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

*Qualité de l'eau — Radon 222 —*

*Partie 3: Méthode d'essai par émanométrie*

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Published in Switzerland

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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, [www.iso.org/directives](http://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](http://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*

## 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 monitored 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<sup>-1</sup>. In groundwater, the activity concentration varies from 1 Bq l<sup>-1</sup> up to 50 Bq l<sup>-1</sup> in sedimentary rock aquifers, from 10 Bq l<sup>-1</sup> up to 300 Bq l<sup>-1</sup> in wells, and from 100 Bq l<sup>-1</sup> up to 1 000 Bq l<sup>-1</sup> in crystalline rocks. The highest activity concentrations are normally measured in rocks with high concentration of uranium (Reference [15]).

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<sup>-1</sup>. It is 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<sup>-1</sup>, treatment of the water source should be undertaken to reduce the radon levels to well below that level (Reference [16]).

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

The origin of radon-222 and its short-lived decay products in water and other measurement methods are described generally in ISO 13164-1.

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# Water quality — Radon-222 —

## Part 3: Test method using emanometry

**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 specifies a test method for the determination of radon-222 activity concentration in a sample of water following its transfer from the aqueous phase to the air phase by degassing and its detection. It gives recommendations for rapid measurements performed within less than 1 h.

The radon-222 activity concentrations, which can be measured by this test method utilizing currently available instruments, range from 0,1 Bq l<sup>-1</sup> to several hundred thousand becquerels per litre for a 100 ml test sample.

This test method is used successfully with drinking water samples. The laboratory is responsible for ensuring the validity of this test method for water samples of untested matrices.

This test method can be applied on field sites or in the laboratory.

[Annexes A](#) and [B](#) give indications on the necessary counting conditions to meet the required sensitivity for drinking water monitoring.

### 2 Normative references

The following referenced documents are indispensable for the application 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 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 11929, *Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation — Fundamentals and application*

ISO 13164-1, *Water quality — Radon-222 — Part 1: General principles*

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*

IEC 61577-1, *Radiation protection instrumentation — Radon and radon decay product measuring instruments — Part 1: General principles*

IEC 61577-2, *Radiation protection instrumentation — Radon and radon decay product measuring instruments — Part 2: Specific requirements for radon measuring instruments*

### 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 ISO 13164-1 apply.

#### 3.2 Symbols

For the purposes of this document, the symbols defined in ISO 80000-10, ISO 13164-1, and the following apply.

$c$	measured radon activity concentration in the air of the measuring system after degassing, in becquerels per cubic metre
$c_0$	radon activity concentration in the air of the measuring system before degassing, in becquerels per cubic metre
$c_A$	activity concentration of radon in water, in becquerels per litre
$c_A^*$	decision threshold, in becquerels per litre
$c_A^\#$	detection limit, in becquerels per litre
$c_A^<, c_A^>$	lower and upper limits of the confidence interval, in becquerels per litre
$f_c$	conversion factor from cubic metre to litre: 0,001
$f_d$	correction factor for the decay of radon during time interval $t$ , dimensionless
$k_p, k_q$	quantiles of the standardized normal distribution for the probabilities, $p$ and $q$ , respectively
$L$	Ostwald coefficient
$T_{H_2O}$	water temperature, in Celsius
$t$	time interval between the sampling and the measurement, in seconds
$U$	expanded uncertainty calculated by $U = ku(c_A)$ with $k = 2$
$u(c_A)$	standard uncertainty associated with the measurement result
$V_{H_2O}$	volume of test sample, in litres
$V_a$	volume of air in the measurement system, in cubic metres
$\alpha, \beta$	probability of the error of the first and second kind, respectively
$\gamma$	probability for the confidence interval of the activity concentration
$\lambda$	decay constant of radon-222, in reciprocal second
$\Phi$	distribution function of the standardized normal distribution



## 4 Principle

The determination of radon-222 activity concentration in water by degassing into the air phase is based on the:

- collection of a representative sample of the water at time  $t$  in a suitable container;
- transfer of radon dissolved in the water to the air phase by degassing;
- detection of the alpha-radiation emitted by the radon or its solid decay products present in the air.

The radon activity concentration in the water is determined from the activity concentration in the air phase, taking account of the Ostwald coefficient (see ISO 13164-1).

## 5 Sampling

### 5.1 General requirement

The sample shall be representative of the environment to be analysed at a given time.

### 5.2 Sampling requirement

The sampling shall be carried out in compliance with the conditions and techniques specified in ISO 5667-1, ISO 5667-3, and ISO 13164-1. The temperature of the water shall be measured and recorded during the sampling process.

Fill the container completely and fit the cap in such a way as to avoid the presence of air above the sample.

The container shall be filled in such a way as to avoid degassing the radon in the water sample. The sampling techniques to be used vary according to the actual situation.

When the analytical laboratory is not in charge of sampling, the laboratory shall supply the container for the measurement and specify the sampling procedure to the person carrying out the sampling operation.

It is recommended that several discrete samples be taken in case of problems arising in relation to the sampling conditions or transportation of the samples.

### 5.3 Sample volume

Experience shows that a sample volume of at least 1 l is needed for the sample to be representative of the environment to be analysed.

At least 1 l samples are recommended, but for the effective determination smaller test portions are used.

### 5.4 Container characteristics

The choice and preparation of a suitable container are important (see ISO 5667-3).

The container and cap used to contain the sample shall comply with the following requirements.

- They shall be made from inert materials, impermeable to radon, non-hydrophobic, and conductive (in order not to adsorb radon and its decay products from the surrounding atmosphere).
- They shall be shock-proof.

The volume of the container should be compatible with the water volume required by the degassing technique used.

## 6 Transportation and storage

During transportation and storage, the sample shall be maintained at a temperature below that of the original water (but above 0 °C) until it is ready for analysis. The container shall be protected and tightly sealed. The container shall be packed in an appropriate manner in order to prevent any leakage.

The period 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.

On arrival at the laboratory, the sample shall be maintained at a temperature below that of the original water (but above 0 °C), if it cannot be analysed immediately. The sample shall be analysed as soon as possible.

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

## 7 Transfer of radon by degassing

### 7.1 Purpose

This technique is used to transfer the radon dissolved in the water into the air so that it can be detected and measured in its gaseous state.

### 7.2 Principle

As the Ostwald coefficient of radon in water is fairly low, the dissolved radon degasses naturally into the air with relatively slow kinetics (over a few hours) (see ISO 13164-1).

In order to accelerate the degassing process, several means may be used:

- shaking the sample; <https://standards.iteh.ai/catalog/standards/sist/3938d146-9a03-4b8b-b7ab-6d9240c2fa05/iso-13164-3-2013>
- sparging radon-free air through the water sample using a fine air bubble to increase the air exchange surface;
- decreasing the pressure in the air phase.

In order to improve the detection limit of the measurement method, it is necessary for the radon activity concentration in the air used for the degassing process to be as low as possible and to be measured before degassing the radon from the water.

## 8 Detection

### 8.1 Objective

The purpose of the detector is to quantify the alpha-radiation emitted by the radon and/or its solid decay products that is directly related to the activity concentration of the radon in the air phase.

### 8.2 Principle

A number of detection techniques can be used (see ISO 11665-1[1]).

### 8.3 Silver-activated zinc sulfide ZnS(Ag) scintillation

Some electrons in scintillating media, such as ZnS(Ag), have the particular feature of emitting photons by returning to their ground state when they are excited by an alpha-particle. These emitted photons can be detected using a photomultiplier.

This is the principle adopted for scintillation cells (such as Lucas cells) used for radon spot measurement (see References [5]–[7] and ISO 11665-6[3]).

#### 8.4 Air ionization

When it travels through the air, each alpha-particle creates several tens of thousands of ion pairs which, under some experimental conditions, produce an ionization current. Although very low, this current can be measured using an ionization chamber that gives the activity concentration of radon and its decay products. When the sampling is performed through a filtering medium, only radon diffuses into the ionization chamber and the signal is proportional to the radon activity concentration (see References [8]–[10] and ISO 11665-5[2]).

#### 8.5 Semiconductor (alpha-detection)

A semiconductor detector, e.g. made of silicon, converts the energy from an incident alpha-particle into electric charges. These are converted into pulses with an amplitude proportional to the energy of the alpha-particles emitted by the radon and its short-lived decay products (see References [11]–[13]).

NOTE This detection principle is occasionally associated with electrostatic precipitation of the alpha-emitter isotopes.

### 9 Quality assurance and quality control programme

#### 9.1 General

Quality control operations shall meet the requirements of ISO/IEC 17025.

#### 9.2 Influence quantities

Various quantities can lead to measurement bias that could induce non-representative results. In the specific case of the emanometric method, influence quantities can affect the following stages in the measurement process: sampling; transportation and storage of the sample; transfer of radon from the aqueous phase to another; and the measurement of the radon activity concentration.

During the sampling, consider particularly the:

- water temperature;
- turbulence in the water;
- volume of air in the container.

During the transfer of the radon from the water to the air by degassing, the influence of the water temperature shall be taken into account.

During measurement, consider particularly the:

- detector storage conditions prior to beginning the measurement;
- stability of the characteristics of the detection system (contamination of the detection surface, saturation, etc.);
- possible presence of other alpha-emitters (radon isotopes) in the detection volume.

When the delay between the sampling and the analysis is too long, it is possible that the presence of dissolved radium in the water needs to be taken into account as an influence quantity.

When the presence of  $^{226}\text{Ra}$  is suspected, take a second measurement of the same sample after a period equal to 10 half-lives of  $^{222}\text{Rn}$  (38 days). If the radon activity concentration is insignificant relative to

the initial measurement result, the contribution of  $^{226}\text{Ra}$  is considered to be negligible. If this is not the case, determine the activity concentration of  $^{226}\text{Ra}$  present in the water sample.

### 9.3 Instrument verification

Major instrument parameters (efficiency, background) shall be periodically checked within a quality assurance programme established by the laboratory and following the manufacturer's instructions.

### 9.4 Method verification

Periodically verify the accuracy of the method by:

- participating in intercomparison exercises;
- analysing reference materials.

Method repeatability shall also be checked, e.g. by replicate measurements.

The acceptance limits of the tests mentioned in the preceding shall be defined.

### 9.5 Demonstration of analyst capability

If an analyst has not used this procedure before, a precision and bias test shall be performed by running a duplicate measurement of a reference or spiked material. Acceptance limits shall be defined by the laboratory.

A similar test shall be performed by analysts routinely using this procedure with a periodicity defined by the laboratory. Acceptance limits shall be defined.

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## 10 Expression of results

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### 10.1 Activity concentration

The activity concentration of radon in the water,  $c_A$ , expressed at the date and time of sampling can be obtained using Formula (1):

$$c_A = (c - c_0) \left( L + \frac{V_a}{V_{\text{H}_2\text{O}}} \right) f_c f_d = (c - c_0) \omega \quad (1)$$

where

$$\omega = \left( L + \frac{V_a}{V_{\text{H}_2\text{O}}} \right) f_c f_d \quad (2)$$

$$f_d = \exp(\lambda t) \quad (3)$$

The Ostwald coefficient may be expressed by Formula (4) (Reference [14]):

$$L = 0,105 + 0,403 \exp(-0,0502 T_{\text{H}_2\text{O}}) \quad (4)$$