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

Qualité de l'eau — Strontium 90 et strontium 89 — Méthodes d'essai par comptage des scintillations en milieu liquide ou par comptage proportionnel

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of 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 www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 13160:2012), which has been technically revised. The main changes compared to the previous edition are as follows:

— The way standard the uncertainty, decision threshold and detection limit are calculated has been updated in conformance with ISO 11929-1:2019.

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, and ^{210}Pb, can be found in water for natural reasons (e.g. desorption from the soil and washoff 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 fertilizer production and use).
- Human-made radionuclides, such as transuranium elements (americium, plutonium, neptunium, curium), ^{3}H, ^{14}C, ^{90}Sr, and gamma emitting radionuclides can also be found in natural waters. Small quantities of these radionuclides are 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 a 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]. Water bodies and drinking waters are monitored for their radioactivity content 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 water bodies 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 specified by ISO/IEC Guide 98-3 and ISO 5667-20[4].

Depending on the exposure situation, there are different limits and guidance levels that would result in an action to reduce health risk. As an example, during a planned or existing situation, the WHO guidelines for guidance level in drinking water is 100 Bq·l^{-1} for ^{89}Sr activity concentration and 10 Bq·l^{-1} for ^{90}Sr activity concentration[3].

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

In the event of a nuclear emergency, the WHO Codex guideline levels[5] specifies that the activity concentration might not be greater than 1 000 Bq·kg^{-1} for ^{89}Sr or 100 Bq·kg^{-1} for ^{90}Sr for infant food and 1 000 Bq·kg^{-1} for ^{89}Sr or 100 Bq·kg^{-1} for ^{90}Sr for food other than infant food.

NOTE 2 The Codex guidelines levels (GLs) apply to radionuclides contained in food 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 food, 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, detection limit and uncertainties ensure that the radionuclide activity concentrations test results can be verified to be below the guidance levels required by a national authority for either planned/existing situations or for 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 discharge 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 method described in this document may be used during planned, existing and emergency exposure situations as well as for wastewaters and liquid effluents with specific modifications that could increase the overall uncertainty, detection limit, and threshold.

The test method may be used for water samples after proper sampling, sample handling, and test sample preparation (see the relevant part of the ISO 5667 series [8],[9],[10]).

This document has been developed to answer the need of test laboratories carrying out these measurements, that are sometimes required by national authorities, as they may have to obtain a specific accreditation for radionuclide measurement in drinking water samples.

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WARNING — Persons using this document should be familiar with normal laboratory practice. This document does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of any other restrictions.

IMPORTANT — It is absolutely essential that tests conducted according to this document be carried out by suitably trained staff.

1 Scope

This document specifies conditions for the determination of ^{90}Sr and ^{89}Sr activity concentration in samples of environmental water using liquid scintillation counting (LSC) or proportional counting (PC).

The method is applicable to test samples of drinking water, rainwater, surface and ground water, marine water, as well as cooling water, industrial water, domestic, and industrial wastewater after proper sampling and handling, and test sample preparation. Filtration of the test sample and a chemical separation are required to separate and purify strontium from a test portion of the sample.

The detection limit depends on the sample volume, the instrument used, the sample count time, the background count rate, the detection efficiency and the chemical yield. The method described in this document, using currently available LSC counters, has a detection limit of approximately 10 mBq l^{-1} and 2 mBq l^{-1} for ^{89}Sr and ^{90}Sr, respectively, which is lower than the WHO criteria for safe consumption of drinking water (100 Bq·l^{-1} for ^{89}Sr and 10 Bq·l^{-1} for ^{90}Sr)[3]. These values can be achieved with a counting time of 1 000 min for a sample volume of 2 l.

The methods described in this document are applicable in the event of an emergency situation. When fallout occurs following a nuclear accident, the contribution of ^{89}Sr to the total amount of radioactive strontium is not negligible. This document provides test methods to determine the activity concentration of ^{90}Sr in presence of ^{89}Sr.

The analysis of ^{90}Sr and ^{89}Sr adsorbed to suspended matter is not covered by this method.

It is the user's responsibility to ensure the validity of this test method selected for the water samples tested.

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

ISO 11929-1, *Determination of the characteristic limits (decision threshold, detection limit and limits of the coverage interval) for measurements of ionizing radiation — Fundamentals and application — Part 1: Elementary applications*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 80000-10, *Quantities and units — Part 10: Atomic and nuclear physics*

ISO 3696:1987, *Water for analytical laboratory use — Specification and test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11929-1 and ISO 80000-10 apply.

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

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

Symbol	Definition	Unit
A_i	calibration source activity of radionuclide *i*, at the time of calibration	Bq
$c_{\mathrm{A},i}$	activity concentration of radionuclide *i*	Bq l^{-1}
$c_{\mathrm{A},i}^{*}$	decision threshold of radionuclide *i*	Bq l^{-1}
$c_{\mathrm{A},i}^{\#}$	detection limit of radionuclide *i*	Bq l^{-1}
$c_{\mathrm{A},i}^{\triangleleft}, c_{\mathrm{A},i}^{\triangleright}$	lower and upper limits of the probabilistically symmetric coverage interval of radionuclide *i*	Bq l^{-1}
$c_{\mathrm{A},i}^{<}, c_{\mathrm{A},i}^{>}$	lower and upper limits of the shortest coverage interval of radionuclide *i*	Bq l^{-1}
k_p	quantile of the standardized normal distribution for the probability *p* (for instance $p=1-\alpha$, $1-\beta$ or $1-\gamma/2$)	
$R_{\mathrm{c},i}$	chemical yield of the extraction of radionuclide *i*	
r_0	background count rate	s^{-1}
r_{0j}	background count rate for measurement *j*	s^{-1}
r_g	gross count rate	s^{-1}
$r_{\mathrm{g}j}$	gross count rate for measurement *j*	s^{-1}
r_j	net count rate for measurement *j*	s^{-1}
r_s	calibration source count rate	s^{-1}
t	time elapsed between separation of $^{90}\mathrm{Sr}/^{90}\mathrm{Y}$ ($t = 0$) and mid-point of counting	s
t_0	background counting time	s
t_d, t_f	start and finish time respectively of the measurement, referred to $t = 0$	s
t_g	sample counting time	s
t_j	start time of the measurement *j*, referred to $t = 0$	s
t_s	calibration source counting time	s
U	expanded uncertainty, calculated by $U = ku(c_\mathrm{A})$ with $k = 1, 2 \ldots$	Bq l^{-1}
$u(c_\mathrm{A})$	standard uncertainty associated with the measurement result	Bq l^{-1}
V	volume of the test sample	l
α, β	probability of a false positive and false negative decision, respectively	
ε_i	counting efficiency for radionuclide *i*	
λ_i	decay constant of radionuclide *i*	

4 Principle

4.1 General

The radionuclides $^{90}\mathrm{Sr}$, $^{90}\mathrm{Y}$ and $^{89}\mathrm{Sr}$ are all pure beta-particle emitters. Their beta-emission energies and half-lives are given in Table 1.