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Soil quality — Guidance on leaching procedures for subsequent chemical and ecotoxicological testing of soils and soil materials

Qualité du sol — Lignes directrices relatives aux modes opératoires de lixiviation en vue d'essais chimiques et écotoxicologiques ultérieurs des sols et matériaux du sol

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Contents

Page

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ISO 18772:2008
https://standards.iteh.ai/catalog/standards/sist/57c59f79-0d2e-4508-bbe8-e1b17007c5db/iso-18772-2008

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Foreword

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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 18772 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Soil and site assessment*.

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Introduction

Current soil and soil-materials management (risk assessment practices or regulations) is often based only on the total amount of contaminants in soil. However, total composition is inadequate for the assessment of several types of impacts such as impacts on soil, groundwater and surface water due to leaching and subsequent transport of contaminants (inorganic, organic and natural radionuclides) with water. Indeed, for many constituents, a significant fraction of the total content is essentially non-leachable, that is to say non-removable when it comes into contact with a liquid.

Thus, a key aspect to assess the possible management solutions for soil and soil materials in relation to the presence of contaminant is the release-to-the-water phase. This can be addressed with leaching tests which can be used to characterise the source term when performing impact assessment and also for the determination of a leached amount of contaminants when checking compliance with respect to existing limits or for comparison purposes (e.g. quality control, treatment efficiency).

These statements are relevant for natural, contaminated and agricultural soils and also for soil materials.

Leaching tests, particularly those developed for soil and soil materials, are suitable for the following applications:

a) Application of leaching tests to determine the leaching behaviour in the framework of impact assessment

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Generally, impact assessment is based on the source/pathway/receptor framework.

— Source: assess the release, identify speciation of constituents and retention mechanisms.

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— Receptor: determine the potential targets.

— Pathway: estimate the transfer of the source towards the target (e.g. underground water, surface water, plants, soil organisms, ecosystems).

In this process, leaching tests are used to characterise the source term (so-called characterisation tests) in accordance with a given scenario (e.g. contamination of the groundwater due to a contaminated site or a soil amended with sludges), which can either be generic or site-specific.

Leaching tests may also be used as a tool to assess bioavailability (see ISO 17402).

b) Application of leaching tests for compliance and comparison

Based on the background information on the soil and soil materials sampled (e.g. origin, nature of constituents and contaminants, existing documented information, leaching behaviour), relatively simple and quick leaching tests can be performed for compliance and comparison purposes. In contrast to characterisation tests, this type of test is not designed to provide information on leaching mechanisms and controlling factors. However, it should be possible to link the information obtained with compliance tests to the more elaborate characterisation tests.

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Soil quality — Guidance on leaching procedures for subsequent chemical and ecotoxicological testing of soils and soil materials

1 Scope

This International Standard provides guidance on the appropriate use of leaching tests on soil and soil materials, in order to determine the leaching behaviour in the framework of impact assessment, or for compliance and comparison purposes, including information on the following:

— the choice of leaching tests, depending on the nature of the problem to be solved and the specific features of the different tests;

— the interpretation of the test results;

— the limitations of the tests.

In this respect, it is important to keep in mind that leaching tests do not aim to simulate real field conditions, but are designed to address the contact between a solid and a liquid phase for different purposes that are described in this International Standard.

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This International Standard only concerns natural, contaminated and agricultural soils and soil materials. Questions relating to the leaching of wastes are not covered by this International Standard. It also does not cover the subject of bioavailability of contaminants to living organisms, which is covered by ISO 17402.

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Leaching tests are designed and used for characterisation of the source term. It may be possible to address transport aspects with leaching tests if some basic requirements are known (e.g. hydrodynamic), thus allowing the determination of key transport parameters (e.g. retardation factors, particle-facilitated transport, attenuation processes).

In this International Standard, when the term “soil” is only quoted to simplify the writing, the broader term “soil and soil materials” shall be considered.

2 Normative references

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

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

ISO/TS 21268-2, *Soil quality — Leaching procedures for subsequent chemical and ecotoxicological testing of soil and soil materials — Part 2: Bach test using a liquid to solid ratio of 10 l/kg dry matter*

ISO/TS 21268-3:2007, *Soil quality — Leaching procedures for subsequent chemical and ecotoxicological testing of soil and soil materials — Part 3: Up-flow percolation test*

ISO/TS 21268-4, *Soil quality — Leaching procedures for subsequent chemical and ecotoxicological testing of soil and soil materials — Part 4: Influence of pH on leaching with initial acid/base addition*

EN 12920, *Characterization of waste — Methodology for the determination of the leaching behaviour of waste under specificied conditions*

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3 Terms and definitions

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

3.1
contaminants
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.

[ISO 11074:2005]

3.2
eluate
solution obtained after the laboratory leaching procedure of a soil in contact with a leachant

3.3
leachant
liquid used in a leaching test

3.4
leachate
liquid that has percolated through soil under field conditions

3.5
leaching
dissolution and movement of dissolved substances caused by the movement and quality (e.g. pH, ionic strength) of water or other liquids in the soil

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NOTE 1 In pedology, leaching is defined as the movement of dissolved substances caused by the movement of water or other liquids in the soil.

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NOTE 2 Adapted from ISO 11074:2005.

3.6
leaching behaviour
release and time change in release from the soil upon contact with a leachant as affected by the conditions specified in the scenario, especially within the specified time frame

3.7
liquid to solid ratio
L/S
ratio between the total amount of liquid (L in litres), which in this extraction is in contact with the soil sample, and the dry mass of the sample (S in kilograms of dry matter)

NOTE L/S is expressed in l/kg.

3.8
lysimeter
large-scale experiment set-up to simulate scenario-specific exposure conditions under more controlled conditions than in full-scale field conditions

3.9
multiparametric test
test aimed at measuring the influence of interrelated specific parameters on the release from a soil in the considered scenario

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3.10
parametric test
test aimed at measuring an intrinsic property of a soil or to measure the influence of a specific parameter on the release from a soil in the considered scenario

NOTE This does not exclude the fact that other parameters may be influenced at the same time.

3.11
percolation
transport of infiltration water through a layer of soil

3.12
release
emission of constituents from a soil which pass through the external surface of a soil mass as specified in the considered scenario

3.13
scenario
case defined by a set of normal and exceptional conditions relevant to a particular disposal or utilisation situation for soil for the determination of the leaching behaviour within a specified time frame

3.14
simulation test
test aimed at simulating the combined effect of various parameters on the release in the scenario under consideration

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3.15
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

ISO 18772:2008
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[ISO 17402:—[1)]]

3.16
source term
set of information characterising the release of constituents from soil

3.17
transfer term
set of information characterising the transfer of the source term through the soil and/or the groundwater

4 General approach

4.1 Aim of leaching tests

The aim of performing a leaching test is to determine the expected constituent concentrations in solution when the leachant is placed in contact with a sample specimen under specified conditions. Many factors that influence dissolution and subsequent release of organic and inorganic constituents from a soil can be assessed through leaching tests.

Two main categories of leaching tests can be identified: static and dynamic tests. Among these categories, a wide variety of test procedures is available in literature, depending on a limited set of test conditions (e.g. pH of the leachant, liquid to solid ratio, contact time). The first question to emerge then is to know how to select the appropriate leaching test. It shall be considered that this question can be reformulated in some situations as how to select the appropriate set of leaching tests.

1) To be published.

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4.2 How to choose leaching tests

4.2.1 For which purposes are leaching tests performed?

The first question is to determine whether leaching tests are performed to determine the leaching behaviour in the framework of impact assessment, or for compliance and comparison purposes. In the first case, the general approach to assess the leaching behaviour of contaminants from soils can be relevantly derived from the methodology described in EN 12920. The second case implies that background information to which leaching test results are to be compared is available (e.g. regulation, variability study, treatment efficiency).

This general approach is illustrated in Figure 1.

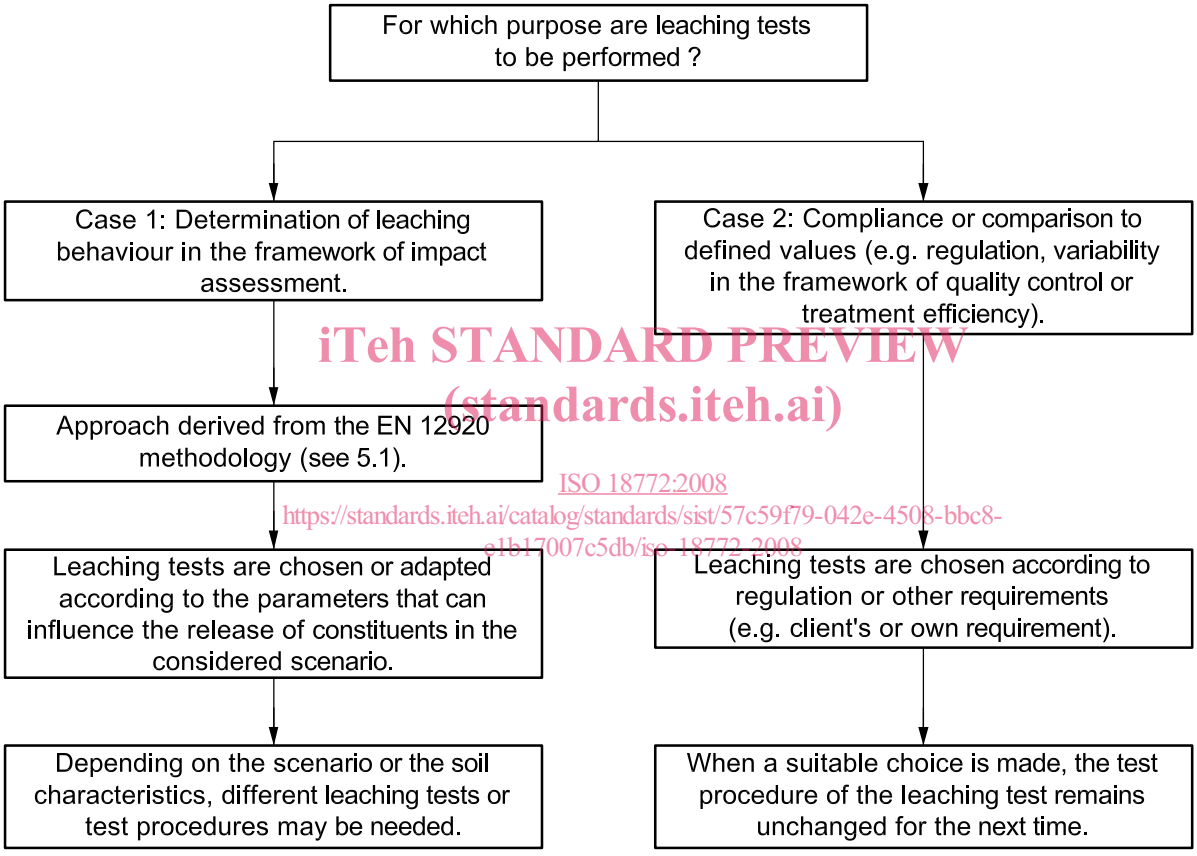

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Figure 1 — General approach for the selection of the type of leaching tests

The aim of Table 1 is to allow easier identification of how to make the connection between the two cases of approach (cases 1 and 2) and the situations that stakeholders face up to in terms of soil management strategies.

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Table 1 — Examples of management strategies and knowledge needed to fulfil the purpose

Management strategy	Problem	Related case	Description
Impact assessment, including beneficial use/ utilisation	Do the leaching properties of soil make it possible to comply with water quality criteria downstream of the site?	Case 1	No quality criteria are generally available that are related directly to the leaching of organic compounds from soil. However, quality criteria are available for groundwater and drinking water. In order to comply with these criteria, the leaching properties of the soil shall be determined and used as input for site-specific impact assessment.
	What is the present release of contaminants (snapshot) and what is the impact on groundwater?	Case 1	The release of contaminants from the soil under present conditions may be determined. The measured release may be used to evaluate the present impact on groundwater. This provides a first impression of the soil properties with respect to leaching and whether the soil is suitable for beneficial use/utilisation.
	What is the maximal leachable amount of contaminant?	Case 1	The maximal amount of contaminants that are available for leaching may be determined according to a defined time frame. For most soils (and other kinds of materials) there is no correlation between the total solid content of contaminants (either inorganic or hydrophobic for organic ones) and the leachable amount.
	How will the release of contaminants change with time?	Case 1	In risk assessment, it may be valuable to know if leaching from the source term is almost constant for a longer period or if it decreases within a shorter time period. The leachate or eluate quality may be estimated as a function of time.
	May the release of contaminant change significantly due to external influence over time?	Case 1	It shall be identified if there is a risk that the environment may influence the properties of the soil (e.g. pH changes) and whether the consequences of these changes with respect to leaching of contaminants from the soil should be known.
Disposal, or beneficial use/ utilisation	Do the leaching properties comply with leaching-based regulatory criteria or with an available variability frame of leaching characteristics?	Case 2	Leaching-based acceptance criteria generally only concerned inorganic compounds. Soils for disposal or beneficial use/utilisation containing organic compounds are still evaluated based on the total solid content.
Treatment	Does this treatment process change the leaching properties of the soil so that leaching criteria for disposal are fulfilled?	Case 2	Leaching properties may be determined for a given soil before and after a treatment in order to determine the ability of this treatment to make the soil comply with acceptance criteria in disposal or beneficial use/utilisation.
	Does this treatment process change the leaching properties?	Case 1	Leaching properties may be determined for a given material before and after treatment of the soil in order to evaluate if the treatment process is effective with respect to reducing the release of contaminants.
	Is it possible to improve the environmental properties of this soil with respect to the release of contaminant by leaching?	Case 1	By knowing the processes that control the release of contaminants from the soil, it may be possible to design or optimise the effective treatment processes.
Agricultural practices	To what extent will the added fertilisers or soil improvers be leached out of the soil? First assessment	Case 1	Leaching the soil sample after the addition of fertiliser or soil improver will provide information for assessing the amount remaining in the soil after exposure in the field (it will help in defining whether a new treatment is needed).
	To what extent will the added fertilisers or soil improvers be leached out of the soil? Routine testing	Case 2	After having established a relationship between laboratory testing and field exposure (see above), routine testing can be designed and performed.

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4.2.2 Hierarchy in testing

A hierarchy in test use is promoted, in which more realistic and sophisticated tests are used to determine the leaching behaviour in the framework of impact assessment, whereas for quality control in soil processing or quality variations within a specific source of soil or, more generally, for compliance verification, more simplified tests are used.

The different kind of leaching tests can be gathered in three main categories, classified in ascending order of representativity and complexity.

a) **Compliance and quality control (QC) leaching tests**

These tests can be used for an initial screening of the release of soil constituents to water (contact times generally of one to a few days) or for checking compliance with respect to existing limit values or for the intercomparison and classification of different types of soils. This kind of test does not cover, and hence cannot allow, the assessment of the leaching behaviour of a soil in a given scenario. For typical compliance and QC tests, see ISO/TS 21268-1 and ISO/TS 21268-2.

b) **Basic characterisation**

This type of test can provide the intrinsic properties of soils to be used in subsequent modelling of release prediction.

— **Parametric tests.** These tests are intended for measuring an intrinsic property of a material or the effects (correlated) of specific parameters on release, on the basis of a contaminated material in an envisaged scenario. ISO/TS 21268-4 describes a typical parametric test.

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NOTE Diffusion coefficients, solubility or physical properties are examples of intrinsic properties of materials.

ISO 18772:2008
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Temperature, pH-value, liquid/solid ratio, redox potential, chemical properties or leaching-agent flow rate are examples of specific parameters which influence the behaviour towards leaching.

— **Multiparametric tests.** These tests are intended for measuring the combined effect of different parameters on release in the relevant scenario. For a typical multiparametric leaching test, see ISO/TS 21268-3.

For the first characterisation of a soil with these kinds of leaching tests, a direct use of test results, such as multiplication by a factor to extrapolate from laboratory scale to field scale, is generally not possible.

c) **Simulation tests**

These tests are aimed at reproducing, as well as possible, the field conditions and/or conditions when checking, on a large scale, the behaviour towards leaching predicted on the basis of the previous parametric or multiparametric tests. Lysimetric tests (so-called lysimeters) or large-scale column tests are examples of simulation tests.

Further information is given in 7.1.4.

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4.3 Usefulness of leaching tests to understand and characterise different mechanisms occurring in soil

Soils are made up of three distinct phases: the solid matrix itself, the liquid phase (sometimes including the non-aqueous liquid phases) and the gaseous phase. Soil is also an ecosystem where biological activity takes place. The behaviour of the soil constituents (inorganic constituents consisting of major, minor and trace elements and organic constituents consisting of compounds of varying volatility and water solubility) within these porous media is governed by very diverse mechanisms, among which can be cited:

a) mobilisation and release of constituents and their chemical or mineralogical form;

b) pattern of water circulation through the granular bed (convection, dispersion, preferential flow) which regulates both the transfer and transport of constituents;

c) possible transport of dissolved constituents, especially constituents associated with organic carbon, and substances bound to fine particles (e.g. colloids, clay particles) within the granular bed;

d) physico-chemical interactions of the liquid phase with the solid matrix (e.g. mineral oxides, organic matter): adsorption/desorption, diffusion in stagnant water or other liquid or solid phases, diverse physico-chemical reactions (precipitation/dissolution, complexing, acid/base neutralisation, oxido-reduction, carbonation, ionic association/dissociation, etc.);

e) possible biological interactions (action of micro-organisms, mainly biodegradation or bioaccumulation).

The usefulness of leaching tests to the understanding and characterisation of the above mechanisms is presented in Table 2 (in this table each mechanism is referenced by the letter of the above list).

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Table 2 — Usefulness of leaching tests to understand and characterise different mechanisms occurring in soil

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Mechanism	Compliance and quality control tests	Parametric tests	Multiparametric tests	Simulation tests/ lysimeters
a)	x	x	x	x
b)	—	—	x [a]	x [a]
c)	—	—	x [b]	x [c]
d)	—	x	—	x [c]
e)	—	x [d]	—	x [c]

[a] With hydrodynamic characterisation, scenario information and modelling.

[b] Without filtration device.

[c] Previous information obtained with parametric and/or multiparametric tests, together with modelling, are needed to help in interpreting results and in qualifying the mechanisms.

[d] For example, by carrying out two tests in parallel, the first under biotic conditions and the second under abiotic conditions (all other test conditions being equivalent), it is possible to determine the effect of biological activity on the release.

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