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Soil quality — Guidance on the determination of background values

Qualité du sol — Recommandations pour la détermination des valeurs de fond

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Foreword

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

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

This document was prepared by Technical Committee ISO/TC 190, *Soil quality,* Subcommittee SC 7, *Impact assessment*.

This second edition cancels and replaces the first edition (ISO 19258:2005), which has been technically revised. The main changes compared to the previous edition are as follows:

— Clauses 2 and 3, and subclauses 5.3, 5.4, 5.4 and Annex B (formerly Annex C) have been completely technically revised;

— 5.2.2 has been revised and the structure of its subclauses has been changed to 5.2.2.1, *Basic parameters*, 5.2.2.2, *Persistent compounds* (split up into 5.2.2.2.1, *Inorganic substances,* and 5.2.2.2.2, *Organic substances*), and 5.2.2.3 *Non persistent compounds* (added);

— text has been added to 5.2.5;

— "typological" has been replaced by "judgemental" throughout the document;

— "scale of sampling" has been deleted from Annex A;

— the Bibliography has been updated.

Soil quality — Guidance on the determination of background values

1 Scope

This document gives guidelines for the principles and main methods for the determination of background values for inorganic and organic substances in soils at a local/regional scale. The site scale is excluded.

It gives guidelines for sampling and data processing strategies. It identifies methods for sampling and analysis.

This document does not apply to the determination of background values for groundwater and sediments.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11074, *Soil quality — Vocabulary*

3 Terms and definitions

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

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

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

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

3.1
background concentration
concentration of an element or a substance characteristic of a soil type in an area or region arising from both natural sources and anthropogenic diffuse sources such as atmospheric deposition

[SOURCE: ISO 11074:2015, 3.5.1, modified — In the definition, "an element or" has been introduced before "a substance" and "anthropogenic" has replaced "non-natural". Note 1 to entry has been removed.]

3.2
background value
statistical characteristics (3.8) of the total (natural pedo-geochemical and anthropogenic) content of a substances in soil

Note 1 to entry: Commonly expressed in terms of average, typical, median, mode, a range of values or a background value.

[SOURCE: ISO 11074:2015, 3.5.2, modified — Note 1 to entry has been added from ISO 11075:2014, 3.5.1.]

3.3
diffuse source input
input of a substance emitted from moving sources, from sources with a large area or from many sources

Note 1 to entry: In practice, two situations are commonly recognized: rural areas with diffuse source inputs typically from land spreading and aerial deposition; and urban areas where the diffuse source inputs come typically from traffic and industrial activities.

Note 2 to entry: Diffuse source input usually leads to sites that are relatively uniformly contaminated. At some sites, the input conditions can nevertheless cause a higher local input, such as near the source or where atmospheric deposition/rain is increased. Two types of main diffuse source input can be considered: one in rural areas (e.g. atmospheric deposits, spreading); and one in urban areas (e.g. traffic, industries).

[SOURCE: ISO 11074:2015, 3.3.9, modified — Note 1 to entry has been replaced with new text. The last sentence in Note 2 to entry has been added.]

3.4
pedo-geochemical concentration
concentration of a substance in a soil resulting from natural geological and pedological processes, excluding any addition of anthropogenic origin

Note 1 to entry: It is difficult to determine the precise pedo-geochemical concentration of certain substances in soil due to the presence of anthropogenic diffuse contamination.

3.5
pedo-geochemical background value
statistical characteristic (3.8) of the *pedo-geochemical concentration* (3.4)

Note 1 to entry: Any estimate of pedo-geochemical background value is prone to certain errors given the uncertainty associated with determining the pedo-geochemical concentration.

[SOURCE: ISO 11074:2015, 3.5.9, modified — In the definition, "concentration" has replaced "content".]

3.6
anthropogenic concentration
concentration of a substance in a soil resulting from anthropogenic origin

3.7
anthropogenic background value
statistical characteristic (3.8) of the anthropogenic *background concentration* (3.1) of a substance in soils

3.8
statistical characteristic
numerical value calculated from a *variate* (3.10) of a selected parameter of the population

EXAMPLE Mean, median, standard deviation, standard error, percentiles of the ordered frequency distribution.

[SOURCE: ISO 11074:2015, 3.5.11, modified — "selected" has replaced "chosen" and "standard error" has been added in the example.]

3.9
study area
three-dimensional definition of the area where samples are to be obtained from and, thus, for which the *background values* (3.2) are to be determined

[SOURCE: ISO 11074:2015, 5.2.29]

3.10
variate
set of observed values of a variable

EXAMPLE Series of numbers of the concentration of a substance in soil; 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 determination of background values of inorganic and organic substances in soils consists 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 concentration is dominated by the pedo-geochemical concentration and, consequently, by the mineralogical composition of the soils' parent material. Pedogenetic processes can 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. Therefore, the background concentration 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 concentration of soils. Nonetheless, a detailed knowledge of the background concentration and its natural fraction for the substances of concern is essential for any evaluation of the current status of soils for environmental or land use related aspects, as well as 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 should 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 should be defined, which together form the basis of the technical programme.

This guidance identifies:

— essential requirements of sampling strategies and procedures;

— minimum requirements regarding the necessary steps and ways of sample pretreatment;

— analytical methods;

— statistical evaluation procedures for determining sound and comparable background values.

Guidance is given on:

a) evaluating existing data from different data sources;

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

These situations represent the two extreme starting positions for the process of compiling background values. In practice, there is also a third intermediate situation in which additional data are collected because the quantity or quality of the existing data are insufficient.

5 Procedures

5.1 General

The procedures to determine background values encompass aspects of sampling (e.g. strategy, procedure), soil analysis (e.g. pretreatment, extraction, 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;

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 that are determined. The technical approaches describe aspects such as the “where”, “what”, “how” and “when”. Together, the technical approaches determine the technical programme that will provide the required background values.

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 could be:

— to identify the current concentrations of substances in soils, e.g. in the context of soil-related regulations;

— 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 chemical substance contents due to geogenic reasons or human impact, etc.

In order to meet the objective, the technical approaches could include:

— definition of the substances and parameters, e.g. the background values to be estimated may be the total metal concentration or the bioavailable metal concentration (see 5.2.2);

— definition of the study area, e.g. the (three-dimensional) definition of the area where samples are obtained from, including 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, e.g. whether the historical or current concentration is relevant for the objective (see 5.2.4);

— definition of the size and geometry of the area to be sampled at a sampling location (see 5.2.5);

— definition of the pretreatment of the sample (see 5.4.2.2) and the fraction of soil to be analysed.

5.2.2 Substances and parameters

5.2.2.1 Basic 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 substances are of primary interest because of their potential to adsorb and accumulate in the soil. Substances in which the concentration can be influenced by 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) should be provided to assist in the interpretation of the concentrations of substances. A number of so-called basic soil parameters influence soil processes that affect the concentrations of inorganic and organic substances. Table B.1 lists these parameters, which should be analysed in accordance with the given International Standards.

5.2.2.2 Persistent compounds

5.2.2.2.1 Inorganic substances

Within the group of inorganic substances, trace elements (e.g. metals, micronutrients) are most often analysed (see Table B.2). While constituting an urban geochemical background, it is recommended to analyse the whole package listed in Table B.2; most of these elements are found with high values due to human activities, but some minerals can appear with high value naturally.

Concerning the analytical methods, a distinction should be drawn between different extraction/preparation methods (see Table B.2), as very few methods determine the total concentration that could be needed, e.g. when calculating element stocks. Besides total concentrations, the (eco-) toxicologically more relevant mobile fractions (see Table B.2) are of increasing interest, e.g. if pathway-related questions are to be examined. An analysis of the parameters in Table B.2 should be carried out in accordance with International Standards given in Table B.2.

5.2.2.2.2 Organic substances

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

It is not recommended to sample and analyse non-persistent substances as they will not be detected by the laboratory because of their behaviour (e.g. volatilization, high degradation). These kinds of substances are normally analysed for detecting sources of contamination.

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 can be extracted from naturally occurring organic materials (e.g. organic matter, decaying vegetation, peat, charcoal), and that non-specific analyses, in particular, can, therefore, give misleading results.

When collecting new data for determining background values, it is recommended that the investigation programme 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, suitable storage of soil samples for subsequent analyses of organic or inorganic substances is of crucial importance. Besides the substances of concern (see Tables B.2 and B.3) and additional soil parameters (see Table B.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 are to be of use for other assessments in future investigations.

NOTE Guidance on the storage of soil samples is provided in ISO 18512.

5.2.2.3 Non-persistent compounds

In some cases, generating background values on non-persistent substances could be of interest. Special care should be taken when volatile, degradable organic substances or transformable, inorganic species are the subject of the study. A detailed description and documentation of sampling and analysis is of particular importance in such cases. Storage or archiving of samples is not recommended because of the behaviour of such organic and inorganic species.

5.2.3 Study area

The definition of the study area (see 5.2.3) can be based on two different principles:

— 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 horizon of interest that is to be studied should also be defined;

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

It is possible, of course, to combine the spatial and typological definition of the study area.

EXAMPLE A combination of spatial and typological definitions of the study area could 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 should be detailed at a level where there cannot be any misinterpretation of 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 should be defined.

As the general objective is to determine background values, a safety zone around that (type of) source can be defined, which thereby excludes parts of the more generally defined study area. There could also be specific zones in which the data are considered separately from the rest of the study area.

Samples to be used for the determination of background values should not be taken from near potential localized sources of contamination (e.g. roads, industrial sites).

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 (e.g. pedogenesis, biogeochemical cycles) as well as by anthropogenic diffuse source input. Two different time scales can be distinguished:

— the period in which the background value can vary significantly 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 could 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 the following (see also ISO 16133):

— the expected enrichment of substances in soils (accumulation, e.g. due to diffuse source input);

— the expected loss of substances in soils (e.g. due to leaching, biodegradation, plant uptake);

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

5.2.5 Scale of sampling

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 could be different. The scale is, therefore, an important technical aspect on which a decision is to be made prior to data collection.

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

The variability of the natural pedo-geochemical concentration and of the background concentration often increases with the size of the study area (population), but decreases with the size of the sample support (scale of sampling). Increasing the sampling support is a method that can reduce the variability of the background concentration. However, increasing the sampling support often makes the sampling more laborious and is only recommended under conditions where the sampling and sampling preparation errors can be minimized. It is recommended to use the same scale of sampling if the natural pedo-geochemical value is used to evaluate soil contamination. If the background values are used to support delineation of contaminated land, it is recommended to use the same scale of sampling. For large scale sampling support, composite sampling (see 5.4.1.6) is often preferred in order to avoid the handling of excessively large amounts of soil.

5.3 Evaluation of existing data

5.3.1 General

When using existing data, specific care should be taken concerning the quality and comparability of data, particularly if the data originate from different sources, by consideration of the measurement uncertainty. Data with appropriate information should 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 bias between the data sets[36]. Harmonization of sample sets is essential if sound and reliable evaluation of the combined data is to be achieved. The harmonization strategy should include:

a) a check on the completeness of the data sets (including estimates of the uncertainty of each measurement);

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

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

NOTE Natural anomalies of the pedo-geochemical background can generate high values that can appear as contaminated samples. It is important to anticipate these cases with an accurate desk study in order to not eliminate these samples.

5.3.2 Completeness of data sets/minimum requirements

In order to ensure a minimum level of data quality, sufficient and sound information about the data should be provided, for example:

— the date of sampling;

— the procedure used to select sampling locations (plots);

— the scale of sampling (area or local);

— the site location (coordinates);

— the sampling depth intervals;

— the number and configuration of samples (e.g. regular grid, random sampling) taken at a sampling location (plot);

— the method of sample preparation (e.g. dying, crushing, sieving);

— the method used to extract and analyse the components (including quality assurance data, estimate of analytical uncertainty and detection limits in accordance with ISO 18400-106);

— the site-specific information (e.g. pedology/lithology, land use);

— the urban areas specificities (e.g. excavated materials).

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

The minimum information required about a data set depends, among other things, on the substances of concern, the area, spatial reference to be considered and the approach pursued to achieve an adequate spatial representation of the sampling location.

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

5.3.3 Comparability of data (sampling, nomenclatures, analyses)

Different sampling strategies can have a crucial impact on the comparability of data sets. Problems arise, in particular, through the comparison of horizon versus depth level-related samples and that of composite versus individual samples. In addition, the representative nature of the variate for a sample population with regard to the same scale for an area should be taken into account. Also, an uneven spatial distribution of the sampling points within an area can cause biased estimates of the parameters of the frequency distribution due to an overestimation of some parts of the study area. Following an initial review of the raw data on a map, an appropriate spatial interpolation method should be used. Geographical information system (GIS) software is particularly useful for this task, especially for data sets (see ISO 18400-104:—, 6.1 and Annex H). It is strongly recommended to carefully balance the possible inaccuracies introduced by merging data sets from different campaigns with the advantage of an increasing number of samples and, consequently, an increasing representation of a population.

The extent to which different sample pretreatments and analytical procedures (e.g. extraction, measurements) can be compared and harmonized should be evaluated in each individual case (e.g. against the intended accuracy of the background value). For all the 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 B.2). If the ranges of classified background values as target variables are broader, the demands of data comparability are lower. Nonetheless, the assessor should bear in mind that merging data sets analysed by different analytical procedures invariably requires compromises to be made. By definition, the background values are relatively low, except in natural high pedo-geochemical background zones. It can be important to take into account detection and quantification limits of each device of analysis when judging the comparability of data.

5.3.4 Examination of outliers

The background concentration of substances in soils includes the moderate diffuse input into the soil. Therefore, locally contaminated sites and natural anomalies are excluded from the population of background concentrations. Consequently, data obviously stemming from locally contaminated sites should be identified and eliminated from the respective data set. The detection of data outliers and unusual data behaviour is one of the main tasks in the statistical analysis of geochemical data. To this end, several statistical tests for identifying outliers are applicable, e.g. tests on the distribution

