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Soil quality — Guidance on the determination of background values

Qualité du sol — Guide pour la détermination des valeurs de bruit de fond

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Foreword

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Soil quality — Guidance on the determination of background values

1 Scope

This International Standard provides guidance on the principles and main methods for the determination of pedo-geochemical background values and background values for inorganic and organic substances in soils.

This International Standard gives guidance on strategies for sampling and data processing and identifies methods for sampling and analysis.

This International Standard does not give guidance on the determination of background values for groundwater and sediments.

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 10381-5, *Soil quality — Sampling — Part 5: Guidance on the procedure for the investigation of urban and industrial sites with regard to soil contamination*

ISO 11074:2005, *Soil quality — Vocabulary*

3 Terms and definitions

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

3.1
background content
content of a substance in a soil resulting from both natural geological and pedological processes and including diffuse source inputs

3.2
background value
statistical characteristic (3.8) of the background content

3.3
contaminant
substance or agent present in the soil as a result of human activity

NOTE There is no assumption in this definition that harm results from the presence of the contaminant.

3.4
diffuse 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 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 such as near the source or where atmospheric deposition/rain is increased.

[ISO 11074:2005]

3.5
pedo-geochemical content
content of a substance in a soil resulting from natural geological and pedological processes, excluding any addition of human origin

NOTE It may be hardly possible to determine the precise pedo-geochemical content of certain substances in a soil due to anthropogenic diffuse contamination.

3.6
pedo-geochemical background value
statistical characteristic (3.8) of the pedo-geochemical content

NOTE Any estimate of pedo-geochemical background value will be prone to a certain amount of error given the uncertainty associated with determining the pedo-geochemical content.

3.7
soil
upper layer of the Earth's crust composed of mineral parts, organic substance, water, air and living organisms

[ISO 11074:2005]

3.8
statistical characteristic
numerical value calculated from a variate of a chosen parameter of the population

EXAMPLE Examples of the statistical characteristics are the mean, the median, the standard deviation or the percentiles of the ordered frequency distribution.

3.9
study area
three-dimensional definition of the area where samples are to be obtained from and thus for which the background value(s) are to be estimated

3.10
support
size, shape and orientation of a soil sample

NOTE For the purpose of analysing spatial variation in soils geostatistically (by estimation of the variogram of a soil property), the support should be the same at each sampling site.

3.11
variate
set of observed values of a variable

EXAMPLE A variate could for instance be the series of numbers of the concentration of a substance in soil or numerous, individual soil samples.

4 General

Soils retain the evidence of their past history including impacts due to natural events or human activities. Chemical impacts related to human activities can be detected in soils all over the world, even in regions far from any source of contamination. For this reason, the background contents of inorganic and organic substances in soils consist of a pedo-geochemical fraction and an anthropogenic fraction. The ratio of these fractions varies widely depending on the type of substances, the type of soil and land use, and the kind and extent of external impacts.

For many inorganic substances, the background content of unpolluted soils is dominated by the pedo-geochemical content and consequently by the mineralogical composition of the soils parent material. Pedogenetic processes may lead to a redistribution (enrichment/impoverishment) and consequently to a horizon-specific differentiation of the substances within a soil profile. Persistent organic substances in soils originate more often from non-natural sources and therefore the background content of soils is governed by the kind and extent of diffuse contamination from non-soil sources.

In practice, it is often difficult to distinguish clearly between the pedo-geochemical and the anthropogenic fraction of the background content of soils. Nonetheless, a detailed knowledge of the background content as well as of its natural fraction for the substances of concern is essential both for any evaluation of the current status of soils for environmental or land use related aspects or just for scientific purposes within the scope of pedology or geochemistry. To this end, so-called background values in terms of the statistical characteristics of both, the pedo-geochemical and the anthropogenic fraction have to be determined.

A variety of different objectives can be identified for the determination of background values of inorganic and/or organic substances in soils. The objectives themselves provide insufficient information to define the technical programme that will produce the desired background values. Thus a number of technical approaches have to be defined which together form the basis of the technical programme.

This guidance provides essential aspects of sampling strategies and procedures, minimum requirements regarding the necessary steps and ways of sample pre-treatment, analytical methods and statistical evaluation procedures for determining sound and comparable background values.

Guidance is given for

a) evaluating existing data from different data sources and

b) setting up complete investigation programs aiming to compile background values for a clearly defined three-dimensional picture of the soil.

These situations are representing the two extreme starting positions for the process of compiling background values. In practice, a third intermediate situation may be dealt with when additional data need to be collected because the quantity or quality of the existing data is insufficient.

5 Procedures

5.1 General

The procedures to determine background values encompass aspects of sampling (strategy, procedure), soil analysis (pre-treatment, extraction and measurement), data processing and presentation. In general, two starting positions can be distinguished, namely

a) the evaluation of existing data mostly from different data sources, and

b) the collection of new data based on an appropriate investigation strategy.

5.2 Objectives and technical approaches

5.2.1 General

Before commencing any survey on background values in soils it is of crucial importance to define the objective of the survey and the related technical approach.

The objective is, in general terms, the definition of 'why' background values are to be determined. The technical approaches describe aspects like the 'where', 'what', 'how' and 'when'. Together the technical approaches determine the technical programme that will provide the required background values.

NOTE It should be noted that a technical approach that is fit for one objective, will often be unfit for other objectives.

The objectives for defining background values might be:

- to identify the current contents of substances in soils, e.g. in the context of soil-related directives;
- to assess the degree of contamination by human activities;
- to derive reference values for soil protection;
- to define soil values for reuse of soil material and waste;
- to calculate critical levels and tolerable additional critical loads;
- to identify areas/sites with atypically enhanced levels of element contents due to geogenic reasons or human impact;
- etc.

In order to meet the objective, the technical approaches might include the following.

- Definition of the substances and parameters
  - For example, the background values to be estimated may be the total heavy metal content or the bioavailable heavy metal content. (See 5.2.2)
- Definition of the study area
  - The (three-dimensional) definition of the area where samples are to be obtained from. This has to be a detailed description of what is to be considered as the study area, and what is not. (See 5.2.3.)
- Definition of the time period of interest:
  - Are the historical or current contents relevant for the objective? (See 5.2.4.)
- Definition of the size and geometry (support) of the area sampled at a sampling location. (See 5.2.5.)

5.2.2 Substances and parameters

Background values can be determined for all kinds of inorganic and organic substances in soils as well as soil characteristics. In practice, the more persistent and immobile compounds are of primary interest because of their potential to adsorb and accumulate in soil, whereas remobilization and intrinsic biodegradation are of less significance.

As well as the substances of concern, basic soil parameters and site characteristics (see 5.4.1.3) need to be provided to assist in interpretation of the contents of substances. A number of so-called basic soil parameters influence soil processes that affect the contents of inorganic and organic substances. Table 1 lists these parameters which should be analysed according to the given International Standards.

Within the group of inorganic substances, trace elements (e.g. heavy metals, micronutrients) are most often analysed (Table 2). Concerning the analytical methods, a distinction has to be drawn between different extraction/preparation methods (Table 2), whereof very few determine the total content which may be needed for instance for calculating element stocks. Besides total contents, the (eco-) toxicologically more relevant mobile fractions (Table 2) are of increasing interest, e.g. if pathway-related questions are to be examined. Analysis of parameters in Table 2 should be carried out according to International Standards given in Table 2.

Table 1 — Basic soil parameters

Parameter	Method	ISO International Standard
Texture	Sieving, sedimentation	ISO 11277
Fraction of coarse material	Sieving	ISO 11277
Amount of non-soil material	Sieving/visual control	ISO 11259, ISO 11277
Bulk density	Direct measurement of undisturbed soil samples, estimation form soil water retention curves	ISO 11272
pH	pH-electrode	ISO 10390
Content of organic carbon	Dry combustion	ISO 14235
Cation exchange capacity, exchangeable cations	*BASECOMP*	ISO 11260
	$BaCl_2$	ISO 13536
Carbonate content	CO_2-evolution	ISO 10693

Table 2 — Examples for the analysis of inorganic substances

Parameter	Speciation/form	Extraction/preparation Method	ISO International Standard	
			Extraction/preparation	Determination
Metalloids, e.g.	Total	Alkaline fusion + X-ray fluorescence HF + $HClO_4$	ISO 14869-1	ISO 14869-1
arsenic and selenium			ISO 14869-2	ISO 11047
Metals,	Pseudo total	aqua regia	ISO 11466	ISO 11047
barium, cadmium,	Complexing	EDTA		
chromium, cobalt,		DTPA	ISO 14870	ISO 11047
copper, iron, lead,	Exchangeable	$NaNO_3$		
manganese, mercury,		NH_4NO_3		
molybdenum, nickel,		$CaCl_2$		
thallium, zinc		KCl		
Cyanides	Water soluble	H_2O, leaching tests	See NOTE.	See NOTE.
NOTE There are a variety of extraction and analytical methods for soil-water in the series of International Standards on water quality which may also be applicable. However, it is important to confirm that they will work with the extracts obtained form particular soil material.				

Surveys on organic substances usually refer to persistent compounds. The persistent organic contaminants listed in Table 3 are some of the more commonly encountered, but the list is not complete. Analysis should be carried out according to International Standards listed in Table 3.

Various methods are used for the analysis of organic substances. The aim of these methods is usually to extract the greatest possible quantity of organic substances from soils. It is important to recognize that organic compounds may be extracted from naturally occurring organic materials (e.g. organic matter, decaying vegetation, peat, charcoal), and that non-specific analyses in particular may, therefore, give misleading results.

Table 3 — Examples for the analysis of organic substances

Substance/groups of substances	Method	ISO International Standard
PAH	Soxhlet/HPLC/UV Thin-layer chromatography RP C-18/HPLC GC/MS	ISO 13877 ISO 7981-1 ISO 7981-2 ISO 18287
Dioxins/Furane		
Chlorophenols	Hexane/GC/ECD	ISO 8165-1
Chlorpesticides	RP C-18/HPLC/UV	ISO 11369
PCBs	GC-ECD	ISO 10382
Chlornaphthalene		
Chlorparafin		
Bromodiphenylethers		
NOTE There are a variety of extraction and analytical methods for water in the series of International Standards on water quality which may also be applicable. However it is important to confirm that they will work with the extracts obtained from a particular soil material.		

When collecting new data for determining background values, it is recommended that the investigation program be designed with regard to additional questions that could arise in future. In most cases, carrying out new sampling campaigns is much more expensive than analysing additional substances in the first place. To this end, a suitable storage of soil samples for subsequent analyses of organic or inorganic substances is of crucial importance. Besides the substances of concern (Tables 2 and 3) and additional soil parameters (Table 1), it is essential to provide a comprehensive site description (see 5.4.1.3) for interpretation purposes. The documentation of all the actions taken is of utmost importance if the data measured is to be of use for other assessments in future investigations.

5.2.3 Study area

The definition of the study area (3.9) can be based on two different principles, that is:

— a purely spatial definition (X, Y, Z), defining the contours of the study area by the coordinates within which the study area lies. Apart from the definition in a horizontal plane, the soil depth that is to be studied should also be defined;

— a typological definition of the study area, based on one or more characteristic(s), e.g. soil type (for example, the A-horizon of a specific soil type), land use (also considering the potential effects on the background values), elevation level, etc.

Of course, it is possible to mix the spatial and typological definition of the study area.

EXAMPLE Examples of a mix of the spatial and typological definition of the study area might be:

— the grassland in a county or province;

— the A-horizon in an area defined by X- and Y-coordinates.

The definition of the study area must be detailed at a level where there cannot be any misinterpretation on what is and what is not part of the study area. For an unambiguous definition of the study area, all actual point and diffuse sources within the study area need to be defined. As the general objective is to determine background values, a safety zone around that (type of) source might be defined and thereby excluding parts of the more generally defined study area. It might also result in specific zones for which the data is to be considered separately from the rest of the study area.

The definition of the study area as described is independent of whether the soil samples are still to be taken, or whether already existing soil samples (or results) are to be used. In the latter situation, the detailed definition of the study area will define which samples/results are to be included or excluded.

5.2.4 Time period

Background values are influenced both by the natural processes (pedogenesis, biogeochemical cycles) as well as by diffuse source input. Two different time scales can be distinguished:

— the period in which the background value may significantly vary due to natural processes;

— the period in which the background value will most probably only change due to human influences (except for large scale natural phenomena).

The second period is generally smaller than the first one.

It might be that a specific historic period is of interest when measuring background values. When a soil layer is formed during this same period, it is indeed possible to determine background values for a certain time period.

When background values are to be re-determined after a period of time in order to determine if changes occur, the time period between measurements should be based on (see also ISO 16133):

— the expected enrichment of substances in soils (accumulation for example due to diffuse source input);

— the expected loss of substances in soils (for example, due to leaching, biodegradation or plant uptake);

— changes in concentration level that can be determined both analytically and statistically.

5.2.5 Scale of sampling (Support)

Variability in concentrations is by definition a scale-related characteristic. Depending on the volume for which an analytical result is to be considered representative, the variability in concentrations encountered might be different. The scale — or in more technical terms the (geo-statistical) support (3.10) — is therefore an important technical aspect on which a decision is to be made prior to data collection.

For (mainly) two-dimensional surveys, the support is the size (and geometry) of the area sampled at a sampling location.

The study will always involve a certain soil layer of depth. However, as in the horizontal plane, the dimensions are much larger than in the vertical plane, the support in soil surveys is most often defined in a two-dimensional way.

More information on support is given in Annex A.

5.3 Evaluation of existing data

5.3.1 General

When using existing data, specific care must be taken concerning the quality and comparability of data particularly if the data originate from different sources. Data with appropriate information have to be harmonized in a step-wise procedure with regard to the specific evaluation objectives. In general, the harmonization of data sets results in a more or less significant reduction of the respective variate. Nonetheless, the procedure of harmonization of data sets is inevitable to produce a sound and reliable evaluation. The respective harmonization strategy should encompass aspects like

a) the check of the completeness of the data sets related to minimum requirements,

b) the harmonization of different sampling strategies, references, nomenclatures and analytical procedures,

c) the identification and elimination of contaminated samples (excluded from the population of background values by definition).

5.3.2 Completeness of data sets/minimum requirements

In order to ensure a minimum level of data quality, it is essential to provide sufficient and sound information of the data, for instance

- the date of sampling,
- the procedure used to select sampling locations (plots),
- the scale of sampling (e.g. support),
- the site location (coordinates),
- the sampling depth intervals,
- the number and configuration of samples (e.g. regular grid or random sampling) taken at a sampling location (plot),
- the method used to extract and analyse the components (including quality assurance and detection limits),
- the site-specific information (e.g. pedology/lithology, land use).

This information can be used to screen the data on their suitability for the objective of compiling background values.

The definition of minimum requirements on information of the data set depends, amongst others, on the substances of concern, the area and spatial reference to be considered and the approach pursued to achieve an adequate spatial representation of the point-related data.

Apart from the information listed above, the type and degree of accuracy, e.g. of site-specific information depends on soil and other parameters influencing the behaviour and hence the contents of the substances in soils. For instance, inorganic substances need to be related at first priority to lithogenic soil properties due to their predominant geogenic origin, whereas the content of organic substances of soils is more strongly correlated to, e.g. land-use-related parameters.

5.3.3 Comparability of data (Sampling, nomenclatures, analyses)

Different sampling strategies may have a crucial impact on the comparability of data sets. Problems arise here in particular through the comparison of horizon versus depth level-related samples and that of mixed versus individual samples. Further on, the representative nature of the variate for a sample population with regard to the same support for an area needs to be taken into account. Also, an uneven spatial distribution of the sampling points within an area may cause biased estimates of the parameters of the frequency distribution due to an overestimation of some parts of the study area. Block-kriging is recommended to deal with this problem. It is strongly recommended to carefully balance the possible inaccuracies introduced by merging data sets from different campaigns, versus the advantage of an increasing number of samples and consequently an increasing representation of a population.

The extent to which different sample pre-treatments and analytical procedures (extraction, measurements) can be compared and harmonized has to be evaluated in each individual case, e.g. against the intended accuracy of the background value. For inorganic substances, the analytical results originating from different analytical procedures may be transformed by applying regression functions or constants provided the respective relations are known. Alternatively, the analytical procedures may be grouped roughly according to the operationally defined extracted fractions (see Table 2). The broader the ranges of classified background values as target variables are, the lower may be the demand of data comparability. Nonetheless, the assessor should bear in mind, that merging data sets analysed by different analytical procedures invariably requires compromises to be made.

