
**Measurement of radioactivity in the
environment — Soil —**

**Part 5:
Strontium 90 — Test method using
proportional counting or liquid
scintillation counting**

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*Mesurage de la radioactivité dans l'environnement — Sol —
Partie 5: Strontium 90 — Méthode d'essai par comptage
proportionnel et scintillation liquide*

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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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

This second edition cancels and replaces the first edition (ISO 18589-5:2009), which has been technically revised.

The main change compared to the previous edition are as follows:

- The introduction has been reviewed accordingly to the generic introduction adopted for the standards published on the radioactivity measurement in the environment.

A list of all parts in the ISO 18589 series can be found on the ISO website.

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

Everyone is exposed to natural radiation. The natural sources of radiation are cosmic rays and naturally occurring radioactive substances which exist in the earth and flora and fauna, including the human body. Human activities involving the use of radiation and radioactive substances add to the radiation exposure from this natural exposure. Some of those activities, such as the mining and use of ores containing naturally-occurring radioactive materials (NORM) and the production of energy by burning coal that contains such substances, simply enhance the exposure from natural radiation sources. Nuclear power plants and other nuclear installations use radioactive materials and produce radioactive effluent and waste during operation and decommissioning. The use of radioactive materials in industry, agriculture and research is expanding around the globe.

All these human activities give rise to radiation exposures that are only a small fraction of the global average level of natural exposure. The medical use of radiation is the largest and a growing man-made source of radiation exposure in developed countries. It includes diagnostic radiology, radiotherapy, nuclear medicine and interventional radiology.

Radiation exposure also occurs as a result of occupational activities. It is incurred by workers in industry, medicine and research using radiation or radioactive substances, as well as by passengers and crew during air travel. The average level of occupational exposures is generally below the global average level of natural radiation exposure (see Reference [1]).

As uses of radiation increase, so do the potential health risk and the public's concerns. Thus, all these exposures are regularly assessed in order to:

- improve the understanding of global levels and temporal trends of public and worker exposure;
- evaluate the components of exposure so as to provide a measure of their relative importance;
- identify emerging issues that may warrant more attention and study. While doses to workers are mostly directly measured, doses to the public are usually assessed by indirect methods using the results of radioactivity measurements of waste, effluent and/or environmental samples.

To ensure that the data obtained from radioactivity monitoring programs support their intended use, it is essential that the stakeholders (for example nuclear site operators, regulatory and local authorities) agree on appropriate methods and procedures for obtaining representative samples and for handling, storing, preparing and measuring the test samples. An assessment of the overall measurement uncertainty also needs to be carried out systematically. As reliable, comparable and 'fit for purpose' data are an essential requirement for any public health decision based on radioactivity measurements, international standards of tested and validated radionuclide test methods are an important tool for the production of such measurement results. The application of standards serves also to guarantee comparability of the test results over time and between different testing laboratories. Laboratories apply them to demonstrate their technical competences and to complete proficiency tests successfully during interlaboratory comparisons, two prerequisites for obtaining national accreditation.

Today, over a hundred International Standards are available to testing laboratories for measuring radionuclides in different matrices.

Generic standards help testing laboratories to manage the measurement process by setting out the general requirements and methods to calibrate equipment and validate techniques. These standards underpin specific standards which describe the test methods to be performed by staff, for example, for different types of sample. The specific standards cover test methods for:

- naturally-occurring 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 and ^{210}Pb) which can be found in materials from natural sources 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, and curium), ^3H , ^{14}C , ^{90}Sr and gamma-ray emitting radionuclides found in waste, liquid and gaseous effluent, in environmental matrices (water, air, soil and biota), in food and in animal feed as a result of authorized releases into the environment, fallout from the explosion in the atmosphere of nuclear devices and fallout from accidents, such as those that occurred in Chernobyl and Fukushima.

The fraction of the background dose rate to man from environmental radiation, mainly gamma radiation, is very variable and depends on factors such as the radioactivity of the local rock and soil, the nature of building materials and the construction of buildings in which people live and work.

A reliable determination of the activity concentration of gamma-ray emitting radionuclides in various matrices is necessary to assess the potential human exposure, to verify compliance with radiation protection and environmental protection regulations or to provide guidance on reducing health risks. Gamma-ray emitting radionuclides are also used as tracers in biology, medicine, physics, chemistry, and engineering. Accurate measurement of the activities of the radionuclides is also needed for homeland security and in connection with the Non-Proliferation Treaty (NPT).

This document describes the requirements to quantify the activity of ^{90}Sr in soil samples after proper sampling, sample handling and test sample preparation in a testing laboratory or in situ.

This document is to be used in the context of a quality assurance management system (ISO/IEC 17025).

This document is published in several parts for use jointly or separately according to needs. These parts are complementary and are addressed to those responsible for determining the radioactivity present in soil, bedrocks and ore (NORM or TENORM). The first two parts are general in nature describe the setting up of programmes and sampling techniques, methods of general processing of samples in the laboratory (ISO 18589-1), the sampling strategy and the soil sampling technique, soil sample handling and preparation (ISO 18589-2). ISO 18589-3 to ISO 18589-5 deal with nuclide-specific test methods to quantify the activity concentration of gamma emitters radionuclides (ISO 18589-3 and ISO 20042), plutonium isotopes (ISO 18589-4) and ^{90}Sr (ISO 18589-5) of soil samples. ISO 18589-6 deals with non-specific measurements to quantify rapidly gross alpha or gross beta activities and ISO 18589-7 describes in situ measurement of gamma-emitting radionuclides.

The test methods described in ISO 18589-3 to ISO 18589-6 can also be used to measure the radionuclides in sludge, sediment, construction material and products following proper sampling procedure.

This document is one of a set of International Standards on measurement of radioactivity in the environment.

Additional parts can be added to ISO 18589 in the future if the standardization of the measurement of other radionuclides becomes necessary.

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Measurement of radioactivity in the environment — Soil —

Part 5: Strontium 90 — Test method using proportional counting or liquid scintillation counting

1 Scope

This document describes the principles for the measurement of the activity of ^{90}Sr in equilibrium with ^{90}Y and ^{89}Sr , pure beta emitting radionuclides, in soil samples. Different chemical separation methods are presented to produce strontium and yttrium sources, the activity of which is determined using proportional counters (PC) or liquid scintillation counters (LSC). ^{90}Sr can be obtained from the test samples when the equilibrium between ^{90}Sr and ^{90}Y is reached or through direct ^{90}Y measurement. The selection of the measuring method depends on the origin of the contamination, the characteristics of the soil to be analysed, the required accuracy of measurement and the resources of the available laboratories.

These methods are used for soil monitoring following discharges, whether past or present, accidental or routine, liquid or gaseous. It also covers the monitoring of contamination caused by global nuclear fallout.

In case of recent fallout immediately following a nuclear accident, the contribution of ^{89}Sr to the total amount of strontium activity will not be negligible. This standard provides the measurement method to determine the activity of ^{90}Sr in presence of ^{89}Sr .

The test methods described in this document can also be used to measure the radionuclides in sludge, sediment, construction material and products by following proper sampling procedure.

Using samples sizes of 20 g and counting times of 1 000 min, detection limits of (0,1 to 0,5) $\text{Bq}\cdot\text{kg}^{-1}$ can be achievable for ^{90}Sr using conventional and commercially available proportional counter or liquid scintillation counter when the presence of ^{89}Sr can be neglected. If ^{89}Sr is present in the test sample, detection limits of (1 to 2) $\text{Bq}\cdot\text{kg}^{-1}$ can be obtained for both ^{90}Sr and ^{89}Sr using the same sample size, counting time and proportional counter or liquid scintillation counter as in the previous situation.

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 11074, *Soil quality — Vocabulary*

ISO 11929 (all parts), *Determination of the characteristic limits (decision threshold, detection limit and limits of the coverage interval) for measurements of ionizing radiation — Fundamentals and application*

ISO 19361, *Measurement of radioactivity — Determination of beta emitters activities — Test method using liquid scintillation counting*

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

ISO 18589-2, *Measurement of radioactivity in the environment — Soil — Part 2: Guidance for the selection of the sampling strategy, sampling and pre-treatment of samples*

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

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

3 Terms and definitions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11074, ISO 18589-1, ISO 11929 (all parts) 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/>

3.2 Symbols

m	mass of the test portion, in unit of mass
a_i	activity per unit of mass, of radionuclide i , in becquerel per unit of mass
$A_{s,i}$	reference measurement standard activity of radionuclide i , at the calibration time, in becquerel
A_i	sample source activity of radionuclide i , at time $t = 0$, in becquerel
t_g	sample counting time, in seconds
t_0	background counting time, in seconds
t_s	reference measurement standard counting time
r_g	gross count rate, in per second
r_0	background count rate, in per second
r_s	reference measurement standard count rate, in per second
$R_{c,i}$	chemical yield of the extraction of radionuclide i
ε_i	counting efficiency of radionuclide i
λ_i	decay constant of radionuclide i
t_d, t_f	start and stop time respectively of the measurement, referred to $t = 0$, in seconds
r_{gj}	gross count rate, for measurement j , in per second
r_{0j}	background count rate, for measurement j , in per second
r_j	net count rate, for measurement j , in per second
t_j	start time of the measurement j , referred to $t = 0$
$u(X)$	standard uncertainty associated with X
U	expanded uncertainty, calculated by $U = k \cdot u(X)$ with $k = 1, 2, \dots$

a_i^*	decision threshold of radionuclide i , in becquerel per unit of mass
$a_i^{\#}$	detection limit of radionuclide i , in becquerel per unit of mass
$a_i^{<}, a_i^{>}$	lower and upper limits of the confidence interval, of radionuclide i , in becquerel per unit of mass

4 Principle

4.1 General

From a detection perspective, it can be considered that ^{90}Sr , ^{90}Y and ^{89}Sr are pure beta emitter radionuclides. Their beta emission energies and half-lives are given in [Table 1](#) [2][3].

Table 1 — Beta emission average energies and half-lives of ^{90}Sr , ^{90}Y and ^{89}Sr

	^{90}Sr	^{90}Y	^{89}Sr
Beta energy, keV	196	926,7	584,6
Half-life	28,8 y	2,67 d	50,6 d

^{89}Sr and ^{90}Sr can be directly measured. ^{90}Sr can be estimated through the measurement of its daughter product ^{90}Y . All the measurements are based on a chemical separation step followed by beta counting of the element using a PC or using a LSC (See [Table 2](#)).

In a previous step, strontium will be desorbed from the soil test portion by acid treatment and will be in solution in the leachate fraction. The tracer or carrier is added at the start of this step of the procedure, and time allowed, usually up to one day, to obtain equilibrium before starting the strontium desorption.

A strontium desorption method for soil samples is specified in [Clause 6](#).

4.2 Chemical separation

Following the desorption step of the soil test portion, strontium shall be isolated from the soil solution using precipitation or specific chromatographic resin separation such as crown ether resin. Yttrium can be isolated by precipitation or liquid-liquid extraction.

The separation step should maximise the extraction of the pure element. The method chosen shall be selective with a high radiochemical separation yield. As thorium, lead, and bismuth radioisotopes are present in soil at high activity levels they shall be removed from the sample because they may interfere with ^{90}Sr or ^{90}Y or ^{89}Sr emissions during the detection step. Other matrix constituents which can interfere, such as alkaline earth elements, calcium for strontium, or transuranic and lanthanide elements for yttrium, shall also be removed as they reduce the chemical yield of the extraction.

The radiochemical separation yield is calculated using a carrier such as stable Sr or Y, or a radioactive tracer such as ^{85}Sr . Techniques like atomic absorption spectroscopy (AAS) or atomic emission spectroscopy (ICP-AES) or mass spectrometry (ICP-MS) to measure the carrier, and gamma spectrometry to measure ^{85}Sr , are recommended. A carrier can also be measured by gravimetric methods, but the presence of inactive elements, essentially alkaline earth elements, in the leaching solutions can lead to an overestimation of the radiochemical separation yields, particularly for the measurement of Sr.

When stable strontium is added as a carrier, its original concentration shall be known in the test sample before the addition of the carrier to avoid the overestimation of the radiochemical separation yield.

There are three usual techniques for the chemical separation: precipitation liquid-liquid extraction and chromatography extraction using selective crown-ether resin [4][5][6]. [Clauses 7, 8](#) and [9](#) give a procedure for each of these techniques.

4.3 Detection

4.3.1 General

The use of a LSC is recommended, depending on the compatibility between the LSC solvent and the sample, because it can provide energy spectra and discriminate interference from unwanted radionuclides. LSC can also be used, with water as the solvent, to count Cerenkov photons. However, LSC is subject to optical and chemical quenching. A PC, on the other hand, does not distinguish between emissions from different beta emitters, but can exclude alpha contamination and is not subject to the Cerenkov effect or sample quenching. When a PC is used, it is recommended that the purity of the precipitate is checked by following the change over an appropriate time of the ^{90}Y or ^{89}Sr activity, even though this method is time consuming.

4.3.2 Source preparation for liquid scintillation counter

The test portion is mixed with the scintillation cocktail in a counting vial to obtain a homogeneous medium (scintillation source). Beta particles emitted from the test portion transfer their energy to the scintillation cocktail molecules, causing them to become excited. Upon returning to the ground state, photons are emitted, which can then be detected by photoelectron multiplier tubes (phototubes). To properly carry out measurements by using a LSC, recommendations contained in ISO 19361 shall be taken into account.

The Sr or Y precipitate is dissolved and mixed with the scintillation cocktail. The solution volume depends on the equipment (vial size) and the specific scintillation cocktail used.

The reference measurement standard shall be prepared from a known amount of tracer (^{90}Sr , ^{89}Sr , $^{90}\text{Sr}+^{90}\text{Y}$ or ^{90}Y) with the same geometry and chemical composition as the source to be measured. Methods that allow the calibration with different radionuclide are also available.

The blank source should be prepared following the method chosen starting with a test portion without ^{90}Sr (or directly with distilled water).

4.3.3 Source preparation for proportional counter

The proportional counter measures directly the beta emission from the source prepared from a thin layer deposit to minimize the self-absorption effects.

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

The filter or dish size diameter should be determined by the counter requirements, i.e. the detector diameter and source holder dimensions.

The reference measurement standard shall be prepared from a known amount of tracer (^{90}Sr , ^{89}Sr , $^{90}\text{Sr}+^{90}\text{Y}$ 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 portion (or directly distilled water).

4.3.4 Background determination

Measure the background using a blank source prepared for the method chosen.

Table 2 — Determination procedures for strontium depending on its origin

Origin.		Old Fallout				Fresh Fallout	
Radionucl. Contents		$^{90}\text{Sr}+^{90}\text{Y}$				$^{90}\text{Sr}+^{90}\text{Y}$ ^{89}Sr	
Separation	Element	Sr		Y ^a		Sr	
	Method	Chromatography ^b	Precipitation	Extraction	Precipitation	Chromatography ^c	Precipitation
	Product	^{90}Sr		^{90}Y		$^{90}\text{Sr}+^{89}\text{Sr}$	
	Carrier or Tracer ^d	^{85}Sr or Stable Sr		Stable Y		^{85}Sr or Stable Sr	
Measurement(s)	Equilibrium $^{90}\text{Sr}+^{90}\text{Y}$	Yes 15-20 days (recommended)	No	No		Yes 15-20 days (recommended)	No
	Number	One		One		Two or more	
	Emissions	^{90}Sr ^{90}Y		^{90}Y		^{90}Sr ^{90}Y ^{89}Sr	
	Equipment	PC or LSC (total)		PC or LSC (total or Cerenkov)		PC or LSC (total)	
	Cal. Sources	$^{90}\text{Sr}+^{90}\text{Y}$	^{90}Sr ^{90}Y	^{90}Y		$^{90}\text{Sr}+^{90}\text{Y}$ ^{89}Sr	^{90}Sr ^{90}Y ^{89}Sr

^a Y separation will be performed following the $^{90}\text{Sr}-^{90}\text{Y}$ equilibrium in the test sample.

^b Specific chromatography using crown ether resin.

^c Specific chromatography using crown ether resin.

^d A carrier or tracer measurements are done using gamma spectrometry for ^{85}Sr and gravimetry, atomic absorption (AAS) or mass spectrometry (MS) for Sr and Y.

5 Chemical reagents and equipment

The necessary chemical reagents and equipment for each strontium measurement method are specified in [Clauses 7, 8](#) and [9](#).

All the chemical reagents needed to carry out this procedure shall be analytical grade.

6 Procedure of strontium desorption

6.1 Principles

The Sr contents in the test portion of soil can be extracted by an acid leach cycle (nitric acid, hydrochloric acid, acid mixture).

The tracer or carrier is added at the start of this step of the procedure, and time allowed, usually up to one day, to obtain equilibrium before starting the strontium desorption.