in the coring ring can be placed directly into a vial containing methanol, etc., or the soil can be extruded from the containing ring into a vial.

The stainless steel coring rings do not wear out and can (after cleaning) move several times between the laboratory and the field.

NOTE The device can also be used to eject a core directly into a vial pre-filled with methanol (see 5.3.4).




**Key**

1 soil corer handle
2 stainless steel soil corer
3 stainless steel coring ring (16 ml ~ 25 g)
4 stainless steel plunger (fits into soil corer to expel sample)
5 sideways movement of coring ring scrapes off excess soil to 16 ml

**Figure 9 — Description of a soil corer containing a metal coring ring 16 ml**

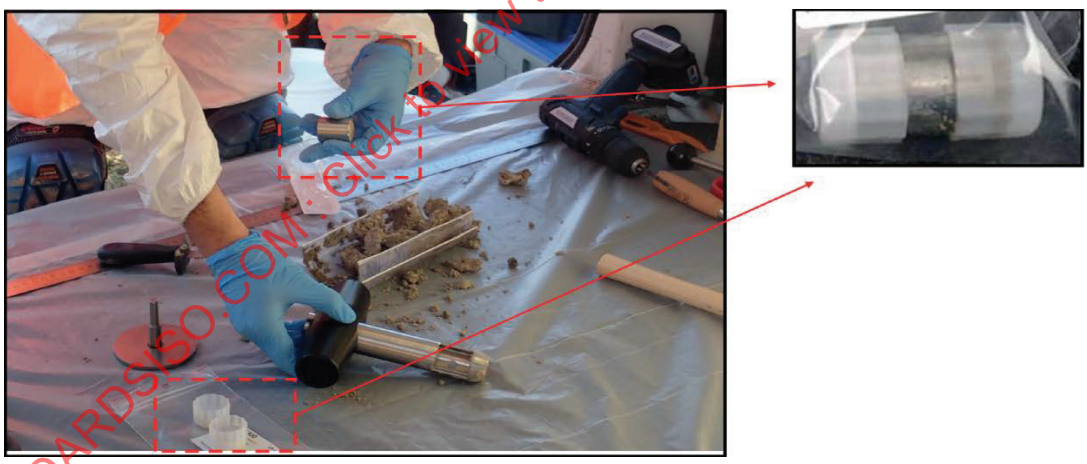


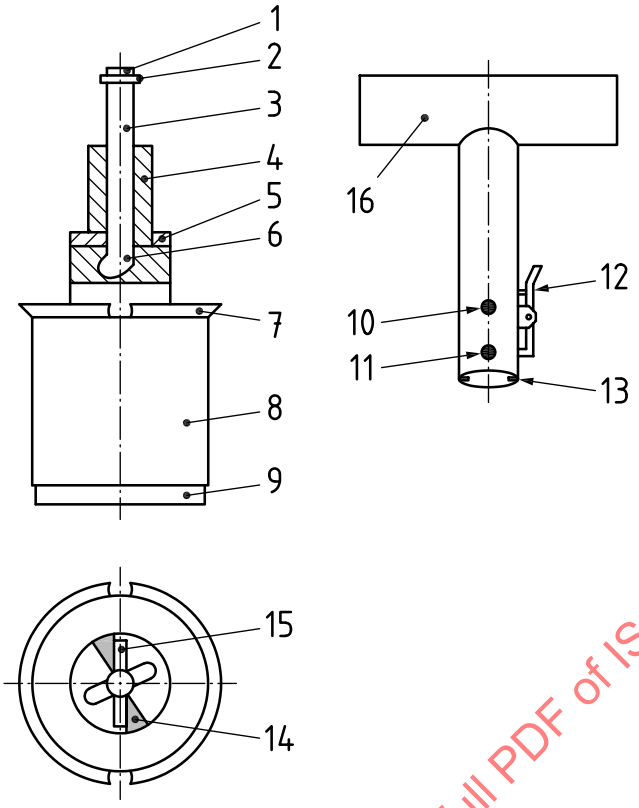
**Figure 10 — Sampling with a soil corer containing a metal coring ring 16 ml**



The soil corer containing a metal coring ring 16 ml is used following the protocol in A.2.1.

#### 5.3.3.3 Soil sampling using a disposable plastic corer

As shown in Figure 11 and Figure 12, the disposable plastic corer is equipped with a single-use coring body (see item 8 in Figure 11), which once filled is hermetically capped and sent to the laboratory. The samplers (3 ml to 15 ml) available allow the sampling of 5 to 25 g of soil.




**Key**

| | | | |
|---|---|---|---|
| 1 | plunger end | 9 | plunger bottom (inside) |
| 2 | small O-ring | 10 | viewing hole for 25 g sampler |
| 3 | plunger rod | 11 | viewing hole for 5 g sampler |
| 4 | wing | 12 | locking lever |
| 5 | tab | 13 | locking pins (inside) |
| 6 | slot | 14 | tab |
| 7 | ridge | 15 | wing |
| 8 | coring body | 16 | T handle |

**Figure 11 — Disposable plastic corer (drawing)**

**Figure 12 — Sampling using a disposable plastic corer (photo)**

The disposable plastic corer-is used following the procedure in A.2.2.

NOTE This sampling technique is described in more details in EPA Method 5035.

Published studies about use of a small coring device are available (see References [19] to [23]).

### 5.3.4 Vial pre-filled with methanol

#### 5.3.4.1 General

It is essential that ahead of the investigation the whole sampling and subsampling procedure is coordinated with the destined laboratory (see 5.3.4.2).

The purpose of methanol is to limit loss of volatiles and prevent biological activity that would otherwise result in their degradation between taking the sample in the field and analysis in the laboratory.

A small portion of soil is subsequently placed in a pre-weighed vial containing methanol (pre-filled) with internal standard, immediately sealed and sent promptly to the laboratory.

A separate sample is collected to determine the moisture content at the laboratory.

The size of soil sample does not allow extra analyses for, for example, organic matter; nor does it allow re-analysis. For that reason, extra samples could be appropriate (apart from duplicate-sampling procedures).

NOTE 1 This causes extra sampling material to be disposed but is in the end reducing the carbon footprint.

NOTE 2 This sampling technique is similar to the one described in EPA Method 5035[23].

#### 5.3.4.2 Procedure

The soil sample should be collected immediately after exposing a fresh soil surface of the drilling core. The incorporation of material like roots or stones should be avoided as far as possible.

A defined volume of soil is extruded from a syringe (or suitable coring tool of known volume) into a vial (or other suitable container such as a small jar) pre-filled with methanol already containing internal standards. For satisfactory VOC extraction, a soil mass to methanol volume ratio close to 1 (e.g. 25 g soil and 25 ml methanol) should be used.

In case of difficulties using a syringe in stiff or coarse soil, a small clean spatula can be used if the ratio soil / methanol is respected, but this operation can result in VOC losses. However, this solution allows to place the soil immediately into the methanol, which avoids losses and biodegradation of VOCs. If this procedure is followed, it should be recorded and reported.

Special attention should be paid to keeping the same amount of methanol before, during and after sampling (no methanol should be lost, so avoid volatilization and splashes, etc.).

NOTE 1 For this purpose, the methanol container can be tilted slightly to avoid splashing.

Figure 13 shows illustrations of using a syringe and a vial pre-filled with methanol.

Figure 14 shows examples of syringe or similar equipment (appropriate coring tool) which allows collection of a known volume of soil.

Prevent leakages by cleaning the top of the vessel before sealing.

Make sure that the sample is completely covered with methanol containing internal standards. Then close the cap of the PTFE coated septum.

At least one blank sample on every site shall be prepared in the field by opening the prepared vial (containing methanol and internal standards) for the same time period as necessary for the filling with soil sample before closing the cap of the vial. If blank values are unusually high (more than 50 % of the lowest value of interest), the reason for these high blanks shall be investigated.

NOTE 2 The procedure described in this subclause assumes that methanol containing internal standards is used. It is also acceptable that the internal standards are added in the methanol in the laboratory at the start of the extraction procedure.

Preserved soil samples using methanol on site should be shipped promptly to the laboratory for analysis (see Clause 7), to avoid any influence on the samples due to external factors (temperature rise, container degradation, etc.).

**Figure 13 — Sampling soil using a syringe and soil placed in a vial pre-filled with methanol**

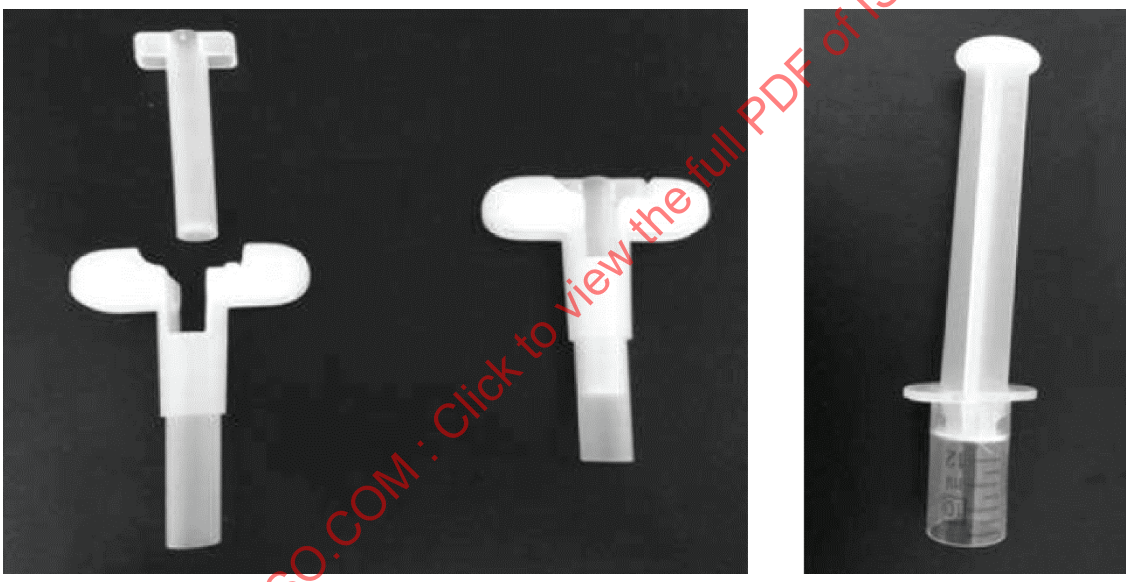


**Figure 14 — Examples of syringe of known volume for sampling soil**

The vial pre-filled with methanol is used following the procedure in A.3.

#### 5.3.4.3 Laboratory preparation and supply of prepared vials

This sampling method relies on the preparation and supply of prepared vials by a laboratory and on full cooperation between the laboratory and those undertaking the sampling. Without that cooperation it is unlikely that reliable analytical results can be obtained.

NOTE Some laboratories can supply sampling kits of their own assembly comprising several sampling vials and a sampling device for use during a single sampling event. Others can supply propriety kits.

The laboratory shall:

a) prepare suitable glass vials (e.g. 40 ml) with PTFE septum caps by adding 25 ml (or such other specified amount as is required) of methanol of the appropriate grade (blank free of compounds to be tested);

b) uniquely label each vial and provide the user with all necessary details of the vials (e.g. masses, date when prepared);

c) weigh the vial containing the methanol to the nearest 0,1 g, record the tare mass and record it in the laboratory information management system (paper or electronic) and (optional) on the label;

d) arrange transportation of syringes and vials to the user in a way that ensures their integrity is maintained;

e) provide instructions on the use of the vials;

f) provide instructions and aids for the return of the used vials to the laboratory;

g) provide any necessary safety instructions;

h) provide instructions on what to do with any vials that are found to be "unfit for use";

i) tell the operator the maximum storage times for pre-filled methanol vials.

The vials should be provided with VOC-tight caps that do not react with or absorb VOCs or any other substances in the soil.

Vials prepared in advance by the laboratory should be check-weighed immediately prior to despatch and the check-mass recorded. If the loss [of mass] exceeds 0,1 g, the vials should be discarded.

If the vials and instruction for use are not supplied directly from the laboratory to the sampler, a specific chain of custody procedure should be in place.

#### 5.3.4.4 Limitations with methanol

Specific training should be given on the handling and use of methanol. The operator should be made aware before the intervention of the handling and the use of vial pre-filled with methanol. The amount of methanol shall be checked before sampling in order to avoid any loss of solvent which will impact the analytical result.

Methanol can be used for most but not all VOCs. Thus preliminary contact with the laboratory with a precise list of expected products is necessary.

VOCs from vehicle exhaust fumes can contaminate samples with methanol during preparation, sampling and transport as methanol can capture VOCs present in the ambient air. A field or transport blank sample shall be prepared on site by opening a prepared vial during the same time interval as for the soil sampling and sending it back to the laboratory for analysis (see Clause 9).

Methanol shall be transported and stored in a safe and secure manner away from sources of ignition. Reference should be made to applicable regulations in particular the constraints in the context of air transport.

NOTE The transport of methanol is regulated with specific rules according to the volumes, the containers, the vehicles, the displays…

Surplus sampling vials and reagents should be returned to the laboratory that supplied them and/or stored in safe and appropriate manner. Vials pre-filled with methanol shall be kept cool, before and after sampling to limit the potential loss of methanol. Samples should be stored away from potential sources of heat.

### 5.3.5 Glass jar with no field preservation

Sampling in a glass jar with no field preservation is not recommended when looking for the presence of VOCs in soils. This method can lead to a recurrent underestimation of the results (i.e. VOCs content in soils). This phenomenon is of varying magnitude according to the nature of the soils, the compounds present such as halogenated VOCs, etc. However, in certain special cases, a glass jar without field

preservation can be used, provided that this is justified (this information should be recorded and the reason notified).

This method has fewer constraints than other methods (ease of use, suitable for different soil typologies, e.g. indurated soils …).

This method does not formally allow for an undisturbed soil sample (varying degrees of soil de-structuring during the handling and filling of the glass jar are unavoidable), which can lead to the loss of volatile compounds.

As shown in Figure 15 and Figure A.5, the soil sample is collected with a trowel, a stainless steel spatula, or a gloved hand, and placed directly into a wide necked and clean glass jar supplied by the laboratory (e.g. 250-375 ml). The jar is filled to capacity, hermetically sealed and sent to the laboratory.

**Figure 15 — Sampling soil using a glass jar with no field preservation**

NOTE 1 Numerous studies have shown that there can be an inherent loss of volatile compounds during sampling (especially in non-cohesive soils) and subsequent transport operations of samples taken in this way.

NOTE 2 A sub-sampling step is necessary in the laboratory to collect approximately 20 g of soil using "suitable tools" and transfer it into a pre-filled methanol vial for analysis. This handling can also lead to the loss of volatile compounds.

When such a method is used, every effort should be made to minimise as far as practical the loss of volatiles to the atmosphere prior, during and after to sampling

This sampling protocol should minimise as much as possible the headspace in the sample by lightly compacting the soil in the jar and reducing the time of sampling and direct exposure to the atmosphere.

A note should also be made on the analytical certificate and a justification for the choice of this method should be presented in the reports describing the work.

In addition, because of this risk of losses through volatilisation and biodegradation, the sample should be sent promptly to the laboratory (see Clause 7).

The glass jar with no field preservation is used following the procedure in A.4.

### 5.3.6 Advantages and limitations of sampling techniques

Table 1 presents the advantages and limitations of in-situ sampling techniques and applicability for soil sampling and VOCs.

Table 2 presents the advantages and limitations of ex situ-sampling techniques and applicability for soil In general, to collect a representative sample, the internal diameter of a sampling device should be three times the size of the largest particles to be sampled (see ISO 18400-104).

NOTE The preservation of the different size soil particles in the vial or a jar is of interest if the laboratory proceeds with an analysis of the different particle size fractions. 20 g sample of soil in the vial does not generally allow VOC analysis on the larger soil particles which of necessity are discarded during sub-sampling).

**Table 1 — Advantages and limitations of in situ sampling techniques to determine VOCs**

| In situ sampling method | Advantages[a] | Limitations |
|---|---|---|
| **Cutting cylinder (e.g. volume 226 ml)** | Sampling can be carried out on the soil surface or at greater depths after pre-drilling.<br>In-situ method: no exposure to the atmosphere.<br>Resistant: sealable metal core sampler.<br>Rapid sampling in cohesive soils.<br>Single sample and undisturbed sample.<br>Sealed cylinder limits VOCs losses (by volatilisation).<br>Sample volume in one container which offers possibility for additional analysis (dry matter, organic matter, etc.).<br>No use of chemicals in the field. | Complete filling of the device is sometimes difficult or impossible in the presence of coarse gravel constituting the soil.<br>No observation of the sampled soil possible when filling the cylinder in the field.<br>Possible loss of volatiles sub-sampling in the laboratory.<br>Logistical constraints: For reuse, cylinders must be cleaned and sent back.<br>Some laboratories offer this service. |

[a] The descriptive text under the advantages column is only valid under appropriate sampling conditions.

**Table 2 — Advantages and limitations of ex situ sampling techniques to determine VOCs**

| Ex situ sampling techniques | Advantages[a] | Limitations |
|---|---|---|
| **Small coring device: metal coring ring (e.g. 16 ml)** | Device driven directly into the ground (extracted with a drilling tool): limits exposure to air.<br>Rapid sampling in cohesive soils.<br>Resistant: sealable metal core sampler.<br>Sealed device limits VOCs losses (by volatilisation).<br>Single sample and undisturbed sample.<br>No use of chemicals in the field. | Complete filling of the device may be difficult or impossible in soils rich in fill (pebbles, stones, construction waste etc.) or in very cohesive soils (plastic clay).<br>Closing the device with caps is sometimes difficult (air/water or soil compression).<br>Not easy to use the core hammer (control of filling, cleaning).<br>A second sample should be taken for the measurement of dry matter.<br>Risk of loss of volatile compounds when soil is extruded by the laboratory (transfer to the extraction solvent)<br>Logistical constraints: For reuse, cutting rings must be cleaned and sent back.<br>Note: some laboratories offer this service. |
| **Small coring device: disposable plastic corer (e.g. 3 ml to 15 ml)** | Device driven directly into the ground (extracted with a drilling tool): limits exposure to air.<br>Rapid sampling in cohesive soils (clay, silt, fine sand).<br>Sealed device limits VOCs losses (by volatilisation).<br>Single sample and undisturbed sample.<br>No use of chemicals in the field<br>No cleaning required (single use).<br>No specific logistics with the laboratory. | Complete filling of the device may be difficult or impossible in soils rich in fill (pebbles, stones, construction waste etc.) or in very cohesive soils (plastic clay).<br>Use generally limited to cohesive soil (clay, silt, fine sand).<br>A second sample should be taken for the measurement of dry matter |

[a] The descriptive text under the advantages column is only valid under appropriate sampling conditions.

[b] Sampling technique used in certain special cases (see 5.3.5).

[c] Associated limits are specified in 5.3.4.1: subject to compliance with the soil volume to methanol volume ratio, with a risk of VOC loss in the process.

[d] Vehicle and air transport are highly regulated or even prohibited.

**Table 2** *(continued)*

| Ex situ sampling techniques | Advantages[a] | Limitations |
|---|---|---|
| **Vial pre-filled with methanol**<br>**(e.g. 10 ml to 15 ml)** | Sampling device (syringe): generally easy implementation.<br>Single sample and undisturbed sample.<br>Rapid sampling in cohesive soils (clay, silt, fine sand).<br>Preservation in methanol: strongly limits VOC losses through volatilisation and biodegradation.<br>Field and transportation blanks in the sampling chain.<br>Internal standard to secure the analytical measurement.<br>No physical preparation on soil by the laboratory | Syringe (or another coring tool similar) sometimes difficult to use in soils rich in fill (pebbles, stones, construction waste etc.) or in very cohesive soils (plastic clay, marl, etc.). In this case, a spatula can be used.[c]<br>Use of methanol (prevention of methanol exposure and regulated transport).[d]<br>Limited life of vial prefilled with methanol to give reliable results.<br>Field operators should have appropriate first aid training.<br>A second sample should be taken for the measurement of dry matter. |
| **Glass jar with no field preservation**[b]<br>**(e.g. 250 ml to 375 ml)** | Sampling tools (trowel, spatula) easy to use, regardless of the type of soil.<br>Suitable for different soil types, e.g. indurated soils.<br>Allows soils with a range of grain sizes to be sampled (e.g. clay sheets or pellets, fine to medium gravels.<br>Sample volume in one container which offers possibility to additional analysis (dry matter, organic matter, etc.). | Soil sample is disturbed more or less depending on the type of soil.<br>Potential significant losses of VOCs during the sampling and the transportation (depending on the presence of air in the jar).<br>Requires more manipulation and therefore more time to fill the jar, for example with marl and clay soil.<br>Increased toxicological risks for the field worker because of larger volume and more time taken to fill in the jar.<br>Need a larger diameter drilling technique to fill the jar completely.<br>Possible loss of VOCs during sub-sampling in the laboratory.<br>Need a strict procedure to limit losses of VOCs. |

[a] The descriptive text under the advantages column is only valid under appropriate sampling conditions.

[b] Sampling technique used in certain special cases (see 5.3.5).

[c] Associated limits are specified in 5.3.4.1: subject to compliance with the soil volume to methanol volume ratio, with a risk of VOC loss in the process.

[d] Vehicle and air transport are highly regulated or even prohibited.

# 6 On site semi-quantitative measurement of volatile organic compounds

## 6.1 General

This clause covers semi-quantitative field measurement equipment for detecting the presence or not of volatile organic compounds on site, during soil sampling. When VOCs are suspected or known to be present at a site, semi-quantitative measuring devices should be used on site (e.g. Photo-Ionization Detectors, Flame Ionization Detectors, colorimetric tubes). They allow rapid field screening to identify the potential presence of VOCs (most common volatile contaminants). The use of such devices can help achieve three main goals:

a) aid to designing the sampling plan;

b) selection of relevant soil samples to be sent to a laboratory for analysis;

c) assessment of risks for field workers.

However, taking into account the relative precision of the field equipment, these semi-quantitative measurements do not allow study of soil gas quality based on soil gas concentrations: this type of investigation should be made in accordance with ISO 18400-204[15].

Most on-site measurement equipment is sensitive to field conditions, including soil and ambient humidity, dust, and temperature variations. Some equipment could be more sensitive to specific volatile compounds (e.g. aromatic rather than aliphatic hydrocarbons). Information should be collected about the sensitivity of the devices to the compounds of interest.

All the different types of measuring devices require regular calibration. The calibration information sheet should specify at least the identification number of the device, its characteristics, the calibration specification, the calibration frequency, and the calibration procedure. These elements are very important for "checking" the representativeness of the measurements.

The semi-quantitative VOC measurement equipment is only used to screen the surface of an exposed core after the soil sampling has been carried out (to limit losses), except for the windowless sampler, because the soil obtained from this drilling equipment is not in contact with the atmosphere (as long as it remains inside the corer).

Except for the windowless core sampler, these recommendations should be followed:

— no measurement of the core should be performed until all samples necessary for the determination of VOCs have been taken; these samples should be taken as quickly as possible;

— no attempt should be made prior to sampling to screen the exposed area, and locate particularly high concentrations, as this will delay sampling and likely result in loss of VOCs.

Field screening, such as the use of a PID (photoionization detector) can be used on material remaining after sample collection, to inform the analysis plan.

NOTE A multi-gas analyser ($O_2$, $CO_2$, $H_2S$, $CH_4$, etc.) or direct-reading detector tubes can be used to identify potential risks to field operators, for workplace monitoring and for rough mapping of pollutant plumes. However, this equipment is not covered by this document.

Advantages and limitations of portable equipment to measure volatile organic compounds on site are presented on Table 3.

Details regarding the proper deployment of these screening tools and their applicability are presented in Annex B. An example of a procedure for the PID (most commonly used VOC sampling instrument) is in Annex C.

Non-organic volatile compounds are out of the scope of this document. However, Annex D gives information on the sampling and measurements of some non-organic volatiles that are often found in contaminated areas.

## 6.2 Advantages and limitations of portable equipment

Table 3 presents the advantages and limitations of portable equipment to measure volatile organic compounds on site.

**Table 3 — Portable equipment to measure volatile organic compounds on site**

| Instrument | Gases analysed | Advantages | Limitations |
|---|---|---|---|
| **Photoionization detector (PID)** | Measurement of total concentration of photoionisable VOCs | Immediate results (< 1 min, a measure every 2 s)<br>Easy to use<br>Cost relatively moderate<br>No destruction of the analysed air.<br>VOCs detection range from 0,001 µl/l (ppmV) to 25 000 µl/l (ppmV) | Detection not specific (provides a concentration for all compounds detectable by the installed lamp).<br>Existence of several types of lamps which condition the compounds actually detected by the PID<br>Mandatory preliminary calibration<br>No methane detection<br>Sensitive (humidity, dust) |
| **Flame ionization detector (FID)** | Measurement of total concentration of flammable VOCs | Immediate results (< 1 min)<br>Possibilities of using gas chromatography (GC) to identify specific compounds.<br>VOCs detection range from 1 µl/l (ppmV) to 10 000 µl/l (ppmV) | Requires a certain technical competence on the part of the user, especially for the step of extracting pollutants with solvents before switching to the gas phase.<br>Fairly long calibration<br>Many sources of interference<br>Needs to have a source of $H_2$ on site to power the device<br>Not always intrinsically safe<br>Requires oxygen<br>Possible errors if high levels of carbon dioxide<br>Very sensitive to humidity<br>Very sensitive to dust<br>Sample is destroyed as part of measurement |
| **Indicator (colorimetric) tubes** | Detection of specific elements, chemical compounds or families of compounds in soil | Quick results (5 min - 20 min)<br>Easy to use<br>Low cost<br>Very low maintenance<br>Large number of gases (over 200 compounds)<br>VOCs detection range from 0,1 µl/l (ppmV) to 10 000 µl/l (ppmV) | Limited number of types of kits available<br>Semi-quantitative method<br>Interferences depending on the compounds present<br>Colorimetric interpretation of the response sometimes difficult<br>Limited precision and readability<br>High cross sensitivity to humidity and temperature<br>Interference with other compounds |

## 7 Field storage and transport of samples

After each sampling exercise, soil samples should be kept in the cold and dark in a refrigerator or cool box. Cooling or freezing procedures can be applied to samples to increase the time available for transport. A cooling temperature of (4 ± 2) °C has been found suitable for many applications in accordance with ISO 18400-105[10]. Samples should be shipped promptly to the laboratory for analysis as soon as practical and if possible within 24 h after sampling.

**WARNING — Changes in temperature change the partitioning of VOCs between the different phases in which they appear. Cooling supports condensation that may result in separation within the sample container. Therefore temperature changes should be kept as little as possible. Only samples submerged in methanol are little affected by temperature changes.**

Analysis for volatile compounds should be carried out as quickly as possible after sampling.

A storage period of 4 days of an unpreserved sample is the maximum period allowed according to ISO 18512:2007, Table A.1. This value applies to the total duration of storage on site, in transit and in the laboratory.

NOTE 1 The conditions for storage and transport are outlined in ISO 18512 and in ISO 18400-105.

When samples are submerged in methanol, the maximum allowed storage period may be longer under certain defined conditions.

Laboratories can carry out their own in-house stability trials and set their own procedures for storage and temperature on the basis of such trials. In such cases, the laboratory should provide the client with the evidence for its approach if requested to do so.

The laboratory should always be contacted to agree storage conditions and maximum times before samples arrive at the laboratory.

## 8 Cleaning of sampling equipment

To prevent cross-contamination all devices and apparatus should be made of inert materials (e.g. stainless steel trowel), see ISO 18400-102.

After a soil sample has been taken, the drilling and sampling tools should be cleaned. Depending on the item to be cleaned, a pressure washer or a wire brush with laboratory grade detergent can be used. An inspection for any cross contamination should be made before an item of equipment is reused to collect another sample.

Gloves as protective equipment should be disposable (in which case changed frequently) or if more durable (they may have more than one function) regularly changed or when soiled.

NOTE 1 For guidance on cleaning of sampling equipment, see ISO 18400-102.

NOTE 2 Unlike other contaminants VOCs can be transported by the ambient air into sample containers that are not closed permanently (before and after sampling).

## 9 Quality assurance and quality control

Soil sampling programmes require a quality assurance (QA) and quality control (QC) in their design to ensure that only impartial and representative samples are used to inform project decisions and results. The quality control of a sampling programme helps to ensure that all field activities are representative and that potential sources of contaminants are identified.

NOTE 1 For guidance on QA/QC, see ISO 18400-106[11].

The QA/QC programme should be adapted to the context of the field operation.

In accordance with ISO 18400-106, all people involved in the sampling project shall be qualified for their task, i.e. have had a specific training for the task and keep knowledge, experience and skills relevant to the task up to date.

The number of quality control samples should be decided based on the total number of samples to be taken and the advice of the laboratory undertaking the analysis.

Trip blanks should consist of prepared vials sent to the field and then returned to the laboratory without being opened on site. The trip blanks should accompany the field samples throughout the sample and collection operation. They are not opened on site. They can be used to assess sample contamination originating from sample handling and transport or site conditions.

Field blanks should be used at the location where soil samples are being constituted into containers to best represent on-site conditions, i.e. at the designated sampling station.

Field blanks should consist of vials prepared before arriving on the field. These vials are opened for the same time period as necessary for charging with a soil sample, closed and then returned to the laboratory following the same process as the soil samples (in terms of cooling, etc.). Field blanks can be used to assess contamination arising from field sampling conditions.

## 10 Data quality evaluation

During data evaluation, account shall be taken of the likely losses associated with the sampling conditions and method, referencing, for example, the results for blank samples.

If blank values are unusually high (e.g. more than 50 % of the lowest value of interest), the reason for these high blanks shall be investigated.

The reason for selection of sampling techniques (drilling, sampling, etc.) should be recorded and the potential impact on data reliability noted and taken into account (e.g. using a destructive method of drilling when volatile compounds are researched).

## 11 Recording and reporting

A detailed description of how the samples were taken and subsequently handled should be included in the sampling report and the final site investigation report.

Observations (e.g. visual, texture, appearance) and measurements (e.g. with a PID) in the field should be systematically recorded on the logging recording sheet, which thus constitutes a self-supporting summary document. This information should always be evaluated in conjunction with laboratory analytical data, with all possible correlations established and included in reports.

NOTE For guidance on recording and reporting, see ISO 18400-107[12].

# Annex A
(informative)

# Procedures for application of soil sampling techniques

## A.1 Sampling soil using a cutting cylinder

The procedure for using a cutting cylinder is as follows.

a) Before use check if the sampler is clean, e.g. from adhered materials from previous use. Clean if necessary.

b) Make a borehole to the desired depth.

c) After each sampling action, decontaminate the cylinder (or sample tube) filling blocks and insulation plates in which samples are collected, or use new cylinders.

d) Fit a clean sample tube over the coring apparatus and bring it into the borehole (extension rods and a handle can be used to reach the bottom of the borehole).

e) Drive by hand or hammer the sample tube into the soil taking the length of the tube to be filled into account.

f) Fill the sample tube and rotate it 90° to break the sample free from the soil.

g) After collecting the sample (check the tube is full of soil), clean the outer edge of the sample tube to prevent soil reducing the efficacy of capping.

h) Place the insulation plate and first cap at the end of the sample tube, disconnect the sample tube from coring apparatus, place the filling block in the sample tube and fit the other cap.

i) Label the samples with relevant details, pack and send them immediately to the laboratory.

If the sample tube is partly filled, it should be discarded, cleaned and a new sample taken.

After removing the head, the space that is left (of the head) is filled with filling blocks and insulation plates.

In very loose soil or in a non-cohesive soil (e.g. under groundwater level), soil can drop out. A stainless-steel sampling tube with a core catcher should be used.

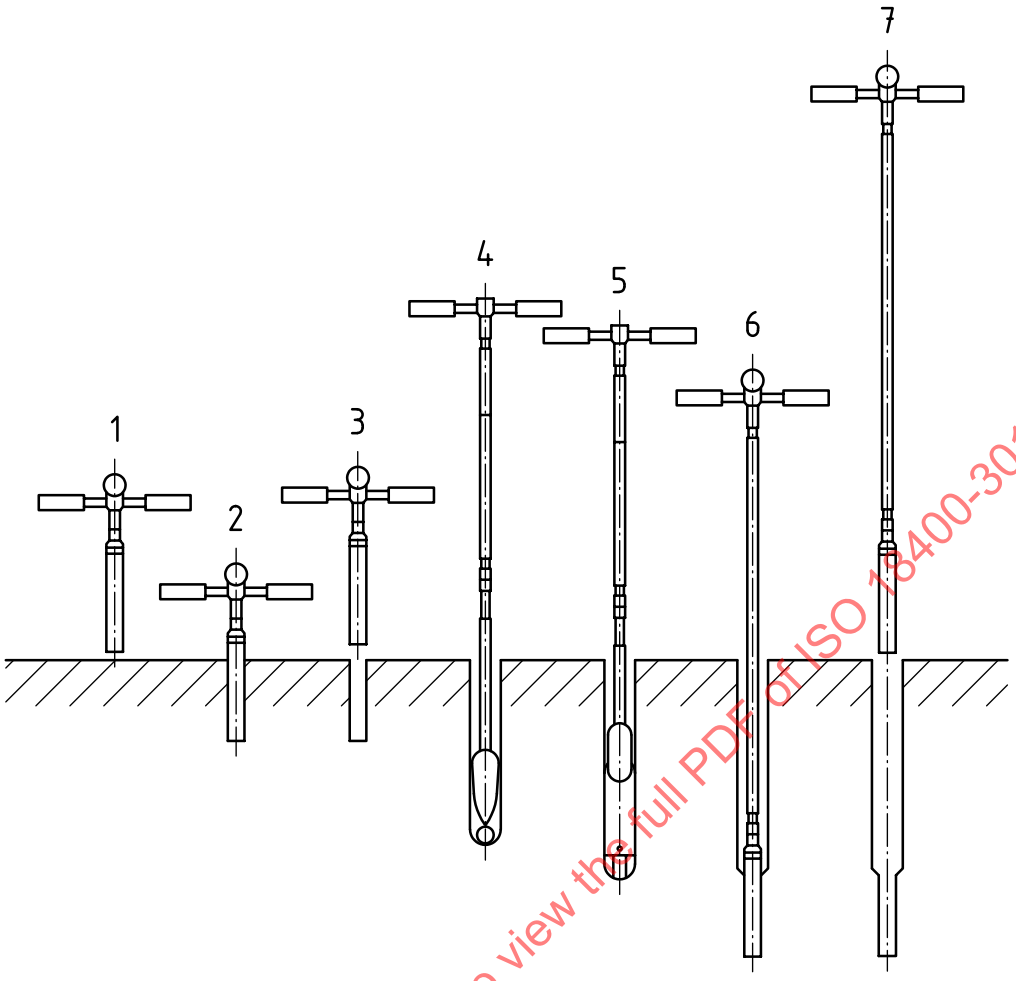
The cutting cylinder is shown in Figure A.1 and used following the procedure in Figure A.2.


**Key**

1 empty cutting cylinder
2 head attached to a connection rod
3 steel filling
4 the two caps

NOTE In red oval: under an empty cutting cylinder, in the middle the head attached to a connection rod; above left a steel filling and right the two caps.

**Figure A.1 — Sampling kit with a cutting cylinder (photo)**




**Key**

Steps:

1-3 the cutting cylinder coring device is pushed or hammered from surface level into soil and retrieved taking an undisturbed sample from surface level until 20 cm below surface level

4 with drilling equipment, a borehole is made to a desired depth and prepared for the next sample.

5 a flat bottom to the borehole is created

6-7 a second undisturbed sample is taken.

**Figure A.2 — Sampling using a cutting cylinder (drawing)**



## A.2 Sampling soil using a small coring device

### A.2.1 soil corer containing a metal coring ring 16 ml

The procedure for using a soil corer containing a metal coring ring 16 ml is as follows.

a) Before each use, clean the soil corer to remove adhered materials from previous use [see Figure A.3 a)].

b) Fully decontaminate the coring ring in which samples are collected before use, or use a new one.

c) Fit the coring ring securely inside the soil corer.

d) Drive the soil corer fitted with the coring ring in by hand or a hammer in certain types of soil (i.e. cohesive soil with gravel/sand components).

e) Fill the coring ring completely to minimize headspace within the sample. The size of gravel could limit the operation of the coring device [see Figure A.3 b)].

f) Push the coring ring sideways out of the soil corer [see Figure A.3 c)].

g) Clean the outer edges of the coring ring to prevent debris reducing the efficacy of capping.

h) Cap the coring ring (suitable capping includes diffusion-proof materials, such as stainless steel or aluminium and can include specialist caps provided with the soil corer).

i) Label the samples appropriately with relevant details, store in refrigerated coolers and send as soon as possible to the laboratory.

For more information about this equipment and the terms employed, see Figure 9.

This procedure is illustrated in Figure A.3.

a) b) c)

**Figure A.3 — Sampling using a soil corer containing a metal coring ring**

### A.2.2 Disposable plastic corer

The procedure for using a disposable plastic corer is as follows.

a) Attach the coring body to the T handle [see Figure A.4 a)].

b) Push the sampling device into the freshly exposed surface of the soil until it is full [see Figure A.4 b)].

c) Use paper towelling to quickly wipe the head of the coring body so that the cap can be tightly attached [see Figure A.4 c)].

d) Push cap on with twisting action [see Figure A.4 d)].

e) Fill out the label and attach this to the capped coring body.

f) Store the coring bodies in refrigerated coolers.

g) Send the capped coring bodies to the laboratory as soon as possible.

For more information about this equipment and the terms employed, see Figure 11.

This procedure is illustrated in Figure A.4.

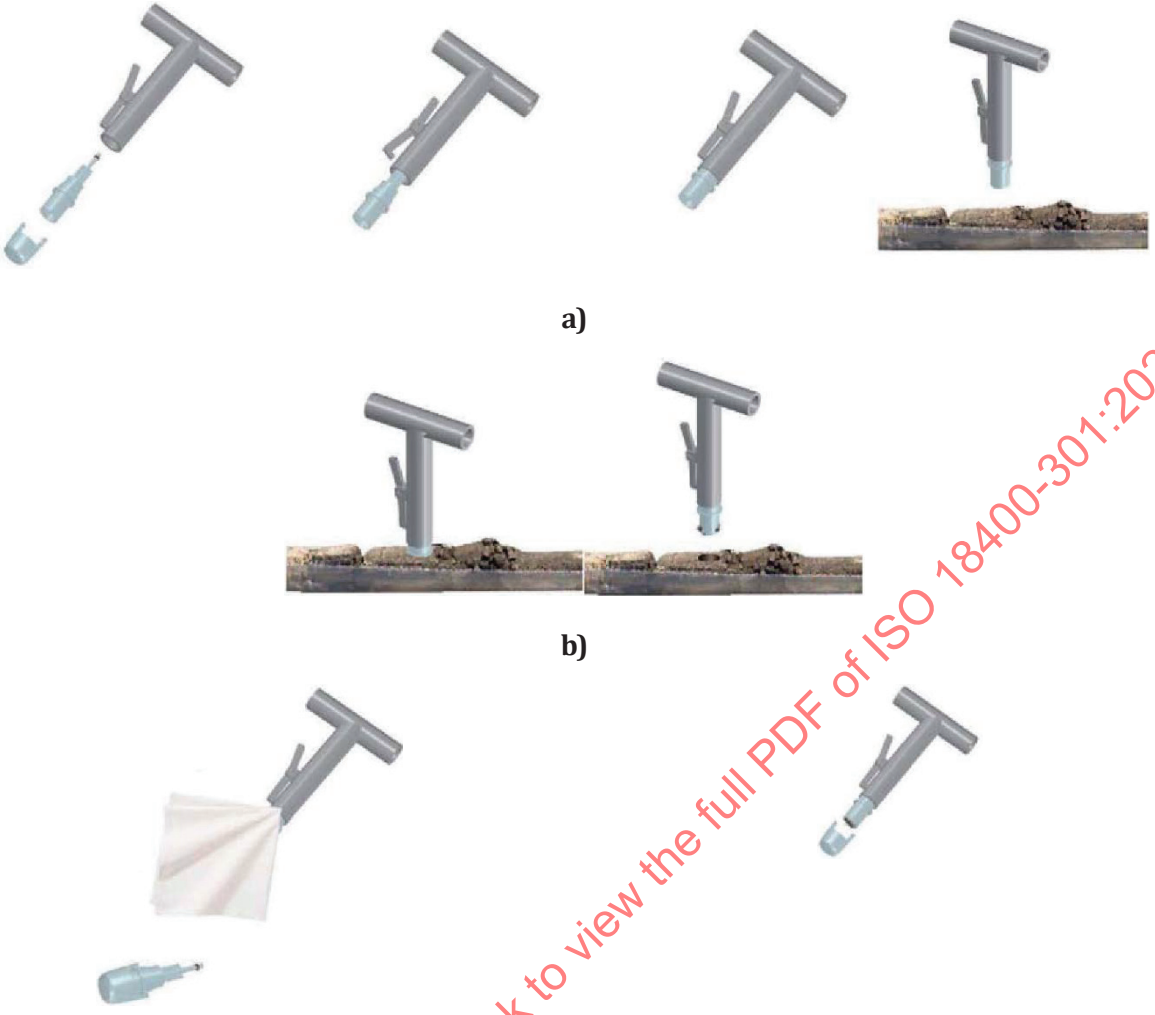


**Figure A.4 — Sampling using a disposable plastic corer**

The whole coring body volume shall be filled to avoid as far as possible the presence of air.

Soil sample shall be collected immediately after soil core extraction.

Verify that the caps (and their internal insulating ring) are correctly placed on the coring device for an optimum tightness (clean/remove soil residual between corer and cap before closing the corer).

This device should be used in accordance with the manufacturer's instructions.

## A.3 Sampling soil using a vial pre-filled with methanol

The procedure for using a vial pre-filled with methanol is as follows.

a) Before sampling, check the quantities of methanol in each vial and discard any that do not contain the correct quantity of methanol.

b) Collect the soil sample immediately after soil core extraction using an appropriate coring tool of known volume, for example a disposable plastic syringe modified by cutting its tip [see Figure A.5 a)].

c) Take the soil in one action if possible (could be difficulties with coarse elements).

d) Introduce the soil carefully (avoiding splashing) into the glass vial containing the defined volume of methanol [see Figure A.5 b)].

e) Check that the methanol completely covers the soil. For example, carefully rinse to allow sample to be drowned by methanol (if this does not work, add a known volume of conservation fluid from another prefilled vial and record this) [see Figure A.5 c)].

f) Clean the top of the vial (neck and screw thread) before closing it to avoid leaks then shake the vial to obtain a homogeneous mixture.

g) Place the vials in the cooler dedicated to this type of support (do not mix it with other supports: risk of contamination in the event of methanol leakage).

h) Keep the sample protected from light in refrigerated coolers (before and after sampling) and during all transport, and send as soon as possible to the laboratory.

NOTE Transport of methanol is regulated with specific rules regarding / the volumes, the containers, the vehicles, the labelling of containers, and signage on vehicles

Having completed the sampling, the following is performed.

— Make one or more field blanks for each sampling series (per site, per sampling day, sampling location): the blank is produced on site by opening a prepared vial pre-filled with methanol during the same time interval as that required for filling with the soil sample.

— Take an unpreserved sample (without methanol) for dry matter determination.

This procedure is illustrated in Figure A.5.

**a)**

**b)**

**c)**

**Figure A.5 — Soil sampling using a vial pre-filled with methanol**

## A.4 Sampling soil using a glass jar with no field preservation

**WARNING — Sampling in a glass jar with no field preservation is not recommended when looking for the presence of VOC in soils. This method can lead to a recurrent underestimation of the results (i.e. VOC content in soils). This phenomenon is of varying magnitude according to the nature of the soils, the compounds present such as halogenated VOCs, etc. However, in certain special cases, a glass jar without field preservation can be used, provided that this is justified (this information should be recorded and the reason notified).**

The procedure for using a glass jar with no field preservation is as follows.

a) Collect the soil sample, immediately after extracting the soil core, with a trowel, a stainless steel spatula, or a gloved hand and place it directly into a suitable laboratory jar [see Figure A.6 a)].

b) Fill in the jar as completely as possible, by lightly compacting the soil in the jar and sealing it. Limit the sampling time and direct exposure to air [see Figure A.6 b)].

c) Clean the top of the jar (neck and screw thread) before closing it is hermetically sealed.

d) Keep the soil samples protected from light in refrigerated coolers immediately after sampling and during transport.

e) Send the samples to the laboratory for analysis as soon as possible after sampling.

This procedure is illustrated in Figure A.6.

a)

b)

**Figure A.6 — Sampling soil using a glass jar with no field preservation**

# Annex B
(Informative)

# On site semi-quantitative measurement of volatiles organic compounds types of measuring devices

## B.1 Photo-ionization detectors (PID)

### B.1.1 Description

Photo-ionization detector (PID) instruments do not measure a specific compound. They determine a total concentration of photo-ionizable organic compounds. These detectors generate an air flux through an ionization chamber equipped with an ultra-violet lamp and two electrodes subject to a high difference in voltage. Three lamp powers are available (9,8 eV, 10,6 eV, 11,7 eV) according to the ionization potential of the compounds to be identified. Depending on the power output, the VOCs detected differ.

A PID can be coupled with gas chromatography to identify volatile compounds, but in practice, it is very rarely done directly in the field.

These measurement devices are sensitive to weather conditions. PIDs are affected by humidity in the atmosphere because moisture is conductive. The methodology employed (see Annex C) and nature of the permeability of the soil will influence the field measurement.

It is necessary to check the instrument's state and its calibration (most often with the iso-butene100 ppmV) prior to using it. Results are expressed in iso-butene ppmV equivalents (see C.1.2 about calibration).

### B.1.2 Principle

Volatiles can be categorized according to their ionisation potential (IP), which is the energy required [measured in electron volts (eV)] to displace an electron and ionise the gas. If the IP of the volatile is less than the eV of the energy source, the contaminant will be ionised and detected. On a standard PID, using a 10,6 eV lamp, Ultraviolet (UV) light ionises some alkanes and chlorinated solvents. The ionised particles are attracted to high voltage plates that create an electrical signal. This lamp does not detect alkanes. This requires a 11,7 eV lamp. However, this lamp has a short life (1 month) and is used only for specific cases (e.g. alkane detection). Without specific adjustment, PIDs are non-selective devices, in the sense that they are unable to discriminate between compounds and thus only give a global sum for the detected compounds present.

Avoid making direct correlations between PID and concentrations from laboratory analysis. PID gives semi-quantitative measurements and the PID measurement is too dependent on field conditions and the method applied.

**WARNING — Though PIDs are measuring all of the ionizable volatiles, it often is possible to present the results as if they are 100 % of a specific volatile. This is an automatic generated mathematical result that is useful if the PID is used for safety reasons. When benzene for instance is the volatile with the highest risk, the PID can present the measurement as if all ionizable volatiles are benzene. This option is often incorrectly interpreted as a specific value of benzene, which it is not. To detect specific volatiles other equipment is needed, for example, colorimetric tubes (see B.3).**

PIDs can detect a broad range of VOCs/volatiles, including both organic and inorganic compounds: organic compounds include aromatic compounds (e.g. the BTEX), ketones and aldehydes, alcohols,

saturated hydrocarbons, chlorinated hydrocarbons and sulphur compounds (mercaptans). Inorganic compounds detected include ammonia, arsine, iodine and nitrous oxide. Instrument manufacturers provide specific details about compounds that can be detected when different lamps are fitted to a PID.

The screening with a PID can be done on subsamples placed in sealable bags or along a recovered soil core, to identify areas where VOCs/volatiles may be present.

As shown in Figure B.1, a photo-ionization detector can be used to measure vapours on sub-samples placed in sealable bags. Once collected, the soil bags are kneaded for a few minutes to allow volatiles to accumulate in the headspace of the bags. The tip of the PID needle is placed into the headspace to measure the volatile compound(s) that are be present in the soil.

**WARNING — Samples that are used for PID measurement shall not be sent to the laboratory. They should be discarded afterwards.**

**Figure B.1 — Measure of volatiles with a PID on sub-samples placed in sealable bags**

A photo-ionization detector can also be used to measure vapours along the length of a recovered soil core, to identify areas where organic contamination could be present.

If the soils are contained in a plastic liner, it is possible to screen the unexposed soil surface prior to sampling with a semi-quantitative measuring device to locate particularly high concentrations and thus orient the areas to be sampled.

In this case, the plastic liner is drilled at different points along the core (e.g. every 25 cm) without passing through the core, and the measuring instrument (or its measuring extremity) can be inserted into the hole to perform the measurement (Figure B.2). In this case, the soils will not be sampled in the area of the measurement hole where the soils will have been reworked.


**Figure B.2 — Measure of volatiles with a PID along an intact soil core (including plastic liner)**

As shown as Figure B.3, the photo-ionization detector can be used to measure vapours along the recovered soil core (in holes made in the window core sampler). In this case, make sure not to do it in ambient air.

**Warning — this apparatus should not suck up soil particles because this could block apparatus. Small filters can be used to prevent this (see the circle in Figure B.3).**

If the core is not retained in a plastic liner, no attempt should be made before sampling to screen the exposed surface, for example using a PID (photo ionization detector) device to locate high and low levels of measures, or to describe the material cored, as this will delay sampling and is likely to lead to loss of VOCs.

**Figure B.3 — Measure of volatiles with a PID along a recovered soil core (window core sampler)**



## B.2 Flame-ionization detector (FID)

### B.2.1 Description

As shown in Figure B.4, a flame ionization detector (FID) samples the gases using a pump. The gases are then sent to a combustion cell comprising a burner (destructive method). Organic compounds ionize in the presence of oxygen.

### B.2.2 Principle

The measurement is based on the proportionality of the ionization current to the total carbon concentration of the gas to be measured.

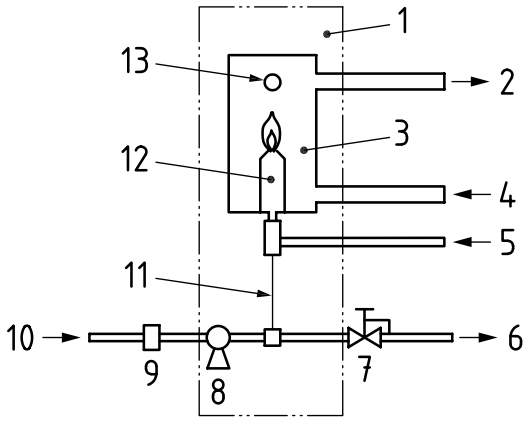
FIDs allow measurement of the overall concentration of organic compounds ionizable by flame. They provide concentrations of total organic compounds and are not specific to particular compounds.

These devices cover ranges from 1 µl/l (ppmV) to 10 000 µl/l (ppmV).

For various compounds, there is a response coefficient also called a response factor which depends on the chemical structure of the organic compound and the characteristics of the detector.

FIDs are used to detect the presence of organic compounds, including hydrocarbons and volatile organic compounds. FIDs detect only compounds containing C-H bonds; they do not respond to inorganic compounds. Simple saturated hydrocarbons (e.g. methane, hexane, ethane, propane, etc.) produce the highest response. However, FIDs are less sensitive to organic compounds that contain nitrogen, oxygen, sulfur, or halogen atoms (Cl, Br, I, F). Compounds without C-H bonds are not detected, even if they are organic compounds (e.g. tetrachloromethane). It does not detect HO, $CO_2$, $CS_2$, $SO_2$, CO, NOx.

Figures B.4 and B.5 illustrate the flame ionization detector.




**Key**

| | | | |
|---|---|---|---|
| 1 | oven | 8 | pump |
| 2 | exhaust | 9 | filter |
| 3 | flame chamber | 10 | sample in |
| 4 | air | 11 | sample capillary |
| 5 | fuel gas | 12 | nozzle |
| 6 | to vacuum | 13 | high voltage ion collector |
| 7 | sample flow regulator | | |

**Figure B.4 — Flame-ionization detector (FID) drawing**

**Figure B.5 — Flame-ionization detector (FID) photo**

FID typically comprises:

— an inlet for the gases sampled using a pump;

— possibly a pole or a sampling pipe;

— possibly a filter for the air inlet;

— an ionization chamber comprising a burner, two electrodes (+ and -);

— an electrometer serves as a current amplifier;

— a hydrogen supply or a hydrogen / helium mixture;

— a number of pressure regulators, to keep the differential pressure constant.

## B.3 Colorimetric tubes

### B.3.1 Description

These tubes contain a chemical reagent absorbed on an internal support. The presence of a specific compound/chemical results in a change of the colour of the chemical reagent. There is then a correlation between colour intensity and concentration, which can be interpreted either visually with standard charts, or instrumentally by spectrophotometry. These tubes cover concentration ranges from 0,1 µl/l (ppmV) to 10 000 µl/l (ppmV).

There are devices with colorimetric tubes, allowing specific measurement for a compound or a group of compounds. There are not colorimetric tubes for all volatile compounds. The presence of certain volatile compounds, other than those measured by colorimetric tube, can induce measurement interference. The interpretation of the response on a colorimetric tube may be subject to error (visual interpretation).

### B.3.2 Principle

A sample of air is drawn through a tube containing a reagent, causing a colour change. The concentration is then read from the length of the colouration in the reagent.

Since each lot is pre-calibrated, no calibration step is required in the field. Errors are avoided by directly marking the calibration information on each tube, and accuracy is further assured by controlling the volume of air sampled. The tubes are thin and are designed to be used with a manual piston pump.

Figure B.6 shows an illustration of the procedure for using the colorimetric tube.

**Figure B.6 — Procedure for using the colorimetric tube**

Colorimetric tubes can be used for compounds that would not be detectable with PID. The screening with a colorimetric tube can be done on subsamples placed in sealable bags to identify areas where VOCs/volatiles may be present. The methodology is the same when using a PID.