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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

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

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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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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, ^{3}H, ^{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), ^{3}H, ^{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 ld^{-1} of drinking water for one year, that results in an effective dose of 0,1 $mSva^{-1}$ 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

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].

[SOURCE: IAEA safety glossary 2016 Rev. Mod]

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 allow exposures to occur, and below which optimisation of protection should be implemented

Note 1 to entry: Note1 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 results and their uncertainties 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, the OILs are also note exceeded, 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 information on the nature and amount of radionuclide that has been released.

In the early phase, rapid measurements 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 to confirm the nature and activity concentration of the radionuclide(s) in the water samples.

When the radionuclides are known, a rapid measurement should be able to determine if the activity concentration(s) measured exceeded the OIL values or not.

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 are also performed to verify the necessity of these protective measures, such as evacuation, emergency sheltering, food restriction, and providing iodine prophylaxis to members of the public.

Decision trees are usually 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 higher priorities to address, for each phase of a nuclear emergency and the rationale behind these priorities are 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 the higher priorities to address for each phase of a nuclear emergency and the rationale behind these priorities

Phases	High priorities	Main concerns for water
Early phase (first days)	Radionuclide identification, global picture of geographic extent of the contamination. Intervention levels exceeded?	Protective measures for public, 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 $Bq \cdot l^{-1}$ for gross alpha activity and 1 $Bq \cdot l^{-1}$ for gross beta activity. If neither of these values is exceeded, the total indicative dose of 0,1 $mSv \cdot y^{-1}$ 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. $mSv \cdot d^{-1}$, $mSv \cdot w^{-1}$ or $mSv \cdot a^{-1}$). 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.

Operational intervention levels (OILs) are usually expressed in activity concentration (Bq·l^{-1}, Bq.m^{-3} or Bq.kg^{-1}). Rapid measurements performed following an emergency situation should produce test results which can be related to OILs.

If required, the conversion from activity to dose to compare with intervention levels should be carried out by experienced scientific staff. For contaminated water, intervention levels are related to ingestion, washing, showering or cooking. Here the conversion from activity concentration in drinking water to dose is done by multiplying the activity concentration by the dose conversion coefficient (for ingestion) and an approximation of the water consumption per unit time.

Intervention levels may vary from one country to another. In this document, data from the EU and the USA are given as examples in Annex B. Other states may apply their own national intervention levels.

Sample measurement data are used for decision making based on the assessment of the confidence that water quality meets given targets, complies with thresholds or lies in a particular range in a classification system.

Principles, basic requirements, and illustrative methods for decision making are described in Reference [14], including methods for preliminary examination of the sensitivity of decisions to error and uncertainty.

4.3 Operational intervention levels (OILs) from EU, USA and IAEA

OILs for the USA[9] and the EU[11][12]are listed in Annex B. In emergency situations, a higher contamination level is accepted for a short period of time, days or weeks.

These levels range up to 500 Bq·l^{-1} for iodine isotopes and to 1 200 Bq·l^{-1} for gamma-emitting isotopes, such as ^{134}Cs and ^{137}Cs. It is clear that rapid measurements should be able to determine these activity concentrations readily.

The IAEA defines a slightly different set of OILs[8]. These OILs are threshold values of concentrations in food, milk or water that warrant the consideration of restrictions on consumption so as to keep the effective dose to any person below 10 mSv per year.

Following the early phase, the OIL values could be revised rapidly by authorities to come back to usual reference values. In such a case, the laboratories would revert to usual laboratory test methods and equipment.

5 Rapid measurements

5.1 Adaptation of the methods used

In the early phase, turnaround time is a very important factor. Other factors considered as primary in routine situations could become of secondary importance. Time-consuming radiological procedures should be avoided in the early phase and intermediate phase. In some cases, the testing laboratory shall apply specific, non-routine, rapid measurement methods. These methods should be validated in advance. As a rule, where possible, rapid methods should be based on routine test methods as the laboratory team is already trained to use them and their analytical characteristics are well known. An optimization of these methods may be based on a smaller size of the sample test portion, simpler radiochemical treatment, and a shorter counting time.

The following test methods, usually performed in routine situations, shall be used and adapted: ISO 9696, ISO 9697, ISO 9698, ISO 10703, ISO 10704, ISO 11704, ISO 13160, ISO 13161, ISO 13162, ISO 13163, ISO 13165-1, ISO 13165-2, ISO 13165-3, ISO 13166, ISO 13167, ISO 13168, ISO 17294-2, ISO 19581 and ISO 20042.