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Soil quality — Sampling —

Part 101: Framework for the preparation and application of a sampling plan

Qualité du sol — Échantillonnage —

Partie 101: Cadre pour la préparation et l'application d'un plan d'échantillonnage

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Foreword

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

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

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

This first edition of ISO 18400-101, together with ISO 18400-104 and ISO 18400-107, cancels and replaces ISO 10381-1:2002, which has been technically and structurally revised. The ISO 18400 series is based on a modular structure and cannot be compared to ISO 10381-1 clause by clause.

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

Introduction

The characterization of soils and soil materials within the scope of this document, in terms of their potential environmental impact, or suitability for a particular use, requires a variety of tests to be performed. These tests may relate to the chemical, physical and biological properties of the soil or soil material. Validity of these tests requires performance on a representative sample or a number of representative samples.

The potential scope of an investigation programme can be complex; the process flowchart in Figure 1 defines seven key elements that make up the essential elements of the investigation programme. The principles outlined in this document provide a framework that can be used to design and develop a sampling plan, which is the first of the seven key elements. Other International Standards provide detailed instructions on how to complete the remaining key elements.

Before any investigation programme is devised, it is important that the objectives be first established since they are the major determining factors for the actual sampling, e.g. the position, density and depth of sampling points, time of sampling, sampling procedures, the acceptable levels of sampling uncertainty and the subsequent treatment of samples and analytical requirements. The details of an investigation programme depend on whether the information needed is the average value, the distribution, or the variability of given soil parameters.

The degree of detail and measurement uncertainty required and also to the manner in which the results are to be expressed and presented, for example, concentration of constituents, maximum and minimum values, arithmetic means, median values, etc. needs some considerations. Additionally, it is advisable to compile a list of constituents of interest and the relevant analytical procedures consulted, since these will usually give guidance on precautions to be observed during sampling and subsequent handling of soil samples. The investigation programme design often involves iterative discussion between the involved parties.

Given that complexity, a sampling plan is defined by the specific objectives of the investigation programme and how those objectives can be practically achieved with reference specifically to the sampling activities for the situation under investigation. The sampling plan provides simple and unambiguous instructions for the sampler, and as a consequence sampling is to be performed only when an approved sampling plan is available.

A large variety of sampling objectives exist, including the following:

— sampling of ex-situ soil (e.g. soil stockpiles) in order to estimate the (average) concentration of constituents in a specified quantity of soil material;

— sampling of agricultural, natural and near natural soils in the landscape in order to estimate the (average) concentration of constituents over a specified soil area and depth;

— sampling to determine chemical, physical or biological characteristics of the soil material;

— sampling of (potentially) contaminated sites in order to characterize and delineate the contamination and to estimate the risks for human health and the environment.

ISO 18400-104[1)] requires that a preliminary (phase 1) investigation comprising a desk study and a site reconnaissance is carried out before any sampling or other intrusive activities are carried out. The extent of the preliminary investigation will depend on the objectives of the overall investigation and the on-site activities expected will be required (see ISO 18400-202[1)].

It will often be necessary to carry out an exploratory (phase 2) investigation as described in ISO 18400-104[1)] before the final objectives for the detailed (phase 3) investigation can be defined.

It is important to take into account all relevant data from previous investigation programmes at the same or similar locations and other information on local conditions. Previous personal experience can

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also be very valuable. Time and money allocated to the design of a proper investigation programme is usually well justified because it ensures that the required information is obtained efficiently and economically.

In addition to the design and development of a sampling plan, this document deals with the actual sampling in accordance with that sampling plan and it deals with the development of the sampling report. A sampling plan shows details of all the information pertinent to a particular sampling exercise.

The procedural elements that will be considered to complete key element 1 'The preparation and application of a sampling plan' are detailed in Figure 2. It is this process map that provides the basic framework for the practitioner developing a sampling plan to meet the requirements of any investigation programme. This document can be used to

— produce standardized sampling plans for use in more routine circumstances,

— incorporate the specific requirements of national legislation, and

— design and develop a sampling plan for use on a case-by-case basis.

This document is part of a series on sampling standards for soil. The role/position of the International Standards within the total investigation programme is shown in Figure 1.

Essential information for the application of this document and reference to all International Standards belonging to the ISO 18400 series is provided in ISO 18400-100. ISO 18400-100 will be updated on a regular basis as long as the International Standards of this series are under development.

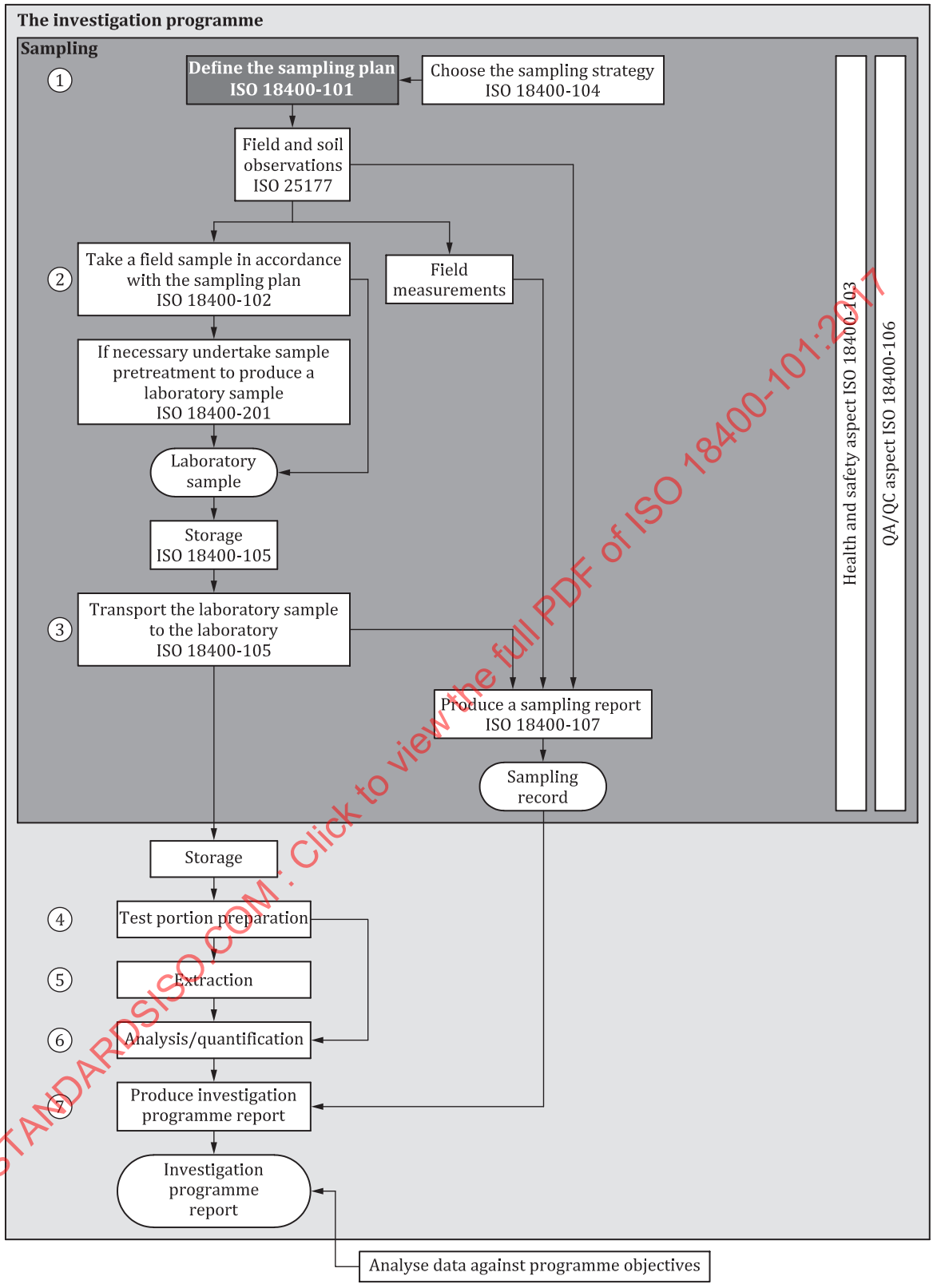

Figure 1 — Links between the essential elements of an investigation programme

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

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

Soil quality — Sampling —

Part 101: Framework for the preparation and application of a sampling plan

1 Scope

This document specifies the procedural elements to be taken in the preparation and application of a sampling plan. The sampling plan describes among other things what laboratory samples are to be taken, how they are to be taken and from where they are to be taken, in order that the objectives of the investigation programme can be achieved. The principles or basic rules outlined in this document provide a framework that can be used to

— produce standardized sampling plans for use in more regular or routine circumstances,

— incorporate the specific requirements of national legislation, and

— design and develop a sampling plan for use on a case-by-case basis.

This document is applicable to sampling of soil and soil material, more specifically, e.g.

— soil in the landscape,

— soil stockpiles,

— potentially contaminated sites,

— agricultural soils,

— landfills, and

— forest soils.

Ultimately, the sampling plan provides the sampler with detailed instructions on how sampling should be carried out.

NOTE 1 There might be a need for more than one sampling plan to meet all the requirements of the investigation programme.

NOTE 2 It might sometimes be appropriate to divide a site or above-ground deposit (e.g. stockpile) into two or more zones and to develop separate sampling plans for each zone. For example, a (potentially) contaminated site might be zoned on the basis of past use, future use, topography or geology and an agricultural site on the basis of known or suspected soil types or use (pasture, type of crops, etc.).

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

No terms and definitions are listed in this document.

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

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

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

4 Preparation of a sampling plan

4.1 Principle

A sampling plan should be completed prior to undertaking any sampling.

The principles laid out in this document can be used to produce a sampling plan for any investigation programme. A checklist for the sampling plan is provided in Annex A.

The essential elements of the investigation programme (see Figure 1) should be addressed when defining a sampling plan (see Figure 2). This standardized process can be used in the three situations as described in Clause 1.

By providing specific and practical instructions to the sampler, the sampling plan defines the boundaries and logistics of the sampling element of the investigation programme in an unambiguous way.

The sampling plan shall

a) meet the requirements arising from other key elements in the investigation programme,

b) set out the sampling design arrived at following consultation with involved parties (see 4.2.2),

c) provide specific instruction for when, where and how samples or increments are to be taken, the number of samples or increments to be taken and by whom they are to be taken,

d) provide specific instructions as to whether and how coarse grained and heterogeneous soil materials are to be sampled, and

e) provide all necessary health and safety precautions to be taken by the sampler (see ISO 18400-103).

NOTE 1 The specific details contained within any sampling plan will differ according to the objectives of the investigation programme.

In the process of defining a sampling plan, the specific objectives of the investigation programme are translated into practical instructions to the sampler. The sampling plan therefore details all the information pertinent to a particular sampling exercise and instructs the sampler how the sampling is to be carried out. Basically, the sampling plan specifies how the objectives of the investigation programme can be achieved for the situation under investigation. In order to facilitate the understanding of the sampling plan and allow the sampler to judge whether changes to the sampling plan can influence the quality of sampling, the sampling plan should normally specify the objective of the investigation programme, as well as the technical objectives derived from it.

NOTE 2 Biological sampling is very specific (see also ISO 18400-206[2)]).

NOTE 3 Figure 2 is mainly based on the assumption that samples will be used for chemical analysis. When other forms of testing are required, the key elements can be different.

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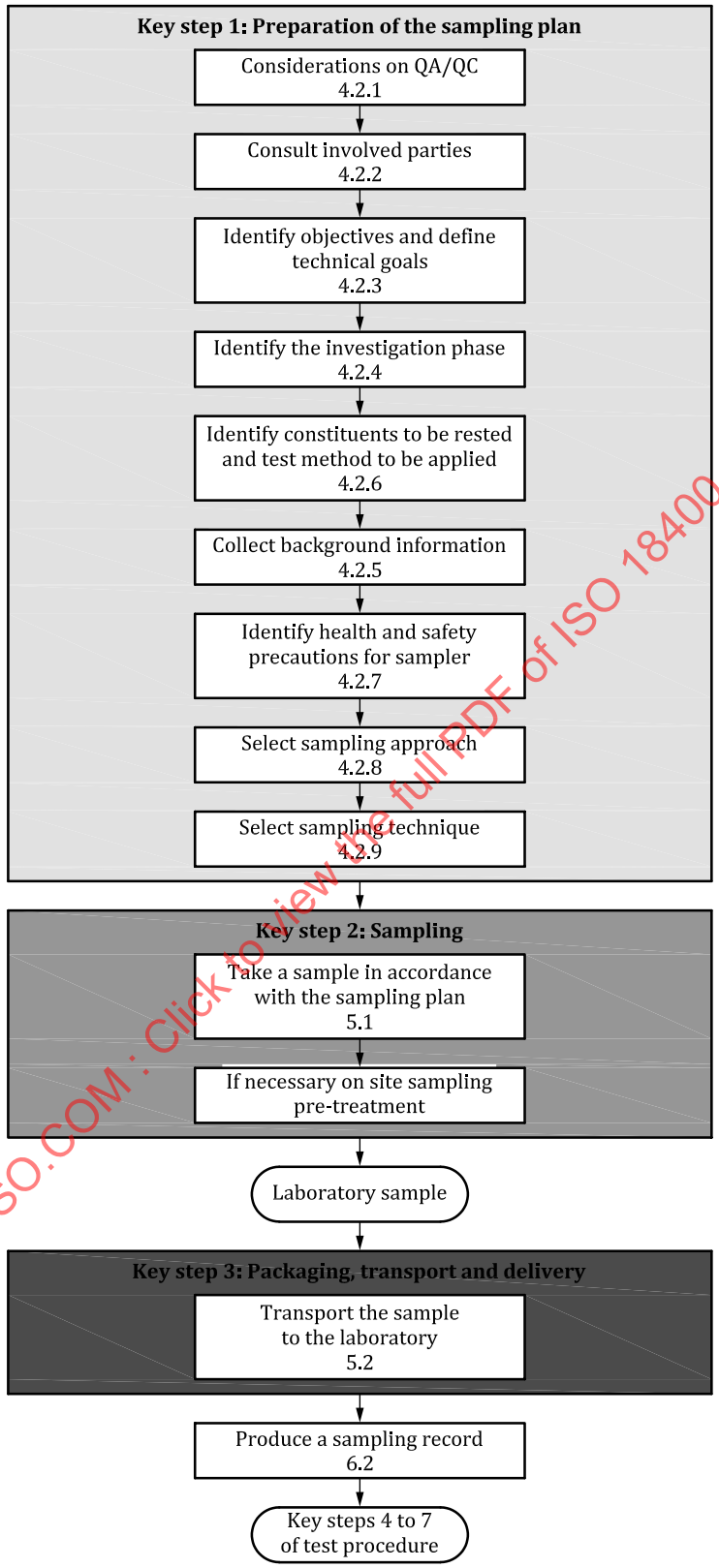

Figure 2 — Key elements for the essential elements for the sampling process (for all essential elements, see Figure 1)

4.2 Key elements of a sampling plan

4.2.1 Quality assurance (QA) and quality control (QC)

Considerations coming from the QA/QC perspective might influence on the sampling to be performed (see ISO 18400-106).

4.2.2 Involved parties

The sampling plan should be prepared in consultation with all appropriate involved parties. Such parties include, for example, the sampler, the analyst, the client, the owner and the regulator.

NOTE 1 The client might be the owner or the user of the soil or soil material, but could also have a different position.

NOTE 2 In cases where the level of complexity is low, a number or all of these roles can be the responsibility of one individual, although responsibilities might still differ. For example, the designer of the sampling plan can be from the organization undertaking the testing and might act as the sampler.

4.2.3 Objectives of the investigation programme

Definition of the objective(s) of the investigation programme by the appropriate involved parties is an essential element towards defining the type and quality of information that is to be obtained through sampling.

NOTE 1 Under certain circumstances, it might be possible to meet a number of testing objectives using a single sampling plan; however, it is to be expected that different (sets of) samples will be required to fulfil different objectives. Despite the fact that sampling for different objectives can be performed simultaneously, a separate sampling plan will need to be defined for each objective, e.g. a sampling plan for the sampling of the topsoil on a former industrial site in order to establish the presence of diffuse contamination for a variety of constituents and a sampling plan for the sampling around an underground storage tank for oil at that same site in order to establish if the tank has been leaking.

NOTE 2 The objectives of the investigation programme might include the following:

— comparison of the test results with set quality levels (e.g. defined in (inter)national legislation);

— characterization of the site to underpin change of ownership;

— delineation of an area of contamination present on the site;

— determination of the constituents of interest;

— confirmation of the history of the site, its use, the hydrology, geology and pedology;

— provision of information requested by a regulator;

— determination of the (re)usability of the soil or soil material;

— determination of the leachability/total composition;

— assessment of the human health and/or environmental risks;

— assessment of the agronomic and horticultural properties.

The defined objective(s) of the investigation programme is an essential input to the definition of the sampling plan. The sampling plan should document and translate the objective of the investigation programme into practical and achievable technical objectives.

NOTE 3 The translation of the objectives into technical objectives is a critical element in the process of defining the sampling plan. It is advisable to consult the involved parties in order to ensure that the correct technical objectives are identified.

These technical objectives can be linked to specific data analysis requirements and a select number of statistical analytical tools that provide a consistent means of assessing and interpreting testing data. Such tools ultimately provide the means to verify whether the testing objective(s) have been met or not.

NOTE 4 This diversity of technical objectives affects the location and minimum requirements for the sampling exercise, as well as the number and volume of the samples. It is therefore important that both the objective and derived technical objectives of the investigation programme are clearly identified to ensure that the collected samples meet the objective.

The sampling plan should identify any anticipated restrictions or limitations which relate to the sampling key elements as identified in Figure 2 that might impact on the reliability of the testing data.

NOTE 5 Guidance on the characterization of soil and soil materials in relation to particular uses and potential impacts on human health and the environment, including appropriate physical, chemical and biological constituents, is provided in a number of International Standards in the ISO 18400 series (e.g. ISO 18400-203[3)], ISO 18400-205[3)]) and also in a variety of other International Standards including the following:

— the assessment of the impact of petroleum hydrocarbons (ISO 11504);

— the characterization of soil related to groundwater protection (ISO 15175);

— the characterization of excavated soil and soil materials intended for reuse (ISO 15176);

— the ecotoxicological characterization of soil and soil materials (ISO 15799);

— the characterization of soil with respect to human exposure (ISO 15800).

4.2.4 Investigation phase

The sampling plan should identify the investigation phase required to meet the technical objectives of the investigation programme. These will dictate the different types and frequency of investigation to be performed. It may specify a quantified level of uncertainty for the contribution of the sampling elements to the overall uncertainty of the investigation programme.

NOTE Examples of investigation phases (see ISO 18400-104[3)]) could include the following:

— obtaining site data with a limited investigation effort [e.g. the exploratory (phase 2) investigation for potentially contaminated sites];

— obtaining site data on a level suitable for informed decisions with respect to the spatial distribution of constituents and the risks to human health and/or environmental risks [e.g. as part of the detailed (phase 3) investigation for contaminated sites];

— comprehensive characterization, consisting of a thorough determination of the behaviour and properties of interest;

— compliance testing, consisting of (periodic) testing to determine compliance with specific conditions or reference conditions, e.g. legislation or contract;

— on-site verification, application of on-site screening methods, consisting of 'quick check' methods to establish consistency with other tests or other formulated documentation.

4.2.5 Background information

4.2.5.1 General

A preliminary (phase 1) investigation (ISO 18400-202) should always be carried out before designing and executing a field investigation.

The sampling plan should list all known physical, chemical, and biological characteristics of the soil and the constituents (suspected to be) present, including all known significant hazards, for as far as directly

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relevant for sampling and the integrity of the obtained samples. The sampling plan should identify operational procedures that could affect the chemical, biological or physical properties of the soil, taking into account the recommendations given in other International Standards for the investigation programme.

NOTE The client might supply general information on the soil or site to be sampled.

4.2.5.2 Site details

The sampling plan should identify details of the site location and restrictions to access, including any perceived hazards relating to the site or above ground deposit (e.g. high stockpiles, non-consolidated stockpiles). Any additional access problems encountered during sampling should be documented in the sampling record in order that any impacts on the quality of the collected samples can be evaluated.

NOTE This includes the presence of, e.g. buildings and infrastructure (e.g. utility lines) or UXO (Unexploded Ordnance) that hampers sampling at desired locations.

4.2.5.3 History of the site or origins of soil

The sampling plan should be based on knowledge of the site's history or the origin of the soil material in the soil stockpile. This information should be available as a result of a preliminary investigation.

4.2.5.4 Soil type and dimensions

The sampling plan should identify all known information relating to the soil type and dimensions of the stockpile or site to be sampled.

— For soil stockpiles or other above ground deposits:
  — origin and method of formation;
  — quantity;
  — soil type;
  — estimated water content;
  — estimated maximum particle size (D_{95});
  — number of stockpiles.
— For sites:
  — dimensions and spatial location of the site;
  — supposed extent of possible contamination (e.g. depth, area, distribution);
  — expected soil types;
  — for agricultural land: the land use phase, for example, ploughed, fallow, or standing crop, previous crop and next crop.

4.2.6 Identify constituents to be tested and test method to be applied

The sampling plan should identify the characteristics or constituents to be investigated. The identification can be based on the following:

— the history of the site, processes and activities performed on the site;

— observations during (previous) field work and reconnaissance;

— measurements made during (previous) field work and reconnaissance;

— the origin of the soil and therefore relevant target constituents;

— total volume or the area (the population) to be assessed;

— the requirement to conform to local and national regulations;

— information and requirements specified in contract;

— information agreed on between involved parties.

The target constituents and properties should be specified in the sampling plan.

Investigating characteristics or constituents does not per definition imply that samples are to be taken and sent to the laboratory for analysis. When defining the sampling plan, in addition to the identification of the characteristic or constituents of interest, also the appropriate method for characterization is to be considered; the consequences of which might influence the sampling plan.

4.2.7 Health and safety

The sampling plan should identify all safety precautions that need to be adhered to by the sampler. For further information on general health and safety aspects of sampling, see ISO 18400-103.

All sampling activities are potentially dangerous. A risk assessment should be carried out prior to undertaking the work and safety precautions identified to protect the sampler and minimize risks.

NOTE Compliance with this document does not confer immunity from (inter)national health and safety regulations and site specific regulations.

4.2.8 Defining the sampling approach

4.2.8.1 General

The sampling plan should identify when, where, by whom and how samples should be taken and collected to ensure that the samples are appropriate to meet the sampling objectives. The quantity of material sampled should be sufficient to meet the requirements as specified in the other documents in this series for the investigation programme. If required, the sampling plan should specify provision for replicate or other types of quality control samples (see ISO 18400-106). The sampling plan should include a justification for the selected sampling approach.

The sampling approach should address the following:

— the use of individual samples or composite samples;

— the increment size (when using composite samples);

— sample size (mass/volume);

— number of samples;

— the choice between probabilistic, judgemental and other forms of sampling, or a combination of approaches;

— sampling pattern, sampling locations, sampling depth;

— sampling frequency (when valid) (with dates clearly specified).

NOTE 1 ISO 18400-104[4)] gives guidance on possible approaches to sampling and the appropriate terminology that should be used.

NOTE 2 Composite samples are usually required in cases where the average concentration of a constituent in a defined horizon/layer is to be determined. Individual samples are required in cases when the distribution of a constituent or property over a defined area or with depth is required. More information on the use of individual or composite samples is given in ISO 18400-104[4)].

NOTE 3 Information on the determination of the increment and sample size and the number of samples linked to a specified level of uncertainty is given in ISO 18400-104[4)].

NOTE 4 When investigating a potentially contaminated site, sampling will most often not be restricted to the soil, but might include sampling of groundwater, surface water and/or soil gas. Guidance on the investigation of potentially contaminated sites is given in ISO 18400-203[4)]; guidance on the investigation of soil gas is provided in ISO 18400-204. Guidance on the sampling of groundwater is provided in ISO 5667-11.

NOTE 5 The choice between probabilistic sampling and judgmental sampling is fundamental. Only in probabilistic sampling can the uncertainty of the results be statistically estimated. This does not imply, however, that there is a preference for probabilistic sampling. The sampling objective determines which approach serves the objective better. Only after making a decision about the approach, can an appropriate sampling pattern be chosen. Note that probabilistic sampling sets very specific demands for the sampling pattern.

NOTE 6 Judgemental sampling is, predominantly, used early in investigations and when investigating (potentially) contaminated sites.

NOTE 7 Sometimes not all samples are sent for laboratory analysis. The selection can be based upon field measurements as well as field observations.

4.2.8.2 Timing of investigation

In some circumstances, it may be necessary to restrict sampling to specific periods of the year.

If the characteristic or constituent to be determined is likely to be affected by seasonal factors or human activities (weather, soil conditioning/fertilization, use of plant-protective agents), this should be taken into account in the design of the sampling programme. This is particularly important where monitoring lasts several months or years or is continued periodically and therefore requires similar preconditions every time sampling is carried out.

4.2.9 Identify sampling technique

4.2.9.1 General

The sampling plan should identify the technique(s) selected to collect the samples and should identify the consequences of deviation from the designated sampling technique or equipment.

NOTE Information on the type and use of sampling techniques is given in ISO 18400-102.

4.2.9.2 Procedures for sub-sampling in the field

The sampling plan should identify any requirements for the production of composite samples from incremental samples and for sub-sampling in the field. The methods required to complete these procedures to produce the laboratory samples should be stated in the sampling plan.

NOTE Information on methods to reduce the sample size for presentation to the laboratory is given in ISO 18400-201.

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4.2.9.3 Procedures for packaging, preservation, storage, transport and delivery

The sampling plan should identify the procedure(s) selected for packaging, preservation, storage, and transport of the laboratory samples, taking into account the requirements specified in the remaining standards for the investigation programme.

The sampling plan should define how samples that are not sent for laboratory analysis shall be stored and for how long and to dispose of them if they are not in due course sent to a laboratory.

NOTE Information on methods for sample packaging, preservation, storage, transport and delivery is given in ISO 18400-105.

5 Sampling

5.1 Taking the samples

Before sampling begins, all elements of the sampling plan should be checked and a description of the soil or site to be sampled should be made by the sampler and checked against any information in the sampling plan.

A documentation should be made of the stockpile or location to be sampled, describing the status of the stockpile or site to be sampled. An appropriate method might be to photograph the sampling location in addition to documenting the sampling locations on a map.

Sampling should be performed as specified by the sampling plan.

If full implementation of the predetermined sampling plan proves not to be feasible in the field, then the sampling plan should be amended taking into account the guidance below:

a) changes that do not affect the objective of the investigation programme in that the required samples are obtained and remain representative at the pre-defined level – the sampler in the field can carry out this level of change;

b) changes which (could) affect the objective of the investigation programme (e.g. resulting in a different quantity of samples/results) – this level of alteration to the sampling plan should only be carried out with written prior agreement between the involved parties.

NOTE Unforeseen practical considerations can make it necessary to change the sampling plan in order to carry out the sampling activity. It is therefore important that the person undertaking sampling is in a position to know what changes are possible without affecting the investigation programme.

The samples should then be taken and collected in accordance with all instructions provided in the sampling plan.

All identified safety requirements shall be adhered to during the sampling exercise (see 4.2.7).

Having obtained the sample, it should be stored either directly in a suitable sample container or after appropriate sub-sampling in the field.

On completion of sampling, a sampling report and chain of custody form should be completed by the sampler (see 5.2 and 6.2).

5.2 Delivery

The samples should be delivered to the testing laboratory at the address stated in the sampling plan and should be accompanied by the chain of custody form (see ISO 18400-105).