International Standard

ISO 18589-3

Measurement of radioactivity in the environment — Soil —

Part 3: Test method of gamma-emitting radionuclides using gamma-ray spectrometry

Mesurage de la radioactivité dans l'environnement — Sol —

Partie 3: Méthode d'essai des radionucléides émetteurs gamma par spectrométrie gamma

Third edition
2023-07

Corrected version
2024-08

Reference number
ISO 18589-3:2023(en)

© ISO 2023



COPYRIGHT PROTECTED DOCUMENT

© ISO 2023

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ..... **v**
Introduction ..... **vi**
1 Scope **1**
2 Normative references **1**
3 Terms, definitions and symbols **2**
3.1 Terms and definitions 2
3.2 Symbols 2
4 Principle **3**
5 Reference sources **4**
5.1 Source(s) for energy calibration 4
5.2 Reference source(s) for efficiency calibration 4
5.2.1 General 4
5.2.2 Reference sources for laboratory gamma spectrometry systems 4
5.2.3 Reference sources used with numerical methods 5
6 Gamma spectrometry equipment **5**
6.1 General description 5
6.2 Detector types 5
6.3 High voltage power supply 6
6.4 Preamplifier 6
6.5 Cryostat or electric cooler 6
6.6 Shielding 6
6.7 Analogue or digital acquisition electronics 6
6.7.1 General 6
6.7.2 Analogue electronic 7
6.7.3 Digital electronic DSP 7
6.8 Computer, including peripherical devices and software 7
7 Nuclear decay data **8**
8 Sample container **8**
9 Procedure **8**
9.1 Packaging of samples for measuring purposes 8
9.2 Laboratory background level 9
9.3 Calibration 9
9.3.1 Energy calibration 9
9.3.2 Efficiency calibration 10
9.4 Correction required for the measurements of natural radionuclides 11
9.5 Quality control 11
10 Expression of results **12**
10.1 Calculation of the activity per unit of mass 12
10.1.1 General 12
10.1.2 Dead time and pile up corrections (see ISO 20042) 12
10.1.3 Decay corrections 13
10.1.4 Self-absorption correction 13
10.1.5 True coincidence summing 14
10.2 Standard uncertainty 15
10.3 Decision threshold 16
10.4 Detection limit 16
10.5 Limits of the coverage intervals 16
10.5.1 Limits of the probabilistically symmetric coverage interval 16
10.5.2 The shortest coverage interval 17
10.6 Corrections for contributions from other radionuclides and background 17
10.6.1 General 17

© ISO 2023 – All rights reserved

10.6.2 Contribution from other radionuclides 18
10.6.3 Contribution from background 19

11 Test report **19**

Annex A (informative) **Analysis of natural radionuclides in soil samples using gamma spectrometry** **21**

Annex B (informative) **Self-attenuation correction**[21][22] **27**

Annex C (informative) **True coincidence summing** **30**

Annex D (informative) **Calculation of the activity per unit mass from a gamma spectrum using a linear background subtraction** **32**

Bibliography **34**

© ISO 2023 – All rights reserved

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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

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 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This third edition cancels and replaces the second edition (ISO 18589-3:2015), which has been technically revised.

The main change is:

— a correction to Formula (4);

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.

This corrected version of ISO 18589-3:2023 incorporates the following corrections:

— In Annex B, Formula (B.8) and Formula (B.10) have been corrected.

© ISO 2023 – All rights reserved

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 samples. The specific standards cover test methods for:

— naturally-occurring 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) 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);

© ISO 2023 – All rights reserved

— human-made radionuclides, such as transuranium elements (americium, plutonium, neptunium, and curium), ^{3}H, ^{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 national security and in connection with the Non-Proliferation Treaty (NPT).

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

ISO 18589 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 and 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, ISO 18589-4 and ISO 18589-5 deal with nuclide-specific test methods to quantify the activity concentration of gamma emitting 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.

© ISO 2023 – All rights reserved

Measurement of radioactivity in the environment — Soil —

Part 3: Test method of gamma-emitting radionuclides using gamma-ray spectrometry

1 Scope

This document specifies the identification and the measurement of the activity in soils of a large number of gamma-emitting radionuclides using gamma spectrometry. This non-destructive method, applicable to large-volume samples (up to about 3 l), covers the determination in a single measurement of all the γ-emitters present for which the photon energy is between 5 keV and 3 MeV.

Generic test method and fundamentals using gamma-ray spectrometry are described in ISO 20042.

This document can be applied by test laboratories performing routine radioactivity measurements as a majority of gamma-emitting radionuclides is characterized by gamma-ray emission between 40 keV and 2 MeV.

The method can be implemented using a germanium or other type of detector with a resolution better than 5 keV.

This document addresses methods and practices for determining gamma-emitting radionuclides activity present in soil, including rock from bedrock and ore, construction materials and products, pottery, etc. This includes such soils and material containing naturally occurring radioactive material (NORM) or those from technological processes involving Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) (e.g. the mining and processing of mineral sands or phosphate fertilizer production and use) as well as of sludge and sediment. This determination of gamma-emitting radionuclides activity is typically performed for the purpose of radiation protection. It is suitable for the surveillance of the environment and the inspection of a site and allows, in case of accidents, a quick evaluation of gamma activity of soil samples. This might concern soils from gardens, farmland, urban or industrial sites that can contain building materials rubble, as well as soil not affected by human activities.

When the radioactivity characterization of the unsieved material above 200 μm or 250 μm, made of petrographic nature or of anthropogenic origin such as building materials rubble, is required, this material can be crushed in order to obtain a homogeneous sample for testing as described in ISO 18589-2.

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 10703, *Water quality — Gamma-ray emitting radionuclides — Test method using high resolution gamma-ray spectrometry*

ISO 11074, *Soil quality — Vocabulary*

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

ISO 18589-1, *Measurement of radioactivity in the environment — Soil — Part 1: General guidelines and definitions*

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

© ISO 2023 – All rights reserved

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

ISO/IEC Guide 98-1, *Uncertainty of measurement — Part 1: Introduction to the expression of uncertainty in measurement*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10703, ISO 11074, ISO 18589-1, ISO 20042 and ISO 80000-10 apply.

3.2 Symbols

For the purposes of this document, the symbols given in ISO 10703, ISO 11074, ISO 18589-1, ISO 20042 and ISO 80000-10 apply.

Symbol	Meaning	Unit
A	Activity of each radionuclide in calibration source, at the calibration time	Bq
a, a_c	Activity per unit of mass of each radionuclide, without and with corrections	$Bq \cdot kg^{-1}$
ε_E	Efficiency of the detector at energy, E, with the actual measurement geometry	
f_E	Correction factor considering all necessary corrections	
$f_{att}(E)$	Correction factor for self-attenuation at photon energy E	
$F_{att}(E)_{sample}$ $F_{att}(E)_{standard}$	Attenuation factor at photon energy E respectively for the sample and the standard	
f_d	Correction factor for decay for a reference date	
$f_{cl,E}$	Correction factor for coincidence losses (summing-out)	
$f_{su,E}$	Correction factor for summing-in effects by coincidences	
$f_{dt\,pu,E}$	Correction factor for dead time and pile up	
h	Height of the sample in the container	cm
λ	Decay constant of each radionuclide	s^{-1}
$\mu_m(E)$	Mass attenuation coefficient, at photon energy, E	$cm^2 \cdot g^{-1}$
$\mu_{sample}(E)$, $\mu_{standard}(E)$	Linear attenuation coefficient at photon energy E respectively for the sample and the standard	cm^{-1}
$n_{N,E}$, $n_{N0,E}$, $n_{Ns,E}$	Number of counts in the net area of the peak, at energy E, in the test sample spectrum, in the background spectrum and in the calibration spectrum, respectively	
$n_{N,E}^T$	Theoretical number of counts in the net area of the peak, at energy E	
$n_{g,E}$, $n_{g0,E}$, $n_{gs,E}$	Number of counts in the gross area of the peak, at energy E, in the test sample spectrum, in the background spectrum and in the calibration spectrum, respectively	
$n_{b,E}$, $n_{b0,E}$, $n_{bs,E}$	Number of counts in the background of the peak, at energy E, in the test sample spectrum in the background spectrum and in the calibration spectrum, respectively	
P_E	Probability of the emission of a gamma-ray with energy E of each radionuclide, per decay	
ρ	Bulk density, in grams per cubic centimetre, of the sample	$g \cdot cm^{-3}$
S	Cross-section of surface	
t_g	Test sample spectrum counting time	s
t_0	Background spectrum counting time	s

© ISO 2023 – All rights reserved