DRAFT INTERNATIONAL STANDARD ISO/DIS 15175

ISO/TC **190**/SC **7** Secretariat: **DIN**

Voting begins on **2001-03-15** Voting terminates on **2001-08-15**

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Soil quality — Characterization of soil related to groundwater protection

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

ICS 13.080.40

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Foreword

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

Soil quality — Characterisation 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. This standard identifies and lists relevant monitoring strategies, methods for sampling, soil processing, and analytical methods.

The standard is relevant to the evaluation of a contaminants impact on groundwater in relation to,

- Drinking water
- Irrigation
- Industrial use
- Natural base flow

It is one of a series of International Standards on Soil and Site Assessment and should be read as appropriate with other standards in the series.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 11259, *Soil Quality — Simplified soil description*

ISO 5667-1: 1980, *Water Quality — Sampling - Design of sampling programmes*

ISO 5667-2: 1991, *Water Quality — Sampling - Guidance on sampling techniques*

ISO 5667-3: 1985, *Water Quality — Sampling — Guidance on the preservation and handling of samples*

ISO 5667-4: 1987, *Water Quality — Sampling — Guidance on sampling from lakes, natural and man-made*

ISO 5667-6: 1991, *Water Quality — Sampling — Guidance on sampling rivers and streams*

ISO 5667-11: 1993, *Water Quality — Sampling — Guidance on sampling groundwater* [Note: TC 147 has a new work item on sampling groundwater for contamination]

ISO 11074-1: 1996, *Soil quality — Vocabulary — Part 1: Terms and definitions relating to the protection and pollution of soil*

ISO/DIS 10381-1: 1996, *Soil quality — sampling — Guidance on the design of sampling programmes*

ISO/DIS 10381-2: 1996, *Soil quality — sampling — Guidance on sampling techniques*

ISO/DIS 10381-3: 1996, *Soil quality — sampling: Guidance on safety*

ISO/DIS 10381-4: 1996, *Soil quality — sampling — Guidance on the procedure for the investigation of natural, nearnatural and cultivated sites*

ISO/DIS 10381-5: 2000, *Soil quality — Sampling — Guidance on procedures for the investigation of soil contamination of urban and industrial sites*

ISO 10381-6: 1993, *Soil quality — Sampling — Guidance on the collection, handling and storage of soil for the assessment of aerobic microbial processes in the laboratory*

3 General

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

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

— chemical filter functions (sorption and mobilisation 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 soils filter 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 have also to be evaluated when designing suitable risk assessment strategies, with respect to contamination of groundwater. Soil and groundwater contamination can be caused by different sources at different spatial scales as indicated in Figure 1. At regional and larger scales, soil contamination is, for example caused 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 may 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.

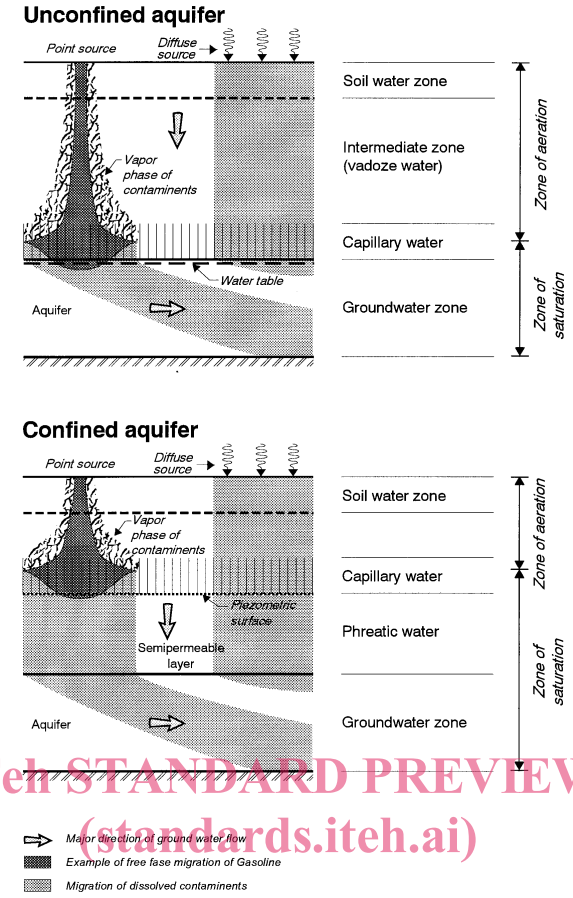

Figure 1 — Definition of groundwater zones and examples of sources of contamination

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. Contrary to quantitative approaches the level of actual soil contamination is not taken into account. Approaches of this type can also be utilised 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 have to take into account natural background concentrations of a substance and other natural conditions affecting the impact on the groundwater. Assessments of impact on groundwater will 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, e.g.:

— conservation of soil functions in order to prevent groundwater contamination

— process-orientated soil and groundwater monitoring

— risk assessment

— controlling remediation measures

A listing of suitable methods are covered in the main part of this standard (see clause 5). Some examples of assessment using principles of this standard are provided in the informative 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 will not be handled explicitly in this standard.

4 Definitions

For the purposes of this International Standard the following definitions are applied:

4.1 Assessment

4.1.1
hazard
Property of a substance or material, or any action, which may cause an adverse effect on soil functions.

4.1.2
risk
An 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.

4.2
background concentration
The concentration of a substance characteristic of an area or region arising from both natural and non-natural diffuse sources such as atmospheric deposition. Commonly expressed in terms of average, "typical" or a range of values or referred to as a baseline.

NOTE See natural background concentration.

4.3
background value
An expression of the upper limit of the range of the background concentration: commonly expressed as the 90 th percentile value.

4.4
contaminant
A 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 - see also Pollutant.

4.5
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 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.

4.6
groundwater
Water which is being held in, and can usually be recovered from an underground formation.

4.7
natural background concentration
The concentration of a substance that is derived solely from natural sources (i.e, of geogenic origin). Commonly expressed in terms of average, "typical" or a range of values.

4.8
percolating water
Undergroundwater that moves downward in the percolating space due to gravity, insofar as it is not groundwater.

4.9
point source input
Input of a substance from a stationary discrete source of definite 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.

4.10
pollutant
A substances 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 Those substances which due to their properties, amount or concentration cause impacts on the soil function or soil use (ISO 11074-1).

4.11
residual contamination
The amount or concentration of contaminants remaining in specific media following remediation (ISO 11074-4).

4.12
saturated zone

Zone of the underground, where the space of the lithosphere is filled uninterruptedly with water at the time of consideration.

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

4.13
soil
The upper layer of the earth's crust composed of mineral parts, organic substance, water, air and living matter (ISO 11074-1).

4.14
soil functions
The soil functions describe the significance of soils to man and the environment (ISO 11074-1). Important soil functions are:

- control of substance and energy cycles as compartment of ecosystems
- basis for the life of plants, animals and man
- basis for the stability of buildings and roads
- basis for the yield of agriculture, horticulture and forestry
- carrier of groundwater and storage sites
- carrier of genetic reservoir
- document of natural history
- archaeological and paleoecological document.

4.15
soil material
Soil material includes excavated soil, dredged materials and soil treated to remove or destroy or reduce the environmental availability of contaminants.

4.16
soil water
Soil water includes all water of the unsaturated and saturated zone.

4.17
sub-soil
The partially decomposed layer of rock underlying the top-soil and overlying the solid parent rock beneath.

4.18
top-soil
The upper part of a natural soil which is generally dark coloured and has a higher organic matter and nutrient content when compared to the sub-soil below (ISO 11074-1).

4.19
unsaturated zone
Zone of the soil and the underground, where the space of the lithosphere is not filled uninterruptedly with water at the time of consideration.

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

5 Site Assessment

A prerequisite for the evaluation of the soil - groundwater pathway, is the determination of the relevant physical, chemical and biological characteristics of soils and the hydrological characteristics of the site. It will therefor normally be necessary to collect data for the assessment of the contamination source in respect of 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 principle description hereof is given in Figure 2 and a further description of the relevant parameters is given in clause 5.1.

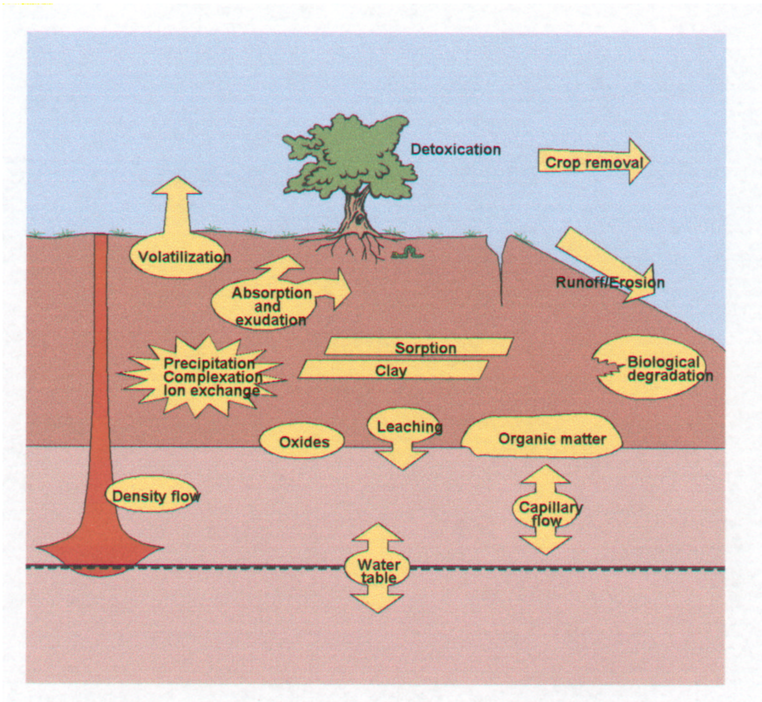

Figure 2 — Schematic diagram illustrating the soil compartment covered by the assessment procedure and processes affecting the impact of contamination on groundwater

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 as described in clause 2. For example the volume is large if the assessment focuses on the general use of pesticides and fertilisers 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.

5.1 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.

5.2 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.

These strategies should be determined on the basis of:

- history of the site or area
- available data and/or results of previous investigations
- the nature of any process based treatment methods that have been applied to the soil
- the intended use of the site.

To optimise the actual need for information in relation to the costs and time demanded for the investigations in the field and laboratory it is recommended to carry out the assessment in a stepwise procedure (Table 2).

The first step includes a preliminary review based on desktop investigations and limited field investigations with the aim to carry out an initial impact assessment. This step includes estimation of the soil geometry, soil unit and hydrological conditions on basis of general knowledge of the area, possibly supplemented with some field data in respect of local conditions. The presence of contaminants of interest and their likely concentrations are estimated on basis of site history and a few analyses of soil and water samples and/or soil gas measurements. The relevant transport and decomposition processes are approximated from data related to the relevant soil conditions and contaminants retrieved from the literature. In step 1 qualitative methods as exemplified in Annex A can be useful as can quantitative methods as described as Level 1 in Annex B.

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

Process	Parameters - soil	Parameters - contaminant	Interaction - soil/contaminant
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, wetability, surface tension, capillary pressure
Contaminant transport in water:			
Advection	Pressure gradient, hydraulic conductivity, porosity		Viscosity
Dispersion/diffusion			
Density transport	Dispersivity, pore water velocity	Diffusion coefficient	
Preferential flow	Pore water velocity, soil layering	Liquid density	Dispersion, change in density
	Pore size distribution, fissure size, macropore size, connectivity	Viscosity, density, diffusion coefficient	
Volatilisation	Water content, temperature, chemical phase content	Vapour pressure, Henry's constant	
Gas phase transport	Water content, tortuosity, pressure differences	Diffusion coefficient	
Dissolution - organics	Hydraulic conductivity, tortuosity, water content	Solubility, composition of chemical phase	
Dissolution - inorganics	Hydraulic conductivity, tortuosity, water content	Solubility product	
Precipitation	pH, redox, other components	Solubility product, complexation constant	
Complexation	pH, ligand concentration	Complexation constant	
Ion Exchange	Cation exchange capacity, ionic strength, other cations, pH	Valence, degree of hydratisation	
Sorption – organics	pH, organic matter content, clay content and mineralogy, specific surface area	Octanol-water distribution coefficient, sorption constant	
Sorption – inorganics	pH, organic matter content, clay content and mineralogy, specific surface area, non-crystalline (short-range ordered) oxide and hydrous oxide gels	Sorption constant	
Degradation –Abiotic –Biotic	 Redox, pH, temperature Micro-organisms, redox, substrate, pH, temperature	 Presence of primary substrate, degradability, toxoicity to micro-organisms	