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

Part 3:

**Spot measurement method of the
potential alpha energy concentration of
its short-lived decay products**

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

*Partie 3: Méthode de mesure ponctuelle de l'énergie alpha potentielle
volumique de ses descendants à vie courte*

ISO 11665-3:2012

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 11665-3 was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

ISO 11665 consists of the following parts, under the general title *Measurement of radioactivity in the environment — Air: radon-222*:

- *Part 1: Origins of radon and its short-lived decay products and associated measurement methods*
- *Part 2: Integrated measurement method for determining average potential alpha energy concentration of its short-lived decay products*
- *Part 3: Spot measurement method of the potential alpha energy concentration of its short-lived decay products*
- *Part 4: Integrated measurement method for determining average activity concentration using passive sampling and delayed analysis*
- *Part 5: Continuous measurement method of the activity concentration*
- *Part 6: Spot measurement method of the activity concentration*
- *Part 7: Accumulation method for estimating surface exhalation rate*
- *Part 8: Methodologies for initial and additional investigations in buildings*

The following parts are under preparation:

- *Part 9: Method for determining exhalation rate of dense building materials*
- *Part 10: Determination of diffusion coefficient in waterproof materials using activity concentration measurement*

Introduction

Radon isotopes 222, 220 and 219 are radioactive gases produced by the disintegration of radium isotopes 226, 224 and 223, which are decay products of uranium-238, thorium-232 and uranium-235 respectively, and are all found in the earth's crust. 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.

Radon is today considered to be the main source of human exposure to natural radiation. The UNSCEAR (2006) report^[2] 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. For this reason, references to radon in this part of ISO 11665 refer only to radon-222.

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

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 and ISO 11665-2). This part of ISO 11665 deals with spot measurement methods. A spot measurement of the potential alpha energy concentration relates to the time when the measurement is taken and has no significance in annual exposure. This type of measurement does not therefore apply when assessing the annual exposure.

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.

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

Part 3: Spot measurement method of the potential alpha energy concentration of its short-lived decay products

1 Scope

This part of ISO 11665 describes spot measurement methods for determining the activity concentration of short-lived radon-222 decay products in the air and for calculating the potential alpha energy concentration.

This part of ISO 11665 gives indications for performing a spot measurement of the potential alpha energy concentration, after sampling at a given place for several minutes, and the conditions of use for the measuring devices.

This measurement method is applicable for a rapid assessment of the potential alpha energy concentration. The result obtained cannot be extrapolated to an annual estimate potential alpha energy concentration of short-lived radon-222 decay products. Thus, this type of measurement is not applicable for the assessment of annual exposure.

This measurement method is applicable to air samples with potential alpha energy concentration greater than 5 nJ/m³.

NOTE This part of ISO 11665 does not address the potential contribution of radon-220 decay products.

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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 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.

3.2 Symbols

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

C_i	activity concentration of the nuclide i , in becquerels per cubic metre
$E_{AE,i}$	alpha particle energy produced by the disintegration of the nuclide i , in joules
$E_{AeT,i}$	total alpha particle energy potentially produced by the nuclide i , in joules
$E_{PAE,i}$	potential alpha energy of the nuclide i , in joules
$E_{PAEC,i}$	potential alpha energy concentration of the nuclide i , in joules per cubic metre
$E_{PAEC,i}^*$	decision threshold of the potential alpha energy concentration of the nuclide i , in joules per cubic metre
$E_{PAEC,i}^\#$	detection limit of the of the potential alpha energy concentration of the nuclide i , in joules per cubic metre
$E_{PAEC,i}^{\triangleleft}$	lower limit of the confidence interval of the potential alpha energy concentration of the nuclide i , in joules per cubic metre
$E_{PAEC,i}^{\triangleright}$	upper limit of the confidence interval of the potential alpha energy concentration of the nuclide i , in joules per cubic metre
I_j	j^{th} number of gross counts obtained between times t_j and t_{cj}
$I_{0,j}$	j^{th} number of background counts obtained between times t_j and t_{cj}
$k_{i,j}$	coefficient related to the j^{th} number of gross count for radon decay product i , depending on the decay constants of the radon decay products, the sampling duration, t_s , and the times t_j and t_{cj} , per square second
N_i	number of atoms of the nuclide i
n	counting number depending on the gross alpha counting protocol used
Q	sampling flow-rate, in cubic metres per second
t_{cj}	end time of counting j , in seconds
t_j	start time of counting j , in seconds
t_s	sampling duration, in seconds
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_c	counting efficiency, in pulses per disintegration
λ_i	decay constant of the nuclide i , per second

4 Principle of the measurement method

Spot measurement of the potential alpha energy concentration of short-lived radon-222 decay products is based on the following elements:

- a) grab sampling, at time t , of short-lived radon decay products contained in a volume of air representative of the atmosphere under investigation, using a high-efficiency filtering membrane;
- b) repeated gross alpha measurements of the collected decay products using a detector sensitive to alpha particles; the counting stage starts after sampling has stopped;
- c) calculation of the activity concentrations of the radon decay products using the laws of radioactive decay and the counting results from a preset duration, repeated at given times.

The gross alpha measurement method quantifies alpha particles emitted by short-lived radon decay products. The ^{222}Rn decay product chain shows that 99,98 % of the decays of ^{218}Po result in the emission of alpha particles. It can, therefore, be considered as a pure alpha emitter. ^{214}Pb and ^{214}Bi are not alpha emitters, but they contribute to the appearance of alpha particles from the decay of ^{214}Po .

After collecting the air sample, the gross alpha activity is measured for various counting durations. Because of the fast decay of radon decay products, the isotopic composition of a sample rapidly changes during collection as well as during the counting durations. Repeated measurements of the gross alpha activity are necessary in order to describe the decay of the sample and thereby calculate the amounts of the various decay products which were originally collected in the air sample.

NOTE Although ^{222}Rn and its decay products are usually found in higher quantity, environmental air samples can also contain significant activity of radionuclides of the ^{220}Rn decay chain as well as other airborne long-lived radionuclides. In such cases, the formulas and procedures given in this part of ISO 11665 need to be adapted to take into account these additional radionuclides.

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5 Equipment

The apparatus shall include a sampling system and a detection system composed of a detector connected to a counting system (see Figure 1). The measuring devices used shall comply with IEC 61577-1 and IEC 61577-3.

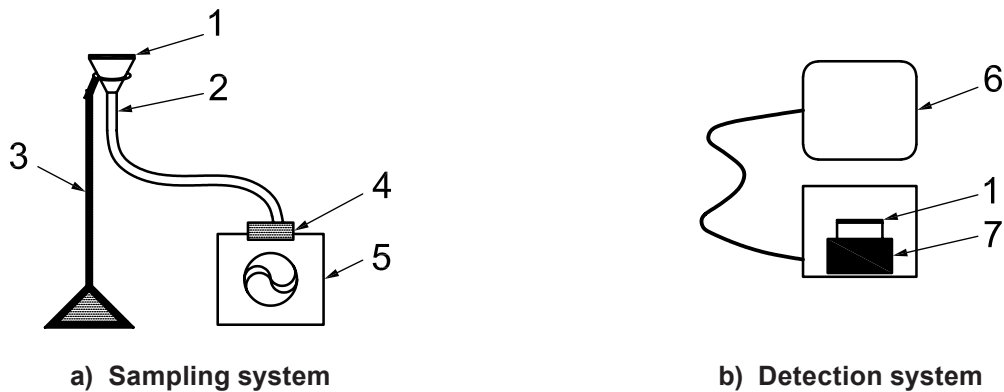
The sampling system shall include the following components:

- a) an open filter holder allowing fast and easy removal of the filter after sampling;
- b) a pump;
- c) a high-efficiency particulate air filter (HEPA filter with a minimum efficiency of 99,97 % for a particle size of 0,3 μm);
- d) a flow-meter and a chronometer;

Possible detectors include the following:

- a photomultiplier associated with a sensitive scintillation surface [$\text{ZnS}(\text{Ag})$, for example];
- a silicon semi-conductor that is sensitive to alpha particles.

The detector, connected to a pulse counting system, shall have a sensitive detection surface at least equal in diameter to the filtering membrane.



Key

- 1 filtering membrane
- 2 filter holder
- 3 support
- 4 flow-meter and chronometer
- 5 pump
- 6 counting system
- 7 detector

Figure 1 — Functional diagram of a spot measuring system for potential alpha energy concentration of short-lived radon decay products

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6 Sampling

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6.1 General

Grab sampling is representative of the potential alpha energy concentration of short-lived radon-222 decay products at a given time and a given place.

6.2 Sampling objective

The sampling objective is to collect, without interruption, all the aerosols, regardless of their size (unattached and attached fractions), carrying short lived radon decay products and contained in the ambient air during a given sampling duration (less than one hour).

6.3 Sampling characteristics

The unattached and attached fractions of short-lived radon decay products shall be sampled without interruption from the atmosphere under investigation by pumping and filtering a known volume of air through a high-efficiency collection membrane located in an open filter holder. The air sampling shall be omni-directional.

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.

6.4 Sampling conditions

6.4.1 General

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

6.4.2 Installation of sampling system

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

6.4.3 Sampling duration

Given the short half-lives of the radon-222 decay products, particularly ^{218}Po , the sampling duration should normally be less than or equal to 20 min. A longer sampling duration would not improve the detection limit of the method.

6.4.4 Volume of air sampled

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

7 Detection method

Detection shall be performed using silver-activated zinc sulphide ZnS(Ag) scintillation or a semi-conductor (alpha detection), as described in ISO 11665-1.

8 Measurement

8.1 Procedure

Measurement shall be carried out as follows.

- a) Select the sampling duration, t_s .
- b) Plan the counting stage, with n countings, and choose start time t_j and end time t_{c_j} for each number of counts I_j . The different sets are organized from $j = 1$ to $j = n$. Before a set of counting, a specific waiting time can be required.

NOTE Examples of gross alpha counting protocols are given in Annex A.

- c) Install the detection system (detector and pulse counting system).
- d) Determine the background level of the filtering membrane. Before carrying out sampling, position the virgin membrane opposite the detector, in accordance with manufacturer recommendations. Measure the virgin membrane by means of n successive gross alpha countings during specific counting durations $t_{c_j} - t_j$ according to the counting stage selected:

- 1) $t = 0$ to $t = t_1$ standby, there is no count if $t_1 > 0$;
- 2) $t = t_1$ to $t = t_{c1}$ count $I_{0,1}$ is performed;
- 3) $t = t_{c_{j-1}}$ to $t = t_j$ standby, there is no count if $t_j > t_{c_{j-1}}$;
- 4) $t = t_j$ to $t = t_{c_j}$ count $I_{0,j}$ is performed.

If $n > 1$, repeat stages 3) and 4) until $j = n$.

- e) Record values of $I_{0,j}$ for $j = 1$ to $j = n$.
- f) Select and locate the measuring point.