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**Water quality — Sampling —**

Part 18:

**Guidance on sampling of groundwater at  
contaminated sites**

*Qualité de l'eau — Échantillonnage —  
Partie 18: Lignes directrices pour l'échantillonnage des eaux souterraines  
sur des sites contaminés*

ISO 5667-18:2001

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Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.ch](mailto:copyright@iso.ch)  
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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO 5667 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 5667-18 was prepared by Technical Committee ISO/TC 147, *Water quality*, Subcommittee SC 6, *Sampling (general methods)*.

ISO 5667 consists of the following parts, under the general title *Water quality — Sampling*:

- *Part 1: Guidance on the design of sampling programmes*
- *Part 2: Guidance on sampling techniques*
- *Part 3: Guidance on the preservation and handling of samples*
- *Part 4: Guidance on sampling from lakes, natural and man-made*
- *Part 5: Guidance on sampling of drinking water and water used for food and beverage processing*
- *Part 6: Guidance on sampling of rivers and streams*
- *Part 7: Guidance on sampling of water and streams in boiler plants*
- *Part 8: Guidance on sampling of wet deposition*
- *Part 9: Guidance on sampling from marine waters*
- *Part 10: Guidance on sampling of waste waters*
- *Part 11: Guidance on sampling of groundwaters*
- *Part 12: Guidance on sampling of bottom sediments*
- *Part 13: Guidance on sampling of sludges from sewage and water-treatment works*
- *Part 14: Guidance on quality assurance of environmental water sampling and handling*
- *Part 15: Guidance on preservation and handling of sludge and sediment samples*
- *Part 16: Guidance on biotesting of samples*

- *Part 17: Guidance on sampling of suspended sediments*
- *Part 18: Guidance on sampling of groundwater at contaminated sites*
- *Part 19: Guidance on sampling of sediments in the marine environment*

Annex A forms a normative part of this part of ISO 5667.

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## Introduction

The guidance in this part of ISO 5667 can be used in parallel with other guidance on investigating contaminated or potentially contaminated sites as any groundwater sampling from such sites is likely to form part of a much wider investigation programme.

Groundwater sampling, in general, is carried out to determine whether or not the groundwater in or beneath a site is contaminated. It can also be used to satisfy the following additional objectives:

- to establish whether any migration of contaminants, derived from the site, is occurring and characterize the spatial extent of any contamination and its form;
- to determine the direction and rate of groundwater flow and contaminant migration;
- to provide data for undertaking a risk assessment;
- to provide an early warning system for the impact of contaminants on the quality of groundwater resources, surface waters and other potential receptors in the vicinity of the site;
- to monitor the performance and effectiveness of remedial measures or facility design.
- to demonstrate compliance with licence conditions, or collect evidence for regulatory purposes.
- to assist in the selection of remedial measures and remediation process design.

This guidance includes sampling of groundwater from both the saturated (below water table) zone and the unsaturated (above the water table) zone.

Development of a groundwater sampling programme depends on the purposes of the investigation. This part of ISO 5667 provides guidance to inform the user of the necessary considerations when planning and undertaking groundwater sampling from potentially contaminated sites. Examples of typical sites include:

- present or former industrial sites with a history of potentially contaminatory activities;
- waste disposal (landfill) sites;
- sites where natural and/or artificial processes have led to potential land and groundwater contamination;
- sites where products have been spilled e.g. as a result of transportation accidents.

The guidance contained in this part of ISO 5667 covers selection of sampling points, the selection of sampling installations and devices, groundwater parameter selection and sampling frequency.

Prescriptive guidance on methods and applications is not possible. Therefore, this guidance provides information on the most commonly applied, and available, techniques and lists their advantages, disadvantages and limitations of use where these are known. When considering design of sampling strategies, the properties of the contaminant source, pathways for migration and the receptors need to be considered.

# Water quality — Sampling —

## Part 18:

# Guidance on sampling of groundwater at contaminated sites

## 1 Scope

This part of ISO 5667 provides guidance on the sampling of groundwater at potentially contaminated sites. It is applicable to situations where contamination of the subsurface could exist as a result of downward migration of pollutants whose source is at the surface or just below it, and when the guidance provided in ISO 5667-11 is inappropriate.

## 2 Terms and definitions

For the purposes of this part of ISO 5667, the following terms and definitions apply.

### 2.1

#### **piezometer**

device consisting of a tube or pipe with a porous element or perforated section (surrounded by a filter) on the lower part (piezometer tip), that is installed and sealed into the ground at an appropriate level within the saturated zone for the purposes of water level measurement, hydraulic pressure measurement and/or groundwater sampling

### 2.2

#### **nested piezometers**

group of piezometers installed within a single larger-diameter borehole

NOTE In general, each piezometer should be designed to allow sampling over a specific depth interval within the aquifer. Piezometer tips are isolated from each other by installing a permanent impermeable seal between them.

### 2.3

#### **multiple boreholes**

group of individual boreholes or piezometers installed separately to form a monitoring network adequate for the purposes of an investigation

### 2.4

#### **multi-level sampler**

single installation for sampling groundwater from discrete depths within the sub-surface

NOTE The device can be driven directly into the ground, installed in a pre-existing borehole or installed in a purpose-drilled hole. When installed in a borehole, integral packers are used to isolate individual sample ports.

### 2.5

#### **aquifer**

geological formation (bed or stratum) of permeable rock or unconsolidated material (e.g. sand and gravels) capable of yielding significant quantities of water

### 2.6

#### **aquitard**

geologic stratum of formation of low permeability that impedes the flow of water between two aquifers

**2.7**

**saturated zone**

part of an aquifer in which the pore spaces of the formation are completely water-saturated

**2.8**

**unsaturated zone**

part of an aquifer in which the pore spaces of the formation are not totally water-saturated

**2.9**

**groundwater**

water in the saturated zone and/or unsaturated zone of an underground geological formation or artificial deposit such as made ground

**2.10**

**perched water table**

isolated body of groundwater, which is limited in lateral and vertical extent, located within the unsaturated zone overlying a much more extensive groundwater body

**2.11**

**matrix potential**

combination of forces, independent of gravity, acting on soil water (water contained within the pores of a soil/rock matrix) that exist as a result of the attraction of solid surfaces to water and the attraction of water molecules to each other

NOTE Generally, the smaller the particle size, the higher the matrix potential.

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**2.12**

**check valve**

mechanical valve which allows fluids to pass in only one direction

NOTE The pressure of fluids flowing through the valve in one direction has the effect of opening the valve and in the other of closing it.

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**2.13**

**receptor**

entity that is vulnerable to the adverse effect(s) of a hazardous substance or agent

EXAMPLES Human, animal, water, vegetation, building services, etc.

**2.14**

**packer**

device or material for temporarily isolating specified vertical sections within boreholes in which to perform groundwater sampling from discrete zones or locations within the borehole or aquifer

**2.15**

**hydraulic conductivity**

property of a water-bearing formation that relates to its capacity to transmit water through its internal, interconnected pathways

**2.16**

**effective porosity**

proportion of saturated openings or pores within a water-bearing formation which contribute directly to the flow of groundwater

NOTE Effective porosity is represented as the ratio of this volume of pore space to the total volume of rock.

**2.17**

**field capacity**

maximum amount of water that a soil or rock can retain after gravitational water has drained away



**2.18****dense non-aqueous phase liquids****DNAPL**

organic compounds that have a low water solubility and a density greater than that of water

EXAMPLES Chlorinated hydrocarbons such as trichloroethane.

**2.19****light non-aqueous phase liquid****LNAPL**

organic compounds that have a low water solubility and a density less than that of water

EXAMPLE Petroleum products.

**3 Sampling strategy and programme design****3.1 General**

Groundwater sampling can be carried out as a single exercise or as part of a larger site or environmental investigation. Regardless of the purpose, a rational approach should be taken that clearly defines the objectives, determines the level of information needed and identifies the various stages of the investigation.

It should be noted that, normally, groundwater sampling from the saturated zone alone cannot fully assess the level of contamination of a site in situations where an unsaturated zone of considerable thickness exists. The potential consequence of ignoring the unsaturated zone is that the unsaturated zone and groundwater system could become extensively contaminated before any tangible evidence of leakage or contamination is evident in samples collected from below the water table.

**3.2 Selection of sampling point location**

The location of monitoring installations and the design of the network for sampling groundwater from (potentially) contaminated sites should take account of the following:

- the hydrogeological setting of the investigation site;
- the past and future use(s) of the site;
- the purpose of the exercise;
- the likely contaminants;
- the extent of contamination.

All of these factors should be considered during the preliminary stages of the site investigation programme to enable the most appropriate and effective sampling programme to be designed. This information can be obtained by examining all available information held by site owners (or their agents), local, regional and national regulatory agencies and other data holders. Table 1 provides an overview of the steps involved in planning an investigation strategy and for sampling groundwater from sites that are potentially contaminated.

In addition to the scientific requirements, other factors can influence the location of sampling points. These include practical, environmental and safety considerations such as the ground slope, proximity of underground services (gas pipes, electricity cables etc) and overhead clearance for drilling rigs and other sampling devices.

To establish whether migration of contaminants is occurring and determining the direction and rate of this migration, monitoring points should be located inside and outside the contaminated area and both up and down the hydraulic gradient. A greater number of sample points should be positioned down gradient, both inside and outside of any contaminant plume.

Where site analysis indicates that the site is underlain by complex geology or that contaminants with a broad range of physical and chemical properties are likely to be present, an increased number of monitoring points should be installed for adequate characterization of the contaminant distribution. In addition to investigating the lateral variation caused by heterogeneity, the sampling strategy should also be designed to investigate any vertical variations.

**Table 1 — Procedural steps for sampling groundwater** (adapted from [9])

Step (with reference to other ISO standards)	Procedure	Essential elements	Notes
Investigation/monitoring strategy (ISO 5667-1)	Collation of available data ↓ Desk study ↓ Develop conceptual model ↓ Reconnaissance survey ↓	Identify data sources  Design borehole/sampling point network and sampling programme	Geological, geochemical and hydrogeological characterization  See 3.2, 3.3 and 3.4
Facility installation	Installation of monitoring points by drilling ↓ Well cleaning and development	Borehole design, material selection and installation technique	See clause 4  See 5.1
Well inspection	Hydrologic measurements ↓	Water level measurements Hydraulic testing	Hydrogeological characterization
Well purging	Removal or isolation of stagnant water ↓ Determination of well-purging parameters (e.g. EC, pH, temperature, redox potential)	Representative groundwater  Verification of representative groundwater	See 5.1  See 5.2
Sample collection Filtration Field determinations (ISO 5667-2, ISO 5667-11, ISO 5667-3)	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border-right: 1px solid black; padding: 5px;">                     Unfiltered sample  Organics (all) Dissolved gases  Sensitive inorganic species, e.g. nitrite, ammonium, iron(II)  Tracer metals for mobile (colloidal) loads                 </div> <div style="text-align: center;">                     ↔                 </div> <div style="border-right: 1px solid black; padding: 5px;">                     Field filtered sample  Alkalinity/pH Dissolved trace metals for specific geochemical information  Sulfide and other sensitive inorganics  Major cations and anions                 </div> </div>	Sample collection by appropriate mechanism  Field determination of sensitive parameters, pH, electrical conductivity, temperature, redox potential, dissolved oxygen as appropriate  Head-space free samples  Minimal aeration or de-pressurization  Minimal air contact  Sample preservation	See 4.2 and 4.3  See 5.4, 5.5 and 5.6  Blanks and spiked samples should be prepared in accordance with ISO 5667-14
Storage and transport of samples (ISO 5667-3)		Minimal loss of sample integrity prior to analysis	See 5.7, clauses 6, 7 and 8

Care should be taken when identifying the prevailing flow regime as localized recharge to the subsurface can alter the regional hydraulic gradient. This can result in groundwater flow and contaminant transportation in a direction that is contrary to flow imposed by the regional gradient. Dense non-aqueous phase liquids (DNAPLs) can also move in a different direction and at a different rate to that of groundwater because their chemical properties are

different to those of water. Their migration is also affected by the geological structure of the low permeability layer underlying the saturated aquifer.

Light non-aqueous phase liquids (LNAPLs) also have different chemical properties to those of water and their migration and distribution will be affected by the geological structure and chemical interactions within the unsaturated zone and zone of water table fluctuation.

Where sampling is aimed at providing an early warning of the impact of contaminants on receptors, monitoring points should be located between the contaminant source (and plume) and the potential receptors as well as within the zone of contamination, e.g. at landfill sites, monitoring points should be established around the outside of, but close to, the landfill.

Sample points within the zone of contamination and outside (both up and down the hydraulic gradient) should be installed to measure performance and effectiveness of remediation and for demonstrating compliance to licence conditions.

### 3.3 Groundwater parameter selection

The parameters selected for analysis should reflect the nature of the investigation and/or the former, current and proposed future use of the site. In some cases, certain contaminants will be the subject of national regulations. Focussing only on these, however, could be inadequate for providing the complete picture of contamination under different geochemical and hydrogeological conditions. For example, where organic contaminants are susceptible to degradation, the list of analytes should also include the degradation products, which in some cases can also be hazardous. An example of this is the degradation of trichloroethylene (TCE), a DNAPL. One of its potential degradation products is vinyl chloride, a relatively soluble and highly volatile compound.

Consideration should also be given to baseline or natural groundwater concentrations. Elevated concentrations can already be present in the environment being investigated as a result of natural sources of contamination.

### 3.4 Sampling frequency

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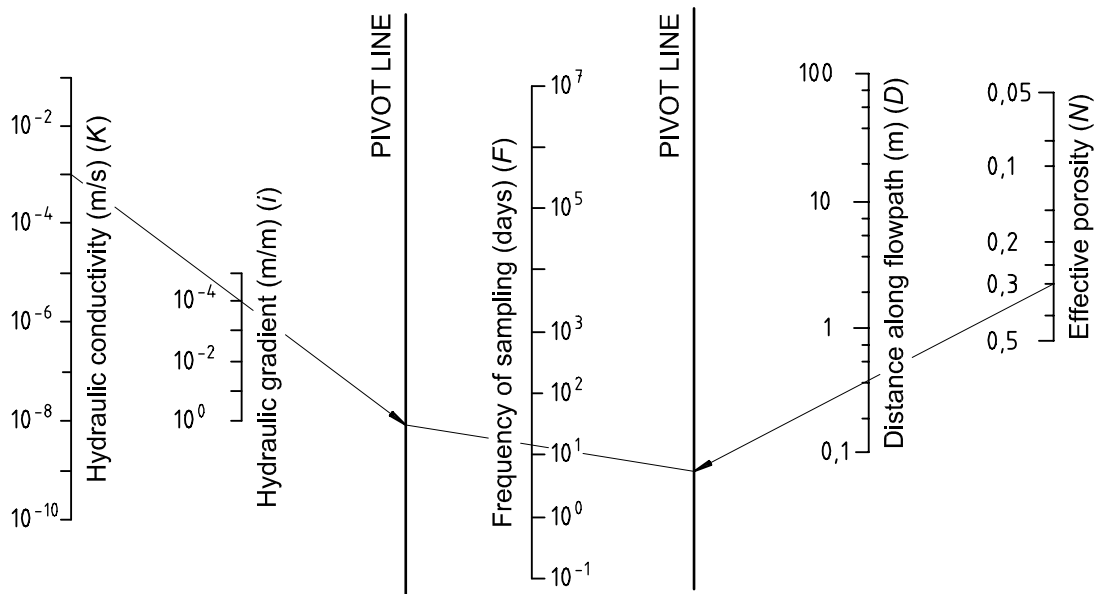
The frequency of sampling depends on the objectives of the investigation. If the investigation is designed to map an established contaminant plume, a single-event sampling exercise may be used. In this case, sampling should be completed as rapidly as possible to minimize the effects of temporal variation. Where the development of a plume is to be monitored and/or the impacts on groundwater resources considered, the frequency should be based on the prevailing hydrogeological and environmental conditions, the objectives of the study and the contaminants present.

Where monitoring is required to provide early warning, where there are compliance issues or for performance assessment of remedial measures, in general, a recommended minimum sampling frequency is quarterly for most chemical constituents (e.g. major ions, etc.) and monthly for those that are more mobile and reactive (e.g. VOCs and dissolved gases).

However, where environmental conditions indicate that changes can occur more rapidly, more frequent sampling should be carried out. In these cases, the exact frequency should be determined by examination of all influencing natural and artificial factors. Examples of short-term influencing factors include tidal influences and localized rainfall as well as ground disturbance caused by ground engineering activities.

One example of how sampling frequency can be determined using prevailing hydrogeological properties (including hydraulic gradient, hydraulic conductivity and effective porosity) is shown in Figure 1. Relevant hydrogeological parameters have been used to develop a nomogram, which has been adapted from [8] to include the effects of dispersion, for rapid estimation of sampling frequency. Dispersion has the effect of distributing the contaminant both along the flow path and perpendicular to it. The modification applied leads to a 10 % increase in sample frequency. A worked example is described in annex A.

Other environmental conditions can also influence the temporal distribution and concentration of contaminants in groundwater and soil water and these should be considered during development of the sampling strategy. Seasonal and more frequent variations in weather and climate can influence the rate of infiltration of contaminants through the unsaturated zone. A rise in water table can also lead to the release (or re-release) of contaminants into the groundwater and/or bring the contaminant source closer to the groundwater.



$$F = \left( \frac{DN}{86\,400Ki} \right) - 0,1 \left( \frac{DN}{86\,400Ki} \right)$$

Figure 1 — Nomogram for estimating sampling frequency (from [8])

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## 4 Types of monitoring installation

### 4.1 General

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Installations suitable for groundwater monitoring typically involve placement of access tubes for portable sampling devices or burial of sensors or samplers *in situ*. These installations may be positioned within the saturated zone (below the water table) or above it (unsaturated zone). In addition to sampling groundwater, installations below the water table can be used to measure water levels and installations above the water table can measure soil gas and soil moisture content.

### 4.2 Unsaturated zone monitoring

#### 4.2.1 Introduction

Sampling techniques that are used for collection of groundwater from the unsaturated zone can be divided into two types:

- solid sampling followed by extraction of groundwater (pore fluids);
- unsaturated pore fluid sampling.

#### 4.2.2 Extraction from solid samples

##### 4.2.2.1 General

The extraction of pore fluids from solid samples is the most widely used method for sampling groundwater in the unsaturated zone. Collection of solid samples as part of this method can also allow useful geological information to be obtained. There are two broad categories of solid sampling methods: hand-operated and power-operated. Table 2 lists a range of suitable techniques that can be used for extracting solid samples for pore fluid collection.