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Water quality — Sampling —

Part 11:
Guidance on sampling of groundwaters

Qualité de l'eau — Échantillonnage —

Partie 11: Guide général pour l'échantillonnage des eaux souterraines

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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.

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.

International Standard ISO 5667-11 was prepared by Technical Committee ISO/TC 147, *Water quality*, Sub-Committee 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 steam in boiler plants*

— *Part 8: Guidance on the sampling of wet deposition*

— *Part 9: Guidance on sampling from marine waters*

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— *Part 10: Guidance on sampling of waste waters*

— *Part 11: Guidance on sampling of groundwaters*

— *Part 12: Guidance on sampling of sediments*

Annex A forms an integral part of this part of ISO 5667.

Introduction

This part of ISO 5667 is one of a group of standards dealing with the sampling of specific types of water. It should be read in conjunction particularly with ISO 5667-1, ISO 5667-2 and ISO 5667-3, which deal respectively, and in a general manner, with the design of sampling programmes, sampling techniques and the preservation and handling of samples. The general terminology used is in accordance with that published in ISO/TC 147, *Water quality*, and more particularly with the terminology on sampling given in ISO 6107-2.

Water quality — Sampling —

Part 11:
Guidance on sampling of groundwaters

1 Scope

This part of ISO 5667 provides guidance on the design of sampling programmes, sampling techniques and the handling of water samples taken from groundwater for physical, chemical and microbiological assessment. It does not cover sampling related to the day-to-day operational control of groundwater abstractions for potable or other purposes, but is concerned with the general surveillance of groundwater quality. Because of the complexity of groundwater systems, many specific sampling applications will require specialist hydrogeological advice which cannot be detailed in this part of ISO 5667.

A definition of the purpose of groundwater sampling is an essential prerequisite before identifying the principles to be applied to a particular sampling problem. The general purpose of sampling programmes commonly devised for groundwaters is to survey the quality of groundwater supplies, to detect and assess groundwater pollution and to assist in groundwater resource management. The principles set out in this part of ISO 5667 also apply to the following more detailed objectives:

a) to determine the suitability of groundwater as a source of drinking water or industrial/agricultural water, and to monitor its quality during supply;

b) to identify, at an early stage, the pollution of aquifers caused by potentially hazardous surface or sub-surface activities (e.g. the operation of waste disposal sites, industrial developments, mineral exploitation, agricultural practices, changes in land use);

c) to monitor and understand the movement of pollutants, in order to assess their impact on groundwater quality and to calibrate and validate suitable groundwater quality models;

d) to develop an understanding of groundwater quality variations, including those caused by deliberate actions (e.g. variations in groundwater pumping regimes, groundwater recharge by effluent, surface clean-up activities arising from contaminated waste disposal sites), in order to achieve optimal resource management;

e) to collect data for pollution-control law-enforcement.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 5667. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 5667 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5667-1:1980, *Water quality — Sampling — Part 1: Guidance on the design of sampling programmes.*

ISO 5667-2:1991, *Water quality — Sampling — Part 2: Guidance on sampling techniques.*

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

ISO 6107-2:1989, *Water quality — Vocabulary — Part 2.*

3 Definitions

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

3.1 aquifer: Water-bearing formation (bed or stratum) of permeable rock, sand or gravel capable of yielding significant quantities of water.

3.2 consolidated aquifer: An aquifer comprising material which is compact due to cementation or compression.

3.3 groundwater: Water which is being held in, and can usually be recovered from, or via, an underground formation.

3.4 well; borehole: A hole sunk into the ground for abstraction of water or for observation purposes. A well is generally of larger diameter than a borehole and dug rather than drilled. A borehole is often used for monitoring purposes only and may be lined with suitable casing and screened at appropriate depths.

3.5 spring: Groundwater emerging naturally through the surface of the land.

3.6 pore water: Water that fills the pores or cavities within a body of rock or soil.

3.7 casing: A solid tube used as a temporary or permanent lining for a well or borehole in order to prevent the ingress of solid aquifer material into the borehole or to ensure that groundwater only enters the borehole at specific depths via a screen.

3.8 screen: A type of lining tube, with apertures, designed to permit the flow of water into a well while preventing the entry of aquifer or filter pack material.

4 Sampling equipment

4.1 Materials

General information on the choice of materials for sampling equipment and bottles is given in ISO 5667-2. Polyethylene, polypropylene, polycarbonate and glass containers are recommended for most sampling situations.

If the biological quality of groundwater is likely to cause changes in the physico-chemical composition of the water, as much light as possible should be excluded by using opaque sample containers.

When sampling groundwater for organic constituents, contamination of the sample by other organic material used in the construction of the borehole or present in the sampling equipment needs to be minimized. This is especially important where trace levels of organic constituents are of interest. In this case, it is advisable to use special equipment manufactured from glass, stainless steel, or other material incapable of leaching organic constituents.

4.1.1 Materials for borehole construction

For monitoring borehole casings and screens, suitable materials are required to avoid modifications to the chemistry of groundwater samples. Threaded joints on well casings are recommended, so that glues and cements do not introduce additional risks of sample modification. A wide variety of materials are available for use in borehole construction. In view of their low cost, widespread availability and easy handling, polypropylene and high-density polyethylene are recommended for most groundwater sampling purposes. However, groundwater that is highly contaminated with synthetic organic solvents will attack and cause deterioration of PVC well casings and screens. In such circumstances, stainless steel or polytetrafluoroethylene are the materials recommended for borehole construction because of their resistant, inert character.

4.2 Types of apparatus

4.2.1 Pumps

A wide variety of pumps, many of which are portable, are suitable for groundwater application. They differ greatly in their design and pumping capacity and are suited to different conditions of borehole construction and sampling depth. Suction lift pumps installed at the surface cannot lift water from more than 8 m and submersible electric pumps are therefore recommended for most groundwater sampling, although bladder-type pumps may also be useful in some applications, particularly in situations where samples must be taken from small diameter boreholes (< 32 mm), where the use of submersible pumps is not possible. Suction lift pumps should not be employed in situations where sampling is carried out primarily to examine the dissolved gaseous content of groundwaters.

4.2.2 Depth sampling equipment

Depth sampling equipment (often known as "thief" or "grab" samplers) are devices that can be lowered into a borehole to collect a sample at a specific depth. Designs differ mainly in their closing mechanism. Open tube samplers allow throughflow of water and can be sealed at a specific depth by means of a mechanical messenger or electrically operated catch. For some specific purposes, such as sampling an aquifer contaminated by an immiscible organic compound, a sealed depth sampler is preferable. The design used should be such that no water comes into contact with the sample container until the device is activated at the required depth. Where other methods of sampling are impractical, such as in very deep aquifers (i.e. greater than 100 m), depth sampling is recommended.

Samples of water may also be collected in a bailer during drilling, to provide crude data on groundwater quality variation with depth. On other occasions, where pumping of a borehole is not possible, a simple bailer, such as a weighed bottle or other open container, can be lowered into the borehole to collect a water sample. The use of a bailer is only recommended for sampling the surface layer of the aquifer and is not recommended where other methods are available.

4.2.3 In-situ sampling devices

These include devices, such as porous cups and piezometer points, that are permanently installed at a specific depth in the aquifer from which discrete samples can be collected. These sampling devices are often installed at different depths in a borehole. Porous ceramic cups may be used in the unsaturated or saturated zones: to extract water that enters the porous cup, a vacuum is applied through a tube attached to the cup. Other devices exist that allow water to enter through a wire mesh into a sample chamber that is evacuated by pressurizing with compressed air. Piezometers (small diameter tubes screened at the end and open to the surface) can provide groundwater samples from small diameter pumps, or by suction if the water level is close to ground level. Several piezometers can be sealed at different depths in a single borehole. (See also 5.3.1.3.)

4.2.4 Packer systems

Packer systems provide a means of extracting water from specific depth intervals within a borehole. The system may consist of one or more sealing devices which can be expanded either hydraulically or pneumatically, once in position down the borehole, to provide a seal. A water sample is obtained from the sealed section by pumping or by gas displacement. A variety of systems are available, some for permanent installation, the others portable. Packers are not suitable for use in boreholes with a gravel pack. (See also 5.3.1.1.)

4.2.5 Pore-water sampling systems

For detailed information about groundwater quality at different depths in either the unsaturated or saturated zone of an aquifer, pore-water samples can be extracted from rock samples obtained from purpose drilled boreholes. The pore-water is extracted by centrifugation, or by squeezing in a high-pressure press. This sampling technique is expensive and is not recommended for routine monitoring because it requires repeated drilling.

5 Sampling procedures

5.1 Sampling point selection

5.1.1 General

When using existing boreholes to obtain and gain access to ground water, it is necessary to determine constructional details to define from which strata the sample is being obtained. When new boreholes are being constructed specifically for sampling, the design of the borehole (e.g. the open area and length) and the method of construction need to be chosen, not only to meet the sampling requirement, but also to minimize contamination or disturbance of the aquifer. The use of degreasants, lubricants, muds, oils and bentonite during drilling should be avoided if at all possible, particularly when considering sampling for organic compounds. In addition, care is necessary to ensure that boreholes completed with a gravel pack around a solid casing and screens at specific levels are not subject to short circuiting of aquifer water from different depths via the gravel pack. This can be achieved by sealing the gravel packing in the vicinity of the screens. Attention should also be given to the design of borehole installations at the ground surface, in order to prevent contamination of the borehole by surface water.

5.1.2 Surveillance of the groundwater quality for potable supplies

When monitoring the quality of groundwater supplies for potable or any other use, all pumped boreholes, wells and springs should be sampled in order to protect the use to which the water is put. For potable supply purposes, any national raw water sampling requirements should be referred to for more detailed advice.

When selecting sampling points for supply surveillance, it is recommended that some boreholes remote from the abstraction be monitored, in order to examine the effect of the abstraction on the dynamic characteristics of the aquifer (e.g. the natural groundwater flow, the variation in thickness of the saturated zone).

5.1.3 Other groundwater quality purposes

For other sampling purposes, the selection of optimal sampling points will be more difficult and be directly influenced by the purpose of sampling, in addition to the particular characteristics of the aquifer that is being sampled [e.g. the nature of the groundwater flow (whether intergranular or fissure), the hydraulic gradient and the direction of flow]. In these cases, it is essential to seek specialist hydrogeological advice to assist in the selection of the most appropriate sampling point(s). The use of existing wells or boreholes should not be considered unless they can be shown to be suitable for the purpose of the sampling programme. (In many cases, existing wells and boreholes may fully penetrate the aquifer and be open, or screened, throughout their depth, thus making it difficult to examine quality at specific depths.)

Nevertheless, some generalized guidance can be given when the objective is to monitor groundwater for contamination from diffuse or point-source inputs.

5.1.3.1 Diffuse contamination of groundwater

When designing monitoring networks to identify extensive diffuse-source pollution of aquifers, the use of existing sampling points in the form of large capacity production boreholes is recommended, as they can provide integrated samples from a large volume of the aquifer. However, in some cases of localized or low intensity pollution, the use of this type of borehole may dilute the contamination to levels below the analytical detection limit: in these cases smaller capacity pumped boreholes are recommended. The part of the aquifer which is most sensitive to pollution is that near the boundary between the saturated and unsaturated zones. At least one of the sampling boreholes should therefore have a screen near to the surface of the saturated zone. Other purpose-drilled boreholes should be completed and screened over different depth intervals of the aquifer. Sampling boreholes should be located throughout the area of interest. It is recommended that sites be chosen to represent the different hydrogeological and land-use conditions and areas considered to be particularly vulnerable to diffuse pollution.

5.1.3.2 Point-source contamination of groundwater

When specifying sampling points to monitor point-source pollution, such as that arising from a waste disposal landfill site, it is necessary to consider the location of the site of the pollution in relation to the groundwater flow direction. Where practical, it is recommended that a sampling borehole to monitor the quality of the groundwater directly beneath the pollution source be installed. In addition, at least one sampling borehole should be screened over a narrow depth range immediately below the water table, so that any pollutants which are less dense than water will be more easily detected. Further sampling points should be located at progressive distances down the hydraulic gradient from the source of contamination, and provision should be made for sampling from a range of depths. Consideration should also be given to the location of one or two boreholes up the hydraulic gradient from the source of contamination, so that the areal extent of the pollution plume can be identified. Such boreholes may also be of assistance to quality control studies, by providing information on the extent of potential contamination by the sampling procedure, particularly where the analysis of trace materials is of interest.

5.2 Frequency and time of sampling

Analytical results from a sampling programme need to provide estimates of the required information within the tolerable errors defined in the objectives of the sampling programme. If the objectives do not include a definition of the magnitude of the tolerable error, a statistically based sampling programme is impossible. For details of the application of statistical techniques to the definition of sampling frequency, refer to ISO 5667-1.

For quality surveillance of potable supplies (or any other use-related monitoring activity), the temporal variation in quality at a single point is the most important factor. For most determinands, monthly or even less frequent sampling will normally be adequate when the purpose of sampling is to asses the suitability of groundwater as a source of drinking water. Refer to ISO 5667-1 and any national statutory requirements for general guidance on the assessment of sampling frequency. More frequent sampling may be required to minimize any public health risks in situations where groundwaters are used for potable supplies without disinfection.

For objectives other than potable supply surveillance, the sampling frequency should be chosen according to the variation in quality of the groundwater under investigation, in both a temporal and spatial sense. Changes in the quality of groundwater are usually much more gradual in time and space than those in surface waters. In some aquifers, factors producing seasonal variations in quality exist. In other cases, particularly where groundwater pollution occurs, short-term variations of between several hours and about two days exist in the composition of samples obtained during a pumping cycle. These variations have to be recognized before a long-term programme is defined.

Continuous monitoring of pH, temperature and electrical conductivity can provide a useful means of identifying the need to increase or decrease the sampling frequency for determinands that must be characterized by sampling. If continuous monitoring indicates that the rate of quality changes is increasing, the sampling frequency should be increased for any determinands of interest. Conversely, if the rate of change decreases, or stops, the sampling frequency may be reduced.

In cases where there has been a considerable change in quality of any continuously monitored determinand, it is advisable to consider also extending the range of determinands to be routinely analysed, as a precaution.

Continuous monitoring is also a useful means of identifying the most appropriate time to sample pumped observation boreholes which are being used to obtain representative samples of aquifer water. Where significant variations are recorded [i.e.

± 10 %, in terms of concentration (mass/unit volume) within the pumped discharge], this probably indicates local transient conditions within the borehole itself during the early stages of pumping, and samples should not be collected until the monitoring suggests that an equilibrium has been reached. If no significant quality variations occur, the time at which the sample is collected after the commencement of pumping need only be sufficient for the borehole to be purged.

5.3 Choice of sampling method

5.3.1 Factors affecting representative sampling

In order to achieve representative sampling within an aquifer, the sampling method needs to be capable of withdrawing samples whose composition reflects the actual spatial and temporal composition of the groundwater under study. Since the majority of sampling points in aquifers are wells or boreholes, they will disturb the natural groundwater system, especially as a result of induced vertical chemical and hydraulic gradients.

In some sampling situations, mineral material may accumulate in sampling boreholes between sampling operations. Therefore, the water within the borehole column will be unrepresentative of that in the aquifer under study. Sampling boreholes should therefore be purged before sampling, by pumping to waste a volume of water equivalent to at least 4 to 6 times the internal volume of the borehole itself. In some situations, it may be necessary to employ two different pumping rates: a short period of high rate pumping may be necessary to clear the borehole, followed by a lower rate designed to achieve quality stabilization before sampling.

Vertical stratification in groundwater quality may be natural or a consequence of pollution. For example, diffuse pollution usually results in a more polluted layer of groundwater at the top of the saturated aquifer, whereas pollutants that are more dense than water tend to accumulate above a less permeable layer at depth, or at the base of the aquifer. Sampling methods therefore need to be capable of detecting vertical as well as areal variations in groundwater quality.

The method of sampling also needs to reflect the complexities of groundwater flow in that it must take account of the aquifer flow mechanism (whether fissure or intergranular), the direction of the flow and the hydraulic gradients in the aquifer, which can produce strong natural flows up or down the borehole column itself. Traditionally, two common sampling methods are employed, namely pumped sampling and depth sampling; both have their uses and limitations, which need to be carefully considered when identifying the scope for their use.

5.3.1.1 Pumped sampling

Pumped samples from production boreholes used for potable or other supplies may comprise a mixture of water entering the open or screened length of the borehole from different depths. This sampling method is, therefore, only recommended where groundwater quality is vertically uniform or where a composite vertical sample of approximately average composition is all that is required, as might be the case when sampling water abstracted from a borehole for potable supply purposes. In these cases, depending on the well-head construction, the water sample should be collected as close as possible to the exit from the borehole, in order to avoid sample instability problems (see 5.4).

Samples should not be collected from pumping boreholes until the pump has been running for a sufficient length of time to remove the standing water in the borehole column, to ensure that new water is being drawn directly from the aquifer. The pumping time required can be calculated approximately from the size of the borehole, the pumping rate and the hydraulic conductivity but should be more accurately confirmed by monitoring any changes in dissolved oxygen, pH, temperature or electrical conductivity of the pumped water. In these cases, samples should not be taken until no significant variations [< ± 10 % in terms of quality (mass/unit volume) or ± 0,2 °C in terms of temperature] are observed. However, it should be noted that, in addition to measuring surrogates such as temperature or electrical conductivity, it may often be necessary to measure determinands of direct interest, for example complex organic material in cases of groundwater contamination.

The most effective methods of taking samples from an aquifer in which groundwater quality varies with depth are to sample specific aquifer horizons using specially constructed observation boreholes or, alternatively, to sample from sealed sections of boreholes. In the former, portable pumping equipment can be used to pump samples from a series of observation boreholes in relatively close proximity, each completed and screened to enable samples to be drawn from a different depth range of the aquifer. In the latter, samples are pumped from a sealed section of a borehole by means of a packer-pump assembly, thereby providing a means of obtaining a discrete sample of water within a specific depth range of the aquifer (see 4.2.4). This sampling method is only recommended for use in consolidated aquifers: it is not appropriate for use in boreholes completed with a screen and gravel pack.

5.3.1.2 Depth sampling

Depth sampling consists of lowering a sampling device (see 4.2.2) into the borehole or well, allowing it to fill with water at a known depth, and retrieving the sample for transfer to an appropriate container, where necessary. This method of sampling is normally only