SLOVENSKI STANDARD
oSIST prEN ISO 13160:2026

01-september-2026

Kakovost vode - Stroncij Sr-90 in stroncij Sr-89 - Preskusne metode s štetjem s tekočinskim scintilatorjem ali proporcionalnim štetjem (ISO/DIS 13160:2026)

Water quality - Strontium 90 and strontium 89 - Test methods using liquid scintillation counting or proportional counting (ISO/DIS 13160:2026)

Wasserbeschaffenheit - Strontium-90 und Strontium-89 - Verfahren mittels Flüssigszintillationszählung oder Proportionalzählung (ISO/DIS 13160:2026)

Qualité de l'eau - Strontium 90 et strontium 89 - Méthodes d'essai par comptage des scintillations en milieu liquide ou par comptage proportionnel (ISO/DIS 13160:2026)

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17.240	Merjenje sevanja	Radiation measurements

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ISO/DIS 13160

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).

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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 third edition cancels and replaces the second edition (ISO 13160:2021), which has been technically revised. The main changes compared to the previous edition are as follows:

— the Clause has been completely revised;

— Annex G dealing with ^{90}Sr analysis from its decay product ^{90}Y in based on extraction chromatography has been added;

— the has been enhanced.

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

Radionuclides are present throughout the environment, thus, water bodies (e.g. surface waters, ground waters, sea waters) contain radionuclides, which can be of either natural, or anthropogenic origin:

— Naturally-occurring radionuclides, including ^{3}H, ^{14}C, ^{40}K, and those originating from the thorium and uranium decay series, in particular ^{210}Pb, ^{210}Po, ^{222}Rn, ^{226}Ra, ^{228}Ra, ^{227}Ac, ^{232}Th, ^{231}Pa, ^{234}U and ^{238}U, can be found in water bodies due to either natural processes (e.g. desorption from the soil and runoff by rain water) or released from technological processes involving naturally occurring radioactive materials (e.g. mining, mineral processing, oil, gas, and coal production, water treatment and the production and use of phosphate fertilizers).

— Anthropogenic radionuclides such as ^{55}Fe, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{99}Tc, transuranic elements (e.g., Np, Pu, Am, and Cm) and some gamma emitting radionuclides such as ^{60}Co and ^{137}Cs can also be found in natural waters. Small quantities of anthropogenic radionuclides can be discharged from nuclear facilities to the environment as a result of discharged routine releases. The radionuclides present in liquid effluents are usually controlled before being discharged to the environment[1] and water bodies. Anthropogenic radionuclides used for medical and industrial applications can be released to the environment after use. Anthropogenic radionuclides are also found in waters due to contamination from fallout resulting from above-ground nuclear detonations and accidents such as those that have occurred at the Chornobyl and Fukushima nuclear facilities.

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 facilities during planned, existing and emergency exposure situations[2][3]. Some drinking-water sources can thus contain radionuclides at activity concentrations that can present a human health risk. The World Health Organization (WHO) recommends to routinely monitor radioactivity in drinking waters[4] and to take proper actions when needed to minimize the health risk.

National regulations usually specify the activity concentration limits that are authorized in drinking waters, water bodies, and liquid effluents to be discharged to the environment. These limits can vary for planned, existing, and emergency exposure situations. As an example, during either a planned or existing situation, the WHO guidance level in drinking water is 100 $Bq \cdot l^{-1}$ for ^{89}Sr activity concentration and 10 $Bq \cdot l^{-1}$ for ^{90}Sr[4], see NOTES 1 and 2. Compliance with these limits is assessed by measuring radioactivity in water samples and by comparing the results obtained, with their associated uncertainties, as specified by ISO/IEC Guide 98-3:2008 [5] and ISO 5667-20:2008 [6].

NOTE 1 If the value is not specified in Annex 6 of Reference [4], the value has been calculated using the formular provided in Reference [4] and the dose coefficient data from References [7] and [8].

NOTE 2 The guidance level is the activity concentration with an intake of 2 $l \cdot d^{-1}$ of drinking water for one year that results in an effective dose of 0,1 $mSv \cdot a^{-1}$ 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[4].

This document contains methods to support laboratories, which need to determine ^{90}Sr and ^{89}Sr in water samples. The methods described in this document can be used for various types of waters (see Clause 1). Minor modifications such as sample volume and counting time can be made if needed to ensure that the decision threshold, detection limit and uncertainties are below the required limits. This can be done for several reasons such as emergency situations, lower national guidance limits and operational requirements.

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

1 Scope

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.

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

This document specifies methods to determine ^{90}Sr and ^{89}Sr by liquid scintillation counting (LSC) or proportional counting (PC) in supply water, drinking water, rainwater, surface and ground water, marine water, as well as cooling water, industrial water, domestic, and industrial wastewater after proper sampling, handling and test sample preparation.

The detection limit depends on the sample volume, the instrument used, the sample counting time, the background count rate, the detection efficiency and the chemical yield. The method described in this document, using currently available LSC and PC instruments, has a detection limit of approximately 2 mBq·l^{-1} and 10 mBq·l^{-1} for ^{90}Sr and ^{89}Sr, respectively, for a volume of 2 l and a measuring time of 60 000 s, 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)[4].

The methods described in this document are applicable in the event of an emergency situation. When contamination contains fresh fission products, the contribution of ^{89}Sr to the total amount of radioactive Sr is not negligible. This document provides test methods to determine the activity concentration of ^{90}Sr in presence of ^{89}Sr, and to determine the activity concentration of ^{90}Sr in large volume of water sample (>50 L).

The analysis of ^{90}Sr and ^{89}Sr adsorbed to suspended matter is not covered by this method. Filtration of the test sample and a chemical separation are required to separate and purify Sr from a test portion of the sample as the analysis of 90Sr and 89Sr 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 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 80000-10:2019/Amd 1:2025, *Quantities and units — Part 10: Atomic and nuclear physics — Amendment 1*

EN ISO 11929-1:2021, *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 11929-1:2019)*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 11929-1:2021 and ISO 80000-10:2019/Amd 1:2025 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/

3.2 Symbols

The symbols are given in Table 1.

Table 1

Symbol	Definition	Unit
A_i	calibration source activity of radionuclide *i*, at the time of calibration	Bq
$c_{A,i}$	activity concentration of radionuclide *i*	$Bq \cdot l^{-1}$
$c^{*}_{A,i}$	decision threshold of radionuclide *i*	$Bq \cdot l^{-1}$
$c^{\#}_{A,i}$	detection limit of radionuclide *i*	$Bq \cdot l^{-1}$
$c^{\triangleleft}_{A,i}$, $c^{\triangleright}_{A,i}$	lower and upper limits of the probabilistically symmetric coverage interval of radionuclide *i*	$Bq \cdot l^{-1}$
$c^{<}_{A,i}$, $c^{>}_{A,i}$	lower and upper limits of the shortest coverage interval of radionuclide *i*	$Bq \cdot l^{-1}$
k_p	quantile of the standardized normal distribution for the probability *p* (for instance p=1-α, 1-β or 1-γ/2)	
$R_{c,i}$	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_{gj}	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 $^{90}Sr/^{90}Y$ ($t = 0$) 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 $U = ku(c_A)$ with $k = 1, 2 \ldots$	$Bq \cdot l^{-1}$
$u(c_A)$	standard uncertainty associated with the measurement result	$Bq \cdot l^{-1}$
$u_{rel}(c_A)$	relative standard uncertainty	
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}Sr, ^{90}Y and ^{89}Sr are all pure beta-particle emitters. Their beta-emission energies and half-lives are given in Table 2.

Table 2 — Half-lives, maximum energies, and average energies of ^{90}Sr, ^{90}Y, and ^{89}Sr [9]

Parameter	^{90}Sr	^{90}Y	^{89}Sr
Maximum energy	546,0 keV	2 283,9 keV	1 491,0 keV
Average energy	196,4 keV	935,3 keV	586,3 keV
Half-life	28,80 (7) a	2,6684 (13) d	50,57 (3) d

Strontium-90 can either be measured directly or calculated through the measurement of its decay progeny ^{90}Y. All the test methods are based on a chemical separation step followed by beta-counting using proportional counting (PC) or liquid scintillation counting (LSC). See Table 3 which contains guidance over method selection.

4.2 Chemical separation

Strontium is isolated from the water using precipitation, ion exchange or specific chromatographic separation by crown ether resin[10]. Yttrium can then be isolated by precipitation, liquid–liquid extraction, or extraction chromatography. Alternatively, yttrium can be isolated directly from the sample.

The method chosen shall be selective with a high chemical yield. When certain radionuclides such of thorium, lead or bismuth radioisotopes are present at high activity levels, they can interfere with ^{90}Sr, ^{90}Y or ^{89}Sr detection. Other matrix constituents, such as other alkaline earth metals, particularly calcium which interferes with Sr separation; or transuranic and lanthanide elements which interfere with yttrium separation, reduce the chemical yield of the various extraction steps.

The radiochemical separation yield is calculated using either a stable element (e.g. Sr or Y), which can be used as both a carrier or as a tracer, or a radioactive tracer such as ^{85}Sr. Techniques such as atomic absorption spectroscopy (AAS), inductively coupled plasma–atomic emission spectroscopy (ICP–AES) EN ISO 11885:2009 [11] or inductively coupled plasma–mass spectrometry (ICP–MS) EN ISO 17294-1:2024 [12] to measure the carrier, and gamma-spectrometry to measure ^{85}Sr, are recommended. A carrier can also be measured by gravimetric methods, which can be an easy, fast, and cost effective method to determine the chemical recovery. However, the element to measure (Sr or Y) has to be well separated or the presence of stable elements, notably alkaline earth elements in the leaching solutions, can lead to an overestimation of the radiochemical separation yields, particularly for the measurement of Sr.

4.3 Detection

The use of LSC, which provides spectra and can allow the detection of interference from unwanted radionuclides, is recommended in preference to PC, which does not does not allow emissions from different beta-emitters to be identified. When PC instrument is used, it is recommended that the purity of the precipitate is checked by monitoring the ingrowth of ^{90}Y, even though this is time consuming.

Seven test methods are presented in Annex A, Annex B, Annex C, Annex D, Annex E, Annex F and Annex G.

5 Chemical reagents and equipment

The necessary chemical reagents and equipment for each Sr or Y measurement method are specified in Annex A, Annex B, Annex C, Annex D, Annex E, Annex F and Annex G.

During the analyses use only reagents of recognized analytical grade and laboratory ultrapure water with a resistivity of more than 18 MΩ·cm at 25 °C.

6 Procedure

6.1 Test sample preparation

Strontium-89/90 activity concentration is determined from the water test sample after appropriate sampling procedures ISO 5667-1 [13], ISO 5667-3 [14] and ISO 5667-14:2014 [15].

Filtration of the test sample should be done prior to the addition of the tracer or carrier and then sufficient time should be allowed for the tracer or carrier to reach chemical equilibrium with the Sr initial present in the sample before starting the test sample preparation.

Unlike the direct determination of ^{90}Sr, indirect determination of ^{90}Sr from its decay product ^{90}Y at equilibrium requires to set aside the sample for over 20 days or longer before analysis, by which time ^{90}Y will be in equilibrium with ^{90}Sr, particularly in the case of a fresh contamination.

When stable Sr is added as a carrier, the original Sr concentration in the test sample shall be known in order to determine the chemical yield. In the case of separation based on extraction chromatography, the total Sr content shall be below the sorption capacity of the resin to avoid saturation of the resin.

6.2 Chemical separation

6.2.1 General

There are several approaches Table 3 to the routine analysis of ^{89}Sr and ^{90}Sr involving the separation and purification of Sr or Y: precipitation, liquid–liquid extraction or chromatographic techniques (ion exchange or chromatographic extraction). Annex A, Annex B, Annex C, Annex D, Annex E, Annex F and Annex G describe a test method for each of these techniques.

Table 3 — Determination procedures for radioactive Sr depending on its origin

Condition		**Old Contamination**				**Fresh Contamination**	
Radionuclide		^{90}Sr+^{90}Y				^{90}Sr+^{90}Y	
						^{89}Sr	
Separation	Element	Sr		Y[a]		Sr	
	Method	Chromatography[b]	Precipitation	Extraction /Chromatography[b]	Precipitation	Chromatography[b]	Precipitation
	Product	^{90}Sr+^{90}Y		^{90}Y		^{90}Sr, ^{90}Y, ^{89}Sr	
	Carrier or Tracer[c]	^{85}Sr or stable Sr		Stable Y		^{85}Sr or stable Sr	
Measurement(s)	Equilibrium ^{90}Sr+^{90}Y 20 d	Yes (recommended)	No	No		Yes	No
	Number	One		One		Two or more	
	Emissions	^{90}Sr ^{90}Y		^{90}Y		^{90}Sr ^{90}Y ^{89}Sr	
	Equipiment	PC or LSC (total)		PC or LSC (total or Cerenkov)		PC + LSC (total)	
	Calibration sources	^{90}Sr+^{90}Y	^{90}Sr ^{90}Y	^{90}Y		^{90}Sr+^{90}Y ^{89}Sr	^{90}Sr ^{90}Y ^{89}Sr

a Y separation is performed following the ^{90}Sr-^{90}Y equilibrium in the test sample.

b Purification of target radionuclide based on exttraction chromatography

c Carrier and tracer element measurments can be taken using gamma-sepctrometry for ^{85}Sr (tracer), by gravimetry, atomic absorption spectrometry (AAS), inductively coupled plasma-atomic emission spectroscopy (ICP-AES) or inductively coupled plasma mass spectrometry (ICP-MS) for Sr and Y (tracer and/or carrier)

NOTE Strontium-89 is not considered in old contamination due to its short half-life, but should be included in fresh contamination scenarios. The number of counts indicated in this Table 3 is valid only in cases of effective separation, i.e. when no interferents are present. In practice, verifying the absence of interference requires monitoring the re-growth or decay of ^{90}Y. In the case of liquid scintillation counting, spectrum examination may occasionally reveal the presence of an interferent, but this method is less sensitive than monitoring the re-growth or decay of ^{90}Y.

6.2.2 Precipitation techniques

The precipitation of Sr with nitrate is a very common method to separate Sr even for water samples with high mineral salt contents. This technique is very efficient, but not selective for Sr.

The addition of fuming nitric acid leads to a Sr precipitate with other interfering elements. Successive dissolution–precipitation cycles concentrate Sr in the precipitate, while yttrium and other elements remain in the supernatant fraction. After further separation of Sr, Sr is usually precipitated as $SrCO_3$.

For the test method with ^{90}Sr and ^{90}Y in equilibrium, either the total concentration of Sr and Y is directly measured in the precipitate or ^{90}Y activity is measured after a separation from ^{90}Sr. In this latter case, the chemical yield is estimated by the addition of an yttrium carrier to the source before the yttrium separation. The final product is an yttrium precipitate, usually in the form of an oxalate.

In the absence of ^{89}Sr, ^{90}Sr is measured by counting the beta-emission of ^{90}Y or of ^{90}Y and ^{90}Sr. In the latter case, the sample can be counted at equilibrium or counted at any time if a mathematical correction for ^{90}Y ingrowth and ^{90}Sr decay is applied. When ^{89}Sr in the water test sample cannot be neglected, the direct measurement method of Sr at two different times shall be chosen.

Two precipitation methods are described: Annex A employs PC for ^{90}Sr and ^{89}Sr; Annex B employs LSC for ^{90}Sr and ^{89}Sr.

6.2.3 Liquid–liquid extraction technique

This technique is based on the extraction of ^{90}Y in equilibrium with its radioactive parent ^{90}Sr using an organic solvent. The chemical separation is fast and requires few technical resources. A provisional result can be achieved after 3 d (approximately one ^{90}Y decay period). However, total selectivity of the extraction is not always possible. In the presence of high levels of natural radioactivity, interference can occur, making it difficult to determine very low levels of ^{90}Sr activity.

Yttrium-90 is extracted from the water test sample fraction using an organic solvent, and then after re-extraction, recovered in the form of an yttrium precipitate. Test methods are presented in Annex C and Annex F.

After the source preparation, the ^{90}Y is measured by PC (Annex F) or LSC (Annex C). The absence of other interfering beta-emitters is verified during the decay of ^{90}Y by measuring the decrease in count rate of the ^{90}Y and once the decay is complete (about 20 days), comparing it with the background level activity.

6.2.4 Chromatographic techniques

6.2.4.1 Ion exchange resin

This technique is based on Sr(II) exchange on a cation exchange resin and is used for the separation and purification of Sr in large volume samples. A method is presented in Annex D in which the measurement is carried out with PC.

6.2.4.2 Crown ether resin

This technique is based on the selective chromatographic separation of Sr using a specific crown ether resin. However, this method has limited application for samples containing high amounts of stable Sr and Ca in amounts exceeding the resin sorption capacity. A method is presented in Annex E in which the measurement is carried out by LSC.

6.3 Preparation of the source for test

6.3.1 Source preparation for liquid scintillation counter

The Sr or Y precipitate is dissolved and mixed with a liquid scintillation cocktail. When Sr or Y is already in solution, it is mixed directly with the liquid scintillator. The volume of the analysed aliquot depends on the equipment (vial size) and the specific scintillation cocktail used.

The calibration source shall be prepared from a known activity of tracer (^{90}Sr, ^{89}Sr, ^{90}Sr + ^{90}Y or ^{90}Y) with the same geometry and chemical composition as the source to be measured.

The blank source should be prepared following the method chosen starting with a clean test sample (or water).

6.3.2 Source preparation for proportional counter

The Sr or Y precipitate is deposited on a filter by filtration or on a stainless steel planchet by direct evaporation.

The filter or planchet size diameter should be similar to the detector size (see Annex A, Annex D and Annex H).

A calibration source shall be prepared from a known amount of tracer (^{90}Sr, ^{89}Sr, ^{90}Sr + ^{90}Y or ^{90}Y) with the same geometry and chemical composition as the source to be measured.

A blank source shall be prepared with the same geometry and chemical composition as the source to be measured.

6.4 Measurement

6.4.1 General

The same equipment conditions should be used for the sample, the background and the calibration source measurements.

The counting time depends on the sample and background count rates and also on the detection limit and decision threshold required.

6.4.2 Liquid scintillation counter

The scintillation phenomenon results from interactions of ionizing radiations with solvents and compounds having fluorescent properties (scintillators). The solvents and scintillators constitute the scintillation cocktail. The scintillation mixture is achieved by adding the scintillation cocktail to the test sample in order to obtain a homogeneous mixture.

The scintillation cocktail is chosen according to the characteristics of the sample to be analysed and according to the properties of the detection equipment (see ISO 19361:2017 [16]). It is recommended that a hydrophilic scintillation cocktail be used, especially for the measurement of natural water.

The characteristics of the scintillation cocktail shall allow the mixture to be homogeneous and stable.

It is recommended that the scintillation cocktail be stored in the dark and, particularly just before use, exposure to direct sunlight or fluorescent light be avoided in order to prevent interfering luminescence and to comply with the storage conditions specified by the scintillation cocktail supplier.

The measurement can be affected by chemiluminescence phenomena, quench due to chemical entities, and the presence of other radionuclides than ^{90}Y. It is then necessary to take into account the characteristics of the water sample.

When assessing the ^{90}Sr activity by its measurement with ^{90}Y in equilibrium, two cases arise:

— If ^{89}Sr activity is negligible, the relevant contribution of ^{90}Y in equilibrium with ^{90}Sr can be assessed using LSC;

— If ^{89}Sr activity is not negligible, it is necessary to measure the Sr at two different times, to estimate the ^{89}Sr activity through its decay.

When assessing ^{90}Sr activity by ^{90}Y measurement, it is preferable to measure the Cerenkov radiation from the ^{90}Y, as there is negligible interference from ^{90}Sr.

6.4.3 Proportional counter

A PC measures directly the beta-radiation, without energy discrimination, from a source usually prepared as a thin layer deposit.

Dual-window alpha/beta discrimination allows the presence of alpha-emitter contaminants in the source to be monitored. If other beta-emitters are present, they can be detected by performing successive measurements of the source over time.

6.4.4 Efficiency calculation

The procedure to calibrate the counters is as follows:

— count the sample until at least 10^4 counts are obtained;

— determine the beta-count rate of the calibration source (in the same chemical and physical form as the samples);