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Soil quality — Guidance on the establishment and maintenance of monitoring programmes

Qualité du sol — Lignes directrices pour l'établissement et l'entretien de programmes de surveillance

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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

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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.

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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 16133 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Soil and site assessment*.

Introduction

Monitoring is the process of repetitive observation, for defined purposes, of one or more components of the environment according to pre-arranged schedules in space and time using comparable methods for environmental sensing and data collection (see reference [1] in the Bibliography). Monitoring schemes are used all over the world for a large number of purposes. Soil monitoring, particularly, is a long-term undertaking. The quality and the utility of the information from the monitoring is to a large degree determined by the choice of monitoring sites and by their maintenance over the years, and by appropriate quality control at all stages of the process.

Monitoring associated with industrial (contaminated) sites can involve many specific considerations, including legal requirements. The guidance in this International Standard is not designed or intended to cover such situations.

Soil quality — Guidance on the establishment and maintenance of monitoring programmes

1 Scope

This International Standard gives general guidance on the selection of procedures for the establishment and maintenance of programmes for long-term monitoring of soil quality. It takes into account the large number of objectives for soil-monitoring programmes.

This International Standard is intended to help provide a basis for dialogue between parties which might be involved in a monitoring scheme. Examples of soil-monitoring programmes from several countries are provided in Annex A.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
accumulation
increase of the concentration of a substance in soil due to substance input being larger than substance output

NOTE Adapted from ISO 11074-1:1996.

2.2
anthropogenic influence
changes in soil properties caused by human activities

[ISO 11074-1:1996]

2.3
background concentration
natural pedogeochemical content
geogeneous or pedogeneous average concentration of a substance in an examined soil

[ISO 11074-1:1996]

2.4
diffuse source input
non-point source input
input of a substance emitted from moving sources, from sources with a large area or from many sources

NOTE 1 The sources can be cars, application of substances through agricultural practices, emissions from town or region, deposition of sediment through flooding of a river.

NOTE 2 Diffuse source input usually leads to sites that are relatively uniformly contaminated. At some sites, the input conditions may nevertheless cause a higher local input near the source or where atmospheric deposition/rain is increased.

[ISO 11074-1:1996]

2.5
leaching
movement of dissolved substances caused by the movement of water or other liquids in the soil

[ISO 11074-1:1996]

2.6
locally contaminated site
site with discrete areas of high concentrations of substances hazardous to soil

NOTE The extent of contamination is usually small and the gradient of concentration within the site is steep.

[ISO 11074-1:1996]

2.7
monitoring
process of repetitive observation, for defined purposes, of one or more elements of the environment according to pre-arranged schedules in space and time using comparable methods for environmental sensing and data collection

2.8
monitoring site
area in which investigations will take place

NOTE Areas which are relatively homogeneous are usually chosen.

2.9
point-source input
input of a substance from a stationary discrete source of definite size

NOTE 1 The sources can be stack emissions, accidental spills, waste dumps, spills on industrial sites, major leaks from sewers and other pipelines.

NOTE 2 Point-source input can cause both locally contaminated sites and relatively uniformly contaminated sites.

[ISO 11074-1:1996]

2.10
risk assessment
assessment of damaging effects of a polluted site on man and the environment with respect to their nature, extent and probability of occurrence

[ISO 11074-1:1996]

2.11
sample
portion of material selected from a large quantity of material

[ISO 11074-2:1998]

2.12
sampling
process of drawing or constituting a sample

[ISO 3534-1:1993]

NOTE For the purpose of soil investigation, “sampling” also relates to selection of locations for the purpose of *in situ* testing carried out in the field without removal of material.

[ISO 11074-2:1998]

2.13
sampling point
location within the monitoring site at which physical sampling takes place

2.14
sampling procedure
operational requirements and/or instructions relating to the use of a particular sampling plan

[ISO 11074-2:1998]

2.15
soil damage
alteration of soil properties which cause negative effects on one or more soil functions, human health or environment

[ISO 11074-1:1996]

2.16
substance input
movement of a substance from another environmental compartment into a soil

[ISO 11074-1:1996]

2.17
substance output
movement of a substance from the soil into another environmental compartment

[ISO 11074-1:1996]

2.18
uniformly contaminated site
site with a generally uniform concentration of a substance hazardous to soil

NOTE The extent of the contamination is usually large and the gradient of concentration within the site is rather shallow.

[ISO 11074-1:1996]

3 Monitoring objectives

3.1 General

Monitoring is an important tool for the early detection of environmental impact on soil and soil processes. It thus has a major role in the prevention or minimization of environmental damage or the detection of environmental improvement. By the early detection of environmental impact, or the potential for such impact, a monitoring programme could help to reduce or remove the costs of reaching or maintaining a given level of environmental management, protection or quality.

Monitoring programmes can also be used to evaluate the outcome of environmental policies, to assist in the development of strategies for soil protection and environment management. They can also serve as research

platforms for the development and validation of field and analytical methods and of models of soil and related environmental processes.

The range of purposes for which soil-monitoring programmes can be designed encompasses such a vast range of time scales, variables and processes that it is not possible to give specific guidance on the design of a monitoring programme to meet all the objectives which might be covered by this diversity. The selection of sites, sampling schemes, etc. should be made from a consideration of the specific objectives of the particular monitoring programme. This International Standard identifies the principles underlying such programmes.

3.2 Examples of monitoring purposes

The following list gives some examples of monitoring purposes:

— short-, intermediate- and long-term environmental impacts varying in magnitude, importance, duration and probability;

— changes in chemical, biological and physical soil properties (e.g. pH, adsorption processes, toxic element accumulation, radiation, compaction, erosion) and the dynamics of changes in such properties;

— effects of human impacts;

— differentiation of human impacts from inter-annual variability and longer-term climate change;

— differentiation of local contamination from long-range transport;

— evaluation of productivity;

— assessment of biological diversity;

— input of elements into the soil environment and output of elements from the soil environment;

— transport processes in the soil profile (gases; particles; elements or compounds in solution);

— calculations of elements uptake and retention by particular components of the ecosystem.

4 Monitoring programme

4.1 General considerations

It is generally not feasible to monitor all variables at all locations. Wherever possible, consideration should be given to the monitoring of soil properties which, as well as being of specific interest themselves, might also act as a surrogate for some property or process which is otherwise difficult, time consuming or expensive to measure directly. For example, soil pH and clay content (a potential surrogate for soil hydrological behaviour) might act as factors for ranking pollutant mobility. It will be important to establish what long-term records already exist at a site before identifying additional variables for monitoring and what degree of continuity of measurement is required into the future. The close reciprocal benefits of monitoring and research on specific scientific questions should be considered.

The final series of potential monitoring options should be ranked according to their value (scientific relevance; sensitivity to impacts; value as an index for changes in many other environmental variables that are not measured) and feasibility (financial, logistic, analytical, ease of interpretation). This prioritization should also be revised and updated at regular intervals. The costs of appropriate storage of samples and long-term quality assurance, e.g. cross-checking when improvements in analytical techniques are made, should not be underestimated.

Identification of habitat types is a key element of the monitoring plan, and is also a logical starting point for the development of an environmental monitoring strategy. It is also necessary to consider the number of sites that might be required to give appropriate spatial and temporal cover for the monitoring, and whether the site density is appropriate for all variables. It is usually impractical to establish sites that cover all combinations of soil and habitat. Consideration needs to be given, for example, to combinations that are most common or most sensitive to a given impact. It should be remembered that other research, into e.g. water quality or biodiversity, might be possible on the same site, thus adding to its value.

Some other factors that have to be considered are the following:

— partners and organizations involved, and an assessment of their objectives and long-term commitment;

— existing guides and protocols, and the degree to which they satisfy the objectives of the programme;

— ownership of sites, and likely long-term commitment of the site or sites to a monitoring programme;

— availability of sites;

— effects of future changes in land use (if this is an important factor), or the landscape in the vicinity of the site(s) since changes might affect the usefulness of the site in the long term;

— the funding of the programme, and its long-term security;

— quality assurance, including documentation (see below);

— data management, accessibility of the data, intellectual property and issues of confidentiality and rights to publish.

It is very strongly recommended that all parties to a long-term monitoring programme agree to the objectives, funding, mutual responsibilities and other relevant issues before a monitoring programme begins, and that they enter into a formal agreement which defines each party's role in the programme, including financial and legal constraints.

4.2 Elements of a monitoring programme

4.2.1 Status of the monitoring sites

The history of all sites, which might be considered, should be documented. This is an essential part of any assessment of representativeness, and ensures that the chances of the unexpected, which might jeopardize the usefulness of the site, are minimized. Such assessment can involve the characterizing of present-day soil properties at representative sites. Issues such as ownership, access, etc. (see 4.1) can usually be resolved at this stage. Information about other monitoring programmes forms part of this preliminary investigation.

4.2.2 Changes at the monitoring sites

The purpose of measuring change in soil properties should be clear from the start. It may also be useful to invert the question and ask what changes could be measured using such a particular site or programme design, even if all the properties might not be required at the start. Sites which allow expansion of activity for future needs can have advantages over more limited sites. It might be that one purpose of the programme is to establish changes in soil properties (e.g. pH, humus content, levels of toxic substances, water permeability, microbiological activity) and the dynamics of changes in such properties over shorter rather than longer time scales. This has large implications for the amount of soil sampling, and thus site disturbance, which the site might have to accommodate without having its functions seriously affected. The possibility of investigating other environmental compartments can make one site a more attractive proposition than another, especially if it interests a larger group of researchers, funders, etc.

4.2.3 Interpretation of status and changes

The data on status and changes may be used to interpret the following:

— reference/background properties;

— degradation/improvement of one or more soil characteristics and functions (and the effect of this on other soil or site properties);

— short-term and long-term environmental impact and bioavailability of extraneous inputs, applied wastes, atmospheric or water-borne substances or off-site management;

— ecological functions of soils;

— productivity functions of soils;

— influence on other environmental compartments, or of these on the soils at the site.

4.2.4 Selection of sites

The sites should be selected so that they are suitable for the objectives of the programme with respect to geology, soil type, vegetation and land use, topography, climate and ecological habitat. Other important criteria are anthropogenic impact and natural background conditions (e.g. trace element levels, acidity, salinity, buffer capacity).

The choice of geographical distribution of monitoring sites is often influenced by the degree of pre-existing knowledge of the landscape or soil pattern. Where relatively little is known, statistical approaches are often the most appropriate, although this can imply considerable preliminary investigation to establish the variability of the area in question. In general, there are four main choices in the selection of geographical distribution. They are listed below without priority.

— **Regular grid.** The sites are selected using a regular grid. In order to provide representative data, this approach generally requires a large number of sites. The interval between the grid points is very dependent on the size of the area of interest, as well as the degree of change being measured in the property. The smaller the change to be measured in a property, the larger the number of sites required in a given area.

— **Statistical approach.** The sites are selected by using (geo)statistically produced patterns, designed to minimize the required number of sites. However, this implies considerable preliminary investigation, as geostatistical investigations have, as their central aim, the establishment of a reliable variogram for a given property. If the different properties have different degrees of spatial dependence, as they often do in soils, then the number of sites needed to establish this can be as large as that for the regular grid.

— **Hypothesis-oriented approach**. The monitoring options are evaluated on the basis of their ability to detect and quantify impacts hypothesized to result from specific human activities. The sensitivity, spatial extent and frequency of monitoring have to be appropriate to detect the hypothesized impacts. This can also involve considerable preliminary investigation.

— **Typological approach**. This is based on a stratification of soils according to land use and/or soil type, or soil horizon, on soil parent material, or soil extent, or distance from potential contamination sources, etc.

In order to make efficient use of available resources, it is always important to consider the possibilities to integrate the sites with other monitoring programmes. Examples of selection of monitoring sites are given in Annex A. Both synergistic and disturbing effects (e.g. caused by sampling activities or experimental treatments) should be considered if sites are to be used for different monitoring programmes.

4.3 Sampling and measurement

4.3.1 General

A sampling and measurement plan is an important part of a monitoring programme. Such a plan should include procedures in the following areas.

4.3.2 Site design and identification

The chosen site(s) should allow the range of measurements appropriate for the objectives of the soil-monitoring programme, and any other monitoring activities which add value to this programme. The layout of the site should allow repeated representative sampling, without compromising the overall functioning of the site or the soils within it. The site should be protected from unwanted external disturbances.

The choice of sampling points within the monitoring site depends on several factors. The sampling point might have to allow for the digging of soil-profile pits, the installation of soil instruments, repeated sampling by augers, possibly the introduction of designed experiments, e.g. to test the effect of different cropping regimes on the properties monitored, and so on. These factors shall be estimated at the preliminary stage, and the site design modified to include them. If none of these larger factors needs to be allowed for, the sampling point may be located at the centroid of the monitoring site.

4.3.3 Soil and site description

Soil and site description should be performed in accordance with ISO 15903 and ISO 11259.

4.3.4 Sampling

Sampling includes for example the sampling strategy, sampling techniques, labelling, transport and storage. Whenever possible International Standards should be used, see Bibliography. Careful thought should be given to sampling schemes so as to cause minimum disturbance to the site and its properties. Some examples covering the principles of the design and implementation of soil monitoring programmes are given in Annex A.

4.3.5 Field and laboratory measurements

Field and laboratory measurements should be selected according to the objectives.

It is strongly recommended that the following minimum data set of chemical and physical parameters be included, as many of these underpin the interpretation of soil data in the wider context: pH, organic carbon content, cation exchange capacity, electrical conductivity, dry matter content, particle size distribution and bulk density. There is no recommended minimum data set for biological parameters, as the choice depends on the objectives. Standardized methods should be used wherever possible.

The relevant International Standards for the recommended minimum data set are given in the Bibliography.

Examples of selection of parameters in relation to the purpose of the monitoring objectives are given in Annex A.

4.3.6 Specimen banking

A specified portion of each sample should be stored for future needs as appropriate. Sufficient sample should be taken so as to allow re-analysis of many of the properties for an extended period into the future. A specimen bank also makes it possible to include new forms of analysis in the monitoring programme at a later date.

It should be considered at the outset whether special storage conditions, e.g. temperature or humidity, have to be maintained in order to guarantee that important parameters will remain stable over time. In some cases