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Water quality — Guidance for rapid radioactivity measurements in nuclear or radiological emergency situation

Qualité de l'eau — Recommandations pour les mesurages rapides de la radioactivité en situation d'urgence nucléaire ou radiologique

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 147, *Water quality*, SC 3, *Radioactivity measurements*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Radioactivity from several naturally-occurring and anthropogenic sources is present throughout the environment. Thus, water bodies (e.g. surface waters, ground waters, sea waters) can contain radionuclides of natural, human made, or both origins:

- Natural radionuclides, including ^{40}K , ^3H , ^{14}C , and those originating from the thorium and uranium decay series, in particular ^{226}Ra , ^{228}Ra , ^{234}U , ^{238}U , ^{210}Po and ^{210}Pb can be found in water for natural reasons (e.g. desorption from the soil and wash off by rain water) or can be released from technological processes involving naturally occurring radioactive materials (e.g. the mining and processing of mineral sands or phosphate fertilizers production and use);
- Human-made radionuclides such as transuranium elements (americium, plutonium, neptunium and curium), ^3H , ^{14}C , ^{90}Sr , and some gamma emitting radionuclides can also be found in natural waters. Small quantities of these radionuclides may be discharged from nuclear fuel cycle facilities into the environment as the result of authorized routine releases. Some of these radionuclides used for medical and industrial applications are also released into the environment after use. Anthropogenic radionuclides are also found in waters as the result of past fallout contaminations resulting from the explosion in the atmosphere of nuclear devices and accidents such as those that occurred in Chernobyl and Fukushima.

Radionuclide activity concentration in water bodies can vary according to local geological characteristics and climatic conditions and can be locally and temporally enhanced by releases from nuclear installation during planned, existing, and emergency exposure situations^[1]. Drinking-water may thus contain radionuclides at activity concentrations which could present a risk to human health.

The radionuclides present in liquid effluents are usually controlled before being discharged into the environment^[2] and water bodies. Drinking waters are monitored for their radioactivity as recommended by the World Health Organization (WHO)^[3] so that proper actions can be taken to ensure that there is no adverse health effect to the public. Following these international recommendations, national regulations usually specify radionuclide authorized concentration limits for liquid effluent discharged to the environment and radionuclide guidance levels for waterbodies and drinking waters for planned, existing, and emergency exposure situations. Compliance with these limits can be assessed using measurement results with their associated uncertainties as requested by ISO/IEC Guide 98-3 and ISO 5667-20^[4].

Depending of the exposure situation, there are different limits and guidance levels that would result in an action to reduce health risk.

NOTE 1 The guidance level is the activity concentration with an intake of 2 l/d of drinking water for one year, that results in an effective dose of 0,1 mSv/a for members of the public. This is an effective dose that represents a very low level of risk that is not expected to give rise to any detectable adverse health effect^[3].

In the event of a nuclear emergency, the WHO Codex Guideline Levels^[5] indicates the activity concentrations corresponding to operational intervention levels.

NOTE 2 The Codex guidelines levels (GLs) apply to radionuclides contained in foods destined for human consumption and traded internationally, which have been contaminated following a nuclear or radiological emergency. These GLs apply to food after reconstitution or as prepared for consumption, i.e. not to dried or concentrated foods, and are based on an intervention exemption level of 1 mSv in a year for members of the public (infant and adult)^[5].

Thus, the test method can be adapted so that the characteristic limits, decision threshold and detection limit, and the uncertainties ensure that the radionuclide activity concentration test results can be verified to be below the guidance levels required by a national authority for either planned-existing situations or an emergency situation^{[6][7]}.

Usually, the test methods can be adjusted to measure the activity concentration of the radionuclide(s) in either wastewaters before storage or in liquid effluents before being discharged to the environment.

The test results will enable the plant/installation operator to verify that, before their discharge, wastewaters/liquid effluent radioactive activity concentrations do not exceed authorized limits.

The test methods described in this document for emergency exposure situations may also be used during planned, existing exposure situations as well as for wastewaters and liquid effluents with specific modifications that could change the overall uncertainty, detection limit, and threshold.

The test method(s) may be used for water samples after proper sampling, sample handling, and test sample preparation (see the relevant part of ISO 5667 series).

This document has been developed to answer the need of test laboratories carrying out these measurements that may be required by national authorities during a nuclear or radiological emergency exposure situation.

This document is one of a set of International Standards on test methods dealing with the measurement of the activity concentration of radionuclides in water samples.

The ISO documents produced for radioactivity measurements in water are detailed methods. In most cases, these methods have been used in laboratory practice for a number of years and the analytical characteristics have been documented. However, these methods are generally time consuming and require well trained analysts to carry them out.

Over the last years, an increasing need was recognized for the addition of guidance on the use of so-called "rapid methods". The nuclear accident at Fukushima in March 2011 accentuated the need for these rapid measurements. During the initial stages of such incidents, decision makers had to deal with taking protective measures for the population, such as sheltering, evacuation, and the distribution of iodine prophylaxis. It has been found that time is critical and limited for taking these protective measures.

Water quality — Guidance for rapid radioactivity measurements in nuclear or radiological emergency situation

1 Scope

This document provides guidelines for testing laboratories wanting to use rapid test methods on water samples that may be contaminated following a nuclear or radiological emergency incident. In an emergency situation, consideration should be given to:

- taking into account the specific context for the tests to be performed, e.g. a potentially high level of contamination;
- using or adjusting, when possible, radioactivity test methods implemented during routine situations to obtain a result rapidly or, for tests not performed routinely, applying specific rapid test methods previously validated by the laboratory, e.g. for ^{89}Sr determination;
- preparing the test laboratory to measure a large number of potentially contaminated samples.

The aim of this document is to ensure decision makers have reliable results needed to take actions quickly and minimize the radiation dose to the public.

Measurements are performed in order to minimize the risk to the public by checking the quality of water supplies. For emergency situations, test results are often compared to operational intervention levels.

NOTE Operational intervention levels (OILs) are derived from IAEA Safety Standards^[8] or national authorities^[9].

A key element of rapid analysis can be the use of routine methods but with a reduced turnaround time. The goal of these rapid measurements is often to check for unusual radioactivity levels in the test sample, to identify the radionuclides present and their activity concentration levels and to establish compliance of the water with intervention levels^{[10][11][12]}. It should be noted that in such circumstances, validation parameters evaluated for routine use (e.g. reproducibility, precision, etc.) may not be applicable to the modified rapid method. However, due to the circumstances arising after an emergency, the modified method may still be fit-for-purpose although uncertainties associated with the test results need to be evaluated and may increase from routine analyses.

The first steps of the analytical approach are usually screening methods based on gross alpha and gross beta test methods (adaptation of ISO 10704 and ISO 11704) and gamma spectrometry (adaptation of ISO 20042, ISO 10703 and ISO 19581). Then, if required^[13], test method standards for specific radionuclides (see [Clause 2](#)) are adapted and applied (for example, ^{90}Sr measurement according to ISO 13160) as proposed in [Annex A](#).

This document refers to published ISO documents. When appropriate, this document also refers to national standards or other publicly available documents.

Screening techniques that can be carried out directly in the field are not part of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9696, *Water quality — Gross alpha activity — Test method using thick source*

ISO 9697, *Water quality — Gross beta activity — Test method using thick source*

ISO 9698, *Water quality — Tritium — Test method using liquid scintillation counting*

ISO 10703, *Water quality — Determination of the activity concentration of radionuclides — Method by high resolution gamma-ray spectrometry*

ISO 10704, *Water quality — Gross alpha and gross beta activity — Test method using thin source deposit*

ISO 11704, *Water quality — Gross alpha and gross beta activity — Test method using liquid scintillation counting*

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

ISO 13160, *Water quality — Strontium 90 and strontium 89 — Test methods using liquid scintillation counting or proportional counting*

ISO 13161, *Water quality — Measurement of polonium 210 activity concentration in water by alpha spectrometry*

ISO 13162, *Water quality — Determination of carbon 14 activity — Liquid scintillation counting method*

ISO 13163, *Water quality — Lead-210 — Test method using liquid scintillation counting*

ISO 13165-1, *Water quality — Radium-226 — Part 1: Test method using liquid scintillation counting*

ISO 13165-2, *Water quality — Radium-226 — Part 2: Test method using emanometry*

ISO 13165-3, *Water quality — Radium-226 — Part 3: Test method using coprecipitation and gamma-spectrometry*

ISO 13166, *Water quality — Uranium isotopes — Test method using alpha-spectrometry*

ISO 13167, *Water quality — Plutonium, americium, curium and neptunium — Test method using alpha spectrometry*

ISO 13168, *Water quality — Simultaneous determination of tritium and carbon 14 activities — Test method using liquid scintillation counting*

ISO 17294-2, *Water quality — Application of inductively coupled plasma mass spectrometry (ICP-MS) — Part 2: Determination of selected elements including uranium isotopes*

ISO 19581, *Measurement of radioactivity — Gamma emitting radionuclides — Rapid screening method using scintillation detector gamma-ray spectrometry*

ISO 20042, *Measurement of radioactivity — Gamma-ray emitting radionuclides — Generic test method using gamma-ray spectrometry*

3 Terms and definitions

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <http://www.iso.org/obp>

— IEC Electropedia: available at <http://www.electropedia.org/>

For the purposes of this document, the following terms and definitions apply.

3.1**emergency situation**

non-routine situation or event that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human health and safety, quality of life, property or the environment

Note 1 to entry: This includes nuclear and radiological emergencies and conventional emergencies such as fires, release of hazardous chemicals, storms or earthquakes. It includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard^[14].

3.2**intervention**

any protective action or countermeasure aimed at reducing, or averting, human exposure to radiation during a nuclear or radiological emergency

3.3**operational intervention level****OIL**

set level of a measurable quantity that corresponds to a generic criterion

[SOURCE: IAEA safety glossary 2016 Rev. Mod]

Note 1 to entry: OILs are calculated levels, measured by instruments or determined by laboratory analysis that correspond to an intervention level or action level. These are typically expressed in terms of dose rates or of activity of radioactive material released, time integrated air activity concentrations, ground or surface concentrations, or activity concentrations of radionuclides in environmental, food or water samples. OILs are used immediately and directly (without further assessment) to determine the appropriate protective actions on the basis of an environmental measurement^[14].

3.4**reference level**

level of dose or risk, in emergency or existing controllable exposure situations, above which it is judged to be inappropriate to plan to allow exposures to occur, and below which optimisation of protection should be implemented

Note 1 to entry: Note 1 to entry: The chosen value for a reference level depends upon the prevailing circumstances of the exposure under consideration^{[8][9]}.

3.5**screening level****SL**

value that takes into account the characteristics of the measuring equipment and the test method to guarantee that the test result and its uncertainty obtained are fit for purpose for comparison with the *operational intervention levels (OILs)* (3.3)

Note 1 to entry: For example, when the screening levels are not exceeded so are the OILs and the water is considered safe for consumption. If the screening level is exceeded so is the OIL and consumption of non-essential food should be stopped, and essential food should be replaced or the people should be relocated if replacements are not available^{[13][14]}.

3.6**intervention level**

radiation dose above which a specific protective action is generally justified

3.7**iodine prophylaxis**

administration of stable iodine to limit the uptake of inhaled/ingested radioactive iodine into the thyroid gland

3.8**emergency exposure situation**

situation of exposure where exposure at an elevated level is inevitable due to unexpected events or needs of important action

4 Guidance on emergency measurement

4.1 Objective of a specific rapid measurement

The type of nuclear or radiological emergency and the initial measurement results provide the information on the mix and magnitude of any radionuclide or radionuclide mix that has been released.

In the early phase, rapid measurement can be performed for screening, e.g. to determine whether the sample is significantly contaminated or not.

In the intermediate phase, rapid measurements can be carried out in order to further confirm the radionuclide or mix of radionuclides in water samples, and to estimate their activity concentrations.

When the radionuclides present are known, a rapid measurement should demonstrate that a fixed value of activity concentration is exceeded or not (compliance to OIL).

In the recovery phase of an emergency situation, when a number of protective measures have been taken in order to minimize the dose to the public, measurements also verify the justification of these protective measures, such as the evacuation planning, emergency sheltering, food restriction and providing iodine prophylaxis to members of the public.

Decision trees are used to determine which test methods should be applied. These methods are often routine test methods in use in testing laboratories, with instructions on how to adapt them during an emergency situation, or existing ISO documents.

A general overview of the high priority issues, duration and goals in the phases described above is shown in [Table 1](#). The relative priority of these issues depend on the type and scale of the nuclear or radiological emergency situation.

Table 1 — Overview of duration, high priority issues and goal in early, intermediate and recovery phases

Phases	High priority	Main goal WATER is concerned
Early phase (first days)	Nuclide identity, large picture of geographic extent of contaminated area. Intervention levels exceeded?	Protective measures for public, cattle livestock, agriculture, water.
Intermediate phase (days — weeks)	Large number of samples, detailed picture of contaminated area. Focus on food chain and water. Evaluation of areas where intervention levels are exceeded.	Evaluate the taken countermeasures with measurement data. May people return to their homes? Is food safe to eat? Is water safe to drink? Monitoring and sampling in large areas, agricultural and urban.
Recovery phase (weeks — months)	More detailed sampling and analyses with lower detection limits for food and water.	Continue monitoring and sampling more in depth in agricultural and urban areas: Food chain and water reservoirs, surface waters.

4.2 Routine screening levels versus intervention levels

In normal situations, the World Health Organization (WHO) has defined routine screening levels for drinking water, below which no further action is required. These screening levels are 0,5 Bq.l⁻¹ for gross alpha activity and 1 Bq.l⁻¹ for gross beta activity. If neither of these values is exceeded, the Total Indicative Dose of 0,1 mSv/year is also not exceeded.

In case of an emergency situation, intervention levels are defined and expressed in terms of a dose limit per unit of time (e.g. mSv/d, mSv/week or mSv/a). They are used by policy makers to decide on actions in order to protect people against high radiation levels. When these intervention levels are exceeded, appropriate actions are carried out following national emergency handbooks or protocols.