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Soil quality — Characterization of soil related to groundwater protection

Qualité du sol — Caractérisation des sols en relation avec la nappe phréatique

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Foreword

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ISO 15175 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Soil and site assessment*.

Soil quality — Characterization of soil related to groundwater protection

1 Scope

This International Standard provides guidance on the principles behind, and main methods for, the evaluation of sites, soils, and soil materials in relation to their role as a source of contamination of groundwater and their function in transporting, degrading and transforming contaminants. It identifies and lists relevant monitoring strategies, methods for sampling, soil processing and analytical methods.

This International Standard is applicable to the evaluation of the impact of contaminants on groundwater in relation to

— drinking water quality,

— irrigation water quality,

— industrial use,

— natural base flow.

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 6341, *Water quality — Determination of the inhibition of the mobility of* Daphnia magna *Straus* (Cladocera, Crustacea) — *Acute toxicity test*

ISO 6468, *Water quality — Determination of certain organochlorine insecticides, polychlorinated biphenyls and chlorobenzenes — Gas chromatographic method after liquid-liquid extraction*

ISO 6878, *Water quality — Spectrometric of phosphorus using ammonium molybdate*

ISO 7150-1, *Water quality — Determination of ammonium — Part 1: Manual spectrometric method*

ISO 7150-2, *Water quality — Determination of ammonium — Part 2: Automated spectrometric method*

ISO 7888, *Water quality — Determination of electrical conductivity*

ISO 7890-1, *Water quality — Determination of nitrate — Part 1: 2,6-Dimethylphenol spectrometric method*

ISO 7890-2, *Water quality — Determination of nitrate — Part 2: 4-Fluorophenol spectrometric method after distillation*

ISO 7890-3, *Water quality — Determination of nitrate — Part 3: Spectrometric method using sulfosalicylic acid*

ISO 7981-2, *Water quality — Determination of six specified polynuclear hydrocarbons* (PAH) — *Part 2: Determination of six PAH by high-performance liquid chromatography with fluorescence detection after liquid-liquid extraction*

ISO 8165-1, *Water quality — Determination of selected monovalent phenols — Part 1: Gas chromatographic method after enrichment by extraction*

ISO 8245, *Water quality — Guidelines for the determination of total organic carbon (TOC) and dissolved organic carbon (DOC)*

ISO 9001:2000, *Quality management systems — Requirements*

ISO 9562, *Water quality — Determination of adsorbable organically bound halogens (AOX)*

ISO 9964-1, *Water quality — Determination of sodium and potassium — Part 1: Determination of sodium by atomic absorption spectrometry*

ISO 9964-2, *Water quality — Determination of sodium and potassium — Part 2: Determination of potassium by atomic absorption spectormetry*

ISO 9964-3, *Water quality — Determination of sodium and potassium — Part 3: Determination of sodium and potassium by flame emission spectrometry*

ISO 10048, *Water quality — Determination of nitrogen — Catalytic digestion after reduction with Devarda's alloy*

ISO 10301, *Water quality — Determination of highly volatile halogenated hydrocarbons — Gas chromatographic methods*

ISO 10382, *Determination of organochlorine pesticides and polychlorinated biphenyls – gas chromatographic method with electron capture detection*

ISO 10390, *Soil quality — Determination of pH*

ISO 10523, *Water quality — Determination of pH*

ISO 10573, *Soil quality — Determination of water content in the unsaturated zone — Neutron depth probe method*

ISO 10693, *Soil quality — Determination of carbonate content — Volumetric method*

ISO 10694, *Soil quality — Determination of organic and total carbon after dry combustion (elementary analysis)*

ISO 11047, *Soil quality — Determination of cadmium, chromium, cobalt, copper, lead, manganese, nickel and zinc — Flame and electrothermal atomic absorption spectrometric methods*

ISO 11048, *Soil quality — Determination of water-soluble and acid-soluble sulfate*

ISO 11074-1, *Soil quality — Vocabulary — Part 1: Terms and definitions relating to the protection and pollution of the soil*

ISO 11074-4 *Soil quality — Vocabulary — Part 4: Terms and definitions relating to the rehabilitation of soils and sites*

ISO 11259, *Soil quality — Simplified soil description*

ISO 11260, *Soil quality — Determination of effective cation exchange capacity and base saturation level using barium chloride solution*

ISO 11261, *Soil quality — Determination of total nitrogen — Modified Kjeldahl method*

ISO 11263, *Soil quality — Determination of phosphorus — Spectrometric determination of phosphorus soluble in sodium hydrogen carbonate solution*

ISO 11264, *Soil quality — Determination of herbicides — Method using HPLC with UV detection*

ISO 11265, *Soil quality — Determination of the specific electrical conductivity*

ISO 11266, *Soil quality — Guidance on laboratory testing for biodegradation of organic chemicals in soil under aerobic conditions*

ISO 11271, *Soil quality — Determination of redox potential — Field method*

ISO 11272, *Soil quality — Determination of dry bulk density*

ISO 11274, *Soil quality — Determination of the water retention characteristic — Laboratory methods*

ISO 11275, *Soil quality — Determination of unsaturated hydraulic conductivity and water-retention characteristic — Wind's evaporation method*

ISO 11277, *Soil quality — Determination of particle size distribution in mineral soil material — Method by sieving and sedimentation*

ISO 11348-1, *Water quality — Determination of the inhibitory effect of water samples on the light emission of* Vibrio fischeri *(Luminescent bacteria test) — Part 1: Method using freshly prepared bacteria*

ISO 11348-2, *Water quality — Determination of the inhibitory effect of water samples on the light emission of* Vibrio fischeri *(Luminescent bacteria test) — Part 2: Method using liquid-dried bacteria*

ISO 11348-3 *Water quality — Determination of the inhibitory effect of water samples on the light emission of* Vibrio fischeri *(Luminescent bacteria test) — Part 3: Method using freeze-dried bacteria*

ISO 11369, *Water quality — Determination of selected plant treatment agents — Method using high performance liquid chromatography with UV detection after solid-liquid extraction*

ISO/TS 11370, *Water quality — Determination of selected organic plant treatment agents — Automated multiple development (AMD) technique*

ISO 11464, *Soil quality — Pretreatment of samples for physico-chemical analyses*

ISO 11423-1, *Water quality — Determination of benzene and some derivatives — Part 1: Head-space gas chromatographic method*

ISO 11423-2, *Water quality — Determination of benzene and some derivatives — Part 2: Method using extraction and gas chromatography*

ISO 11466, *Soil quality — Extraction of trace elements soluble in* aqua regia

ISO 11905-1, *Water quality — Determination of nitrogen — Part 1: Method using oxidative digestion with peroxodisulfate*

ISO/TR 11905-2, *Water quality — Determination of nitrogen — Part 2: Determination of bound nitrogen, after combustion and oxidation to nitrogen dioxide, using chemiluminescence detection*

ISO 13536, *Soil quality — Determination of the potential cation exchange capacity and exchangeable cations using barium chloride solution buffered at pH = 8,1*

ISO 13877, *Soil quality — Determination of polynuclear aromatic hydrocarbons — Method using high-performance liquid chromatography*

ISO 13878, *Soil quality — Determination of total nitrogen content by dry combustion ("elemental analysis")*

ISO 14154, *Soil quality — Determination of selected phenols and chlorophenols — gas chromatographic method*

ISO 14235, *Soil quality — Determination of organic carbon by sulfochromic oxidation*

ISO 14238, *Soil quality — Biological methods — Determination of nitrogen mineralization and nitrification in soils and the influence of chemicals on these processes*

ISO 14239, *Soil quality — Laboratory incubation systems for measuring the mineralization of organic chemicals in soil under aerobic conditions*

ISO 14254, *Soil quality — Determination of exchangeable acidity in barium chloride extracts*

ISO 14255, *Soil quality — Determination of nitrate nitrogen, ammonium nitrogen and total soluble nitrogen in air-dry soils using calcium chloride solution as extractant*

ISO 14256-2, *Soil quality — Determination of nitrate, nitrite and ammonium in field-moist soils by extraction with potassium chloride solution — Part 2: Automated method*

ISO 14507, *Soil quality — Pretreatment of samples for determination of organic contaminants*

ISO 14869-1, *Soil quality — Dissolution for the determination of total element content — Part 1: Dissolution with hydrofluoric and perchloric acids*

ISO 14869-2, *Soil quality — Dissolution for the determination of total element content — Part 2: Dissolution by alkaline fusion*

ISO 14870, *Soil quality — Extraction of trace elements by buffered DTPA solution*

ISO 14911, *Water quality — Determination of dissolved* Li^+, Na^+, NH_4^+, K^+, Mn^{2+}, Ca^{2+}, Mg^{2+}, Sr^{2+} and Ba^{2+} *using ion chromatography — Method for water and waste water*

ISO 15009, *Soil quality — Gas chromatogrphic determination of the content of volatile aromatic hydrocarbons, naphthalene and volatile halogenated hydrocarbons — Purge-and-trap method with thermal desorption*

ISO 15089, *Water quality — Guidelines for selective immunoassays for the determination of plant treatment and pesticide agents*

ISO 15178, *Soil quality — Determination of total sulfur by dry combustion*

ISO 15473: 2002, *Soil quality — Guidance on laboratory testing for biodegradation of organic chemicals in soil under anaerobic conditions*

ISO 15799, *Soil quality — Guidance on the ecotoxicological characterization of soils and soil materials*

ISO 15913, *Water quality — Determination of selected phenoxyalkanoic herbicides, including bentazones and hydroxybenzonitriles by gas chromatography and mass spectrometry after solid phase extraction and derivatization*

ISO 16703, *Soil quality — Determination of content of hydrocarbon in the range* C_{10} *to* C_{40} *by gas chromatography*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 20279, *Soil quality — Extraction of thallium and determination by electrothermal atomic absorption spectrometry*

OIML R 112:1994, *High performance liquid chromatographs for measurement of pesticides and other toxic substances*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11074-1 and ISO 11074-4 and the following apply.

3.1
soil
upper layer of the Earth's crust composed of mineral particles, organic matter, water, air and organisms

[ISO 11074-1]

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

cf. **pollutant** (3.8).

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

3.3
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 for example 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 near the source or where atmospheric deposition/rain is increased.

3.4
groundwater
water which is being held in, and can usually be recovered from, an underground formation

3.5
hazard
property of a substance or material, or any action, which may cause an adverse effect on soil functions

3.6
percolating water
soil water that moves downward in the percolating space due to gravity, insofar as it is not groundwater

3.7
point-source input
input of a substance from a stationary discrete source of defined 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]

3.8
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

NOTE Also described as those substances which due to their properties, amount or concentration cause impacts on soil functions or soil use.

3.9
residual contamination
amount or concentration of contaminants remaining in specific media following remediation

[ISO 11074-4]

3.10
risk
expression of the probability that an adverse effect on soil functions will occur under defined conditions, and the magnitude of the consequences of the effect occurring

3.11
saturated zone
zone of the underground, where the space of the lithosphere is filled uninterruptedly with water at the time under consideration

NOTE The saturated zone encompasses the groundwater zone including the zone of capillary water.

3.12
soil function
function of soil which is significant to man and the environment

NOTE Important soil functions are

— control of matter and energy cycles as compartments of an ecosystem,

— vital support for the life of plants, animals and man,

— basis for the stability of buildings and roads,

— basis for agricultural production,

— buffer inhibiting movement of water, contaminants or other agents into the groundwater,

— source of a gene pool,

— preservation of archaeological remains,

— preservation of paleoecological remains.

[ISO 11074-4]

3.13
soil material
excavated soil, dredged materials and soil treated to remove or destroy or reduce the environmental availability of contaminants

3.14
soil water
all water of the unsaturated and saturated zone

3.15
subsoil
partially decomposed layer of rock underlying the topsoil and overlying the solid parent rock beneath

3.16
topsoil
upper part of a natural soil which is generally dark-coloured and has a higher content of organic matter and nutrient when compared to the subsoil below

[ISO 11074-4]

3.17
unsaturated zone
zone of the soil and the underground, where the space of the lithosphere is not filled uninterruptedly with water at the time under consideration

NOTE The unsaturated zone encompasses the zone of percolating water with the zone of capillary water being excluded.

4 General

Soils are of central importance within the water cycle because their storage and filter functions have a lasting influence on the water balance and groundwater quality. In this context, particular attention shall be paid to the following functions:

— mechanical filter functions (retention of suspended sludge and pollutant particles);

— chemical filter functions (sorption and mobilization of substances);

— transformation functions (degradation or transformation of substances).

Soil is understood as a porous medium consisting of three phases: the solid phase, the liquid phase and the gaseous phase. The ratio of these phases and their respective compositions vary widely in time and space.

The assessment of contamination affecting groundwater quality requires a profound understanding of the governing processes and reactions of potentially toxic compounds in soils. Contaminants are translocated in all three phases of soils as a function of the properties of the chemicals and the soil. Hence strategies for assessing risks to groundwater due to soil contamination should vary with the contaminants considered, and should take into account those soil properties which mainly govern the soil's filter, retention, release and transformation functions.

In addition to considering the properties of the chemicals and the soil governing the behaviour of contaminants in soils, different ways for contaminants to enter soils shall also be evaluated when designing suitable risk assessment strategies, with respect to contamination of groundwater. Soil and groundwater contamination can be caused by different sources on different spatial scales, as indicated in Figure 1. On regional and larger scales, soil contamination is caused, for example, by wet and dry atmospheric deposition and has predominantly diffuse character on a moderate level of contamination. On a local scale, a variety of point sources can cause all kinds and magnitudes of soil and groundwater contamination. Most point sources of contamination may also be regarded as off-site diffuse sources of groundwater contamination. It is evident that different contamination scenarios as a function of contamination sources and scale demand different investigation strategies with respect to groundwater impact. At present there are no uniform principles for the investigation and evaluation of contaminated soils and contaminated sites in relation to the protection of water resources.

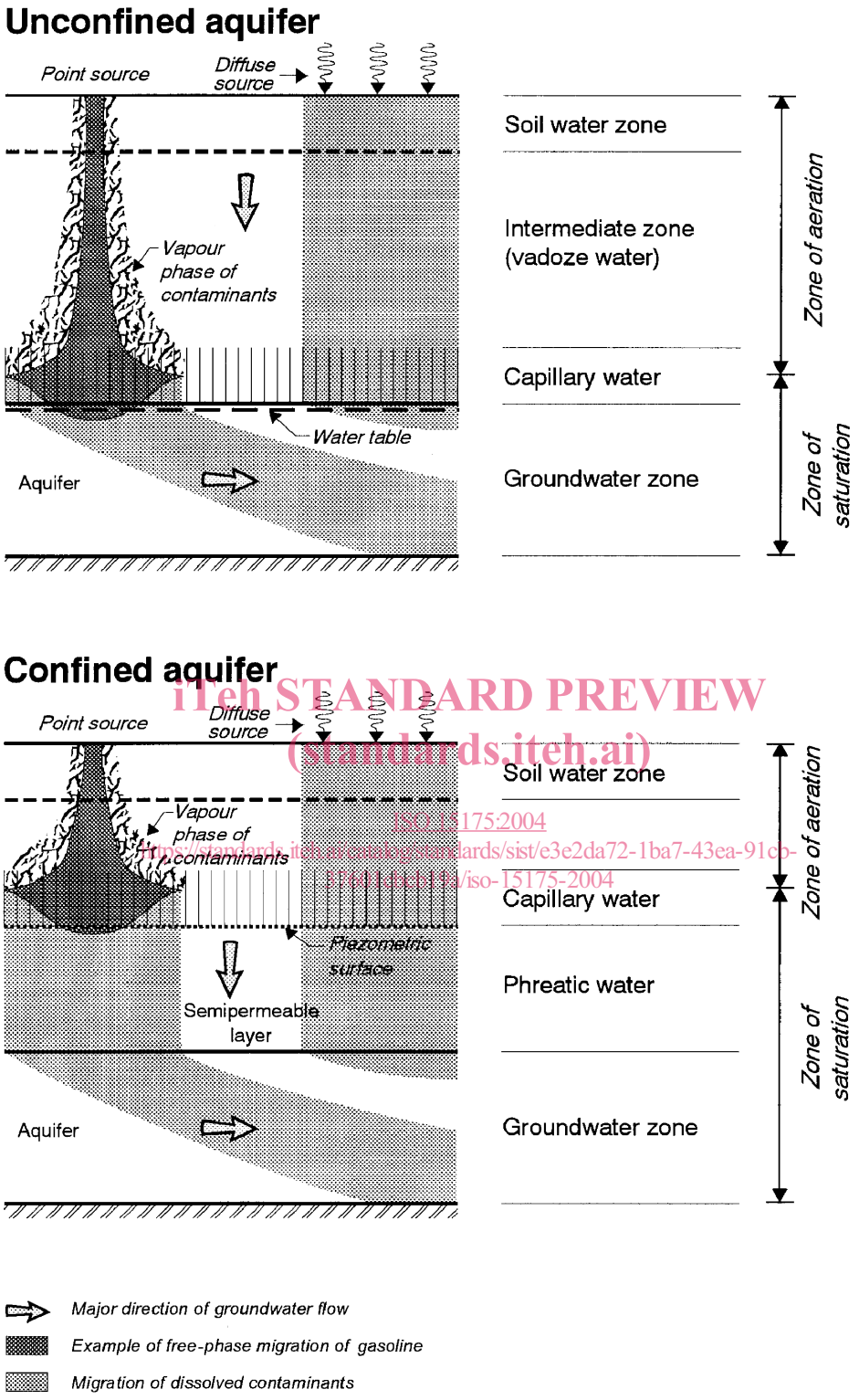

Figure 1 — Definition of groundwater zones and examples of sources of contamination

Investigation strategies may be qualitative or quantitative. Qualitative approaches mostly refer to assessment of, for example, the potential leaching risk of chemicals through the soil towards groundwater. In contrast to quantitative approaches, the level of actual soil contamination is not taken into account. Approaches of this type can also be utilized, e.g. to classify larger areas with respect to their capability of protecting groundwater resources against contamination, or as an introductory step in an assessment of an actual contaminated site.

To assess the on-site impact on groundwater resulting from specific soil contamination, quantitative approaches based on site-specific investigation procedures including laboratory and/or field measurements have to be carried out. Laboratory measurements can include physical, chemical and biological analysis, and leaching tests. Assessments of this kind also shall take into account natural background concentrations of a substance and other natural conditions affecting the impact on the groundwater. Assessments of impact on groundwater often include a temporal aspect, since the actual impact may not be measurable at the time of the investigation, but may happen some time in the future.

Assessments also depend on the purposes of investigations, for example:

— conservation of soil functions in order to prevent groundwater contamination;

— soil and groundwater monitoring;

— risk assessment;

— controlling remediation measures.

A listing of suitable methods are covered in the main part of this International Standard (see Clause 5). Some examples of assessment using principles of this International Standard are provided in Annexes A and B.

Since the impact on groundwater can lead to impact on surface waters, this aspect can in some cases be relevant in an overall impact assessment. This issue is not addressed explicitly in this International Standard.

5 Site assessment

5.1 General

A prerequisite for the evaluation of the soil-to-groundwater pathway is the determination of the relevant physical, chemical and biological characteristics of soils and the hydrological characteristics of the site. It is therefore normally necessary to collect data for the assessment of the contamination source with respect to the type and degree of contamination and extent of source(s).

It is also necessary to describe the soil compartment that is influenced by the source, and the factors in this compartment affecting the actual impact on the groundwater. Many processes influence the groundwater impact in this soil compartment, where a number of physical, chemical and biological processes can take place. In order to evaluate the importance of these processes in a specific assessment, it is necessary to describe the structure of the soil compartment, e.g. the geometry, hydraulic conditions and natural chemical and biologic processes. Input to the soil compartment includes the infiltration of water and specific contaminants. Output is the contaminant flux to the compartment of the groundwater zone investigated. A general description hereof is given in Figure 2 and a further description of the relevant parameters is given in 5.2.

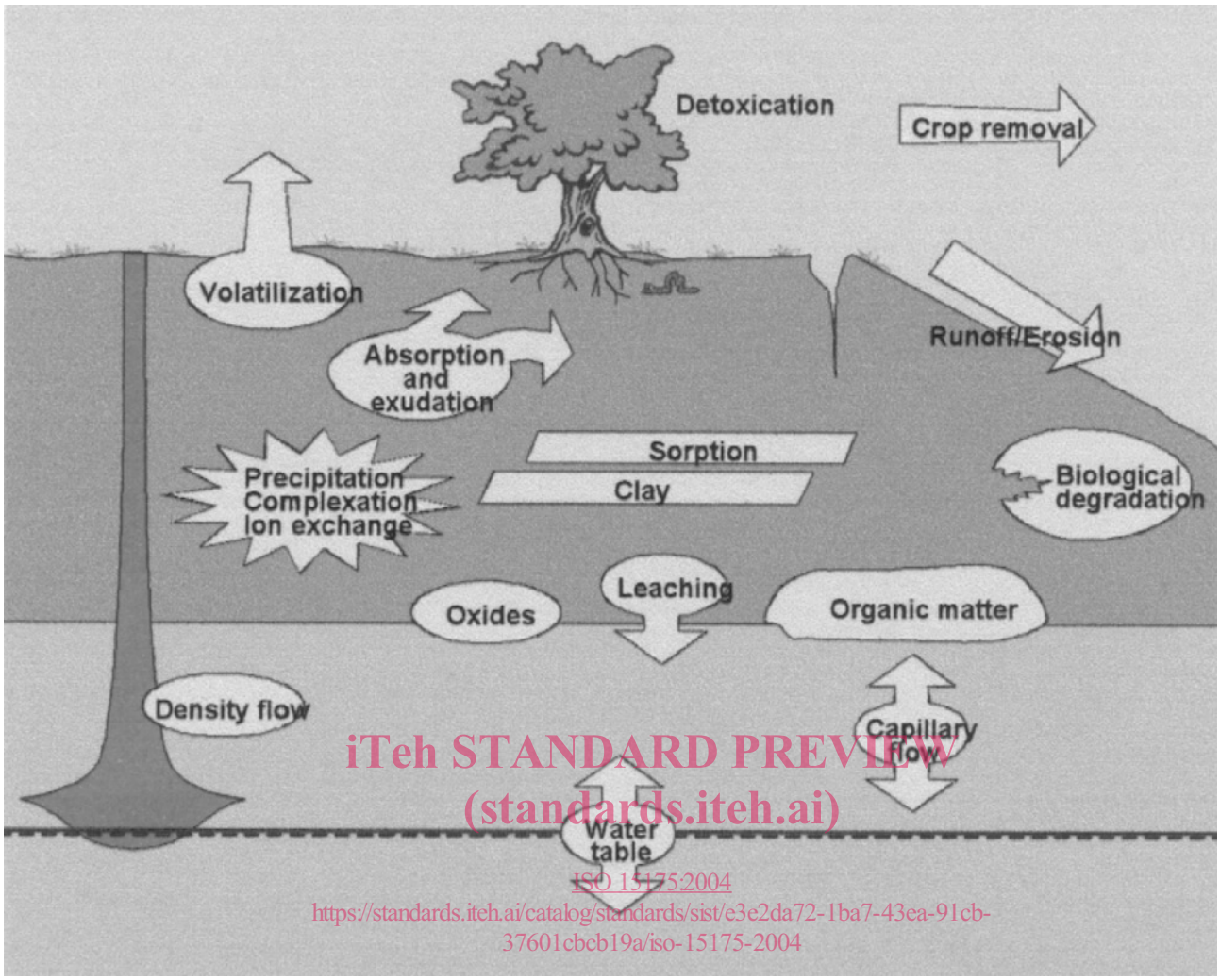

Figure 2 — Schematic diagram illustrating the soil compartment covered by the assessment procedure and processes affecting the impact of contamination on groundwater

The types of information needed to describe the relevant soil compartment include pedology, lithology of parent material, pedology (e.g. soil unit), hydrogeology (e.g. permeability), physico-chemical conditions (e.g. pH) and biological conditions (e.g. substrate availability). How large the actual soil compartment investigated should be (and thus the detail of the investigation) depends on the type of assessment chosen. For example, the volume is large if the assessment focuses on the general use of pesticides and fertilizers in an area covering a groundwater reservoir used as a drinking water source. The area and volume of the soil compartment investigated is considerably smaller if the assessment covers a “hot spot” on a contaminated site with a groundwater-pumping well located on a neighbouring site.

5.2 Relevant soil processes

Contaminant transport in the unsaturated zone is governed not only by the transport of percolating water but also by a number of biological and chemical processes. Which of these processes are to be considered important within a given context will depend on the type of contaminants and the actual soil conditions. An overview of soil and contaminant parameters related to contaminant transport is given in Table 1.

Table 1 — Soil and contaminant parameters related to different processes in soil

Process	Soil parameters	Contaminant parameters	Soil/contaminant interactions
Mass transport of contaminants	Hydraulic conductivity, degree of saturation, porosity, pore size distribution, soil water-retention functions	Solubility, volatility, density, viscosity	Relative permeability, residual saturation, wettability, surface tension, capillary pressure
Contaminant transport in water:			
Advection	Pressure gradient, hydraulic conductivity, porosity		Viscosity
Dispersion/diffusion	Dispersivity, pore water velocity	Diffusion coefficient	
Density transport	Pore water velocity, soil layering	Liquid density	Dispersion, change in density
Preferential flow	Pore size distribution, fissure size, macropore size, connectivity	Viscosity, density, diffusion coefficient	
Volatilization	Water content, temperature, chemical-phase content	Vapour pressure, Henry's constant	
Gas-phase transport	Water content, tortuosity, pressure differences	Diffusion coefficient	
Dissolution of organics	Hydraulic conductivity, tortuosity, water content	Solubility, composition of chemical phase	
Dissolution of inorganics	Hydraulic conductivity, tortuosity, water content	Solubility product	
Precipitation	pH, redox, other components	Solubility product, complexation constant	
Complexation	pH, ligand concentration, DOC	Complexation constant	
Ion exchange	Cation exchange capacity, ionic strength, other cations, pH	Valence, degree of hydratization	
Sorption of organics	pH, organic matter content, clay content and mineralogy, specific surface area	Octanol-water distribution coefficient, sorption constant	Ageing
Sorption of inorganics	pH, organic matter content, clay content and mineralogy, specific surface area, non-crystalline (short-range ordered) oxide and hydrous oxide gels	Sorption constant	Ageing
Degradation			
Abiotic	Redox, pH, temperature	Presence of primary substrate, degradability, toxicity to microorganisms	
Biotic	Microorganisms, redox, substrate, pH, temperature		

5.3 Impact assessment procedures

In order to complete a description of the source and the soil it is necessary to develop

— strategies for evaluation of site-specific parameters,

— sampling strategies, and

— analytical and testing strategies

for each site and/or media (soil, groundwater, soil air) that influences the impact on the groundwater.