Requirements for environmental monitoring and investigation of cultural deposits

English version of the Norwegian National Standard

The Directorate for Cultural Heritage is responsible for the management of all archaeological and architectural monuments and sites and cultural environments in accordance with relevant legislation.

We are responsible for ensuring that a representative selection of monuments and sites from all periods is preserved for present and future generations. The selection of monuments and sites must provide an overview of historical developments, the way of life and the range of works of art and craftsmanship of each period.

RIKSANTIKVAREN

Archaeological Sites and Monuments
Requirements for environmental monitoring and investigation of cultural deposits

This is the English version of the Norwegian Standard NS 9451:2009, Kulturminner – Krav til miljøovervåking og –undersøkelse av kulturlag. Riksantikvaren, the Norwegian Directorate for Cultural Heritage, took the initiative to translate the Norwegian Standard.

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Contents

This standard is based on the Norwegian Directorate for Cultural Heritage's [*Riksantikvaren*] strategy for monitoring of subsurface deposits of archaeological or cultural significance ("cultural deposits") and on the guidance document that was developed as a part of this strategy[1]. The standard has been produced by a committee consisting mainly of representatives of Norwegian organizations involved in the field of *environmental investigation of cultural deposits.*

[1] See The Monitoring Manual: Procedures and guidelines for the monitoring, recording and preservation/management of urban archaeological deposits.

Background

This standard will assist both developers and those responsible for sites of archaeological/historical significance in abiding by the relevant legislation and conditions for environmental monitoring when disturbing or building upon cultural deposits. It will also specify the responsibilities of the developer in such cases. The standard applies to activities pertaining to the Directorate for Cultural Heritage's management of the automatically protected medieval towns of Trondheim, Oslo, Tønsberg, Skien, Sarpsborg, Hamar, Stavanger and Bergen.

Development of such sites requires archaeological assessments of the state of preservation and chemical and physical assessments to evaluate the preservation conditions. The objectives are to protect a representative selection of these non-renewable assets in a long-term perspective[2] and also to facilitate appropriate land use and the development of "living" urban centres.

The heritage management authorities will require monitoring in the case of building/ redevelopment works and also in the case of other types of activity potentially disturbing the cultural deposits. The monitoring will be carried out before, during and after the development phase. Different monitoring methods are available, but selection of an appropriate method will depend on ground conditions. The Directorate for Cultural Heritage will determine the extent and duration of necessary monitoring. The primary objective will be to protect the site of historical/archaeological significance.

The medieval towns are the largest continuous, automatically protected sites of historical/archaeological significance in Norway. They are important both as a resource for experiential learning and as a source of knowledge on life in the Middle Ages. Thick cultural deposits have accumulated as residues of human activity and construction/development through time. Large parts of today's urban areas directly overlie, or have their foundations within, cultural deposits containing building- and other remains dating from prehistoric times, the Middle Ages and later periods. In most cases, the medieval town remains coincide with today's town/city centre and they form the basis for the urban culture that we observe today. This means that such remains will be threatened and impacted to a greater extent than any other form of archaeological/historical site in Norway. While older methods of construction did not normally come into significant conflict with the underlying cultural deposits, these deposits have now become vulnerable to destructive penetration in connection with road building, technical infrastructure (water and sewage pipes, telecom and electricity cables) and building construction. Penetration into the cultural deposits often results in drainage of any adjacent cultural deposits, and this in turn causes the water in the soil pore spaces to be replaced with air. Since there is 1000 times as much oxygen in air than in water, and since oxygen is by far the most efficient source of

[2] According to the State Declaration no. 16; *Living with sites of cultural and archaeological significance*, Chapter 4.5.7.

energy for the micro-organisms that consume organic materials, the rate of decomposition may increase dramatically. The heritage management authorities can require preventative actions to be undertaken in order to protect the cultural deposits.

The cultural deposits in medieval towns display large variations in state of preservation, preservation conditions, and vulnerability. Cultural deposits containing organic matter are especially vulnerable to changes in the immediate environment. Access to oxygen is the most important factor for the microorganisms that decompose organic matter in the cultural deposits. Stable ground conditions, with low groundwater throughflow and high water content in the sediments, will normally reduce access to oxygen and will tend to promote the preservation of cultural deposits. Drying/desiccation, increases in temperature, and exposure to oxygen and microbes are among the greatest threats to such deposits.

Accelerated decomposition of cultural deposits can also have serious consequences for existing buildings, roads and infrastructure, as a result of shrinkage/subsidence of the sediments.

Monitoring of the conditions and state of preservation in the cultural deposits is important for knowledge-based management of sites of historical/archaeological significance. Systematic, regular monitoring of selected parameters, using standardised methods, ensures the comparability of data and results throughout time and between different investigations. The use of traceable and reproducible methods and actions will increase the quality and reliability of the data collected. Changes in the cultural deposits will be detected and prompt remedial action can be undertaken. The objective of this is not necessarily a permanent preservation of degradable cultural deposits in medieval towns. What is important is the systematic mapping and checking of the deposits' state of preservation and their preservation conditions, and thereby the acquisition of valid, high quality data on their rate of decomposition. Increased knowledge will, through time, provide a better basis for protection strategies and decisions about permitted developments.

1 Coverage

This standard specifies the requirements for environmental monitoring of cultural deposits in the protected Norwegian Medieval towns, and for the accompanying documentation of their condition and state of preservation.

The standard specifies the main parameters to be included in the environmental monitoring, and ensures that the monitoring methodology for cultural deposits is uniform and well-defined.

2 Reference Norms

Reference to the following documents is necessary for the use of this document. Dated references refer only to the specified edition of the document. Undated references refer to the most recent edition of the document in question (including any official alteration or addendum).

NS-EN ISO 5667-3	Water quality - Sampling - Part 3: Guidance on the preservation and handling of water samples
NS-ISO 5667-11	Water quality - Sampling - Part 11: Guidance on sampling of groundwaters
NS-EN ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories
NS-EN 22475-1	Geotechnical investigation and testing - Sampling methods and groundwater measurements - Part 1: Technical principles for execution
NS 9420	Rules for field work in connection with environmental monitoring and mapping
NS 9427	Guidelines for storing environmental specimens - General requirements
ISO 10381-2	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Statens kartverk	Guidelines for the specification of geographical coordinates of natural and sociogeographical information.

3 Definitions

The following definitions should be applied in the context of this standard:

3.1 Preservation conditions

the physical, chemical and microbiological conditions in the ground, which determine the current rate of decomposition of the cultural deposits.

3.2 Archaeological state of preservation

the current condition of the cultural deposits, which will depend on both current and historical rates of decomposition.

3.3 Cultural deposits

strata, ground or subsurface deposits containing materials connected to human activity

COMMENT 1 The strata/deposits may be continuous or fragmented and of varying thickness.

COMMENT 2 Cultural deposits from prior to the Reformation (1537) are automatically protected according to the Cultural Heritage Act (*Kulturminneloven*).

3.4 Cultural deposits in medieval towns

cultural deposits that had accumulated in the towns prior to the Reformation (1537)

3.5 Cultural environment

the physical surroundings in cases where objects of historical or archaeological significance comprise a part of a greater complex or context

3.6 Objects of historical or archaeological significance

all signs or indicators of human activity in our physical environment, including localities related to historical occurrences, beliefs or traditions

3.7 Saturated zone

zone of the ground where all pore spaces are filled with water

COMMENT also referred to as the phreatic (groundwater) zone.

3.8 Unsaturated zone

zone from the water table up to the ground surface

COMMENT The pores in this zone contain both water and air. The unsaturated zone includes the root zone, the vadose zone and the capillary fringe. The unsaturated zone can include some saturated areas, for example, perched water tables.

3.9 Medieval town

a locality that attained status as a town, or was regarded as a town, in the Middle Ages

COMMENT 1 In Norway, the Middle Ages encompasses the period from around 1000 to 1537 AD.

COMMENT 2 The locality in question may have developed further as a town or city since the Middle Ages or it may have been abandoned. In both cases, cultural deposits and other traces of human activity from the Middle Ages will be preserved below the current land surface.

3.10 Environmental monitoring

the systematic collection of data using verifiable methods, preferably based on a hypothesis of cause and effect

COMMENT Environmental monitoring encompasses causal factors, effects and environmental status. The processing of various types of environmental data, including quality control, provision of references, evaluation and reporting, are also deemed to be activities encompassed by the term "monitoring". The aim is to document the current state and development of the environment, in both time and space, as a result of human influences or as a result of natural change. The extent of the monitoring can be long-term or limited in time, and it can be national, regional or purely local in geographic extent.

3.11 Environmental monitoring of cultural deposits

environmental monitoring of the **preservation conditions** [3.1] and **state of preservation** [3.2] in the cultural deposits

4 Objective and strategy

The objective of the activities governed by this Standard is to document the preservation conditions and state of preservation of the cultural deposits, and their evolution in time and space, as a result of human influences or of natural changes.

The various phases of an environmental monitoring programme are:

- preliminary survey (see 5.2)

- status investigation (see 5.3)
- supplementary investigations (see 5.4)

The programme of environmental monitoring shall investigate, document, describe and evaluate:

- the state of the cultural deposits and their preservation conditions; see Sections 7 and 8 of this Standard;
- the cultural and historical context, including topographic, chronological and historical interpretations;
- the hydrogeological situation of the cultural deposits, including groundwater conditions and moisture content;
- geochemical conditions, *inter alia* pH, temperature, oxygen concentration and redox conditions in both soils and groundwater;
- physical ground properties, such as descriptions of soil type, texture, moisture content and depth to bedrock;
- conditions governing the degradation of organic materials, metal, ceramics and other anthropogenic objects;
- the availability of oxygen in the cultural deposits, either via passive diffusion or via active convection or transport with water;

Norwegian Standard NS 9420 shall govern the implementation of field-work in connection with environmental monitoring.

5 The various phases of an environmental monitoring programme

5.1 General

The extent of a monitoring programme should be continually reviewed in the light of results obtained. Any deviation between expected, measured and acceptable values should lead to a reassessment of the preservation conditions and action in the form of supplementary investigations or the initiation of remedial measures.

COMMENT The heritage management authorities, namely the Directorate for Cultural Heritage in Norway (*Riksantikvaren*), shall be the deciding authority in the case of supplementary investigations.

5.2 Preliminary survey

A preliminary survey shall be undertaken to collect existing relevant information on the investigation site.

This preliminary survey shall include the following elements:

- a review of archives and other archaeological sources of information from the area;
- an assessment of previous environmental investigations;
- a field trip to the investigation site.

Other relevant information that may be collected includes: information on the possible placement of equipment, how the equipment should be transported to the points of investigation, access to electricity and location of storage facilities.

The preliminary survey shall obtain adequate information to be able to:

- evaluate the need for further investigations of the conditions and state of preservation in the cultural deposits;
- contribute to designing a scientifically relevant, technically efficient and cost-effective environmental monitoring programme;
- identify any necessary measures to optimally protect objects of archaeological or historical significance prior to, during and after the monitoring or intervention;
- identify any possible need to protect field-deployed personnel against dangerous chemicals, and evaluate the need for any necessary health, environmental and safety precautions.

This preliminary survey shall form the basis for the design of the status investigation of the cultural deposits. A short report shall be written according to 11.2 in this Standard. The preliminary survey may conclude that there is no requirement for further investigation.

5.3 Status investigation

The status investigation is a detailed investigation of specific parameters within the cultural deposits, which aims to document and evaluate their preservation conditions and state of preservation.

Measurements shall be made at fixed, marked measurement stations, using standardised methods. The results from the status investigation will determine the monitoring frequency and will form the basis for any supplementary investigations.

The status investigation shall include the following elements:

- an evaluation of the state of preservation (see section 7);
- sampling and analysis of soils, see 6.7 and 8.3;
- microbiological investigations, see 8.4.

In addition, the following shall be included within the saturated zone:

- determination of hydrogeological conditions, such as groundwater level, groundwater pressure and groundwater flow within and around the site, see 8.2;
- sampling and analysis of groundwater and pore water; description of stratification of deposits, see 6.8 and 8.2.

A report shall be written following the status investigation in accordance with 11.3. This status report may conclude that there is no necessity for any supplementary follow-up investigations.

5.4 Supplementary investigations

5.4.1 General

The design of any supplementary investigations will depend on the results of the status investigation. The objective is to repeat control measurements, at regular time intervals, of those parameters measured during the status investigation (or a selection of those parameters) in order to document the natural variability and any gradual trend over time in the preservation conditions in the cultural deposits. If significant changes are demonstrated in continuously monitored parameters, the need to increase the number of parameters shall be evaluated. The monitoring (selection of parameters and frequency) can be more limited or more extensive, as compared with the status investigation.

5.4.2 Saturated zone

Monitoring may be performed by regular measurement or by permanently installed loggers, and by analysis of water samples from dipwells. The continuous measurements should be made at fixed, marked measurement stations, using standardised methods. This implies that the monitoring should take place either in environmental observation wells, by the extraction and analysis of water samples from the wells, or by continuous monitoring of physical-chemical parameters in the soil using measurement sondes installed at selected locations. Regular surveying of fixed stations located on buildings or the surface of the terrain can be used to identify any ground movement. The availability of any wells, sondes and surveying stations should be ensured for the foreseeable future, following the completion of any construction or development work on the site.

It is deemed to be the responsibility of the developer to investigate and determine the groundwater/saturation status within the area under consideration. A programme for the monitoring of groundwater and soil moisture status shall be initiated and continue during and after the construction/development phase.

COMMENT The Norwegian Directorate for Cultural Heritage will determine the extent and duration of any monitoring.

5.4.3 Unsaturated zone

The analysis of environmental conditions in the unsaturated zone should aim to disclose how organic remains, e.g. wooden structures, are decomposing, and whether corrosion of metal objects and/or weathering of stone and ceramics is taking place. The investigations should reveal whether oxygen can be transported into the cultural deposits. If the deposits are highly heterogeneous, one should consider the need to take a larger number of samples and to determine more parameters in order to characterise the environmental conditions.

COMMENT The sampling and monitoring of the unsaturated zone can be highly challenging, as the deposits are often extremely heterogeneous in both the vertical and horizontal directions. Environmental conditions in the soil can vary significantly within short distances. Heterogeneity will affect the movement of both air and water through the soil.

In the unsaturated zone, moisture content, oxygen content, pH, electrical conductivity and temperature should be determined in the field. Other parameters, including the decomposition rate of organic material and the oxygen content of the cultural deposits, are analysed in the laboratory. The determination of the following parameters may be considered in order to obtain information concerning air and water transport: the soil’s moisture content; the soil’s content of organic matter; and the proportion of air-filled and water-filled pore spaces.

5.5 Remedial action

If environmental monitoring demonstrates changes in the state of preservation of the cultural deposits, i.e. ongoing destructive processes, a programme of further surveys should be initiated, specific to the changes observed. The objective will be to initiate remedial actions to stabilise or improve the ground conditions. Such surveys require significant resources and are required either when signs of visible damage appear or when monitoring has demonstrated changes.

EXAMPLE Examples of remedial action can include: the re-establishment of previous groundwater levels, prevention of leakages, re-establishment of previous chemical conditions within the ground. The Directorate for Cultural Heritage will contact the developer when monitoring has demonstrated changes in the preservation conditions. Any remedial action will be funded by the developer.

If monitoring has, over time, shown stable conditions in the cultural deposits, further detailed surveys should not be necessary.

6 Sampling

6.1 General

Sampling can be undertaken either in connection with normal archaeological investigations, by the excavation of archaeological test pits, by drilling with subsequent extraction of soil samples, or by groundwater sampling (in the latter case provided an environmental monitoring well has been installed in the borehole). Samples should be transported in the dark, under cool conditions.

From the commencement of field work, an adequate quantity of samples should be collected. It will often prove unnecessary to analyse all of the samples, but it can prove extremely expensive or impossible to venture back to the site to collect supplementary samples at a later date.

The sampling equipment should be clean and only sample containers approved by the laboratory should be used. The quantity of samples should be determined within the sampling schedule and the samples should be delivered to the laboratory no later than the day after they have been taken.

Three samples should be taken from each cultural layer penetrated by a borehole and/ or at least for every 0.5 m. The sampling should be performed by a person with proven knowledge of sedimentology and stratigraphy and especially of medieval towns.

Storage of environmental samples in connection with environmental monitoring shall be undertaken according to NS 9427.

6.2 Recording

Information shall be recorded concerning the sampling method, sampling station and the individual samples.

As a minimum, the following data concerning sampling method and location should be recorded:

- person responsible for sampling;
- project identifier or description of contract;
- geographical coordinates for every sampling station where samples have been taken, in accordance with 6.4, together with sample depth;
- the sampling schedule for each sampling station, with information on total number of samples taken and which parameters will be analysed;
- date and time for every sample and/or every station;
- sampler’s name or initials;
- weather conditions, such as temperature and precipitation;
- layer number;
- groundwater level, if possible;

- other information, such as rejected samples, delays and sampling problems, with explanations of causes.

A report shall be prepared which provides documentation of the methodologies for collection, storage and preparation of samples, manipulation of data and presentation of results. Refer to the individual standards for sampling and analysis as regards the requirements for documentation. The presentation of results shall be in a form that is designed to address the issues of concern which form the basis for the investigation. If the investigation is carried out over the course of several years, a final report shall be prepared. The raw data and processed data shall be archived at the institution responsible for the investigation.

It shall be possible to trace the publications, measurement series and samples collected by means of reference to the meta-database of the *National Reference System for Environmental Data. Environmental References*[3]. Such a reference shall contain an indexation according to the *Norwegian Environmental Thesaurus [Norsk miljøtesaurus - NMT].* This implies that the contractor shall deliver all the relevant references to this database. The deadline for delivery of such references shall be specified within the contract's timeline or contract description.

For each individual project, the programme under which each project is defined should be specified.

6.3 Labelling

The samples shall be labelled with a waterproof pen on the exterior of the sample container/packaging, providing information on:

- sampling date;
- sample identifier;
- name of sample locality and exact location/coordinates;
- name of person responsible for sampling;
- layer/context.

The labelling shall allow any information relating to the sample to be located in the registers described under 6.2.

[3] *Nasjonalt referansesystem for miljødata, Miljøreferanser*

6.4 Location

An unambiguous identification of the measurement locality and measurement point/station shall be provided, and every measurement point shall be identified such that it can be relocated by subsequent investigators. The description of location shall be facilitated by the use of geographical coordinates based on the UTM Euref 89 system. The location shall be specified in accordance with the current *Guidelines for the specification of geographical coordinates of natural and sociogeographical information [Retningslinjer for stedfesting av natur- og samfunnsgeografisk informasjon]* published by the Norwegian Mapping Authority [*Statens Kartverk*]. In addition to geographical coordinates, the sampling point can be specified by direction and distance relative to landmarks or other fixed objects.

In addition to surface location, the depth of the sampling excavation shall also be specified.

6.5 Sampling frequency

Sampling frequency shall be specified on the basis of topographic, stratigraphic and hydrological conditions at the locality, and on the basis of the nature of the data to be collected. The sampling frequency shall be decided such that it takes due regard of differing climatic conditions (different seasons) and other special occurrences (e.g. flood events, rain/snowfall events, and snow melt episodes). Continuous monitoring of oxygen content, soil moisture content, pH, temperature and electrical conductivity can provide useful information indicating a need to increase, or even reduce, sampling frequency. In cases where there is significant variation in the monitored parameters, consideration should be given to increasing the number of parameters that are continually monitored.

6.6 Photographic documentation

Photographs should be taken of both the sampling locality and the samples themselves (borehole profile). The schedule for photo-documentation should comply with the Norwegian Directorate for Cultural Heritage’s requirements for digital photography at archaeological investigations, as provided in Annex A.

6.7 Sampling of soils

6.7.1 General

Samples shall be taken from all relevant soil layers overlying, underlying and within the layers of cultural/archaeological interest. Samples from an excavated profile can be extracted with a cylindrical soil corer. In the case of boreholes, samples should be taken from the drilled core or directly from the auger, using a trowel. Normative Annex B documents the requirements for various drilling and excavation methods used in connection with soil sampling.

Data loggers can monitor ground conditions via sensors installed to measure various parameters in the ground. In moist soils, it may be appropriate to measure redox potential.

6.7.2 Treatment of soil samples

Soil samples shall be handled in accordance with ISO-10381-2. For each sampling location, a 400 g soil sample should be taken. If the soil sample is to be stored frozen, the sample quantity should be doubled to 800 g.

COMMENT Where drilling is undertaken, the most commonly used sampling techniques are either an earth auger or a piston sampler. The earth auger is often the best suited method for sampling cultural deposits as it does not become stuck as easily as a piston sampler can do. On the other hand, a piston sampler should provide intact cores, giving a better insight into the soil's physical properties.

The soil samples shall be transferred as rapidly as possible into a plastic bag made of an airtight material, such as polythene or ethyl vinyl acetate. The gas volume in the container or bag should be minimised. The bag should then be placed in a second, outer bag containing a chemical that removes oxygen. This second bag should also have an airtight seal. This ensures that the chemical and biological conditions in the sample most closely resemble the natural *in situ* conditions in the cultural deposits. The samples should be analysed as soon as possible after sampling.

If piston sampling is employed, the steel or plastic tube containing the core should be transported to the laboratory with both ends of the tube sealed in an airtight manner. The sample core should only be extruded from the tube immediately prior to the analysis of the sample at the laboratory, preferably under oxygen-free conditions.

Samples taken from a pit shall be extracted with a suitable sampling tool (e.g. a soil corer) which is pushed horizontally into the wall of the profile. Depending on the time elapsed between the pit's excavation and the soil's being sampled, and on how coarse-grained the soil is, the portion of the sample closest to the tool's point of entry should be discarded.

6.8 Sampling of water

6.8.1 Water sampling

The sampling procedure can vary, but should commence with a determination of the water level. Before sampling, several well volumes of water should be slowly removed ("purged") from the well, preferably until the water becomes clear. If the oxygen concentration in the water is to be determined, any air in the tube should be replaced by an inert gas such as argon. Any water samples intended to be analysed for iron and manganese should be filtered at a 0.45 µm mesh size in the field. It is important that the water does not come into contact with oxygen prior to filtration. Preservation of water samples should be undertaken in accordance with guidance from the analytical laboratory.

Refer to NS-ISO 5667-11 and NS-EN ISO 5667-3 in connection with sampling of groundwater and handling/treatment of water samples. Some deviation from these standards may be necessary, because cultural deposits may have low permeability. Any environmental monitoring well may, therefore, only re-fill with groundwater slowly after it has been purged.

6.8.2 Construction of environmental monitoring dipwells

If the cultural deposits are located in the saturated zone or within 75 cm of the average water table, the environmental conditions in the groundwater should be monitored.

If *in situ* measurements of chemical, physical or hydrological parameters are required, or if samples are to be taken of groundwater or soil gas, a groundwater well should be installed. The following requirements apply to such groundwater wells:

- surface water shall not enter the well;
- the well screen (well filter) shall only span a single stratum (type of deposit) and should not be longer than 1 m;
- if the cultural deposits have a thickness exceeding 2 m, it can be appropriate to install several wells to varying depths. Alternatively, multi-level piezometers can be installed.

As drilling progresses, an assessment should be made of whether the filter should be placed above, within or under the cultural deposits, depending on where an evaluation of water quality and hydrogeological conditions is required. See 8.2 for more information on preservation conditions in groundwater or pore water.

7 Evaluation of state of preservation in archaeological investigations

The state of preservation of cultural deposits shall be evaluated as a component of all types of archaeological investigation.

COMMENT Archaeological state of preservation can always be registered, whether during a single investigation or during a more extensive monitoring programme. The term encompasses an investigation of the individual cultural layers' current status, which depends on both current and historic decomposition processes.

The state of the cultural layers shall be registered. One soil sample shall be extracted from each of several selected layers, and the degree of preservation for each individual layer shall be evaluated on the basis of the State of Preservation Scale in Table 1. For samples extracted from a borehole, every layer shall be registered and samples labelled with the layer's location relative to ground level, its thickness and its description.

The degree of preservation shall be assigned a value from 0 to 5, where 1 indicates *lousy preserved* and 5 indicates *best preserved*. A value of 0 indicates that it has not been possible to extract any sample material. Deposits above the water table (unsaturated zone) shall be assigned the prefix A, deposits within the zone of groundwater fluctuation shall be assigned the prefix B, while deposits within the permanently groundwater-saturated zone shall be assigned the prefix C. The Table provides an indication of the state of preservation, and requires that all personnel carrying out the assessment have a relevant training in, and mutual understanding of, the use of the scale.

Table 1. State of Preservation Scale, indicating the state of the cultural layer

Position relative to groundwater	**Degree of preservation**					
	0 (none)	**1** (lousy)	**2** (poor)	**3** (average)	**4** (good)	**5** (excellent)
Above groundwater (unsaturated zone) = A	A0	A1	A2	A3	A4	A5
Within zone of groundwater fluctuation = B	B0	B1	B2	B3	B4	B5
Below groundwater (saturated zone) = C	C0	C1	C2	C3	C4	C5
Infilled material (and similar) from after the year 1900	D0	D1	D2	D3	D4	D5

The evaluation of the state of preservation of the cultural deposits shall be based on the following indicators/criteria:

Smell:

- for organic cultural deposits: the presence of a “rotten-egg” smell (H_2S odour) - the stronger the smell, the better the preservation;
- for wood: the presence and strength of a “freshly-cut” odour - the stronger the smell, the better the preservation.

Colour/colour change:

- a rapid colour change when the soil sample is exposed to air/oxygen is a sign of good preservation. The brighter the soil’s colour when first exposed to air/oxygen and the faster the change in colour, the better the preservation.
  COMMENT Soil will almost always change from a lighter to a darker colour on exposure to air. A layer that oxidises rapidly will have been deposited and covered fairly fast, such that the organic components have not been exposed to oxidation during or after deposition.

Mechanical strength:

- the stress that is required to break fragments of wood - the greater the stress required, the better the preservation;

  COMMENT For this purpose, relatively thin woodchips or sticks should be selected, rather than natural, hard pieces of tree.

- the effort that is required to pull a stem of moss in two - the greater the effort required, the better the preservation;
- the sponginess of a clod of soil, the softness of wood fragments, the elasticity of moss stems, hair or fur.

Holistic appearance:

- the general appearance of organic components, such as colour and structure, that are visible to the unaided eye.

Annex C provides an example of the use of the State of Preservation Scale.

8 Analysis of preservation conditions in the status investigation

8.1 General

An evaluation of the preservation conditions comprises an elucidation of the physical and chemical conditions in the ground that will control the current rate of decomposition of the cultural deposits. The extent of the evaluation will depend on the archaeological materials that are present.

The decomposition of organic cultural deposits is caused by chemical and microbiological processes and is controlled by the physical and chemical composition of the soil. In order to assess the preservation conditions of the cultural deposits, field samples of groundwater, pore water and soil should be taken. Parameters that provide information on the speed at which archaeological materials are decomposing and on the extent to which oxygen has reached the cultural deposits, shall be analysed in the field and in the laboratory. Such analyses should include compounds that are consumed or produced by micro-organisms when they decompose organic materials, plants, macro- and micro-fossils, insects and other fauna. Norwegian or international Standards should be employed. Analyses that are not carried out in accordance with such Standards shall be described and appended to the report(s). Annex D provides references to Standards for the determination of individual parameters.

8.2 Groundwater and pore water

The water level in environmental monitoring wells and piezometers shall be measured in the field using a “dipping tape” or battery-powered automatic water level loggers. If automatic loggers are used, atmospheric pressure should additionally be monitored.

The following parameters should be determined in the field:

- odour, turbidity, colour;
- temperature;
- pH;
- oxygen concentration;
- electrical conductivity.

The following should be measured in the laboratory. All parameters should be included in the initial characterisation of the groundwater, on the assumption that individual parameters will be selected for continued monitoring:

- sodium;
- potassium;

- calcium;
- magnesium;
- ammonium;
- iron;
- manganese;
- hydrogen carbonate/alkalinity;
- chloride;
- sulphate;
- sulphide;
- nitrate;
- phosphate;
- pH
- electrical conductivity.

Other parameters may also be relevant. Reporting shall include a documentation of whether the samples were filtered or not prior to analysis.

8.3 Soil

The following parameters shall be determined in the field, within the cultural deposits' soil profile:

- temperature;
- pH;
- soil moisture content;
- electrical conductivity. Additionally, where soil conditions permit, the composition of the soil gas should be determined (oxygen, carbon dioxide, methane, hydrogen sulphide).

At the laboratory, two suites of analyses are used:

- S1: dry matter content, loss on ignition; pH, electrical conductivity and/or chloride;
- S2: matrix potential (pF); porosity, sulphate, sulphide, ferrous and ferric iron, extractable ammonium and nitrate.

Other parameters that describe the hydraulic and decomposition conditions in the cultural deposits may be relevant, depending on local conditions and their significance for the cultural deposits.

S1 should be analysed on all soil samples, while S2 is applied to a representative subset of the samples. S2 provides information on the redox conditions in the soil.

8.4 Microbiological investigations

At the laboratory, an assessment shall be made of whether it is most appropriate to determine the total number of micro-organisms that thrive in the presence of:

- aerobic conditions;
- anaerobic conditions;
- nitrate;
- iron;
- sulphate-reducing or methanogenic conditions.

Additionally, the measurement of respiration and fungal damage shall be considered.

9 Analysis of preservation conditions in a supplementary investigation

The extent of any monitoring will depend on the results of the status investigation. It should be based, as far as possible, on automated loggers. The monitoring should include:

- logging of water level in environmental monitoring wells/piezometers and/or soil moisture content;
- logging of temperature;
- logging of electrical conductivity and groundwater or soil;
- measurement of oxygen content or redox potential;
- periodic surveying of fixed stations (e.g. subsidence markers mounted on buildings or on the terrain).

The loggers should be downloaded at least once per year. The monitoring can also include repeat collection of water samples, which should be analysed for the same parameters as during the status investigation, or a selection of those parameters.

Automatic logging of water level/pressure or temperature in environmental wells or piezometers should include monitoring for barometric correction. Equipment can be utilised which employs an inbuilt barometric correction, or independent logging of atmospheric pressure can be carried out. The data from independent barometric loggers are downloaded and used to correct nearby water level measurements for fluctuations in barometric pressure. When automatically logging oxygen content, it is important to ensure that the measurement equipment itself does not consume oxygen.

Calibration measurements of groundwater level in environmental monitoring wells should be made using a dipping tape, prior to every electronic download.

If any changes are observed in the environmental conditions, the need for additional investigations shall be evaluated.

Other parameters that may be relevant include TOC (total organic carbon), phosphorus, total nitrogen, charred and non-charred organic matter and hydraulic conductivity.

10 Evaluation of preservation conditions in a soil survey

The preservation conditions shall be assessed on the basis of water and soil samples, as described in Sections 8 and 9. The assessment shall also include other factors that may influence environmental conditions, such as meteorological conditions, hydrogeological conditions, location, aspect and topography.

As was the case for the archaeological state of preservation (Section 7), the preservation conditions shall also be specified using numerals from 1 to 5, where 1 indicates lousy preservation conditions and 5 indicates excellent preservation conditions (see Table 2). The degree of preservation shall be specified for all sampled soil layers. The assessment of layers in the unsaturated zone shall be prefixed with the letter A and shall be based on analyses of soil samples and soil fluids. The assessment of layers within the zone of groundwater fluctuation shall be prefixed with the letter B moisture, while that of layers permanently within the saturated zone shall be prefixed with the letter C. Both these types of assessment shall be based on analyses of soil samples and groundwater. The evaluation of the state of preservation in accordance with Table 2 is based on a holistic assessment of the various factors that affect the degree of preservation in cultural deposits, and requires that persons with the necessary soil science and hydrogeological expertise carry out the assessment.

Table 2. Preservation Conditions Scale, for use in soil investigations

Position relative to groundwater	Preservation conditions				
	1 (lousy)	2 (poor)	3 (average)	4 (good)	5 (excellent)
Above groundwater (unsaturated zone) = A	A1	A2	A3	A4	A5
Within zone of groundwater fluctuation = B	B1	B2	B3	B4	B5
Below groundwater (saturated zone) = C	C1	C2	C3	C4	C5

The following processes shall be considered when evaluating preservation conditions:

- factors that influence the decomposition of organic objects or organic material;
    - conditions (*inter alia* the porosity of the strata, water saturation) for transport of oxygen and other oxidising substances (e.g. sulphate) to the cultural deposits;
    - redox conditions and conditions for microbiological decomposition (e.g. presence of toxic compounds, microbial activity);
    - temperature conditions.
- factors that influence the corrosion and weathering of objects;
- hydrological conditions.

11 Reporting

11.1 General

If changes are discovered in the state of preservation or in the preservation conditions that require immediate action, the heritage management authorities shall immediately be informed.

The preliminary survey and the status investigation shall be reported. In addition, results shall be reported from supplementary monitoring and control measurements that are carried out in subsequent periods.

The report from the preliminary survey shall document and present the necessary information required for decision making. This shall form the basis for the design of the status investigation. The formulations used in the report shall provide decision makers with an adequate overview and a reliable basis for their decisions. Factual information should be clearly distinguishable from description and interpretation.

11.2 Reporting of the preliminary survey

The report from the preliminary survey shall contain:

- the objective of the survey;
- a description of the strategy and the design of the environmental monitoring programme;
- a description of the works carried out, to include any sampling/techniques;
- any comparison with previous surveys/results (if possible), or with surveys/results from other sites;
- a general description of likely hydrogeological conditions, based on previous investigations and literature sources;
- conclusions and recommendations regarding parameters that should be investigated, proposals for measurement frequency and how the equipment should be located, both with respect to areal location and to depth.

11.3 Reporting of the status investigation

The report from the status investigation should aim to document and evaluate the state of preservation of and preservation conditions in the cultural deposits. This will largely form the basis for any terms or conditions for dispensation according to the Cultural Heritage Act, will make recommendations for any continued monitoring programme in the form of supplementary investigations (the parameters that shall be monitored and the monitoring frequency), and the extent to which remedial action may or may not be necessary at the current time.

The report from the status investigation shall contain:

- the objective of the investigation;
- a description of the works carried out, to include any sampling/techniques;
- documentation of field observations, including basic information such as site name, date, person responsible, layer or context number and stratigraphic context;
- a justification for the samples selected for analysis and a documentation of all relevant details regarding sample preservation, storage, transport, preparation, analysis and evaluation of analyses;
- analytical results (state of preservation and preservation conditions), with interpretation;
- description of the site’s local hydrogeological conditions and relationship to regional hydrogeological conditions;

- any possible comparison with other investigation results (earlier results or results from other localities);
- evaluation of the investigation's reliability;
- an integrated presentation of the locality's state of preservation and preservation conditions;
- a summary of any uncertainties or limitations in the investigation;
- conclusion and recommendations for supplementary investigations (parameters that should be investigated, proposals for measurement frequency and continuation of the monitoring programme);
- conclusions and recommendations for remedial action;
- descriptions of, and any references to, the methods that were utilised.

Compliance with paragraph 46 of the Water Resource Law [*Vannressursloven*], regarding reporting obligations to the Geological Survey of Norway [*NGU*], shall be documented. This applies to all reports from groundwater investigations and to any borehole drilling covered by the scope of the legislation - including pilot boreholes, investigation boreholes, ground source energy boreholes etc.

Depending on local circumstances, it may be necessary to include other aspects. The formulation of the report shall provide the decision makers and/or the client a satisfactory overview and a reliable basis for decision making. Factual information should be clearly distinguishable from description, interpretation and hypothesis.

COMMENT Separate factual and interpretative reports (two distinct parts) can be useful, but are not generally recommended.

The measurement results, analysis results and the report shall be delivered to the client in electronic form. If the client is not the Directorate for Cultural Heritage in Norway (*Riksantikvaren*), the Directorate for Cultural Heritage in Norway shall always be sent the results in electronic form.

12 Quality assurance requirements

Quality assurance shall form a part of all stages of the environmental monitoring programme. Quality management principles shall be used to ensure the reliability and traceability of analytical results.

All procedures shall be described. Laboratory investigations shall be carried out by laboratories satisfying the requirements of NS-EN ISO 17025 or corresponding criteria.

Annex A (normative)
Photographic documentation

A.1 Photography

Photographic documentation shall be carried out in the following manner:

- All photography shall be performed by digital capture. Images shall be captured only by use of a tripod or other stand;
- The RAW file format shall be quality-controlled prior to archiving by the person who has captured the image, via management and approval of colour conversion (from “negative” to “positive” colour image). This can also be performed by the responsible field manager in collaboration with the photographer. The objective is to achieve readable archaeological colour information. Where colour adjustment of the RAW file format has not been undertaken, a JPG image can be used as template;
- If the camera does not automatically produce a JPG or RAW file format, two exposures of every image shall be captured. This makes subsequent colour conversion of the RAW files more exact;
- If the camera does not utilise RAW files in Photoshop format or DNG files, a compatible RAW format shall be selected;
- JPG files shall not be rotated or re-saved following image capture. If changes are made, the resulting file shall be stored as a copy. FotoStation permits virtual rotation, which does not affect the orientation of the stored image on disc - only the screen image appears rotated;
- Backup copies of all digital images shall be made on disc or other approved media. Print-out of “contact copies” (for example, 4 images per A4 side) will not retain sufficient quality for subsequent scanning if the digital original is lost;
- All images shall be delivered as JPG file formats or on disc for RAW file formats. Eventually, all photos shall be stored at a single location.

A.2 Photogrammetry

Photogrammetric data shall be converted to formats that are compatible with the formats used in the “Askeladden” database of Historical and Archaeological Monuments; i.e. DWG, PDF and VRML formats. For security, all materials shall be submitted as 2 copies of raw data and documentation, on DVD and portable HDD, respectively - or to a server with well-established back-up copying routines.

A.3 Rights to photographic material

Guidance on copyright and usage of photographic material shall be regulated via the contract with the client.

Annex B (normative)
Drilling and excavation methods

B.1 Drilling

The objectives with drilling are:

- *in-situ* evaluation of the stratigraphy of the cultural deposits by measuring resistance to drilling and visual evaluation of the cultural deposits in the field;
- collection of soil samples for investigation, over and above the field-based, purely visual evaluation;
- installation of an environmental monitoring well and/or other monitoring equipment (such as water level, soil moisture or electrical conductivity loggers).

The drilling equipment utilised shall be suited to the locality and for the purpose, and it should have the capacity to penetrate the strata in question. The equipment should be well-maintained and fully operational. The weight and manoeuvrability of the drilling equipment shall not result in damage to the ground surface, the soil horizons or any installation.

The location of boreholes and the drilling method shall be decided on the basis of the drilling objectives and existing knowledge about the soil layers and groundwater conditions.

The drilling shall be performed by a trained, certified and experienced drilling supervisor. The drilling company shall be responsible for the quality of the drilling work, for health and safety and for any damage to cables/conduits, property or persons. The drilling company shall also be responsible for obtaining necessary permissions, such as permission to drill and to excavate, for signage, for removal of excavated material/drilling cuttings, for drainage of water, etc. and for obtaining information on all buried services from the appropriate authorities.

Over and above the aforementioned factors, other relevant conditions shall be documented in the contract between the drilling company and the organization responsible for the monitoring, including time schedules, division of liability, insurances, prices, invoicing etc.

Two different drilling methods may be used:

1. (Flight) augering
2. Drilling with core sampler
    a. Push sampling
    b. Coring

All samples shall be labelled using a waterproof marker, identifying location, project, date, borehole number, running sample number, depth and, if necessary, elevation. Samples shall be stored in a dark and cool environment.

B.2 Augering

Augering can be undertaken using a manual auger, a lightweight vibro-hammer or a drilling rig. Augering can often, but not always, yield a good overview of the stratigraphy. The disadvantage of the method is that the sediments are disturbed.

The outer diameter of the auger shall be 100 mm when sediment samples are to be collected, otherwise the samples can easily become too small. A pitch of 0.1 m is common between the threads of the auger screw.

Auger drilling typically progresses in 0.5 m to 1.0 m stages, with the auger being removed without rotation. The outer sediments on the flight will be contaminated during the withdrawal of the auger and should be removed using a spatula or other suitable tool, before the sediment samples for laboratory investigation are collected.

Dry, sandy, gravelly or stony sediments, or very moist sediments, are not readily retained by the auger's flights. Augering should not therefore be used for sampling in such sediments.

The auger can be impeded by large stones, well-preserved massive timbers and other types of compact and hard material. Obstructions of this type, if they are of limited vertical extent, can be penetrated by use of a drilling bit, and the augering can thereafter continue unimpeded. If the borehole is not to be used for the installation of monitoring equipment, it shall be completely backfilled with pelletised bentonite. This is in order to seal the hole and prevent access by water, oxygen or other materials that could encourage decomposition or contamination of the locality's remaining sediments.

B.3 Coring

For coring, it is normal to use a drilling rig. The standard diameter of the core barrel is 54 mm, but samplers of larger diameter can be used. The advantage of coring is that the stratigraphy of the sediment samples is preserved intact. The disadvantages are that the sediments cannot be inspected during the course of the fieldwork, and that it is difficult to collect a continuous cored profile, which is a precondition for a complete understanding of the stratigraphy. The reason for this difficulty is that anthropogenic sediments are heterogeneous or comprise organic materials such as wood shavings, moss etc., which will be compressed by the core cylinder and will not enter it.

COMMENT The risk of losing core length increases with increasing core diameter.

The sampling methodology is the same for all types of core sampler, but the length of the core barrel can vary somewhat.

After the sampler has been removed from the borehole, the core cylinder is sealed at both ends to prevent desiccation of the sediment sample during transport and storage. The core is removed from the cylinder in the laboratory, so that the core can be inspected and described and so that samples can be taken from the core for analysis.

B.4 Excavations/test holes

This encompasses all investigations where the archaeological remains are excavated manually. In contrast to trench registration or drilling, the advantage of this method is that every layer of cultural deposit can be examined in detail *in situ*, so that the depositional history of the area can be reconstructed in its entirety. This facilitates the evaluation of, *inter alia*, whether any poor state of preservation in an individual cultural horizon is due to current or to historic decomposition. The disadvantage is that the cultural deposits in the area of excavation are irrevocably removed.

Layer recording: each layer of the cultural deposits is documented, via the use of a suitable context registration form.

Status assessment: the context registration form shall allow each individual layer's preservation category to be recorded, according to the State of Preservation Scale, see Section 7, Table 1.

Soil sampling: the strategy will vary, depending on the exact situation in question. It is, however, important that an adequate number of samples is collected from the peripheral portions of the site, in order to yield the best possible basis for comparison with any subsequent investigations of adjacent areas.

B.5 Trench registration

This term encompasses all investigations where trenching is undertaken, usually by machine. It is a precondition that any cultural deposits within the trench wall(s) are carefully investigated and documented by photography, drawings and, if possible, context registration forms.

Previously registered trenches: if a profile has previously been archaeologically registered in a trench, using profile drawings or context registration forms, comparison of profile drawings/context registration forms from the previous and the most recent investigations can be used to disclose possible changes in the cultural deposits.

Soil sampling: the strategy will vary, depending on the exact situation in question. One possible procedure is to take two samples from each location: one sample from the outermost part of the excavated surface and one sample from 15 - 20 cm behind the initial sample (in other words, somewhat further “into” the layer). By this means, differences in the state of preservation and preservation conditions can be mapped.

B.6 Borehole drilling

Combined archaeological investigation and environmental monitoring can be conducted by the use of drilled boreholes. Such boreholes can be a cost-effective method to investigate thick cultural deposits and are often combined with the installation of environmental wells for groundwater monitoring.

Layer recording: individual strata or structures are termed “layers” when we are describing cultural deposits. The layers should be registered, where possible, using a structure form. Alternatively, a drilling log should be recorded for the stratigraphic sequence, where each layer is described as completely as possible, with the following information being regarded as a minimum: depth from ground surface, description of composition/content, evaluation of state of preservation, any artefacts/objects, soil samples taken, samples taken for ^{14}C-dating and photographic documentation.

Annex C (for information)
Example of the characterisation of the state of preservation in a cultural deposit

The table (see next page) shows how one can characterise cultural deposits, using a rapid scoring of the state of preservation. In the table, colours have been used, rather than the A0 to D5 system used in Section 7, Table 1.

The samples have been taken during the drilling of environmental wells numbers 10, 12 and 13 on the Bryggen (Wharf) in Bergen.

The layers' state of preservation has been evaluated every 20 cm. This means that a complete top-to-bottom overview can be gained of the state of preservation in a drilled sample, and also across a larger area. The presence of groundwater and a high water content are the most important factors in ensuring good preservation conditions in the cultural deposits. The Table below shows that the cultural deposits in the uppermost horizons are worse preserved than those located deeper and below the groundwater level.

Table C1. Example of a tabular presentation of the state of preservation

Environmental well no. 10	Environmental well no. 12	Environmental well no. 13	Metres above sea level
?		?????	2.0 - 1.0
???GWXX	?????	??XGWXX	1.0 - 0.0
??XXX	GW??XXX	XXXXX	0.0 - -1.0
XX?XX	?XXXX	XXXXX	-1.0 - -2.0
XXXXX	XXXXX	XXXXX	-2.0 - -3.0
XXXXX	XXXXX	XXXXX	-3.0 - -4.0
XXXXX	XXXXX	XXXXX	-4.0 - -5.0
XXXXX	XXXXX	XXXXX	-5.0 - -6.0
XXN	XX??X	N	-6.0 - -7.0
	XX?XX		-7.0 - -8.0
	XN		-8.0 - -9.0
			-9.0 - -10.0
Increasing depth in 1 m intervals			

X - Lousy = 1
X - Poor = 2
X - Average = 3
X - Good = 4
X - Excellent = 5
? - Indeterminable = 0
0 - No soil recovered from borehole
N - Natural ground
GW - average groundwater level

The figures correspond to the State of Preservation Scale in Section 7, Table 1.

Annex D (for information)
Methods for parameter determination in soil and water

D.1 General

This Annex gives a summary of standard methods for measurement of relevant parameters in soil and water. The summary is not necessarily complete. Standard Online AS has up-to-date archives of relevant standards.

D.2 Electrical conductivity

Electrical conductivity provides information on the content of soluble salts in soil and this may, in turn, provide information on the influence of seawater and leaching of salts as a result of high water throughflow. Electrical conductivity may also indicate whether certain human activities have taken place. The salt content of soil affects the corrosion of metal objects and weathering of bone. In addition, the salt content influences the viability of micro-organisms. Electrical conductivity can be measured in the laboratory or in the field.

Electrical conductivity is determined by adding 25 ml oxygen-free water to 10 g soil. The sample is shaken for 1 hour (preferably without access to oxygen). After the particulate matter has settled out, the electrical conductivity of the water phase is measured. The electrical conductivity is multiplied by a factor of 3.6 to estimate the electrical conductivity of a soil-saturated extract.

Standards for determination of electrical conductivity:

NS-ISO 7888	Water quality - Determination of electrical conductivity
NS-EN 13038	Soil improvers and growing media - Determination of electrical conductivity

D.3 Chloride

Chloride can be determined as an alternative to electrical conductivity and also provides an indication of the salt concentration in the soil.

Standards for determination of chloride:

NS 4756	Water analysis - Determination of chloride - Potentiometric titration
NS 4769	Water analysis - Determination of chloride - Photometric method

NS-EN ISO 10304-1	Water quality - Determination of dissolved anions by liquid chromatography of ions - Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate
NS-EN ISO 10304-4	Water quality - Determination of dissolved anions by liquid chromatography of ions - Part 4: Determination of dissolved chlorate, chloride and chlorite in water with low contamination

D.4 Moisture content (dry residue)

The content of dry matter provides information on moisture conditions in the soil horizons. Moisture influences microbiological decomposition, corrosion of metal objects and weathering of bone. Very wet or dry conditions often hinder biological and chemical decomposition.

The content of dry matter ("dry residue") is determined by drying a soil sample of known weight at 105°C for 24 hours. The loss in weight after drying corresponds to the sample's water content, while the content of dry matter corresponds to the ratio between dry weight and wet weight. Stones of diameter > 1 cm should be removed prior to the determination of dry residue. Soil moisture can be determined in the laboratory and in the field.

Standards for determination of dry matter:

NS-EN 12880	Characterization of sludges - Determination of dry residue and water content
NS-EN 13040	Soil improvers and growing media - Sample preparation for chemical and physical tests, determination of dry matter content, moisture content and laboratory compacted bulk density
NS-EN 14346	Characterization of waste - Calculation of dry matter by determination of dry residue or water content
NS 4764	Water analysis - Total residue, and total fixed residue in water, sludge and sediments

D.5 Loss on ignition

Loss on ignition is used to estimate the proportion of organic matter in soils and cultural deposits. A high content of clay or iron oxides can lead to overestimation of the proportion of organic matter, as water bound in the crystalline structure of these components is liberated at temperatures between 130°C - 500°C. The organic content can indicate the presence of cultural deposits and that decomposable organic material is present. There is often a correlation between organic matter content and soil moisture content.

Loss on ignition is determined by igniting a dried soil sample at 550°C ± 25°C for at least six hours. The loss in weight (loss on ignition) is an indicator of the proportion of organic matter present. After ignition, the sample is stored in a desiccator prior to weighing.

Standards for determination of loss on ignition:

NS-EN 12879	Characterization of sludges - Determination of the loss on ignition of dry mass.
NS-EN 15169	Characterization of waste - Determination of loss on ignition in waste, sludge and sediments

D.6 Matrix potential pF

The relationship between the soil's moisture content and the binding energy of the water (capillary "suction") describes the soil's moisture characteristics. The pF curve is also termed the matrix potential or water retention curve. The matrix potential is related to the pore diameter and the pF curve can be used to calculate the proportion of pores filled with water and air, respectively. pF 2 (field capacity) describes the amount of water in the soil after downward free drainage of water from the soil has ceased. At field capacity, the larger pores will be filled with air and the smaller ones with water.

Soil-filled pF rings are pressurised (1 m head of water, 0.1 bar, pF 2 - field capacity) and the amount of water remaining in the pores after a given time is determined gravimetrically. The distribution of air-filled and water-filled pores at pF 2 is determined. Thereafter, the air permeability of the sample (l/min) is determined and the sample is then pressurised at 1 bar (pF 3). The amount of water remaining in the pores after a given time is re-measured (pF 3).

The grain size distribution of the soil can be determined as an alternative to the soil's pF characteristics. Such an analysis is, however, only possible if the sample's organic content is relatively low (<5%). Organic material is removed in connection with the analysis.

D.7 pH (hydronium ion activity)

The pH value provides information on the concentration of hydronium ("acid") cations (H_3O^+) and hydroxide anions (OH^-). pH conditions influence corrosion of metal objects, weathering of biological material and the viability of micro-organisms. The pH value can be measured in the laboratory or the field.

The pH value is measured with a pH electrode in the same water suspension as electrical conductivity. Alternatively, pH can be determined in the field with a semiconductor electrode (solid state pH electrode).

Standards for determination of pH:

NS-EN 12176	Characterization of sludge - Determination of pH value
NS 4720	Water analysis - Determination of pH
NS-EN 13037	Soil improvers and growing media - Determination of pH

D.8 Redox potential

Redox potential is a parameter that indicates whether the ground conditions are aerobic or anaerobic. The parameter is often used to evaluate which reactions will occur when organic matter decomposes. The parameter only gives a coarse indication, however, which should be empirically verified.

Redox potential is determined using a platinum electrode (with integrated reference electrode) which is inserted into moist soil. It is important that the redox electrode is in good contact with soil and pore water. If necessary, a modest amount of oxygen-free, demineralised water should be added and the soil-water system left to equilibrate for 12 hours. The determination should be made in an oxygen-free environment.

Characterisation of redox conditions may be undertaken by analysing oxidised and reduced species of nitrogen, iron or sulphur. Methods for the determination of oxidised and reduced manganese compounds are problematic and such analyses are thus not required. Analyses of methane and oxygen content are made on the soil pore gas. Determination of the various redox “pairs” should indicate the redox processes which dominate in the soil.

D.9 Extractable nitrate and ammonium

The determination is made by preparing an extract from the sample using 2 mol/l KCl (in the ratio 1:5) for a period of 1 hour. The concentrations of nitrate and ammonium are determined colorimetrically (e.g. using a spectrophotometer or FIA).

Standards for determination of extractable nitrate and ammonium:

NS 4746	Water analysis - Determination of ammonia-nitrogen
NS-EN ISO 11732	Water quality - Determination of ammonium nitrogen. Method by flow analysis (CFA and FIA) and spectrometric detection

D.10 Ferrous and ferric iron (Fe(II), Fe(III))

Determination of iron (II) and iron (III) can be made according to a method developed by Stookey (1970), which uses ferrozine for determination of iron (II). An extract is prepared from the soil sample, using 0.5 molar hydrochloric acid for 24 hours, under anaerobic conditions. Iron (II) is determined photometrically at 562 nm. Extractable iron (III) is thereafter reduced to iron (II) using hydroxylamine before the total iron content is determined using the method described above. Iron (III) is calculated as the difference between total iron and iron (II) in the extract.

Standards for determination of ferrous and ferric iron:

NS 4741	Water analysis - Determination of iron - Photometric method
NS 4773	Water analysis - Atomic absorption spectrometry, atomization in flame - Special guidelines for aluminium, lead, iron, cadmium, copper, cobalt, chromium, manganese, nickel and zinc
NS 4781[4]	Water analysis - Metal content of water, sludge and sediment determined by flameless atomic absorption spectrometry - Electrothermal atomization in a graphite furnace - Special guidelines for aluminium, lead, iron, cadmium, copper, cobalt, chromium, manganese and nickel

D.11 Sulphate and sulphide

Sulphate can be determined either using ion chromatography or turbidimetrically. Ion chromatographic analysis often involves extraction using demineralised water. For turbidimetric analysis, an extract is often prepared from the sample using 10 mM monocalcium phosphate solution ($Ca(H_2PO_4)_2.H_2O$), or 0.5 M acidic ammonium acetate solution.

Sulphide is determined as "acid-soluble" sulphide if the sample extract is prepared with 6 M hydrochloric acid for 60 minutes in a nitrogen atmosphere. The hydrogen sulphide liberated by this extraction is precipitated with zinc acetate and determined using titrimetric or potentiometric analysis. This extraction extracts biological and amorphous sulphide, but relatively little geological sulphide and pyrite.

Standards for determination of sulphate and sulphide:

NS 4762	Water analysis - Determination of sulphate content of water - Nephelometric method

[4] It appears that this standard, NS 4781, has been withdrawn in the meantime

NS-EN ISO 10304-1	Water quality - Determination of dissolved anions by liquid chromatography of ions - Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate
NS-EN ISO 10304-3	Water quality - Determination of dissolved anions by liquid chromatography of ions - Part 3: Determination of chromate, iodide, sulfite, thiocyanate and thiosulfate

D.12 Microbiological investigations

Microbiological investigations can supplement and verify any evaluations that are made on the basis of chemical determinations. In contrast to chemical analyses, microbiological investigations can provide information on the numbers and activity of biodegrading microbes present. This information can contribute to an assessment of how favourable the preservation conditions are and how rapidly the cultural deposits are being decomposed.

The following screening techniques may be relevant:

Total micro-organisms cultivable under aerobic, nitrate-, iron- or sulphate-reducing or methanogenic conditions. These can be determined using the "most probable number" method, which employs various types of medium for different types of micro-organism.

Microbial activity can be determined by studying the rate of turnover of a radioactively-labelled oxidising agent (e.g. ^{34}S-sulphate) or substrate (e.g. ^{14}C-cellulose).

The measurement of respiration, under conditions similar to the natural *in situ* environment, can also provide insight into the rate of biodegradation.

Standards for microbiological investigations:

ISO 10381-6	Soil quality - Sampling - Part 6: Guidance on the collection, handling and storage of soil under aerobic conditions for the assessment of microbiological processes, biomass and diversity in the laboratory

D.13 Chemicals harmful to health or the environment

If there is any suspicion of the presence of elevated concentrations of chemicals that are harmful to health or the environment, a health/environmental risk assessment shall be prepared in accordance with national regulations. Relevant parameters to be determined in soil samples are: Lead (Pb), cadmium (Cd), nickel (Ni), copper (Cu), chromium (Cr), zinc (Zn), mercury (Hg), arsenic (As) and hydrocarbons.

Standards for the determination of lead (Pb), cadmium (Cd), nickel (Ni), copper (Cu), chromium (Cr) and zinc (Zn):

ISO 11047	Soil quality - Determination of cadmium, chromium, cobalt, copper, lead, manganese, nickel and zinc - Flame and electrothermal atomic absorption spectrometric methods
NS 4781[5]	Water analysis - Metal content of water, sludge and sediment determined by flameless atomic absorption spectrometry - Electrothermal atomization in a graphite furnace - Special guidelines for aluminium, lead, iron, cadmium, copper, cobalt, chromium, manganese and nickel
NS 4773	Water analysis - Atomic absorption spectrometry, atomization in flame - Special guidelines for aluminium, lead, iron, cadmium, copper, cobalt, chromium, manganese, nickel and zinc

Standards for the determination of mercury (Hg) and arsenic (As):

NS-ISO 6595	Water quality - Determination of total arsenic. Silver diethyldithiocarbamate spectrophotometric method
NS-EN ISO 11969	Water quality - Determination of arsenic - Atomic absorption spectrometric method (hydride technique)
NS-EN 1483	Water quality - Determination of mercury - Method using atomic absorption spectrometry
NS-EN ISO 17852	Water quality - Determination of mercury - Method using a combined preservation and digestion step followed by atomic fluorescence spectrometry
ISO 20280	Soil quality - Determination of arsenic, antimony and selenium in aqua regia soil extracts with electrothermal or hydride-generation atomic absorption spectrometry
ISO 16772	Soil quality - Determination of mercury in aqua regia soil extracts with cold-vapour atomic spectrometry or cold-vapour atomic fluorescence spectrometry

[5] See note 4

Standards for the determination of hydrocarbons:

ISO 13877	Soil quality - Determination of polynuclear aromatic hydrocarbons - Method using high-performance liquid chromatography
ISO 15009	Soil quality - Gas chromatographic determination of the content of volatile aromatic hydrocarbons, naphthalene and volatile halogenated hydrocarbons - Purge-and-trap method with thermal desorption
ISO16703	Soil quality - Determination of content of hydrocarbon in the range C10 to C40 by gas chromatography
ISO 22155	Soil quality - Gas chromatographic quantitative determination of volatile aromatic and halogenated hydrocarbons and selected ethers - Static headspace method
ISO 18287	Soil quality - Determination of polycyclic aromatic hydrocarbons (PAH) - Gas chromatographic method with mass spectrometric detection (GC-MS)

Literature

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