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**Measurement of radioactivity in the  
environment — Soil —**

Part 2:  
**Guidance for the selection of the  
sampling strategy, sampling and pre-  
treatment of samples**

*Mesurage de la radioactivité dans l'environnement — Sol —*

*Partie 2: Lignes directrices pour la sélection de la stratégie  
d'échantillonnage, l'échantillonnage et le prétraitement des échantillons*



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## Foreword

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

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

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

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

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: [Foreword — Supplementary information](#).

The committee responsible for this document is ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This second edition cancels and replaces the first edition (ISO 18589-2:2007), which has been technically revised.

ISO 18589 consists of the following parts, under the general title *Measurement of radioactivity in the environment — Soil*:

- *Part 1: General guidelines and definitions*
- *Part 2: Guidance for the selection of the sampling strategy, sampling and pre-treatment of samples*
- *Part 3: Test method for gamma-emitting radionuclides using gamma ray spectrometry*
- *Part 4: Measurement of plutonium isotopes (plutonium 238 and plutonium 239+240) by alpha spectrometry*
- *Part 5: Measurement of strontium 90*
- *Part 6: Measurement of gross alpha and gross beta activities*
- *Part 7: In situ measurement of gamma-emitting radionuclides*

## Introduction

This International Standard is published in several parts to be used jointly or separately according to needs. ISO 18589-1 to ISO 18589-6 concerning the measurements of radioactivity in the soil, have been prepared simultaneously. These parts are complementary and are addressed to those responsible for determining the radioactivity present in soils. The first two parts are general in nature. ISO 18589-3 to ISO 18589-5 deal with radionuclide-specific measurements and ISO 18589-6 deals with non-specific measurements of gross alpha or gross beta activities. ISO 18589-7 deals with the measurement of gamma emitters radionuclides using *in situ* spectrometry.

Additional parts can be added to ISO 18589 in the future if the standardization of the measurement of other radionuclides becomes necessary.

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# Measurement of radioactivity in the environment — Soil —

## Part 2:

## Guidance for the selection of the sampling strategy, sampling and pre-treatment of samples

### 1 Scope

This part of ISO 18589 specifies the general requirements, based on ISO 11074 and ISO/IEC 17025, for all steps in the planning (desk study and area reconnaissance) of the sampling and the preparation of samples for testing. It includes the selection of the sampling strategy, the outline of the sampling plan, the presentation of general sampling methods and equipment, as well as the methodology of the pre-treatment of samples adapted to the measurements of the activity of radionuclides in soil.

This part of ISO 18589 is addressed to the people responsible for determining the radioactivity present in soil for the purpose of radiation protection. It is applicable to soil from gardens, farmland, urban, or industrial sites, as well as soil not affected by human activities.

This part of ISO 18589 is applicable to all laboratories regardless of the number of personnel or the range of the testing performed. When a laboratory does not undertake one or more of the activities covered by this part of ISO 18589, such as planning, sampling, or testing, the corresponding requirements do not apply.

### 2 Normative references

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

ISO 31-9, *Quantities and units — Part 9: Atomic and nuclear physics*

ISO 11074, *Soil quality — Vocabulary*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 18589-1, *Measurement of radioactivity in the environment — Soil — Part 1: General guidelines and definitions*

### 3 Terms, definitions, and symbols

For the purposes of this document, the terms, definitions, and symbols given in ISO 31-9, ISO 18589-1, ISO 11074, and the following apply.

- $e$  thickness of the layer sampled
- $m_{SS}$  wet mass of the sorted sample
- $m'_{SS}$  wet mass of a subsample of the sorted sample
- $m_{tS}$  dry mass of the test sample
- $a$  activity per unit of mass of the test sample
- $A_S$  activity per unit area

*S* surface area sampled

## 4 Principle

The purpose of the measurement of soil radioactivity is to monitor the environmental impact of radioactive substances<sup>[1]</sup> and/or to assess the radiological impact on the population.<sup>[2],[3],[4],[5]</sup>

The main objectives of the measurement of radionuclides in soil (see ISO 18589-1) are the following:

- characterization of radioactivity in the environment;
- routine surveillance of the impact of radioactivity released from nuclear installations or of the general evolution of the radioactivity in a region;
- investigations of accidents and incidents;
- planning and surveillance of remedial action;
- decommissioning of installations or the disposal of materials.

Consequently, measurements of soil radioactivity are performed in a variety of situations, but a generic approach can be described, with the following steps as outlined in this part of ISO 18589:

### a) Planning process — Selection of the sampling strategy

The selection of the sampling strategy depends on the main objectives and on the results of the initial investigation of the area. The sampling strategy shall lead to the knowledge of the nature, activity concentrations, spatial distribution, as well as temporal evolution of the radionuclides, taking into account changes caused by migration, atmospheric conditions, and land/soil use.

An initial investigation of the area shall be carried out to determine the sampling strategy.

ISO 10381-1<sup>[6]</sup> gives general guidance on the selection of the sampling strategy; ISO 10381-4<sup>[7]</sup> gives specific guidance for the investigation of natural, near-natural, and cultivated areas; and ISO 10381-5<sup>[8]</sup> deals with the investigation of soil contamination at urban and industrial sites.

Details are given in [Clause 5](#) and a scheme for the selection of the sampling strategy is given in [Annex A](#).

### b) Planning process — Sampling plan

The sampling plan shall be developed according to the sampling strategy selected. It shall specify the selection of sampling areas and units, the sampling pattern, the sampling points, the types of samples, the sampling procedures and equipment, as well as the safety requirements for the personnel.

Details, such as the selection of sampling areas and the sampling units that result from the type of grid applied to these areas, are given in [Clause 6](#). Definitions of the types of sample are given in ISO 18589-1. The relationship between sample types is given in [Annex B](#).

### c) Sampling process — Collection of samples

The collection of any soil samples in the field shall conform to the established sampling plan.

- For sampling of the top layer, a *single sample* or *n increments* of a defined thickness are taken from each of the selected sampling units.
- For vertical sampling of several soil layers, samples are taken at increasing depth vertically below the surface sampling point. A *single sample* or *n increments* are collected from the various soil layers with different thicknesses according to the sampling depth. Special care should be exercised in order not to mix samples from different soil layers.

Details are given in [Clauses 6](#) and [7](#).

## d) Sampling process — Preparation of the sorted sample

The preparation of *sorted samples* is carried out by the reduction of single or composite samples. A sorted sample should be representative of the average value of one or more given soil characteristics. The identification, labelling, packaging, and transport procedures of sorted samples to the laboratory shall guarantee the preservation of their characteristics.

Details are given in [7.3](#), [7.4](#), and [7.5](#).

## e) Laboratory process — Handling of the laboratory sample

After arrival at the laboratory, the sorted samples are considered as *laboratory samples* for storage and further pre-treatment before their analysis.

Details are given in [Clause 8](#).

## f) Laboratory process — Preparation of the test sample

Before any testing, the laboratory samples are pre-treated by drying, crushing, sieving, and homogenizing to produce *test samples* in the form of a fine, homogeneous powder. Pre-treatment shall guarantee that the physical and chemical characteristics of the test sample are constant over time, thus rendering the results easier to interpret. Representative subsamples with masses determined by the specifications of the different radioactivity measurements shall be isolated from the test sample as test portions.

Details are given in [Clause 8](#).

If some material is stored for future investigations or for the purpose of settling a potential dispute, subsamples shall be taken from the laboratory sample or the test sample in an acceptable and documented manner.

## 5 Sampling strategy

### 5.1 General

During the planning process, the sampling strategy for the site under investigation is determined according to the objectives described in [Clause 4](#) item a), resulting in the definition of a sampling plan. [\[1\],\[2\],\[4\],\[9\],\[11\],\[12\]](#)

### 5.2 Initial investigation

Whatever the objective of the work being carried out, certain preliminaries shall be undertaken during the initial investigation phase to help define the sampling strategy, such as the following:

- analysis of historical and administrative data, company archives, previous studies, and interviews with former employees, which help identify potential sources of radioactive contamination;
- collection of information on geological, hydrological, and pedological characteristics and on the main climatic parameters, in order to characterize the spatial and temporal development of the characteristics of the radioactivity of an area;
- survey of the site under investigation to identify its topography, the nature of the vegetation cover, and any peculiarities that can affect the techniques and the sampling plan;
- for farmland, collection of information from the farmers on the nature and depth of works (subsoiling or drainage, ploughing and harrowing ditches, etc.) and on chemical fertilizers and additives that can lead to excessive natural radioactivity (nature and quantity of products applied).

When data on radioactive soil contamination are not available or in case of suspicion of contamination, *in situ* analytical investigation using portable detectors or some preliminary sampling and subsequent laboratory analysis can be necessary in order to select the sampling areas and strategy.

### 5.3 Types of sampling strategies

Sampling strategies are either orientated or probabilistic depending upon the objectives and the initial knowledge of radioactivity distribution over the area under investigation.

Orientated strategies are based on *a priori* constraints that lead to a selection of sampling units in a specific area under special scrutiny because of particular interest or level of contamination.

Probabilistic strategies are based on a selection of sampling units without any *a priori* constraints.

The selection of sampling units and points is described in [6.2](#).

### 5.4 Selection of the sampling strategy

The approach or sampling strategy shall be selected depending on the objective pursued and the relevant end points, for example the protection of humans and the environment, taking into account social and economic constraints. The sampling strategy selected should ensure that the radioactivity of the samples is representative of the distribution of radionuclides in the soil of the area under investigation. [\[1\]](#), [\[2\]](#), [\[4\]](#), [\[6\]](#), [\[9\]](#)

Although the strategy can only be defined on a case-by-case basis, the selection of the sampling strategy should follow these stages:

- analysis of the records, which enables an historic study of the sampling site, in particular of its previous use (identification of the source);
- evaluation of preferential migration pathways and/or accumulation areas;
- site reconnaissance with respect to the boundaries of the sampling areas and sampling undertaken;
- site reconnaissance: a rapid analytical investigation using portable radioactivity detectors can be used to characterize the distribution of the radioactivity of the areas to be studied.

This step in the planning process determines a large number of choices and can generate important and costly activities. It also includes the definition of the objectives of the data quality according to the parameters to be analysed.

[Annex A](#) gives a flow diagram that helps in the selection of a sampling strategy according to the objectives of the investigation.

The choice of the strategy determines the sampling density, the temporal and spatial distribution of the units from which samples are collected and the timing of the sampling, taking into account the following:

- potential distribution of radionuclide: homogeneous or heterogeneous ("hot" spots);
- characteristics of the environment;
- minimum mass of soil necessary to carry out all the laboratory tests; and
- maximum number of tests that can be performed by the laboratory for the study.

In many cases, a prediction of the possible presence of soil contamination and its distribution (homogeneous or heterogeneous) can be drawn up. It is then necessary to verify these hypotheses by an orientated sampling strategy. One variant of this strategy, which is systematic with selected representative sampling points, is adapted for the routine monitoring of sites whose radioactive origins and distribution patterns are known. This allows a more accurate definition of the number and location of the sampling points than a purely probabilistic sampling strategy. This subjective selection of the sampling points can be combined with a statistical approach to meet the quality requirements for the

interpretation. When the spatial radioactivity distribution is unknown, it is necessary to adopt an orientated spatially random strategy.

Probabilistic strategies with random sampling (random distribution of sampling points) are suitable only if the distribution of the radioactivity on the site is considered homogeneous. For a site with occasional heterogeneities (point sources), the implementation of a systematic sampling strategy that is dependent upon the degree of knowledge of the distribution of these heterogeneities in the different sampling areas is recommended.

When the objective of the investigation is the characterization of a recent deposit on the soil surface, such as in the case of fallout following a routine, authorized gaseous release, or an accident, the collection of the top layer is recommended.

When the objective is the study of a polluted site, where it is necessary to know the vertical migration of radionuclides with depth (in order to predict the potential contamination of the groundwater), samples from layers at various depths shall be collected. Layers can be defined either with the same thickness or as representative of the different soil horizons.

The sampling strategy leads to a set of technical options that are detailed in [Clause 6](#).

## 6 Sampling plan

### 6.1 General

The sampling plan is a precise procedure that, depending on the application of the principles of the strategy adopted, defines all actions to be realized in the field. The plan also defines the human resources needed for the sampling operation. The plan is directly linked to the purposes of the study, the characteristics of the environment of the site, the capacity of the laboratory testing facilities, and the objectives for the data quality requisite for the interpretation of the results of the measurements.

The sampling plan shall be set up on a case-by-case basis. The plan shall contain all information needed to perform the sampling, i.e. sampling areas, sampling units, location of sampling points in the sampling units, types of samples, single or composite, number of increments for composite samples, periodicity, required mass of a sample considering the planned tests, requirement for archiving the material, vertical distribution, etc.

### 6.2 Selection of sampling areas, units, and points

#### 6.2.1 General

After deciding on the sampling strategy, sampling areas and units are defined based on the results of the initial investigation. In some cases, the boundaries of sampling areas and the location of sampling units for routine surveillance/monitoring can be fixed by legal requirements, for example as in the operation of a new nuclear installation. They are defined as a result of the reference radiological study performed for the project. For accident investigations, the size of the sampling area and location of the sampling units can also be determined by the environmental conditions (wind strength and direction, topography, etc.) at the time of accident, as well as the variation of the source characteristics (radionuclides, activity, release duration, etc.).

For a probabilistic strategy, the sampling units can be selected either by systematic or random approaches whereas it cannot be done by a random approach for an orientated strategy.

For both strategies, the sampling points can be selected either by a systematic or a random approach.

On the same site, depending on the heterogeneity of the radioactivity distribution, a combination of these strategies can be applied to the different sampling areas.

### 6.2.2 Sampling for use with a probabilistic strategy

For a probabilistic strategy, the sampling areas, following their identification, are covered with a grid that defines the sampling units. The size of the grid mesh should take into account the surface area of the site and is also governed by the analytical capacity of the laboratory and the financial constraints that restrict the number of samples that can be analysed. The surface area of the grid units can range from a few square metres to several square kilometres depending on the site under investigation.

If a radioactivity map is available as a result of a preliminary *in situ* radiological inspection (see ISO 18589-7<sup>[24]</sup>), the grid mesh imposed on the sampling area can correspond to the grid adopted for the radioactive cartography. The radioactivity map can be denser where contaminated areas are suspected, or less dense in the presumed absence of contamination.

For systematic sampling, a sampling point is selected in each knot or centre of the sampling unit. The final number of sampling units that are eventually sampled depends on the heterogeneity of the environmental characteristics and on the access restrictions imposed by the topographical complexity of the area.

For random sampling, the sampling units are referenced and a number chosen at random.

When the purpose of the study is to investigate the impact on the environment of the contribution of a specific source of radioactivity, it shall be compared to the background activity level. The latter can be determined in an area assumed to be uncontaminated by the source under investigation (for example, not influenced by any effluent discharges from the plant under study) and is considered as the reference area.

### 6.2.3 Sampling for use with an orientated strategy

For an orientated sampling strategy, the sampling area is defined by the constraints imposed by the objectives of the investigation on the basis of the environmental data and the cartography results.

The sampling plan is based on a subjective selection of sampling units as a result of prior knowledge of the area and/or initial *in situ* radioactivity investigations.

When the objective is to collect the samples with the highest activity level and there are no radioactivity data available, a preliminary radiological investigation with a portable detector allows the creation of a map of the site that highlights the contaminated area(s) and helps to define the sampling plan with the precise location of the sampling unit (see ISO 18589-7<sup>[24]</sup>).

NOTE One of the aspects of this initial investigation is also to assess the risks of exposure of workers in charge of the sampling operation and, therefore, to define radiation protection measures, in particular, those to be implemented on-site relating to the protection of personnel against radiation.

In routine surveillance of a nuclear installation, the sampling unit can be chosen as the point of maximum concentration of the predicted fallout of gaseous discharges from the plant.

When the radioactivity of the soil and other components of the environment (air, water, bio-indicators, elements of the human food chain) is investigated simultaneously, then the selection of the sampling unit should take into account the presence of the other indicators.

### 6.2.4 Selection criteria of sampling areas and sampling units

Using the data of past environmental studies and visual reconnaissance of the site, sampling areas with homogeneous topological configuration and vegetation cover are identified. This requires the separation of elevated zones from sloping zones, herbaceous areas from bushy ones, forested areas from cultivated and ploughed areas, etc.

If possible, sampling units with a soil layer that has not been disturbed by human activity, and with a well-kept herbaceous cover, should be selected. The surface of the sampling unit shall be at least several square metres. Any disturbance shall be noted, indicating the scale, nature, and origin on the sample sheet.

The radioactive surveillance of disturbed soils may be carried out in addition to radioactivity investigation of plants in the field. For agricultural land, the upper layer with a thickness equal to the ploughed depth

may be considered as homogeneous, if contamination occurred before the zone had been ploughed. In the case of industrial or built-up land, material used for ground fill may be investigated, taking into account its intrinsic heterogeneity and the way it was deposited.

For routine surveillance, the sampling units that are regularly sampled over time have to be kept clear of trees and bushes.

When a description of the soil profile is called for by the sampling strategy, then the layer thickness shall be determined by pedological characteristics<sup>[13],[14],[15],[16]</sup> or by the expected rate of vertical migration of the radionuclides. Details of the sampling method for the collection of samples with depth are given in [7.2.3](#) and an example of a sampling plan is given in [Annex C](#).

For farmland, border effects, in particular, can be avoided by remaining at least 20 m inside the perimeter of the plot, unless otherwise specified in the objectives of the study.

### 6.3 Identification of sampling areas, units, and points

Sampling areas and units shall be identified by the following parameters:

- administrative district, name of the town, site, or commonly accepted name of location;
- name or reference of the sampling area and units;
- geographic coordinates established using a topographic map or a global positioning system.

The use of an official topographic map issued by a national body is recommended, with a sufficiently detailed scale of detail, for the delineation of area(s) limits and, if required, the limits and identification of the sampling units.

The sampling points are described by their geographical coordinates using a topographic map or a global positioning system.

### 6.4 Selection of field equipment

Equipment should be chosen in accordance with ISO 10381-2<sup>[23]</sup>. Particular attention shall be paid to the quality of the sampling equipment and, in particular, that the equipment used should not alter, i.e. allow the pollution or loss of, the radionuclides to be determined.

Depending on the sampling plan that defines the sampling depth and the nature of the soil required, the equipment used can be chosen from the following list:

- a) material for setting the boundaries: posts, tapes, etc.;
- b) for surface or near-surface samples: shovel, coring tool such as metallic frame, gouge auger, gimlet, straight probe, spade (equipment shall be cleaned between sampling);
- c) for samples up to a depth of 2 m: auger or construction machinery, such as
  - mechanical digger with bucket to dig a trench from which samples are taken (attention shall be paid to weak walls in crumbly or disturbed soils);
  - mechanical or hydraulic thrust sampling tube;
- d) for samples at depths greater than 2 m: a core driller equipped with drilling tubes made of material that does not react with the soil;
- e) equipment common to all samples:
  - stainless steel spatula or knife;
  - container(s) with a capacity of at least 10 l;

- clean, dry canvas sheets that do not react with soil, measuring approximately 2 m<sup>2</sup>;
- wide-necked bags, or bottles, or plastics boxes with a capacity of at least 2 l, which are moisture-resistant, waterproof, dustproof, and do not react with the soil;
- sample identification equipment: labels, markers, etc.;

During the investigation of volatile radionuclides, it is necessary to take particular precautions to avoid loss of volatiles during the collection and storage of samples.

- f) specific equipment used to determine surface activity:
- balances with a maximum range and sufficient accuracy;
  - measuring tape or gauge of sufficient length to measure the dimensions of the increments.

## 7 Sampling process

### 7.1 General

The sampling process is defined in the sampling plan and depends on the objectives of the study. The collection of samples and preparation of sorted samples are independent of the sampling strategy (probabilistic or orientated) selected. The objectives of the study are described in 7.2.1 for a given sampling unit for sampling at the upper layers down to 20 cm and at deeper layers for the different applications.

The generic instructions presented in 7.2.2 to 7.2.3 are applicable to the following cases:

- initial characterization of radioactivity in the environment;
- routine surveillance of the impact of nuclear installations or of the evolution of the surrounding general territory;
- investigations of accidents and incidents;
- planning and surveillance of remedial action;
- de-commissioning of installations and disposal of soil from the site;
- specific advice is given on
  - investigation of the vertical distribution of radionuclides, including samples taken from a trench;
  - determination of the activity deposited in the soil.

### 7.2 Collection of samples

#### 7.2.1 Selection of sampling depth versus objectives of the study

##### 7.2.1.1 Initial characterization of radioactivity in the environment

For undisturbed soil, the depth of the layer or layers for sampling can be determined using either of the following two approaches.

- Uniform approach, with sampling performed at depths independent of the natural variations of the soil characteristics.<sup>[13],[14]</sup> For example, a surface layer can be sampled as a single unit down to 20 cm or, if a reference surface layer is needed to identify a potential future fallout, a surface layer can be sampled as two units, one from the surface down to a depth of 5 cm<sup>[17]</sup> and the second one to a depth down to 20 cm.<sup>[18]</sup>

- Non-uniform approach adapted to natural characteristics, in which the sampling layers<sup>[2]</sup> are determined by the depth of the root layer or the pedological characteristic of the profile. In the latter case, when different soil horizons are present, a corresponding number of separate samples should be taken for each horizon.

For soils disturbed by human activities, such as farming, two approaches are distinguished:

- a) uniform approach, with sampling performed at a depth specifically adapted to the local agricultural practice. For example, it can be performed down to a depth of 20 cm or more, depending on the ploughed depth;
- b) non-uniform approach adapted to the actual characteristics of the soil. For profile sampling, the surface layer is determined by the depth of the disturbed horizon and the lower layers by their pedological characteristics. In the latter case, when different soil horizons are present, a corresponding number of separate samples should be taken for each horizon.

### 7.2.1.2 Routine surveillance of the impact of nuclear installations or of the evolution of the surrounding general territory

Undisturbed soils for sampling are selected following a uniform approach as defined in 7.2.1.1. In order for samples to be comparable from one sampling operation to another, it is important to sample the soil in a part of the area that has not been sampled for at least one year. When a reference surface layer is defined during the initial characterization of the site, the same surface depth layer shall be used to identify the potential fallout.

If the physical and chemical properties of the soil are homogeneous in the sampling unit and if there is no potential evolution with time of its radioactive characteristics, sampling may be limited to one sampling point.

Soil increments can be taken using a suitable tool to collect a minimum mass, equivalent to 1 kg of dry soil for each sampling point. For the surveillance of the general territory performed by different groups, the sampling procedure shall guarantee that soil from the same depth is collected in order to compare the results (see 9.2).

### 7.2.1.3 Investigations of accidents and incidents

When an area is likely to be contaminated following an accident, surface sampling should be carried out as soon as it is technically feasible on the whole of the suspect area, taking into account the radiation protection principles. The objective is to determine the extent of the horizontal contamination and, in the event of heterogeneous diffuse pollution (source points identified), the resulting activity gradient.

As a measure of preparedness for an accident or incident, particularly suitable sampling units around facilities can be selected in advance to allow for adequate sampling immediately after an event.

In cases where the assessment concerns the determination of soil radioactivity following recent contamination, it is recommended to sample the surface level to a maximum depth of 5 cm. Since the measurement results shall be expressed in terms of surface activity, it is important to accurately determine the area of the sampled surface, the mass of the sorted sample and that of the laboratory sample. The depth of sampling increments shall be the same and documented (additional details are given in Clause 9).

In cases of past contamination, the sampling procedure shall consider the movement of radionuclides in the soil. Sampling of various levels to a maximum depth, dependent upon the vertical migration rates influenced by the soil characteristics as well as the chemical and physical properties of the radionuclides, shall be performed (additional details are given in 7.2.3).

When debris of installation, for example under the form of building materials, are identified on the site, their radiological characterization can be done to assess if they can be considered as a potential source of radionuclides and radiation exposure.

As fallout can contaminate heterogeneous sites restricting the number of ideal areas available for sampling, for example, in built-up or forested areas, the operation may be carried out in an open area away from housing and/or trees.

#### 7.2.1.4 Planning and surveillance of remedial action

This operation involves horizontal and vertical profile sampling across the entire area under investigation to determine the characteristics of disturbed soil at all levels. This can lead to an extension of the sampling depth to the point where the radionuclides in question are no longer detected. For farmland, the total depth of the sample shall be at least equal to the ploughed depth or to the depth of the root layer (whichever is greater).

Two cases are possible: either the contamination of the site is well known, as in the case of an ancient uranium-mining area, or the contamination, due to a past activity that was not registered, is only recently suspected.

In the case of well-defined contamination, protection measures usually have already been taken. The planning of remedial action can be done following the generic process described in the first paragraph above.

In the case of recently suspected radioactive contamination of the soil, which was discovered as a result of such reasons as a rumour, the request of an individual, the discovery by chance of past uses of radionuclides on a site, the status of the site shall be established and necessary steps for a rapid investigation shall be taken, regardless of the origin of the suspicion.

A gamma dose rate measurement can be carried out as a first step. In the event that the gamma dose rate is normal, a measurement can be carried out using a counter equipped with the appropriate detector. These rapid investigations along with historical research can help to confirm or dispel doubt.

When debris of installation, for example under the form of building materials or rubbles, are identified on the site, their radiological characterization can be done to assess if they can be considered as a potential source of radionuclides and radiation exposure.

If the doubt is not dispelled, protective measures can be taken and a more detailed investigation can be done. The planning of this investigation can be done following the generic process described in the first paragraph above. For the sampling unit to be examined, a series of at least five levels is sampled at every level of the disturbed soil. The surface layer is sampled to a maximum depth of 5 cm. The underlying layers are sampled by successive sections with a thickness equal to the height examined divided by the number of sampling levels. However, the thickness of each layer shall not exceed 10 cm for farmland and 50 cm for landfill sites. Moreover, sampling at each level shall not cause the soil horizons (farmland) or materials (landfill sites) to be mixed.

Samples for disturbed soil are taken following the recommendations given in [7.2.3](#).

#### 7.2.1.5 Decommissioning of installations and re-use of sites

The soil remedial operation and decommissioning of installations that have used radioactive materials can lead to the production of waste and materials to be managed according to national rules. Some of these materials such as rubble of building materials can be re-used or disposed as waste. Compliance with national requirements of their radioactivity levels has to be demonstrated for these materials.

The sampling strategy shall take into account the future use of the site. The sampling strategy for the characterization of waste for disposal and materials for re-use depends on whether the material is

- still spread over the area,
- arranged in piles,
- temporarily stored in bags, drums, or other containers, or
- loaded loose or in containers on trucks.

When contaminated soil or rubble of building materials is spread over an area, characterization of its radioactivity involves horizontal and vertical sampling across the entire area as described in [7.2.1.4](#).

Techniques, such as *in situ* measurements or the monitoring of truck loads for enhanced radioactivity, may also be undertaken but are covered by ISO 18589-7[24].

## 7.2.2 Sampling surface soil

### 7.2.2.1 General

When considering the sampling unit, part of the vegetation above the soil surface should be removed and saved, if necessary, at all sampling points (transfer pathway study, see [6.2.3](#)). Usual precaution has to be taken to avoid any sample cross-contamination during sampling. In a situation where there is a soil level of high activity concentration, the device can be contaminated and thus shall be cleaned between each sampling point.

### 7.2.2.2 Core sampling

Insert the core into the soil down to the desired depth (5 cm or greater) below the soil surface, depending on the objectives of the study. Remove the core and the soil plug, including the residual aerial part of the plant and the roots, is placed in an appropriate container. The operation is repeated for each sampling point of the sampling unit and the soil plugs are mixed into one composite sample.[17],[18]

The coring tool containing the soil plug can be transported to the laboratory, where the extraction, the combination of increments, and their possible reduction with the elimination of coarse elements can take place under conditions more favourable than those on-site.

### 7.2.2.3 Frame sampling

For some types of dry, loose soil, a square frame, 20 cm side with a height of 5 cm,[18] or a ring of 10 cm in diameter and 5 cm deep,[17] can be used. The frame is pressed into the soil surface. The soil inside the frame is removed with a small scoop to the depth of 5 cm and placed in an appropriate container. The operation is repeated at each sampling point of the sampling unit and the soil increments are mixed into one composite sample.

## 7.2.3 Sampling soil profile

### 7.2.3.1 General

This operation involves sampling to determine the extent of contamination at depth and the gradient of the activity concentrations. Sampling is carried out to a depth depending on the pedological characteristics and the objectives of the study. Depending on the depth where activity is encountered or which is sampled, it might be necessary to drill boreholes.

For soils that are cohesive and easy to penetrate to a few tens of centimetres, samples can be taken using a coring tool with an internal sheath, which is filled to the depth of penetration. For other soils, samples can be taken either from a trench to a depth of approximately 2 m, or from cores extracted by tubes in the course of core drilling down to a depth of several metres (see [7.2.3.2](#) and [7.2.3.3](#)).

**NOTE** The trench technique is preferable to other techniques because it allows a better observation of soil horizons with a minimum of disturbance.

For soils with natural or artificial macroscopic heterogeneities (contraction gaps in clay soils, drainage ditches, etc.) that can be preferred migration channels, it is recommended, except where necessary, that samples be taken outside of these structures. Any anomaly encountered shall be noted on the sample sheet.

For very permeable soils (e.g. sand) leading to deeper migration of radionuclides than other soils, sampling shall be continued to a soil horizon where the radionuclides in question are no longer detected.

When layers are sampled by successive sections with a thickness equal to the total profile depth examined divided by the number of sampling levels, care shall be taken to prevent overlapping of sample layers from different soil horizons.

A description of the soil indicating the soil horizons, their physical characteristics (colour, texture, structure, coarse-element content, etc.) shall be joined to the sample file to aid in the interpretation of the results.

### 7.2.3.2 Samples taken from a trench

A trench is dug, with suitable equipment, having a sufficient cross-section (e.g. 0,5 m to 1 m wide with a length of 2 m to 4 m) to observe the full range of the stratification profile (log) of the excavated soil. The dimensions of the trench are determined according to the tool used (e.g. mechanical digger with bucket), the depth to be reached (on average 2 m), and the nature of the soil.

The vertical wall of the trench is scraped using a knife to find the soil horizons that are not compacted or contaminated by the digging instrument.

Increments with a minimum mass of 1 kg are taken from this wall manually using a spatula and from each horizon with stated dimensions, while avoiding mixing separate soil horizons. The number of increments per horizon is defined according to the dimensions of the sampling unit and the required test-sample mass.

Particular care shall be taken to prevent soil falling into the probe trench before and during sampling. The increments from the same horizon are placed in a clean container or plastic bag. The resulting composite sample is mixed thoroughly using a shovel or other suitable tool. During the operation, the clods are broken up and the coarse elements larger than 2 cm are removed (or collected separately, depending on the objective of the study).

### 7.2.3.3 Samples at depth by core drilling

First, a surface sample with a minimum mass of 1 kg of dry matter and from a maximum depth of 5 cm is taken using a suitable piece of equipment as described in [7.2.2.3](#).

Second, the samples at depth are taken to the required depth by core drilling using suitable equipment. The core(s) is (are) removed and then extracted from the coring tool onto a clean, inert, dry surface. The direction of the cores (top-bottom) and the depths of the samples are marked.

When using a uniform approach with predefined depth layers, the cores are cut starting from the surface layer and are sliced into a minimum of five sections (including the surface layer sampled separately), while avoiding mixing the different soil layers. These sections constitute the increments of the different layers sampled.

When using a horizon approach, the cores are cut starting with the surface layer and are sliced according to the boundary of the different soil horizons identified along the core length. These sections constitute the increment of the different horizons sampled.

The number of cores to be extracted, and consequently the number of increments per layer or per horizon, is defined relative to the diameter of the coring tool, the dimensions of the sampling unit, and the required test-sample mass.

The constitution of the composite sample and laboratory sample is described in [7.3](#).

When using a coring tool with an internal sheath, the sheaths can be removed from the coring tool for transportation to the laboratory, where the opening of the sheath, identification, and cutting of the sample horizons or layers, the combining of the increments from the same horizon or layer, and their possible reduction with the elimination of coarse elements can take place under conditions more favourable than those on-site.

### 7.3 Preparation of the sorted sample

The increments from the same sampling unit are placed in a clean container or plastic bag. The resulting composite sample is spread out over a clean, level, inert surface and mixed thoroughly using a shovel or other suitable tool. During the operation, the clods are broken up and the coarse elements larger than 2 cm are removed (or collected separately, depending on the objective of the study) in order to obtain a sorted sample.

For certain studies, the respective proportion of coarse elements compared to the mass of the sampled soil should be estimated and their radioactive characteristics measured. The petrographic nature or the anthropogenic origin for rubble and apparent porosity of the sample should be noted. Latest tests that require special techniques are not included in the scope.

The quartering technique (see ISO 11464<sup>[19]</sup>) can be used to split the sorted sample to obtain a subsample of approximately 1 kg of dry matter.

All sorted samples sent to the laboratory shall be identified and a sample sheet drawn up in conformity with the instructions in 7.4.

For a soil profile, the samples taken from different soil horizons shall not be mixed, unless otherwise required, and increments shall not be combined or undergo any homogenization or clod-crushing treatment when investigating radionuclides in the form of volatile compounds.

### 7.4 Identification and packaging of samples

#### 7.4.1 General

Each sample shall be packed in a container that does not react with the soil, is clean and carefully sealed to avoid loss of the contents or exposure to external agents (infiltration of water, dust, etc.).

The identification label shall be attached to the outside of the packaging.

#### 7.4.2 Sample identification

The label of the container shall identify each sample and contain the following information:

- code identifying the sample, the sampling area, and the sampling unit;
- date of sampling;
- additional information, such as the depth and thickness of the soil horizon sampled, may be added.

#### 7.4.3 Sample sheet

The sample sheet enclosed with the sample or series of samples shall include at least the following information:

- identification and characteristics of the sample (for example: location, depth, and thickness of the soil horizon sampled, etc.) as indicated on the packing label;
- sampling technique and the associated equipment;
- date and time the sample was taken;
- name of the operator;
- any observations necessary to interpret the results.

The topography of the sampling area, if uneven, is specified, particularly if the samples are taken from the following areas:

- 1) in low-lying areas (trenches, plough furrows, depressions, etc.);

- 2) on elevated areas (embankments, ridges, plateaus, etc.);
- 3) in areas where the underlying rock is exposed;
- 4) in marl pits, springs;
- 5) on the edge of the area.

When the study expresses the results of the analysis in terms of the surface activity (see [Clause 9](#)), the sheet shall also include:

- the surface area sampled,  $S$ ;
- the thickness of each layer sampled;
- the mass of the sorted sample,  $m_{SS}$ ;
- the mass of any sorted subsample,  $m'_{SS}$ .

This sheet is completed, where necessary, with:

- an evaluation of area homogeneity;
- a description of the use of the land;
- a description of samples. The information whether impurities such as large stones, roots, etc. were removed from the sample before packaging should be included in the sampling sheet;
- the weather conditions if samples are taken following an incident or accident.

For samples from several depths, the sample sheet shall be completed with a description of the soil horizons, indicating the different layers and their physical characteristics (colour, texture, structure, percentage of coarse elements, etc.).

Examples of sampling sheets for a single/composite sample and for a soil profile are given in [Annex D](#) and [Annex E](#), respectively.

## 7.5 Transport and storage of samples

The packaged samples and their sample sheets should be transported as quickly as possible to the laboratory for analysis.

Transport and storage conditions shall be such as to avoid all contamination of the material. The transport and preservation temperatures of the samples should be specified<sup>[18],[20],[21]</sup> where necessary, in the test report.

The following are particularly recommended:

- to avoid any warming of the sample during transportation to the laboratory and to use, where possible, insulated containers;
- to store the sample upon arrival at the laboratory at a temperature less than or equal to 4 °C and in the dark when necessary and if the time between sampling and treatment of the sample exceeds a few days; for longer periods, the sample may either be preserved in a freezer at -18 °C, or dried at a maximum temperature of 40 °C and preserved in an airtight package;
- to limit the time between sampling and radioactive analyses, especially when researching radionuclides with short half-lives;
- to take particular precautions in the case of the investigation of volatile, organically bound, or highly soluble radionuclides (iodine, tritium, chlorine, etc.) to avoid loss during the storage of the samples;

- to carry out the measurement as soon as possible after the sample is taken; if later tests include the determination of the bulk density of samples taken in their natural state, or even when the determination of their water content is performed, additional precautions are necessary to avoid compacting or loss of water.

## 8 Pre-treatment of samples

### 8.1 Principle

The physical processing of soil laboratory samples to measure radioactive nuclides requires drying, crushing, sieving, and homogenizing steps to be carried out.

Before any pre-treatment, a preliminary analysis of the laboratory sample by gamma spectrometry can allow detection of volatile radionuclides and, if so, the selection of the adequate pre-treatment procedure compatible with the quantification of their activity.

### 8.2 Laboratory equipment

The following equipment is necessary to carry out the pre-treatment of the laboratory sample:

- a ventilated drying room or drying cabinet with a temperature of  $(40 \pm 5)$  °C;
- a heated, ventilated oven with a temperature of  $(105 \pm 10)$  °C;
- equipment for the reduction of clods, possibly combined with a sieve, pestle and mortar, pounder, grinder, crusher, or grip breaker;
- a sieve with a 2 mm mesh size;
- a sieve with a 200 µm or 250 µm mesh size;
- a metal or plastic tray with raised edges;
- a mixer or ball mill;
- freeze-drying equipment (when appropriate).

### 8.3 Procedure

With consideration for the composition of the test sample, the following steps shall be carried out.

- Weigh the laboratory sample.
- Spread a thin layer of 1 cm to 2 cm of the entire initial test sample onto flat containers and manually break up the sample using a suitable instrument.
- Remove all remaining plant parts (tufts of grass, roots, etc.).
- Leave the sample to dry at ambient temperature or in a ventilated cabinet heated to a temperature less than 40 °C for 24 h to 48 h, according to the moisture in the sample.
- Break up the remaining clods of earth with suitable equipment.
- Separate the fine earth from the coarse elements using a 2 mm sieve and note their masses.
- Dry the powder at  $(105 \pm 10)$  °C to a constant weight. When measuring volatile radionuclides, it is better to freeze-dry the sample or dry it to a maximum fixed temperature of  $(40 \pm 5)$  °C.
- Crush with a mortar, a mixer, or a ball mill.
- Sieve using a 200 µm or 250 µm sieve, then homogenize the powder obtained.

- Repeat the crushing and sieving steps until the entire sample has been processed.
- Weigh the total powder and the unsieved material, then discard. Record the mass obtained. The powder part constitutes the test sample.

The above steps should be carried out in accordance with the procedures in ISO 11465[22] with respect to the drying temperatures and grain sizes. Any modification of the above procedure shall be justified and shall be included in the test report.

The operator is warned of the risks of possible contamination from the laboratory environment or by mixing the samples of different layers or origins. Where possible, the samples should be treated in increasing the order of activity.

When it is necessary to quickly obtain the results of radioactive analysis, the sample can be dried directly in the oven then crushed and sieved without being dried at ambient temperature.

The mass of removed parts such as plants, coarse elements, and water can be weighted.

When the radioactivity characterization of the unsieved material above 200 µm or above 250 µm, made of petrographic nature or of anthropogenic origin such as building materials rubble, is required, this material is crushed in order to obtain a homogeneous powder for testing.

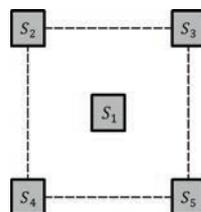
## 9 Determination of the activity deposited onto the soil

### 9.1 General

If the objective of the sampling is to estimate the total amount of the radionuclides deposited onto the soil, for example from fallout following radioactive gaseous effluent discharges from a nuclear installation or from past atmospheric nuclear tests, then samples shall be taken from depths of 5 cm and at least 20 cm to 30 cm, respectively. The thickness,  $e_i$ , and the surface area,  $S_i$ , of the sampled layer are noted.

### 9.2 Determination using surface activity data

A specific procedure can be deduced from the following generic example. It refers to the sampling of a regular square grid from which five increments are taken to make up a composite sample. For each grid, a composite sample is made up from the five increments taken from the centre and at the four nodes of the grids. Each increment is taken from a known surface area, for example using a frame of 20 cm on a side and a maximum depth of 5 cm. See [Figure 1](#).



**Figure 1 — Schematic sketch of a regular square grid and of its five increments with known surface area**

The sum,  $S$ , of the areas corresponding to the soil surface increments,  $S_i$ , for the five surface increments,  $i$ , is defined by Formula (1):

$$S = \sum_i S_i \tag{1}$$

The five increments from the same gridding are placed in a clean container or plastic bag. The resulting composite sample is spread out over a clean, level, inert surface and mixed thoroughly using a shovel or other suitable tool. During the operation, the clods are broken up and the coarse elements larger than

2 cm are removed (or collected separately, depending on the objective of the study). The resulting mass,  $m_{ss}$ , of the sorted sample is noted.

If the test-sample mass,  $m_{ts}$ , represents the whole mass of the sorted sample of the sampled layer, the surface activity,  $A_S$ , is calculated from the activity per unit of mass,  $a$ , using Formula (2):

$$A_S = a \times \frac{m_{ts}}{S} \quad (2)$$

The quartering technique (see ISO 11464[19]) can be used to split the laboratory sample to obtain a mass of 1 kg of dry matter. Then the test sample represents a mass fraction,  $m'_{ss}/m_{ss}$ , of the sorted sample and the surface activity is calculated using Formula (3):

$$A_S = a \times \frac{m_{ts}}{S} \times \frac{m_{ss}}{m'_{ss}} \quad (3)$$

### 9.3 Determination by integration of soil profile activity data

This operation involves sampling across the entire area affected by the deposition to determine the extent of the contamination on the surface and at depth. The surface layer is sampled to a maximum depth of 5 cm and the underlying layers are sampled in 10 cm sections, or at each change in soil horizon, until the radionuclides studied are no longer detected.

The surface activity,  $A_S$ , is computed from the activities per unit of mass,  $a_j$ , over a soil profile of  $j$  layers using Formula (4):

$$A_S = \sum_j a_j \times \frac{m_{ts,j}}{S} \quad (4)$$

The quartering technique (see ISO 11464[19]) can be used to split the laboratory sample to obtain a mass of 1 kg of dry matter. Then the test sample represents a mass fraction,  $m'_{ss,j}/m_{ss,j}$ , of the sorted sample and the surface activity is calculated using Formula (5):

$$A_S = \sum_j a_j \times \frac{m_{ts,j}}{S} \times \frac{m_{ss,j}}{m'_{ss,j}} \quad (5)$$

## 10 Recorded information

All steps and procedures carried out to establish the radioactivity of soil samples shall be completely traceable as specified in ISO/IEC 17025. This implies a complete documentation of the sampling strategy, the plan chosen, the sampling operations performed, and the chain of custody of the sample preparation.

Sheets detailing the sampling and laboratory steps shall be recorded. Each of such records shall be dated and signed by a responsible person to attest the correctness of the results. Any relevant information recorded during the different steps described in this part of ISO 18589 likely to have affected the results should be mentioned in the final test report.

Records of all relevant information on the measuring equipment needed for the confirmation process of a result shall be kept. These records shall demonstrate that each item of the measuring equipment (balance, oven temperature, etc.) satisfies the metrological requirements specified within the confirmation process for the equipment. Calibration certificates or verification reports and other relevant information shall be available.

## Annex A (informative)

### Diagram of the selection of the sampling strategy according to the objectives and the radiological characterization of the site and sampling areas

See [Figure A.1](#).

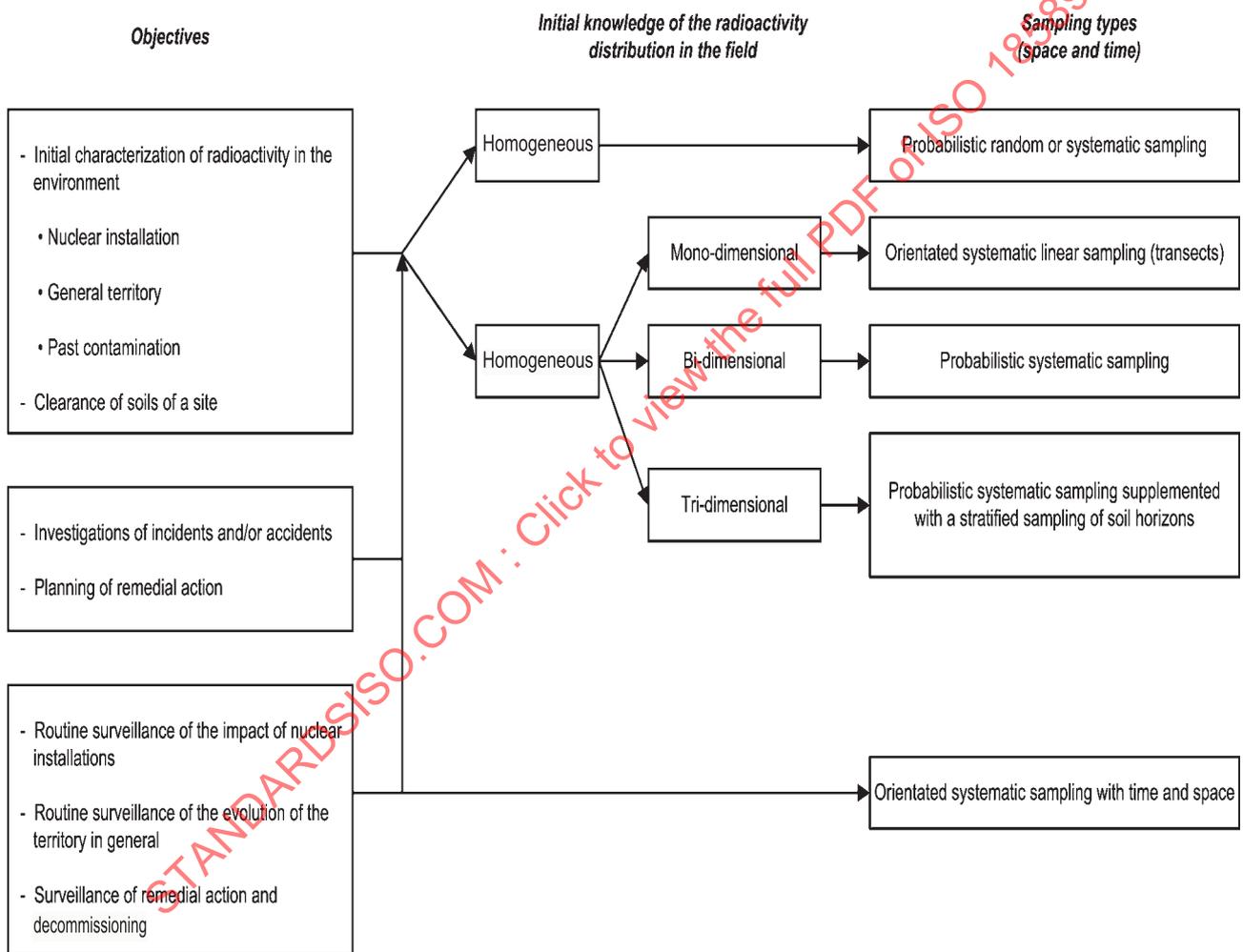


Figure A.1

## Annex B (informative)

### Diagram of the evolution of the sample characteristics from the sampling site to the laboratory

See [Figure B.1](#).

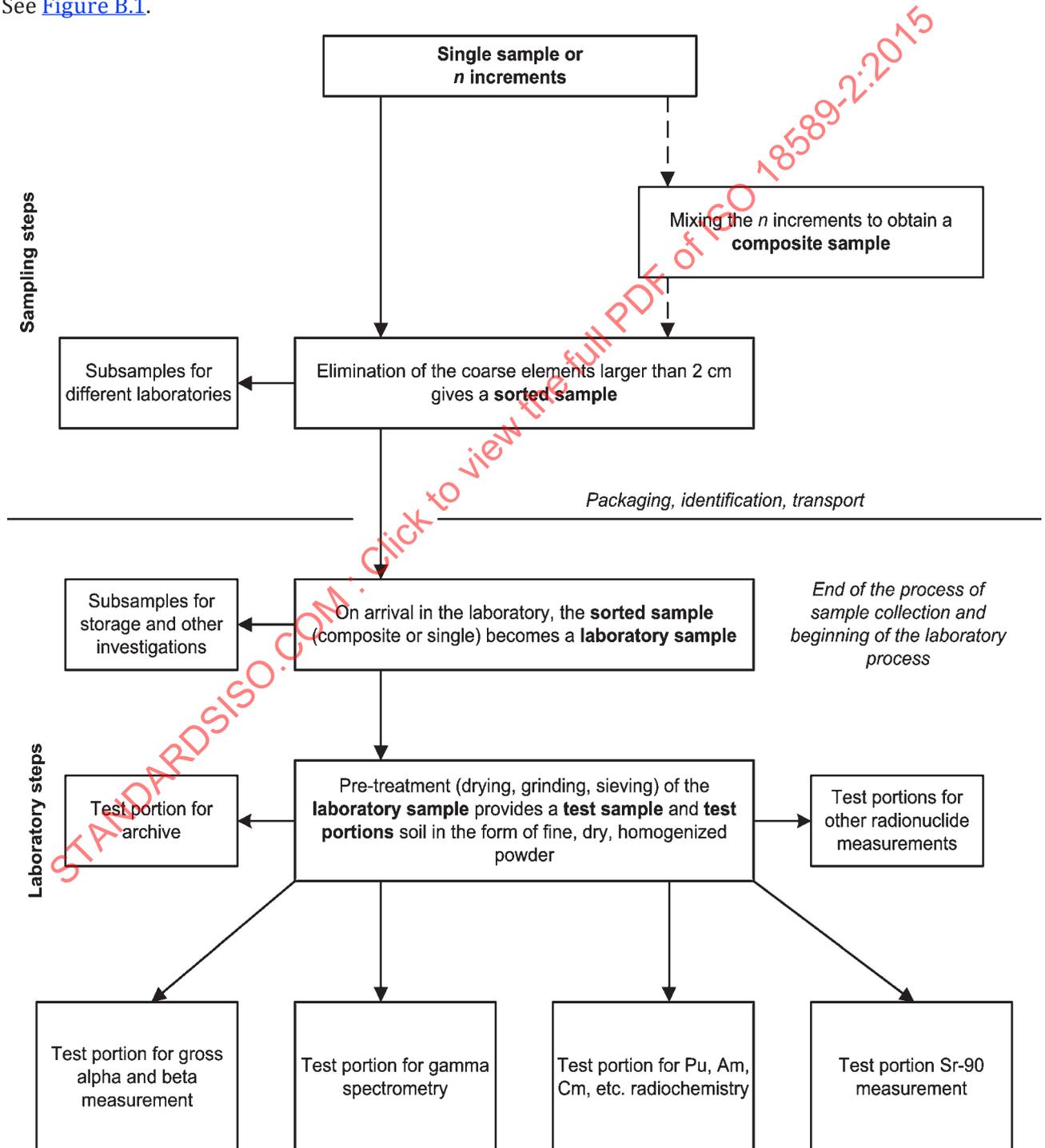


Figure B.1