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Water quality — Radon-222 —

Part 1: General principles

Qualité de l'eau — Radon 222 —

Partie 1: Principes généraux

Reference number
ISO 13164-1:2013(E)

Contents

Page

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, 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, 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.

The committee responsible for this document is ISO/TC 147, *Water quality*, Subcommittee SC 3, *Radioactivity measurements*.

ISO 13164 consists of the following parts, under the general title *Water quality — Radon-222*:

— *Part 1: General principles*

— *Part 2: Test method using gamma-ray spectrometry*

— *Part 3: Test method using emanometry*

The following part is under preparation:

— *Part 4: Test method using two-phase liquid scintillation counting*

This corrected version of ISO 13164-1:2013 incorporates the following corrections:

— Table 2: The check marks which printed out incorrectly in the last two columns have been changed to X's. The X's from the cells "Gamma spectrometry – On-site" and "Liquid scintillation – On-site" have been removed.

— Annex B: The examples of data record forms for B.2 and B.3 were inversed. They are now in the right places.

Introduction

Radioactivity from several naturally occurring and human-made sources is present throughout the environment. Thus, water bodies (surface waters, groundwaters, sea waters) can contain radionuclides of natural and human-made origin.

— Natural radionuclides, including potassium-40, and those of the thorium and uranium decay series, in particular radium-226, radium-228, uranium-234, uranium-238, lead-210, can be found in water for natural reasons (e.g. desorption from the soil and wash-off by rain water) or releases 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), tritium, carbon-14, strontium-90 and gamma-emitting radionuclides can also be found in natural waters as they can be authorized to be routinely released into the environment in small quantities in the effluent discharged from nuclear fuel cycle facilities and following their used in unsealed form in medicine or industry. They are also found in water due to the past fallout of the explosion in the atmosphere of nuclear devices and the accidents at Chernobyl and Fukushima.

Drinking-water can thus contain radionuclides at activity concentration which could present a risk to human health. In order to assess the quality of drinking-water (including mineral waters and spring waters) with respect to its radionuclide content and to provide guidance on reducing health risks by taking measures to decrease radionuclide activity concentrations, water resources (groundwater, river, lake, sea, etc.) and drinking water are monitor for their radioactivity content as recommended by the World Health Organization (WHO).

Standard test methods for radon-222 activity concentrations in water samples are needed by test laboratories carrying out such measurements in fulfillment of national authority requirements. Laboratories may have to obtain a specific accreditation for radionuclide measurement in drinking water samples.

The radon activity concentration in surface water is very low, usually below 1 Bq l^{-1}. In groundwater, the activity concentration varies from 1 Bq l^{-1} up to 50 Bq l^{-1} in sedimentary rock aquifers, from 10 Bq l^{-1} up to 300 Bq l^{-1} in wells, and from 100 Bq l^{-1} up to 1 000 Bq l^{-1} in crystalline rocks. The highest activity concentrations are normally measured in rocks with high concentration of uranium (Reference [30]).

High variations in the activity concentrations of radon in aquifers have been observed. Even in a region with relatively uniform rock types, some well water may exhibit radon activity concentration greatly higher than the average value for the same region. Significant seasonal variations have also been recorded (see Annex A).

Water may dissolve chemical substances as it passes from the soil surface to an aquifer or spring waters. The water may pass through or remain for some time in rock, some formations of which may contain a high concentration of natural radionuclides. Under favourable geochemical conditions, the water may selectively dissolve some of these natural radionuclides.

Guidance on radon in drinking-water supplies provided by WHO in 2008 suggests that controls should be implemented if the radon concentration of drinking-water for public water supplies exceeds 100 Bq l^{-1}. It also recommended that any new, especially public, drinking-water supply using groundwater should be tested prior to being used for general consumption and that if the radon concentration exceeds 100 Bq l^{-1}, treatment of the water source should be undertaken to reduce the radon levels to well below that level (Reference [41]).

This International Standard is one of a series dealing with the measurement of the activity concentration of radionuclides in water samples.

Water quality — Radon-222 —

Part 1:
General principles

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 ensure compliance with any national regulatory conditions.

IMPORTANT — It is absolutely essential that tests conducted in accordance with this document be carried out by suitably qualified staff.

1 Scope

This part of ISO 13164 gives general guidelines for sampling, packaging, and transporting of all kinds of water samples, for the measurement of the activity concentration of radon-222.

The test methods fall into two categories:

a) direct measurement of the water sample without any transfer of phase (see ISO 13164-2);

b) indirect measurement involving the transfer of the radon-222 from the aqueous phase to another phase (see ISO 13164-3).

The test methods can be applied either in the laboratory or on site.

The laboratory is responsible for ensuring the suitability of the test method for the water samples tested.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5667-1, *Water quality — Sampling — Part 1: Guidance on the design of sampling programmes and sampling techniques*

ISO 5667-3, *Water quality — Sampling — Part 3: Preservation and handling of water samples*

ISO 10703, *Water quality — Determination of the activity concentration of radionuclides — Method by high resolution gamma-ray spectrometry*

ISO 13164-2, *Water quality — Radon-222 — Part 2: Test method using gamma-ray spectrometry*

ISO 13164-3, *Water quality — Radon-222 — Part 3: Test method using emanometry*

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

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

3 Terms, definitions, and symbols

3.1 Terms and definitions

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

3.1.1
activity
number of spontaneous nuclear disintegrations occurring in a given quantity of material during a suitably small interval of time divided by that interval of time

[SOURCE: ISO 921:1997,[1] 23]

3.1.2
activity concentration in water
activity per volume of water

Note 1 to entry: The activity concentration in water is expressed in becquerels per litre.

3.1.3
activity concentration in air
activity per volume of air following the degassing phase

Note 1 to entry: The activity concentration in air is expressed in becquerels per cubic metre.

3.1.4
test sample
part of the total sample subjected to analysis

3.1.5
Bunsen coefficient
volume of a gas dissolved at standard temperature (273,15 K) and standard partial pressure (0,1 MPa) divided by the volume of the solvent at a temperature, T, and standard pressure (0,1 MPa)

Note 1 to entry: Adapted from Reference [10], p. 239.

Note 2 to entry: Modern practice recommends that gas solubility be expressed as molality, mole fraction or mole ratio (see Reference [10]). However, in many studies dealing with radon measurement in water, the Bunsen coefficient appears frequently.

Note 3 to entry: The solubility of radon in water increases as the water temperature decreases (see Annex A).

3.1.6
continuous measurement of radon in water
measurement of the radon activity concentration of continuous samples at a given sampling point in the water environment

Note 1 to entry: This form of analysis is used to monitor variations in the activity concentration of radon in the water at the sampling point over time.

3.1.7
continuous sampling
process whereby samples are taken continuously from a body of water

[SOURCE: ISO 6107-2:2006,[3] 32, modified]

3.1.8
degassing
transfer of dissolved radon from water to air, usually by means of a physical process

3.1.9
direct *in-situ* measurement
automatic analysis system in which at least the measurement probe is immersed in the body of water

3.1.10
discrete sample
localized discrete sample
single sample taken from a body of water at a random time or place

3.1.11
dissolution
mixing of two phases with the formation of one new homogeneous phase

3.1.12
drinking water
potable water
water of a quality suitable for drinking purposes

[SOURCE: ISO 6107-1:2004,[2] 30]

3.1.13
groundwater
water which is held in, and can usually be recovered from, an underground formation

[SOURCE: ISO 6107-1:2004,[2] 41, modified]

3.1.14
intermittent sampling
process whereby discrete samples are taken from a body of water

3.1.15
mains water
water fed from a drinking water treatment station, spring or borehole into a distribution system or reservoir

3.1.16
Ostwald coefficient
volume of a gas dissolved at a given temperature and pressure divided by the volume of the solvent at the same temperature and pressure

Note 1 to entry: Adapted from Reference [10], p. 1147.

Note 2 to entry: Modern practice recommends that gas solubility be expressed as molality, mole fraction or mole ratio (see Reference [10]). However, in many studies dealing with radon measurement in water, the Ostwald coefficient appears frequently.

Note 3 to entry: The solubility of radon in a liquid increases as the liquid temperature decreases (see Annex A).

3.1.17
radon transport by permeation
transfer of radon from one medium to another across a third homogeneous medium (membrane)

3.1.18
raw water
water which has received no treatment whatsoever, or water entering a plant for treatment or further treatment

[SOURCE: ISO 6107-1:2004,[2] 59]

3.1.19
reservoir
construction, partially or wholly man-made, for storage or regulation and control of water

[SOURCE: ISO 6107-2:2006,[3] 107, modified]

3.1.20
surface water
water which flows over, or rests on, the surface of a land mass

[SOURCE: ISO 6107-1:2004,[2] 74]

3.1.21
sample
portion, ideally representative, removed from a specified body of water, either discretely or continuously, for the purpose of examination of various defined characteristics

[SOURCE: ISO 6107-2:2006,[3] 111]

3.1.22
sampling
process of removing a portion, intended to be representative, of a body of water for the purpose of examination of various defined characteristics

[SOURCE: ISO 6107-2:2006,[3] 114]

3.1.23
sampling point
precise position within a sampling location from which samples are taken

[SOURCE: ISO 6107-2:2006,[3] 117]

3.1.24
sampling zone
extent of a body of water over which samples are taken

3.1.25
short-lived ^{222}Rn decay products
radionuclides with a half-life <1 h produced by the decay of radon-222 (^{222}Rn), namely polonium-218 (^{218}Po), lead-214 (^{214}Pb), bismuth-214 (^{214}Bi), and polonium-214 (^{214}Po)

Note 1 to entry: See Figure 1.

3.1.26
spot measurement of radon in water
measurement of the radon activity concentration in a water discrete sample carried out either immediately or after a known delay

Note 1 to entry: The result obtained is only representative of the time the sample was taken.

3.1.27
transfer
displacement or transport of radon from one phase to another

3.2 Symbols

For the purpose of this document, the symbols given in ISO 80000-10 and the following apply.

c activity concentration in air following degassing, in becquerels per cubic metre

c_A activity concentration in water, in becquerels per litre

c_A^* decision threshold, in becquerels per litre

$c_A^\#$ detection limit, in becquerels per litre

$c_A^\triangleleft, c_A^\triangleright$ lower and upper limits of the confidence interval, in becquerels per litre

c_l activity concentration in a liquid, in becquerels per litre

L Ostwald coefficient

T_{H_2O} temperature of water sample, in degrees Celsius

U expanded uncertainty calculated by $U = k.u(\ )$ with $k = 2$

$u(c_A)$ standard uncertainty associated with the measurement result

V volume of the test sample, in litres

α Bunsen coefficient

4 Principle of the measurement method

Radon-222 (^{222}Rn) is a radioactive gas produced by the decay of radium-226 (^{226}Ra), which is one of the decay products of the uranium-238 (^{238}U) that is naturally present in the Earth's crust (see Annex A). The decay of radon-222 proceeds through a series of non-volatile radioactive elements resulting in stable lead-206 (see Figure 1) (Reference [9]).

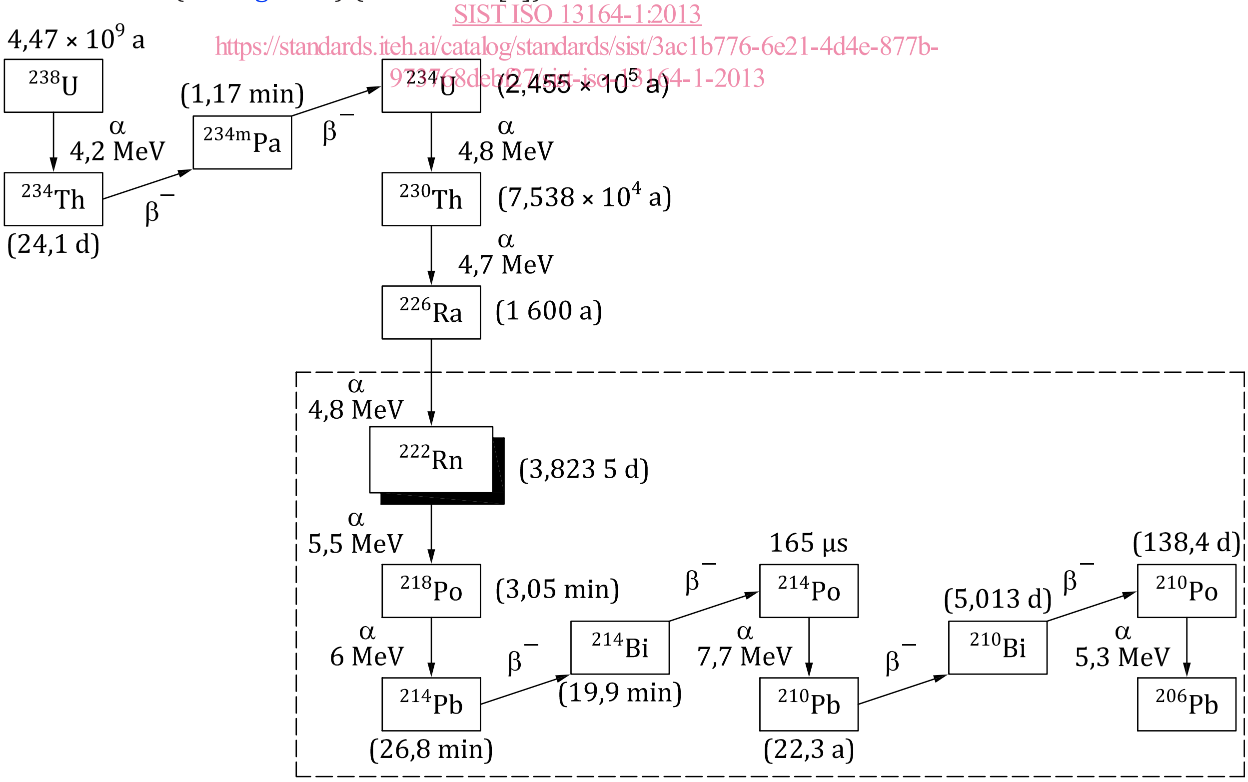

Figure 1 — Uranium-238 and its decay products

A large number of methods are available to measure the activity concentration of radon-222 in water.

The measurement of the activity concentration of radon-222 in water involves the following operations:

— collection of a representative sample of the water at time *t* in a suitable container;

— storage and the transportation of the sample, when the measurement is carried out in a laboratory;

— test sample preparation by transferring the radon dissolved in the water to another phase, when needed by the detection techniques (emanometric or a liquid scintillation counting);

— determination of the radon activity concentration in the water using a variety of detection techniques directly or through its decay products (see Figure 2).

The result of the measurement is expressed in becquerels per litre.

The methods specified in the different parts of this International Standard are applicable to all types of water (see Table 2), and the method is selected according to the purpose of the measurement, phenomenological observation or radiological impact assessment taking into account the level of the radon activity concentration expected in the raw sample.

5 Sampling

Sampling shall be carried out in accordance with ISO 5667-1 and ISO 5667-3.

The sampling conditions shall comply with ISO 5667-1, and shall also satisfy those specified in Table 1 in order to minimize as far as possible any exchange with the atmosphere and to maintain the radon in solution in the water sample.

The sample container shall be labelled.

The sampling location, date and time shall be recorded.

When measuring very low levels of radon activity concentration (< 10 Bq l^{-1}), avoid any contact between the sample and the atmosphere when taking the sample.

When measurement methods require specific precautions, these are listed in the relevant parts of ISO 13164 (e.g. when using degassing techniques, the temperature of the water shall be recorded).

6 Transportation and storage

The transportation and storage conditions shall be adapted to keep the integrity of the sample.

The temperature of the transportation and storage of the sample shall be below that of the original water (but above 0 °C). The container shall be protected and sealed to avoid opening during transportation. The container shall be packed in an appropriate manner, especially around the cap, in order to prevent any leakage.

The sample shall be measured as soon as possible after sampling. When it is necessary to store the sample for an extended period of time prior to measurement, it shall be stored at low temperature in a refrigerator or similar storage facility in accordance with ISO 5667-1 and ISO 5667-3.

The duration of transportation and storage prior to analysis shall be as short as possible given the half-life of radon-222, the expected activity concentration, and the detection limit of the measurement method to be used.

Experience indicates that it is essential that the time between sampling and analysis not exceed 48 h.

