INTERNATIONAL STANDARD

ISO 10381-4

First edition
2003-05-01

Soil quality — Sampling —

Part 4: Guidance on the procedure for investigation of natural, near-natural and cultivated sites

Qualité du sol — Échantillonnage —

Partie 4: Lignes directrices pour les procédures d'investigation des sites naturels, quasi naturels et cultivés

Reference number
ISO 10381-4:2003(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10381-4 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 2, *Sampling*.

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

— *Part 1: Guidance on the design of sampling programmes*

— *Part 2: Guidance on sampling techniques*

— *Part 3: Guidance on safety*

— *Part 4: Guidance on the procedure for investigation of natural, near-natural and cultivated sites*

— *Part 6: Guidance on the collection, handling and storage of soil for the assessment of aerobic microbial processes in the laboratory*

The following parts are under preparation:

— *Part 5: Guidance on investigation of soil contamination of urban and industrial sites*

— *Part 7: Guidance on the investigation and sampling of soil gas*

— *Part 8: Guidance on the sampling of stockpiles*

Introduction

This part of ISO 10381 is one of a group of International Standards intended to be used in conjunction with each other where necessary. ISO 10381 (all parts) deals with sampling procedures for the various purposes of soil investigation.

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

Soil quality — Sampling —

Part 4: Guidance on the procedure for investigation of natural, near-natural and cultivated sites

1 Scope

This part of ISO 10381 describes the sampling of soils of

— natural and near-natural sites,

— areas used for agriculture (arable and pasture sites),

— areas used for horticulture (including domestic gardens, allotments),

— areas used for special crop-cultivation, arboreal, vineyard, etc.,

— forest areas and woods.

It is applicable to

— soil investigations and evaluations in the field,

— chemical, geochemical, physical, biological and radiological characterization of soil and soil materials in the laboratory after sampling.

This part of ISO 10381, sets out appropriate strategies for the design of sampling programmes, field procedures and subsequent treatment of samples for transport and storage prior to sample pretreatment (e.g. drying, milling).

NOTE This part of ISO 10381 is intended to be used in conjunction with the other parts of ISO 10381 when appropriate.

2 Normative references

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

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

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

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

ISO 10381-5, *Soil quality — Sampling — Part 5: Guidance on investigation of soil contamination of urban and industrial sites*

ISO 10381-6, *Soil quality — Sampling — Part 6: Guidance on the collection, handling and storage of soil for the assessment of aerobic microbial processes in the laboratory*

ISO 11074-1:1996, *Soil quality — Vocabulary — Part 1: Terms and definitions relating to the protection and pollution of the soil*

ISO 11074-2:1998, *Soil quality — Vocabulary — Part 2: Terms and definitions relating to sampling*

ISO 11277, *Soil quality — Determination of particle size distribution in mineral soil material — Method by sieving and sedimentation*

ISO 11464, *Soil quality — Pretreatment of samples for physico-chemical analyses*

3 Terms and definitions

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

4 Objectives of sampling

The sampling strategy is mainly affected by

— the objective of the investigation,

— current and previous soil/land use.

The objective of investigations may be

— collection of information on general soil quality with regard to preservation and improvement of ecological soil functions,

— collection of information for evaluation of soil quality and nutrient supply or nutrient demand with regard to preservation and improvement of productivity of soils,

— collection of information for soil mapping, classification and taxation,

— collection of information for establishment and maintenance of soil monitoring areas,

— collection of information for replicate samples used for soil specimen banks or environmental specimen banks.

Table 1 gives information on different objectives and strategies for the sampling of soils.

More information about the objectives for soil sampling is given in ISO 10381-1.

Table 1 — Objectives of soil sampling

No.	Objectives	Land use	Average concentration	Spatial variability		Time change	ISO 10381 reference to Part
				horizontal	vertical		
1	Mapping	all	−	+	+	−	1, 2, 3
2	Classification	all	+	−	+	−	1, 2, 3
3	Monitoring	agricultural	+	−	+/−	+	1, 2, 3
		forestry	+/−	+	+	+	1, 2, 3
		natural	+/−	+	+	+	1, 2, 3
4	Taxation	all	+/−	+	+/−	plot	1, 2, 3
5	Improving soil function	all	+	−	−	+/−	1, 2, 3, 5
6	Maximum[a] loading	agricultural	+	−	+/−	+	1, 2, 3, 5
− not important +/− not too important + important							
[a] Nutrient supply/residues of pesticides and organic substances, metals in traces							

5 General principles, requirements and considerations of soil sampling

5.1 This clause summarizes general principles, requirements and considerations of soil sampling which should be taken into account for natural, near-natural and cultivated sites. ISO 10381-1 gives further information to be used in conjunction with this part of ISO 10381.

The aspects in 5.2 to 5.19 should be considered when developing a sampling strategy.

5.2 Selection of sampling locations should take into consideration uniformity of soil quality, land use and type of cultivation (the sampling locations should be representative of the total area to be sampled).

5.3 A field sampling pattern may be adopted to provide either single samples or incremental samples to be mixed, to provide a composite sample.

5.4 Selection of sampling points (e.g. for borings) for sampling the area or systematic (patternlike) point sampling.

5.5 Sampling patterns may be based on statistical models, numerical random distributions or systematic patterns.

5.6 Avoidance of locations such as dead patches, field margins, damp areas and other areas which obviously deviate from the average.

5.7 Types of sample, including

— disturbed samples (mass-proportional sampling, samples obtained without any attempt to preserve the soil structure);

— undisturbed samples (volume-proportional sampling, samples obtained using a method designed to preserve the soil structure).

5.8 Sampling of

— soil horizons (preferably for agricultural, forestry and natural land use);

— soil layers (e.g. artificial urban sites, mixed soils or forced by the objective).

5.9 Sampling procedure, e.g.

— probing,

— boring/augering,

— trial pit.

5.10 Sampling equipment.

Detailed guidance on the selection and application of suitable equipment is given in ISO 10381-2.

5.11 Depth of sampling in regard to the actual case and representativeness.

5.12 Time and frequency of sampling, depending on

— the objective of sampling,

— use of land (e.g. periodic sampling for soil fertility analysis),

— soil quality.

5.13 Sample quantity, depending on the type and extent of intended field and laboratory investigations and the need for bulk density determination. The following amounts are recommended:

— in the case of sandy, loamy and clay soils: up to 1 kg;

— in the case of peat soils and organic horizons from forest soils: up to 0,5 kg;

— in the case of soils with increasing fractions of gravel, cobbles and stones: greater masses are required (see ISO 11277).

Additional soil material is needed for preparation of replicate samples.

5.14 Sample containers:

— should have been shown not to contribute to the level of the determinant;

— should correspond to the objective of sampling;

— may require cooling in certain cases;

— should be suitable to avoid losses of volatile substances and water as well as losses by reaction with light (refined steel, fluorinated polymer compounds, aluminium, brown glass);

— should have suitable labels.

Bags can be used for collection of a number of smaller containers. Special bags are used for soil sample rings or drill cores.

5.15 Samples should be transported:

— as soon as possible and with cooling if necessary, e.g. for determination of mobile nitrogen in order to prevent losses caused by microbiological reactions;

— avoiding vibration as far as possible;

— avoiding loss of water by evaporation.

5.16 Storage, taking into account the following:

— in the case of short-term storage outside the laboratory and before the start of sample pretreatments in the laboratory, storage under appropriate conditions;

— in the case of recent preparation, storage of fresh sample(s) in a refrigerated room;

— in other cases, quick drying (40 °C)(see ISO 11464 for instructions).

5.17 Safety precautions: detailed instructions for safety aspects in relation to soil sampling are given in ISO 10381-3.

5.18 Quality control measures, conducted by technically qualified personnel with knowledge and experience in soil science, geological and hydrological aspects, including

— application of suitable sampling equipment to avoid cross-contamination, losses, etc.;

— application of reproducible sampling systems and procedures;

— off-site estimation of sampling variance.

5.19 Sampling report, to facilitate comparison of soil characteristics in soil inventories, land evaluation, etc., should

— include information on the site (location and utilization of the area, soil conditions, conditions of cultivation and climate, etc.);

— be supplemented by sketch maps of location, field maps, photographs, etc.

6 Special remarks

6.1 Number of samples in relation to agricultural objectives

In the case of uniform land use, soil quality and soil management, the number of samples taken should be as shown in Table 2.

Table 2 — Relationships between the number of samples and area to be sampled

Number of composite samples n	Area A ha
1	0 to 2
2	$>$ 2 to 5
3	$>$ 5 to 10
4	$>$ 10 to 15
5	$>$ 15 to 20
6	$>$ 20 to 30
For areas larger than those given, the following equation should be used to specify the number n of composite samples: $n = 1 + \sqrt{A}$	

6.2 Sampling for the determination of mobile nitrogen

The determination of mobile nitrogen is among the routine determinations in agricultural soil investigation, thus the procedures of sampling require special attention in order to obtain reliable results. Details are given in the following to address this special case.

The determination of the mobile (bioavailable and readily leachable) part of the total soil nitrogen provides important baseline data when making recommendations for nitrogen fertilization. In agriculture and horticulture, data on the nitrogen residuals after the vegetation period are also important in order to minimize leaching to groundwater.

Usually samples from three soil layers: 0 m to 0,3 m; 0,3 m to 0,6 m and 0,6 m to 0,9 m, are taken. There may be occasions when the specific needs of the investigation dictate that layers of incremental resolution greater than 0,3 m are required. Thus, the actual supply of mobile nitrogen can be determined and evaluated. Sampling can be carried out manually or by use of machinery. Up to 15 incremental samples, obtained with regard to site and layer, form a composite sample. To avoid losses of mobile nitrogen, the composite samples should be stored at 4 °C in a refrigerated box in darkness and transferred to the laboratory. It is strongly recommended that sampling, transport, pretreatment and analysis be carried out in as short a time as possible.

Consideration should be given to the maximum root depth of plants in order to increase or decrease the number of layers to be analysed.

6.3 Forest soils

For the investigation of forest soils, a special approach is required for the selection of sampling points. Within a forest unit of area, for example, at least 10 sampling circles should be selected in a pattern so that each of the circles encloses approximately the same number of trees. From these sampling circles, near-trunk zones (approximately 1 m distance from trunks), areas in between, and canopy areas are sampled. Incremental samples obtained in this way may be used to form horizon-related composite samples per unit area.

6.4 Peat soils

In the case of peat soil layers close to the surface and peat soils for agricultural use, the top soil can be sampled using hand augers. Peat probes are suitable for sampling at greater depth or at groundwater level. Preparation of trial pits is appropriate in some cases. Sampling is then usually carried out at different depths, e.g. 0,10 m, 0,30 m, 0,50 m, 1,0 m and 1,5 m.

6.5 Saturated-zone soils

Special procedures are required for sampling water-saturated soil (influenced by groundwater) in order to avoid negative influences on structure and physical properties as well as loss or displacement of substances of interest. See ISO 10381-2 for further information.

6.6 Special types of land use

For fruit or arboreal cultivation, the sampling pattern should be arranged symmetrically with the tree trunk in the centre. Sample spacing and depth vary in relation to planting type and location.

At least 15 incremental samples should be taken for a composite sample. Sampling between two rows of trees at one point at different depths can be as useful as taking samples at several points between trees. This also applies to soft fruit cultivation. Sampling between rows of plants is preferred here if drilling fertilization has not been used. Sampling in vineyards is affected primarily by slope and depth of soils. Sampling two soil layers may be necessary.

7 Taking disturbed soil samples

7.1 Sampling top soil

7.1.1 Application

According to Table 1, samples of top soil are required to enable field and laboratory determination of chemical, biological, radiological and, to some extent, physical parameters.

7.1.2 Sampling technique

Any of the following tools may be used as appropriate:

— hand auger;

— spade or similar;

— cutting frame (for sampling organic matter such as mull, moder, mor, peat);

— other additional tools and equipment.

For further details and selection of equipment in relation to soil parameters to be examined, see ISO 10381-2.

7.1.3 Procedure

After selection of a suitable sampling pattern (see ISO 10381-1 for suitable examples), single samples or n incremental samples are obtained to form a composite sample per area unit or soil unit. The depth of sampling depends on the objective of investigation and on the utilization of the area.

Personnel should be experienced in the use of sampling equipment; procedures are therefore not described in detail here. Details of sampling procedures can be found in ISO 10381-2.

To form a composite sample per area unit or soil unit, procedures should be selected so that the final sample contains equal parts of the incremental samples, and to ensure that it is representative of all the incremental samples.

If the stone content is small, it usually can be neglected. Larger stone contents should be estimated or, in special cases, precisely determined following separation of soil particles smaller than 2 mm.

For sampling organic horizons (undecomposed or partially decomposed litter) above mineral horizons in forest soils, place a cutting frame on the surface, and sample the content of the framed area to the underlying soil horizon. If the complete soil profile has to be sampled in the investigation of forest soils, preparation of a trial pit is required to provide accurate and distinct sampling of horizons.

7.1.4 Storage and transport

Subsampling, to reduce the mass or volume of field samples to obtain laboratory samples, should be avoided in the field. If this is impossible, ensure that the composite samples are well mixed before taking a representative subsample. Containers should be selected in accordance with ISO 10381-2. Samples should be labelled using pens resistant to environmental influences. Water-resistant labels should be used. The same sample identification should be used in the sampling report. In the case of volatile compounds (for example nitrogen), the container should be filled completely, closed tightly and stored in suitable outer containers. If cooling is required, the samples should be maintained at cooled temperature throughout the storage period to prevent change in the composition of the sample. In some cases, use of light-absorbent containers is advantageous.

In special circumstances it is better to prepare the composite sample in the laboratory.

7.1.5 Sampling report

The sampling report prepared by the field staff should contain the following details:

— sample designation and number (identical to the marking on the sample container);

— date of sampling;

— information on the site (e.g. location, land use, textural class, weather conditions);

— description of soil profile in special cases;

— information on the procedure (field pattern, sampling equipment, depth of sampling, number of increments or composite samples etc.);

— information on storage and transport;

— information on the time and place of delivery to the laboratory;

— identification of sampler;

— counter-signature of customer or programme supervisor;

— confirmation of receipt by laboratory.

7.2 Sampling at greater soil depths

7.2.1 Application

If soil samples are required from subsoil or underground for the investigation, more extensive procedures are necessary. Probing and drilling may be used and trial pits may be prepared. All objectives listed in Table 1 may be relevant.

7.2.2 Sampling technique

Any of the following tools may be used as appropriate:

— boring tools;

— special boring tools to obtain samples from water-saturated soil layers and from peat soils;

— static and dynamic probes;

— soil sample rings (for application in trial pits).

For sampling under difficult conditions (e.g. clay soils, sampling at very great depth, large number of subsamples) labour-saving techniques are available (e.g. partially or fully mechanical sampling tools, tools coupled to vehicles, mobile sampling tools).

Further details are given in ISO 10381-2.

7.2.3 Procedure

The reasons for and objective of investigations in the field and in the laboratory determine the type and procedure of sampling. For the determination of nutrient supply in the subsoil of agricultural areas, incremental samples can be taken following comparable field patterns and then combined in a composite sample to represent an area or soil unit.

Sampling in connection with investigations of deeper soil horizons or soil layers (e.g. at near-groundwater level or water-saturated soil level) is seldom carried out by boring due to high costs. Special sampling techniques should be applied.

Professional application of the sampling techniques is expected from qualified personnel.

7.2.4 Storage and transport

The recommendations in 7.1.4 apply.

Drill cores intended for specific physical investigations, or which will serve for pedological evaluations in the laboratory, should be stored and transported avoiding vibration as far as possible.

7.2.5 Sampling report

The sampling report prepared by the field staff should contain the details given in 7.1.5.

8 Taking undisturbed soil samples

8.1 Sampling top soil

8.1.1 Application

According to Table 1, undisturbed samples are suitable for the following field and laboratory investigations:

a) visual examinations and testing procedures in the field;

b) physical investigations in the laboratory [e.g. moisture tension (pF), water permeability];

c) special chemical and biological investigations;

d) bulk density studies.

8.1.2 Sampling technique

Any of the following tools may be used as appropriate:

a) cutting cylinders of different size, cutting frame;

b) special hand augers [gauge auger (shallow-profile sampler), bucket auger to bring down borings for cutting cylinder application)];

c) protective cap, hydraulic or handpowered supporting ring;

d) other additional tools and equipment.

Special bags should be used for storage and transport of sample rings to prevent disturbance and drying out.

8.1.3 Procedure (see Figure A.1)

The aim is to obtain a sample in such a way that the natural soil structure of the sample is not changed compared to the bedding of the soil at the site, i.e. volume-proportional sampling. In top soil, horizontal sampling is common.

Following the selection of predetermined sampling points, clear the soil surface of loose materials and remnants of vegetation. If necessary, level the soil surface.

If several cylinder samples are taken at one level, a systematic arrangement of the sampling rings, preferably equidistant, is advantageous. It is recommended that five parallel samples be obtained at each level, e.g. for investigations of percolating soil water, pore volume or bulk density.

Join the cutting cylinder and fix it to the protective cap. Using a hydraulically or manually operated device, drive the cylinder into the soil until the lower edge of the protective cap penetrates into the soil. Remove the cap and supporting ring. Then undercut the cutting cylinder and remove it from the soil using appropriate tools. Level the upper cutting area of the cylinder, cut the roots, and remove projecting stones. Then cap the cylinder, carefully remove it from its base (using a spade or similar tool) and lay it into the special case.

When taking ring samples from top soil, the mostly loose bedding of soil should be rejected. Loss of soil should be avoided.

If soil is silty, loamy or clay-like, sampling is only possible in moist conditions.

While the surface is being levelled, the pores of the ring contents should not be closed by smearing or pressing.

To reduce wall friction, soil sampling rings should be plunged into water or greased with vegetable oil before application.

Tilting of the soil sample ring while pushing it into soil should be avoided.

If undisturbed samples cannot be taken, casting techniques (using gypsum, paraffin, wax, resin) should be considered.

When sampling a soil profile, it is recommended that samples be numbered from top to bottom.

8.1.4 Storage and transport

A special case should be used for the storage of cut soil cylinders, which should not move during transport. The same applies to samples obtained using cutting frames. Great care is required for transporting cutting frames containing soil samples.

8.1.5 Sampling report

In addition to the reporting recommendations set out in 7.1.5, the number of soil sample rings (usually engraved) and arrangement of rows should be reported. It is recommended that sketches of the sampling sites be made.

8.2 Sampling at greater soil depths

8.2.1 Application

Borings are of restricted applicability when taking undisturbed samples. Just the inner core can be used for specific physical determinations after careful preparation.

Therefore preparation of trial pits is normally preferred. From trial pits both undisturbed and disturbed samples can be obtained. These techniques are preferred for carrying out pedological, geological and hydrogeological evaluations.

8.2.2 Preparation of a trial pit

The reasons and objective of the investigations and the intended field and laboratory activities determine the locations and dimensions of a trial pit.

Trial pits should have the following properties:

— large dimensions, to provide professional, safe working conditions (a depth at least of 1 m and appropriate width and length depending on the type and cohesion of soil);

— the head side of the trial pit should be exposed to the sunshine;

— steps available to enter and leave the pit;

— no removed material stored directly at the pit shoulders;

— compliance with national regulations regarding safety (see ISO 10381-3);

— pit security, for example fencing in the case of long-term operation.

After preparation of a trial pit, walls should be cleared carefully of loose soil material, so that the natural structure of horizons can clearly be seen. Treading on the pit shoulders should be avoided (changes in soil structure are possible).

After completion of fieldwork and sampling, trial pits shall be refilled. A horizon-related refilling should be strived for. To compensate for subsidence of a refilled pit, additional filling material shall be added to level uneven soil surface. If notably harmful material is present, excavated material shall not be used as refill. Arrangements for safe disposal complying with national regulations should be made.

When material containing harmful substances unavoidably is to be refilled, clean imported material should be used to form the upper layers.

8.2.3 Sampling soil at trial pits (Figure A.1)

A trial pit permits undisturbed and disturbed samples to be obtained related to horizon, layer or depth, depending on the reasons and objective of field and laboratory investigations. Sampling is possible in both horizontal and vertical directions.

Different sampling techniques can be used. Hand augers, soil sampling rings, cutting frames and other tools are suitable.

In order to apply cutting cylinders at each of the predetermined sampling depths, a horizontal area has to be prepared starting at the top, i.e. the undisturbed soil is cut and levelled, and loose material removed. From this

area cutting cylinders are taken as described in 8.1.3. If the cylinders are arranged in rows, it is appropriate to start at the inside of the area to be sampled. After all the rings are pushed into the soil, they are dug out from the side, cut and smoothed at the ends, and the remaining soil material of this area dug out until the top of the next sampling level is reached.

For collecting undisturbed soil samples at depths down to 1 m and more, (hydraulic) sample tubes with or without plastic liners are suitable for various physical measurements and soil research. For example, transparent sampling tubes, split tube samplers, soil column cylinders and core samplers are appropriate.

Undisturbed samples may also be obtained using a spade, shovel or similar tools carefully. The soil aggregate to be removed in such a way needs to be of greater volume for subsequent shaping, e.g. using a knife to obtain an adequate volume of soil for field and laboratory investigations.

When dealing with highly contaminated sites, other sampling techniques minimizing contact of the investigator with the soil should be employed (see ISO 10381-3 and ISO 10381-5 for further details).

8.2.4 Storage and transport

The recommendations in 7.1.4 apply. For larger volumes of soil, large containers suitable for storage and transport should be used to avoid physical decomposition of the soil sample.

8.2.5 Sampling report

The sampling report prepared by the field staff should contain the details given in 7.1.5.

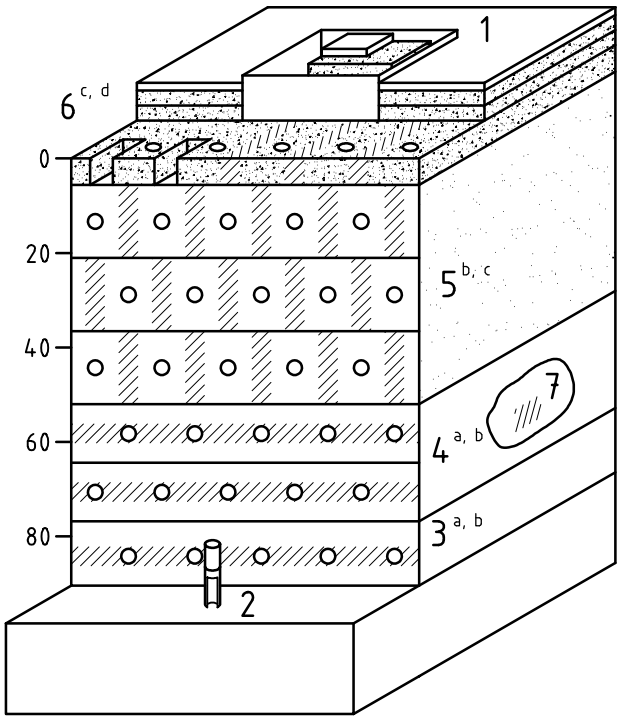
9 Storage in laboratory

When there is a delay before pretreatment and analysis or when a long storage period is foreseen, soil samples shall be stored under suitable conditions. It should be decided whether, in special cases, they should remain in the sampling container or not. To avoid chemical, physicochemical or biological changes in the soil samples caused by contamination, losses or chemical reactions, appropriate requirements are to be taken in account. Drying, cooling or freezing of the original samples are the most common treatments; chemical or UV treatment is used in special cases. Further details are given in ISO 10381-2.

Annex A
(informative)

Example of soil sampling in a trial pit

Depth scale in centimetres



Key

1 sampling of organic matter (e.g. forest soils) by cutting frame
2 sampling from deeper horizons by boring tools
3 sampling from middle of horizon (thickness $<$ 0,2 m)
4 sampling in case of share samples (horizon thickness $>$ 0,2 m)
5 sampling of total horizon thickness (share samples at thickness $>$ 0,2 m)
6 sampling of total horizon thickness ($<$ 0,2 m)
7 share sample out of the typical area
O undisturbed soil sample removed by cutting cylinders.
/// disturbed soil sample removed by boring tools.

[a] Horizontal sampling by split boring.

[b] Horizontal sampling by cutting cylinders.

[c] Vertical sampling by split boring.

[d] Vertical sampling by cutting cylinders.

Figure A.1 — Schematic description of soil sampling in trial pits

Bibliography

[1] FAC (1989): *Methoden für Bodenuntersuchungen/Méthodes pour l'Analyse des sols. Schriftenreihe* Nr. 5. Eidgenössische Forschungsanstalt für Agrikulturchemie und Umwelthygiene 3097 Liebefeld-Bern, Schweiz

[2] *Guidelines for soil description*, 3rd edn., Soil Resources, Management and Conservation. Service Land and Water Development Division, UN Food and Agriculture Organization, 1990, Rome

[3] MELCHER, R.G., PETERS, Th.L. and EMMEL, H.W. Sampling and environmental material. In: *Topics in current chemistry*, **134**, 1985, pp. 61-109

[4] VDLUFA (1991): *Die Untersuchung von Böden*, Methodenbuch Vol. 1; VDLUFA-Verlag, Darmstadt

[5] BMELF (1990): *Bundesweite Bodenzustandserhebung im Wald* (BZE), Arbeitsanleitung Bundesmin. Ernährg., Landw., Forsten (BMELF) Bonn

[6] AG Boden (1994): Bodenkundliche Kartieranleitung, 4th edn., 392 pp., Hannover. In Kommission: E. Schweizerbart'sche Verlagsbuchhandlung (Nägel u. Obermiller), Stuttgart

[7] HARTGE, K.H. and HORN, R. (1989): *Die physikalische Untersuchung von Böden*, 2nd edn., Enke Verlag, Stuttgart

[8] JENNISCHE, P. (1987): *Handledning i provtagning för lantbrukskemisk analys*. SLL Rapport nr. 48, Uppsala

[9] LUNDMARK, J.-E. and ODELL, G. (1984): *Fältinstruktion för Standortskartering av permanenta provytor vid riksskogstaxeringen*. Sveriges lantbruksuniversitet, Uppsala

[10] Anonymous (1993). 2. Verwaltungsvorschrift des Umweltministeriums Baden-Württemberg zum Bodenschutzgesetz über die Probenahme und -aufbereitung (VwV Bodenproben) v. 24.8.1993; Umweltministerium Baden-Württemberg, Deutschland

[11] Öster. Bodenkundliche Gesellschaft (1986): *Waldbodenuntersuchung — Geländeaufnahme, Probenahme, Analyse*. Empfehlungen zur Vereinheitlichung der Vorgangsweise in Österreich; Öster. Bodenkdl. Ges., Wien

ICS 13.080.05

Price based on 13 pages