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

Part 5:
Continuous measurement methods of the activity concentration

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

Partie 5: Méthodes de mesure en continu de l'activité volumique

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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 (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 11665-5:2012), 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 (also known as thoron) 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 ISO 11665-1:2019, 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 ISO 11665-1:2019, 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[7].

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.

The activity concentration of radon-222 in the atmosphere can be measured by spot, continuous and integrated measurement methods with active or passive air sampling (see ISO 11665-1). This document deals with continuous measurement methods for radon-222.

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 5: Continuous measurement methods of the activity concentration

1 Scope

This document describes continuous measurement methods for radon-222. It gives indications for continuous measuring of the temporal variations of radon activity concentration in open or confined atmospheres.

This document is intended for assessing temporal changes in radon activity concentration in the environment, in public buildings, in homes and in work places, as a function of influence quantities such as ventilation and/or meteorological conditions.

The measurement method described is applicable to air samples with radon activity concentration greater than 5 Bq/m^3.

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

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 61577-2, *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 11665-1 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

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

C	activity concentration, in becquerels per cubic metre
C^*	decision threshold of the activity concentration, in becquerels per cubic metre
$C^\#$	detection limit of the activity concentration, in becquerels per cubic metre
$C^\triangleleft$	lower limit of the confidence interval of the activity concentration, in becquerels per cubic metre
$C^\triangleright$	upper limit of the confidence interval of the activity concentration, in becquerels per cubic metre
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
μ	quantity to be measured
μ_0	background level
ω	correction factor linked to the calibration factor and climatic correction factors

4 Principle

Continuous measurement of the radon activity concentration is based on the following elements:

a) continuous in situ sampling of a volume of air previously filtered and representative of the atmosphere under investigation;

b) continuous detection of radiations emitted by radon and its decay products accumulated in the detection chamber.

Several measurement methods meet the requirements of this document. They are basically distinguished by the type of physical quantity and how it is detected. The physical quantity and its related detection may be as follows, for example:

— ionization current produced by several tens of thousands of ion pairs created by each alpha particle emitted by the radon that is present in the detection chamber and its decay products formed therein (see Annex A);

— charges produced in a solid [semi-conductor medium (silicon)] by ionization from alpha particles of radon and its decay products; the charges are detected by related electronics.

Measurement results are instantly available. A mean or integrated value can be obtained through appropriate processing based on an integration interval compatible with the phenomenon studied but in all cases less than or equal to one hour.

In order to monitor the temporal variation of radon activity concentration, the measurement period shall be compatible with the dynamics of the phenomenon studied. For example, the minimum significant period for detecting daily variations is approximately one week.

Continuous monitoring allows for the assessment of temporal changes in radon activity concentration. For measurements performed outdoors, the season and climatic conditions shall be taken into account.

For measurements performed inside a building, the lifestyles of its inhabitants, the level at which the measurement place is located (basement, ground floor, upper levels) and the natural ventilation characteristics (condition of doors and windows, open or closed) shall be taken into account.

5 Equipment

The apparatus shall include the following:

a) a sampling device, including a filtering medium, for taking the air sample in the detection chamber, a device to pump the air for sampling if active sampling is necessary, and the detection chamber;

b) a measuring system adapted to the physical quantity to be measured.

The instrument used for measurement shall satisfy the requirements of IEC 61577-2.

An example of the equipment (ionization chamber) for a specific measurement method is given in Annex A.

6 Sampling

6.1 Sampling objective

The sampling objective is to ensure air samples representative of the atmosphere under investigation are in continuous contact with the detector.

6.2 Sampling characteristics

Sampling may be passive (natural diffusion) or active (pumping).

Sampling shall be performed through a filtering medium which prevents access of aerosol particles present in the air at the time of sampling, especially radon decay products.

The filter shall not trap radon gas.

The sampling system shall be used under conditions that do not cause clogging of the filter (this would result in a modification of the measurement conditions, e.g. decrease of gas quantity sampled due to pressure drop in measurement chamber).

In case of clogging during sampling by pumping, the pressure drop might increase, leading to a degradation in the performance of the measurement system, and possibly resulting in the perforation of the filter.

Clogging during sampling by natural diffusion can lead to the non-renewal of air in the detection chamber.

6.3 Sampling conditions

6.3.1 General

Sampling shall be carried out as specified in ISO 11665-1. The sampling location, date and time shall be recorded.

6.3.2 Installation of sampling device

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

6.3.3 Sampling duration

For continuous sampling, the sampling duration corresponds to the measurement period, which shall be compatible with the dynamics of the phenomenon studied.

6.3.4 Integration interval

The integration interval determines the time resolution of the measurement. Different parameters such as the expected radon activity concentration or dynamics of radon level changes need to be taken into account when selecting the appropriate integration interval.

6.3.5 Volume of air sampled

For active sampling, the volume of air sampled shall be measured by a flowmeter corrected for the temperature and pressure variation (expressed in cubic metres at a standard pressure and temperature of 1,013 hPa and 0 °C respectively).

For passive sampling, direct measurement of the air volume sampled is not necessary; a calibration factor (activity per unit volume) shall be used.

7 Detection

Detection shall be carried out using a suitable method as outlined in ISO 11665-1.

8 Measurement

8.1 Procedure

The measurement procedure is specific to the detection method used.

An example of a measurement procedure using an ionization chamber is given in Annex A.

8.2 Influence quantities

Various quantities can lead to measurement bias that could induce non-representative results. Depending on the measurement method and the control of usual influence quantities specified in IEC 61577-1 and ISO 11665-1, the following quantities shall be considered in particular:

a) temperature, humidity and atmospheric turbulence; these variables are taken into account when choosing a location for the device;

b) background radiation;

c) instrumental background noise;

d) electromagnetic field;

e) increase in pressure drop due to clogging of the intake filter;

f) possible presence of other alpha emitters (radium, radon isotopes, actinides, etc.) in the detection volume; if the presence of other radon isotopes is suspected, it shall be ruled out using an appropriate system, e.g. ageing chamber;

g) possible presence of other gamma emitters in the detection volume.

Manufacturer recommendations in the operating instructions for the measuring devices shall be followed.

8.3 Calibration

The entire measuring instrument (sampling system, flowmeter, detector and related electronics) shall be calibrated annually as specified in ISO 11665-1.

The relationship between the physical parameter measured by the detection device (number of electric charges, count rate, etc.) and the activity concentration of the radon in the air shall be established based on the measurement of a radon-222 reference atmosphere. The radon-222 activity concentration in the reference atmosphere shall be traceable to a primary radon-222 gas standard.

An instrument calibration result shall allow traceability of the measurement result against a primary standard.

9 Expression of results

9.1 Radon activity concentration

The radon activity concentration is calculated as given in Formula (1):

$$C = (\mu - \mu_0) \cdot \omega \tag{1}$$

9.2 Standard uncertainty

In accordance with ISO/IEC Guide 98-3, the standard uncertainty of C shall be calculated as given in Formula (2):

$$u(C) = \sqrt{\omega^2 \cdot \left[u^2(u) + u^2(u_0) \right] + C^2 \cdot u_{rel}^2(\omega)} \tag{2}$$

9.3 Decision threshold and detection limit

The characteristic limits associated with the measurand shall be calculated in accordance with ISO 11929 (all parts). An example of the calculations of uncertainties and characteristic limits is given in Annex A for a specific measurement method.

9.4 Limits of the confidence interval

The lower, $C^{\triangleleft}$, and upper, $C^{\triangleright}$, limits of the confidence interval shall be calculated using Formulae (3) and (4) (see ISO 11929 (all parts)):

$$C^{\triangleleft} = C - k_p \cdot u(C); p = \omega \cdot (1 - \gamma / 2) \tag{3}$$

$$C^{\triangleright} = C + k_q \cdot u(C); q = 1 - \omega \cdot \gamma / 2 \tag{4}$$

where

$\omega = \Phi[y/u(y)]$, Φ being the distribution function of the standardized normal distribution;

$\omega = 1$ may be set if $C \geq 4 \cdot u(C)$, in which case:

$$C^{\triangleleft\triangleright} = C \pm k_{1-\gamma/2} \cdot u(C) \tag{5}$$

$\gamma = 0,05$ with $k_{1-\gamma/2} = 1,96$ are often chosen by default.

