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Measurement of radioactivity in the environment — Air: radon-222 —

Part 2:
Integrated measurement method for determining average potential alpha energy concentration of its short-lived decay products

Mesurage de la radioactivité dans l'environnement — Air: radon 222 —

Partie 2: Méthode de mesure intégrée pour la détermination de l'énergie alpha potentielle volumique moyenne de ses descendants à vie courte

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

This second edition cancels and replaces the first edition (ISO 11665-2:2012), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

— update of the Introduction;

— update of the Bibliography.

A list of all the parts in the ISO 11665 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

Radon isotopes 222, 219 and 220 are radioactive gases produced by the disintegration of radium isotopes 226, 223 and 224, which are decay products of uranium-238, uranium-235 and thorium-232 respectively, and are all found in the earth's crust (see Annex A for further information). Solid elements, also radioactive, followed by stable lead are produced by radon disintegration[1].

When disintegrating, radon emits alpha particles and generates solid decay products, which are also radioactive (polonium, bismuth, lead, etc.). The potential effects on human health of radon lie in its solid decay products rather than the gas itself. Whether or not they are attached to atmospheric aerosols, radon decay products can be inhaled and deposited in the bronchopulmonary tree to varying depths according to their size [2][3][4][5].

Radon is today considered to be the main source of human exposure to natural radiation. UNSCEAR[6] suggests that, at the worldwide level, radon accounts for around 52 % of global average exposure to natural radiation. The radiological impact of isotope 222 (48 %) is far more significant than isotope 220 (4 %), while isotope 219 is considered negligible (see Annex A). For this reason, references to radon in this document refer only to radon-222.

Radon activity concentration can vary from one to more orders of magnitude over time and space. Exposure to radon and its decay products varies tremendously from one area to another, as it depends on the amount of radon emitted by the soil and building materials, weather conditions, and on the degree of containment in the areas where individuals are exposed.

As radon tends to concentrate in enclosed spaces like houses, the main part of the population exposure is due to indoor radon. Soil gas is recognized as the most important source of residential radon through infiltration pathways. Other sources are described in other parts of ISO 11665 and ISO 13164 series for water [58].

Radon enters into buildings via diffusion mechanism caused by the all-time existing difference between radon activity concentrations in the underlying soil and inside the building, and via convection mechanism inconstantly generated by a difference in pressure between the air in the building and the air contained in the underlying soil. Indoor radon activity concentration depends on radon activity concentration in the underlying soil, the building structure, the equipment (chimney, ventilation systems, among others), the environmental parameters of the building (temperature, pressure, etc.) and the occupants' lifestyle.

To limit the risk to individuals, a national reference level of 100 $Bq \cdot m^{-3}$ is recommended by the World Health Organization[5]. Wherever this is not possible, this reference level should not exceed 300 $Bq \cdot m^{-3}$. This recommendation was endorsed by the European Community Member States that shall establish national reference levels for indoor radon activity concentrations. The reference levels for the annual average activity concentration in air shall not be higher than 300 $Bq \cdot m^{-3}$[5].

To reduce the risk to the overall population, building codes should be implemented that require radon prevention measures in buildings under construction and radon mitigating measures in existing buildings. Radon measurements are needed because building codes alone cannot guarantee that radon concentrations are below the reference level.

Variations of a few nanojoules per cubic metre to several thousand nanojoules per cubic metre are observed in the potential alpha energy concentration of short-lived radon decay products.

The potential alpha energy concentration of short-lived radon-222 decay products in the atmosphere can be measured by spot and integrated measurement methods (see ISO 11665-1). This document deals with integrated measurement methods. Integrated measuring methods are applicable in assessing human exposure to radiation[4].

NOTE The origin of radon-222 and its short-lived decay products in the atmospheric environment and other measurement methods are described generally in ISO 11665-1.

Measurement of radioactivity in the environment — Air: radon-222 —

Part 2: Integrated measurement method for determining average potential alpha energy concentration of its short-lived decay products

1 Scope

This document describes integrated measurement methods for short-lived radon-222 decay products[4]. It gives indications for measuring the average potential alpha energy concentration of short-lived radon-222 decay products in the air and the conditions of use for the measuring devices.

This document covers samples taken over periods varying from a few weeks to one year. This document is not applicable to systems with a maximum sampling duration of less than one week.

The measurement method described is applicable to air samples with potential alpha energy concentration of short-lived radon-222 decay products greater than 10 nJ/m^3 and lower than 1 000 nJ/m^3.

NOTE For informative purposes only, this document also addresses the case of radon-220 decay products, given the similarity in behaviour of the radon isotopes 222 and 220.

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 11665-1, *Measurement of radioactivity in the environment — Air: radon-222 — Part 1: Origins of radon and its short-lived decay products and associated measurement methods*

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

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

IEC 61577-3, *Radiation protection instrumentation — Radon and radon decay product measuring instruments — Part 3: Specific requirements for radon decay product 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 11665-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.2 Symbols

For the purposes of this document, the symbols given in ISO 11665-1 and the following apply.

a	attenuation coefficient relating to the ^{222}Rn found in the collimators corresponding to the range P_1 (established theoretically and provided by the manufacturer)
b	attenuation coefficient relating to the ^{222}Rn found in the collimators corresponding to the range P_2 (established theoretically and provided by the manufacturer)
$E_{AE,i}$	alpha particle energy produced by the disintegration of the nuclide i, in joules
$\bar{E}_{PAEC,i}$	average potential alpha energy concentration of the nuclide i, in joules per cubic metre
$\bar{E}^{*}_{PAEC,i}$	decision threshold of the average potential alpha energy concentration of the nuclide i, in joules per cubic metre
$\bar{E}^{\#}_{PAEC,i}$	detection limit of the average potential alpha energy concentration of the nuclide i, in joules per cubic metre
$\bar{E}^{\triangleleft}_{PAEC,i}$	lower limit of the confidence interval of the average potential alpha energy concentration of the nuclide i, in joules per cubic metre
$\bar{E}^{\triangleright}_{PAEC,i}$	upper limit of the confidence interval of the average potential alpha energy concentration of the nuclide i, in joules per cubic metre
n	counting number of each range P_i
P_i	range recording alpha particles for i = 1, 2, 3, 4
$R_{P_i,j}$	j^{th} number of net count of range P_i with deduced background for i = 1, 2, 3, 4
$\bar{R}_{P_i}$	mean number of net count of range P_i with deduced background for i = 1, 2, 3, 4
$\bar{R}_0$	mean number of count due to background
r	ratio between the number of alpha particles emitted by ^{212}Bi (α emitter at 36 %) and the number of alpha particles emitted by ^{212}Po (produced by β disintegration at 64 % of ^{212}Bi); 0,56
U	expanded uncertainty calculated by $U = k \cdot u(\,)$ with $k = 2$
$u(\,)$	standard uncertainty associated with the measurement result
$u_{rel}(\,)$	relative standard uncertainty
V	sampled volume, in cubic metres
ε_{gd}	geometric detection efficiency (established theoretically), i.e. the ratio between the number of tracks counted and the number of alpha particles emitted by the deposit collected on the filter
ε_{hc}	collection efficiency (established experimentally), i.e. the ratio between the number of atoms of short-lived decay products collected per unit of sampled volume of air and the number of atoms per unit of volume of air present in the detection system environment

4 Principle

Integrated measurement of potential alpha energy concentration of short-lived radon decay products is based on the following elements:

a) continuous sampling of short-lived radon decay products contained in an air volume representative of the atmosphere under investigation, using a high-efficiency filtering membrane;

b) counting, and discriminating over four energy ranges, the alpha particles emitted by the collected short-lived radon-222 decay products (alpha particles with an energy $E_{\text{AE},^{218}\text{Po}}$ and $E_{\text{AE},^{214}\text{Po}}$ produced by the disintegration of ^{218}Po and ^{214}Po, and the disintegration of ^{214}Pb and ^{214}Bi potential emitters of alpha particles of this type), using a solid-state nuclear track detector;

c) calculation of the potential alpha energy concentration of the short-lived radon-222 decay products.

NOTE For the radon-220 decay products, this involves distinguishing between, and counting, the alpha particles, with an energy $E_{\text{AE},^{212}\text{Bi}}$ and $E_{\text{AE},^{212}\text{Po}}$, released through disintegration of ^{216}Po and ^{212}Po, and disintegration of ^{212}Pb and ^{212}Bi potential emitters of alpha particles of this type.

5 Equipment

5.1 General

The apparatus shall include a measuring device, composed of a sampling system and a detection system (see Figure 1), and a counting system. The measuring device shall be in accordance with IEC 61577-1 and IEC 61577-3.

5.2 Measuring device

5.2.1 Sampling system

The sampling system shall include the following components:

a) a high-efficiency filtering membrane in cellulose acetate to collect the radon decay products;

b) a sampling pump which provides a volume rate compatible with the air and metrological characteristics of the detection system;

c) a mass flow-meter which measures the flow-rate of air sampled throughout the sampling duration.

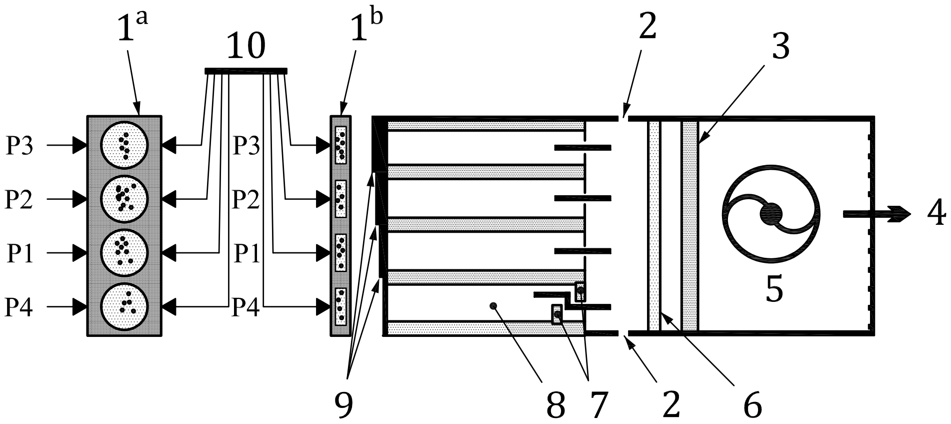
The sampling system is located downstream of the detection system.

5.2.2 Detection system

The detection system shall include the following components:

a) three boPET screens of different thickness placed at one end of the collimators are used to discriminate between the particles over three energy ranges. This geometry is used to mitigate the initial energy of each alpha particle emitted by the collected radionuclides in an energy range compatible with the characteristics of the sensor (SSNTD) used;

b) a solid-state nuclear track detector (SSNTD).



Key

1 solid state nuclear track detector (SSNTD)
2 air inlet
3 mass flow-meter
4 air outlet
5 vacuum pump
6 high-efficiency filter
7 baffles (diffusion barrier)
8 collimator
9 boPET (biaxially oriented polyethylene teraphthalate) screen
10 scanning range
a Front view.
b Side view.

Figure 1 — Example set-up of a measuring device for determination over four energy ranges of average potential alpha energy concentration of short-lived radon-222 decay products

5.3 Counting system

The counting system shall include the following components:

a) equipment and suitable chemical reagents for etching the detector (SSNTD);

b) an optical microscope and associated equipment for scanning and counting the etched tracks.

6 Sampling

6.1 Sampling objective

The sampling objective is to collect, without interruption, all the aerosols carrying short-lived radon decay products, regardless of size (unattached and attached fractions), that are contained in the ambient air during a given sampling duration (at least one week).

6.2 Sampling characteristics

Sampling shall be carried out under the conditions specified in ISO 11665-1.

The short-lived radon decay products shall be sampled continuously and directly in the atmosphere under investigation by pumping and filtering a known volume of air through a high-efficiency collection membrane. The air sample shall be omni-directional.

The filtering membrane shall be as close as possible to the sampler inlet section, so as to collect the ambient decay products with the maximum efficiency.

In order to count the emitted alpha particles correctly, the sampling system shall conduct to the surface deposit of the radionuclides on the filter and shall prevent the aerosols from being buried.

The sampling system shall be used in conditions that preclude clogging of the filtering membrane, which would cause self-absorption of the alpha emissions of particles collected on the filter or a reduction in the sampling flow-rate over time.

The sampling flow-rate shall be stable (no more than 10 % variation from the average value) in order for the sampling to remain representative throughout the sampling duration. This can be achieved by using a flow-rate controller (sonic throat, servo-controlled valve, etc.).

6.3 Sampling conditions

6.3.1 General

Sampling shall be carried out as specified in ISO 11665-1.

6.3.2 Installation of sampling system

Installation of the sampling system shall be carried out as specified in ISO 11665-1.

In the specific case of an indoor measurement, the sampling system shall be installed as follows:

a) in an area not directly exposed to solar radiation;

b) away from a heat source (radiator, picture windows, electrical equipment, etc.);

c) away from traffic areas, doors and windows, walls and ventilation sources (it could, for example, be sited on an item of furniture like a shelf or sideboard).

6.3.3 Sampling duration

The sampling duration is equal to the time interval between installation and removal of the sampling system at a given point.

Time (date and hour) of installation and time of removal of the sampling system shall be recorded.

Sampling duration shall be determined according to the intended use of the measurement results and the phenomenon under investigation.

A sampling duration of at least one week is required in order to obtain a measurement result above the detection limit.

It is recommended that measurements be performed with a sampling duration of several months when assessing the annual human exposure.

Users should be aware of the saturation characteristics of the sensor (SSNTD) and should perform their sampling regime so as to ensure that saturation does not occur.

6.3.4 Volume of air sampled

The volume of air sampled shall be ascertained by measuring the flow-rate or volume during sampling with a calibrated system (for example a sonic nozzle) (see IEC 61577-3).

The total volume of air sampled throughout the sampling duration shall be recorded.