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Soil quality — Requirements and guidance for the selection and application of methods for the assessment of bioavailability of contaminants in soil and soil materials

Qualité du sol — Lignes directrices pour la sélection et l'application des méthodes d'évaluation de la biodisponibilité des contaminants dans le sol et les matériaux du sol

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Foreword

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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 17402 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Soil and site assessment*.

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Introduction

Laboratory and field studies have demonstrated that biological effects are not related to the total concentration of a contaminant in the soil. Instead, an organism responds only to the fraction that is biologically available (bioavailable) for that organism. This is particularly true in soils that undergo interaction of contaminant molecules with the soil, in such a way that the contaminant is not attainable anymore by the organism or is present in a non-available form (sometimes referred to as sequestration or irreversible sorption). The bioavailable fractions of contaminants are dependent on soil properties and various processes varying with time and on the biological receptors. The conservative approach of exposure assessment, as typically described in a regulatory context, assumes that the total concentration of a contaminant present in a soil or soil material is available for uptake by organisms, including man, and as such will overestimate the risks. Therefore, a risk assessment can be optimised by using an approach that is based on estimated exposure representing the available, effective concentration of the contaminant(s) and on (existing) intrinsic toxicity data.

This assumption is not new as, already in the last half of the nineteenth century, agronomists and soil scientists began to search for chemical methods to determine the concentration of individual plant-available nutrients in agricultural soils. The impetus for this search was the need for recommended nutrient additions to achieve maximum crop yield. Mulder [1] stated already in 1860: "*The unnecessary full analysis of soil to learn if it is fertile or not cannot be argued enough. The long and short of it is availability, which cannot be derived beforehand. The analysis shows what there is, agriculture must draw its own conclusions from that.*" Chemical methods were devised to reasonably predict the availability of inorganic ions necessary for plant development. Chemical partial extraction methods are now commonly used to evaluate available levels of nutrients in soils. Extraction methods have been optimised by correlating extraction results with response of susceptible crop species to the addition of fertilisers.

The concept of availability is nowadays applied to the risk assessment of contaminants and can be tailored to the specific protection goals. Depending on the intended use of a soil or soil material, soil characterisation for different purposes (e.g. assessment of habitat and retention functions, risk assessment and compliance with regulatory values) may include chemical testing and ecotoxicological testing with selected representative test organisms. These tests will, in many cases, be soil- or site-specific at a given point in time, and cannot be extrapolated to other soils or points in time where other factors may control bioavailability.

Bioavailability may be assessed in two complementary ways (see also Figure 1):

— Chemical methods (e.g. extraction methods) which determine the fraction of a well-defined class of contaminants available for defined specific biotic receptors or the mobility of the contaminants in the soil. Usually these chemical methods were developed to predict the amount of contaminants taken up by the organisms. Nevertheless, these analytically determined values can also be correlated with effects. In a routine assessment of soil quality, chemical measurements may replace biological testing, if a correlation between the resulting chemical values and effect or accumulation has been demonstrated.

— Biological methods which expose organisms to soil or soil eluates in order to monitor effects. If accumulation and/or effects (e.g. mortality, growth inhibition) are encountered, bioavailable contaminants are likely to be present even if they cannot be chemically identified. More knowledge on processes controlling bioavailability can close the still existing gap between chemical measurements and biological effects.

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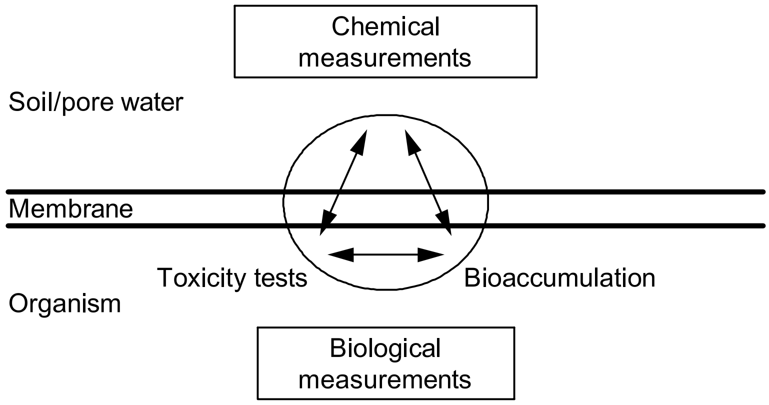

Figure 1 — Methods to assess bioavailability — Relation between chemical and biological assays and bioaccumulation

Under regulatory aspects of soil protection, the risk assessment should be based upon the same common concept with regard to determination/assessment of exposure and measurement/assessment of effects. Thus, existing concepts and derived trigger values based on total concentrations of pollutants in soils or soil materials can be transferred to the proposed concept based on the prediction of the bioavailable fraction by using the more accurate description of exposure. For instance, the translation of information on bioavailability into acceptable evaluations of “how clean is clean” (e.g. site-specific limits for regulating the extent to which the remediation of soil is required) is essential for establishing realistic risk assessments and the determination of proper endpoints for remediation.

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A harmonised framework on bioavailability is considered in order to promote the development and introduction of workable standard methods to be used in soil and site assessment. In addition, methods for the estimation of bioavailable effective concentrations of contaminants according to the protection goals envisaged are required. These methods should preferably be described in International Standards and that standardization process should result in a limited set of established methods for the measurement of bioavailability [2]. As described in this International Standard, this process will not lead to one single method to measure bioavailability, because bioavailability depends on variables such as the contaminant, the target and the actual soil properties. Therefore, methods should not only use the word bioavailability but also refer to these variables (bioavailable *for*).

In this International Standard, requirements and guidance are given to select methods to assess bioavailability for different target species with regard to several classes of contaminants. Methods to assess bioavailability are not described in this International Standard. Reference is made to existing International Standards and additional principles of measurement, which may need to be worked out in these International Standards. As only a few standards exist, reference is also made to measuring principles. Guidance is also provided for further standardization of a method where promising first results are reported.

After a short description of methods (Clause 6), the pathways of a contaminant to the target organism are discussed (Clause 7). A summary of existing methods and promising methods that should be further developed is given in Clause 8. Clause 9 gives recommendations and includes the minimal requirements for application and further development.

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Soil quality — Requirements and guidance for the selection and application of methods for the assessment of bioavailability of contaminants in soil and soil materials

1 Scope

This International Standard provides guidance for the selection and application of methods to assess bioavailability for the characterisation of contaminated soil and soil materials. This International Standard does not give a selection of the best applicable methods, but specifies boundary conditions and principles of methods to be used and gives the minimal requirements for the development of methods. The results obtained from such methods can be used as an estimate of bioavailability in a risk-assessment approach.

In this International Standard, when the term “soil” is only quoted for simplification, the broader term “soil and soil material” shall be considered.

The contaminants considered in this International Standard are metals, including metalloids, and organic contaminants, including organometal compounds. This International Standard is also applicable to metals originating from natural geological and pedological processes (natural pedo-geochemical content).

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This International Standard can also be applied to sediments.

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NOTE An assessment procedure based on the bioavailable fraction of the total amount of contaminants in the soil or soil material can contribute to the development of regulatory requirements of risk-based assessment procedures for soils.

According to the protection goals envisaged, applications of existing methods are recommended and their limitations discussed, with the intention of promoting the development and introduction of workable standard methods to be used in soil and site assessment. These methods are required to allow for the quantification of factors influencing bioavailability.

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 11074:2005, *Soil quality — Vocabulary*

ISO/TS 21268-1:2007, *Soil quality — Leaching procedures for subsequent chemical and ecotoxicological testing of soil and soil materials — Part 1: Batch test using a liquid to solid ratio of 2 l/kg dry matter*

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3 Terms and definitions

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

3.1
bioavailability
degree to which chemicals present in the soil may be taken up or metabolised by human or ecological receptors or are available for interaction with biological systems

NOTE 1 Adapted from ISO 11074:2005.

NOTE 2 The concept of bioavailability is further explained in Clause 5.

NOTE 3 In ISO/TS 17924, a definition specific for human uptake through ingestion is given as the fraction of a substance present in ingested soil that reaches the systemic circulation (blood stream).

3.2
contaminant
substance or agent present in the soil as a result of human activity

[ISO 11074:2005]

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

3.3
critical body residues
CBR
internal concentration accumulated in a tissue, organ or all of the body that is correlated with an adverse effect

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3.4
environmental availability
fraction of contaminant physico-chemically driven by desorption processes potentially available to organisms

NOTE 1 See also Figure 2.

NOTE 2 Environmental availability contains

1) an actual available fraction or the actual dissolved amount of pollutant at ambient conditions, or

2) a potentially available fraction, which is the maximum amount that can be released under (predefined) worst-case conditions. The potentially available fraction includes the actual available fraction.

3.5
environmental bioavailability
fraction of the environmentally available compound which an organism takes up through physiologically driven processes

NOTE See also Figure 2.

3.6
habitat function
ability of soil/soil materials to serve as a habitat for micro-organisms, plants, soil-living animals and their interactions (biocenosis)

[ISO 11074:2005]

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3.7
leaching test
test during which a material is put into contact with a leachant under strictly defined conditions and some constituents of the material are extracted

[ISO/TS 21268-1:2007]

3.8
leachant
liquid used in a leaching test

[ISO/TS 21268-1:2007]

3.9
natural pedo-geochemical content
concentration of a substance in soils, resulting from natural geological and pedological processes, excluding any addition of human origin

[ISO 11074:2005]

NOTE In the background content [concentration of a substance in soil, resulting from natural geological and pedological processes, including diffuse source inputs (ISO 19258)], the natural pedo-chemical content is combined with the content resulting from diffuse pollution.

3.10
pollutant
substance or agent present in the soil (or groundwater), which due to its properties, amount or concentration causes adverse impacts on soil functions or soil use

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NOTE Adapted from ISO 11074:2005.

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3.11
potentially harmful substance
substance which, when present in a sufficient concentration or amount, may be harmful to humans or the environment

NOTE It may be present as a result of human activity or naturally.

3.12
receptor
potentially exposed person or part of ecosystem

3.13
retention function
ability of soils/soil materials to adsorb pollutants in such a way that they cannot be mobilised via the water pathway and translocated into the terrestrial food chain

[ISO 11074:2005]

NOTE In this International Standard, reversible adsorption and desorption processes are also considered.

3.14
sediment or subhydric soil
soil and its parent material beneath the surface water body

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3.15
soil
upper layer of the Earth's crust composed of mineral particles, organic matter, water, air and living organisms

NOTE 1 In a broader civil engineering sense soil includes top-soil and subsoils; deposits such as clays, silts, sands, gravels, cobbles, boulders and organic deposits such as peat; and materials of natural origin or of human origin (e.g. fills and deposited wastes).

NOTE 2 Adapted from ISO 11074:2005.

3.16
soil material
material coming from soil and displaced and/or modified by human activity, including excavated soil, dredged materials, manufactured soils, and treated soils and fill materials

NOTE For the purposes of this International Standard, sediments are considered as soil material.

3.17
soil organisms
all organisms living completely, or during specific parts of their lifetime, in the soil or on the soil surface (including the litter layer) and which contribute to soil processes (e.g. nutrient cycling), including plants (including soil algae), microflora, invertebrate and (a few) vertebrate species

3.18
toxicological bioavailability
internal concentration of pollutant accumulated and/or related to a toxic effect

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NOTE 1 See also Figure 2.

NOTE 2 This definition refers to internal concentrations in humans, mammals and other organisms.

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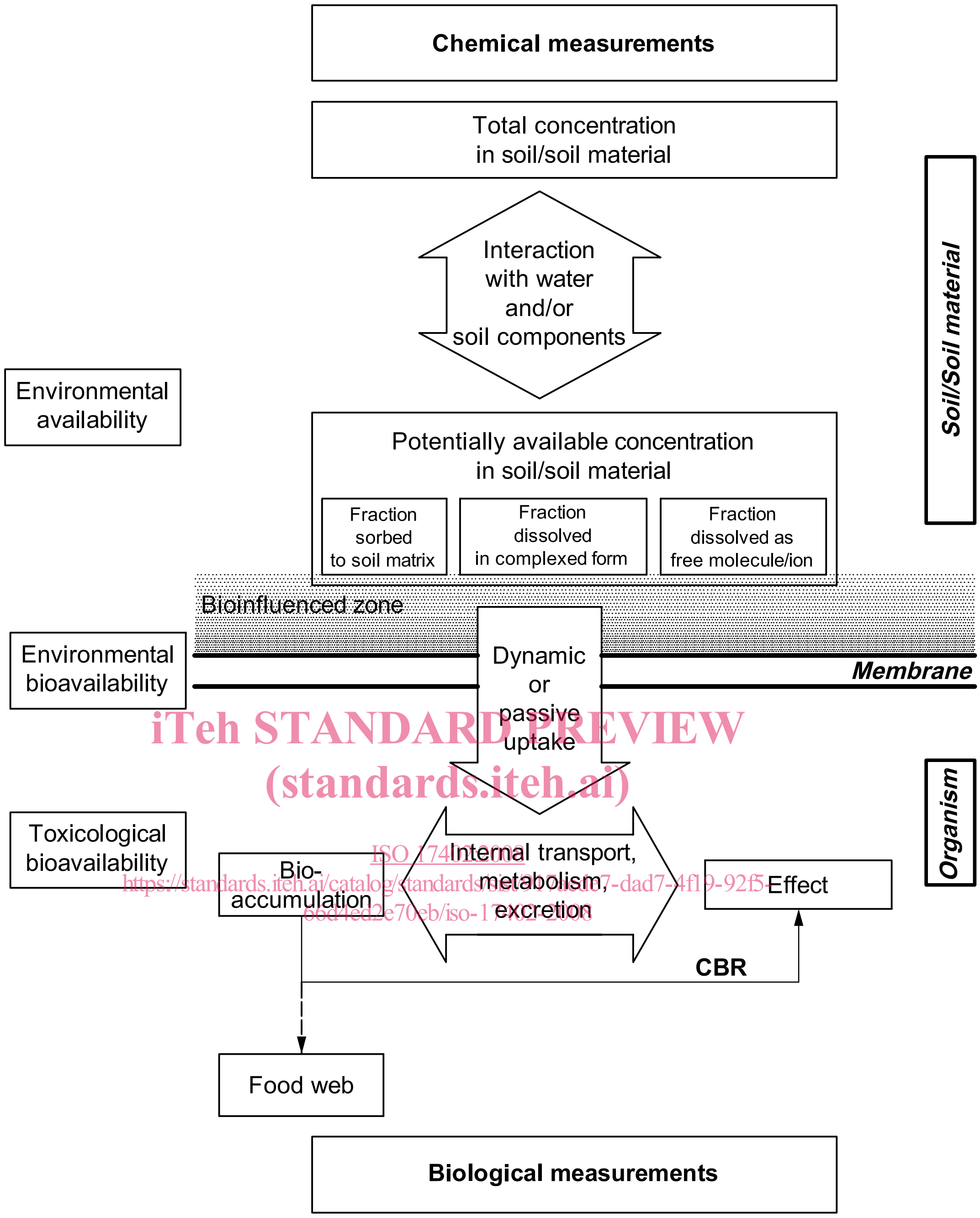

Figure 2 — From total concentration in soil to effect
(modified after Reference [7] in the Bibliography)

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