ISO TC 85/SC 2

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ISO TC 85/SC 2

Secretariat: AFNOR

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

Mesurage de la radioactivité dans l'environnement — Air: radon 222 — Partie 1 : Origine du radon et de ses descendants à vie courte et méthodes de mesure associées

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Contents

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Foreword

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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).

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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.

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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 11665-1:2012), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

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— update of the Introduction;

— in A.2.4, details added for change in radon activities concentration in time and space in buildings;

— 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.

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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·m^{-3} is recommended by the World Health Organization[5]. Wherever this is not possible, this reference level should not exceed 300 Bq·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·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.

ISO 11665 consists of several parts (see Figure 1) dealing with:

— measurement methods for radon-222 and its short-lived decay products (see ISO 11665-2, ISO 11665-3, ISO 11665-4, ISO 11665-5 and ISO 11665-6);

NOTE 1 There are many methods for measuring the radon-222 activity concentration and the potential alpha energy concentration of its short-lived decay products. The choice of measurement method depends on the expected level of concentration and on the intended use of the data, such as scientific research and health-related assessments[8][9].

— measurement methods for the radon-222 exhalation rate (see ISO 11665-7 and ISO 11665-9);

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NOTE 2 ISO 11665-7 refers back to ISO 11665-5 and ISO 11665-6.

— measurement methods for the radon-222 in the soil (see ISO 11665-11);

— methodologies for radon-222 measurements in buildings (see ISO 11665-8);

— measurement methods for the radon-222 diffusion coefficient (see ISO/TS 11665-12 and ISO/TS 11665-13)

NOTE 3 ISO 11665-8 refers back to ISO 11665-4 for radon measurements for initial investigation purposes in a building and to ISO 11665-5, ISO 11665-6 and ISO 11665-7 for measurements for any additional investigation.

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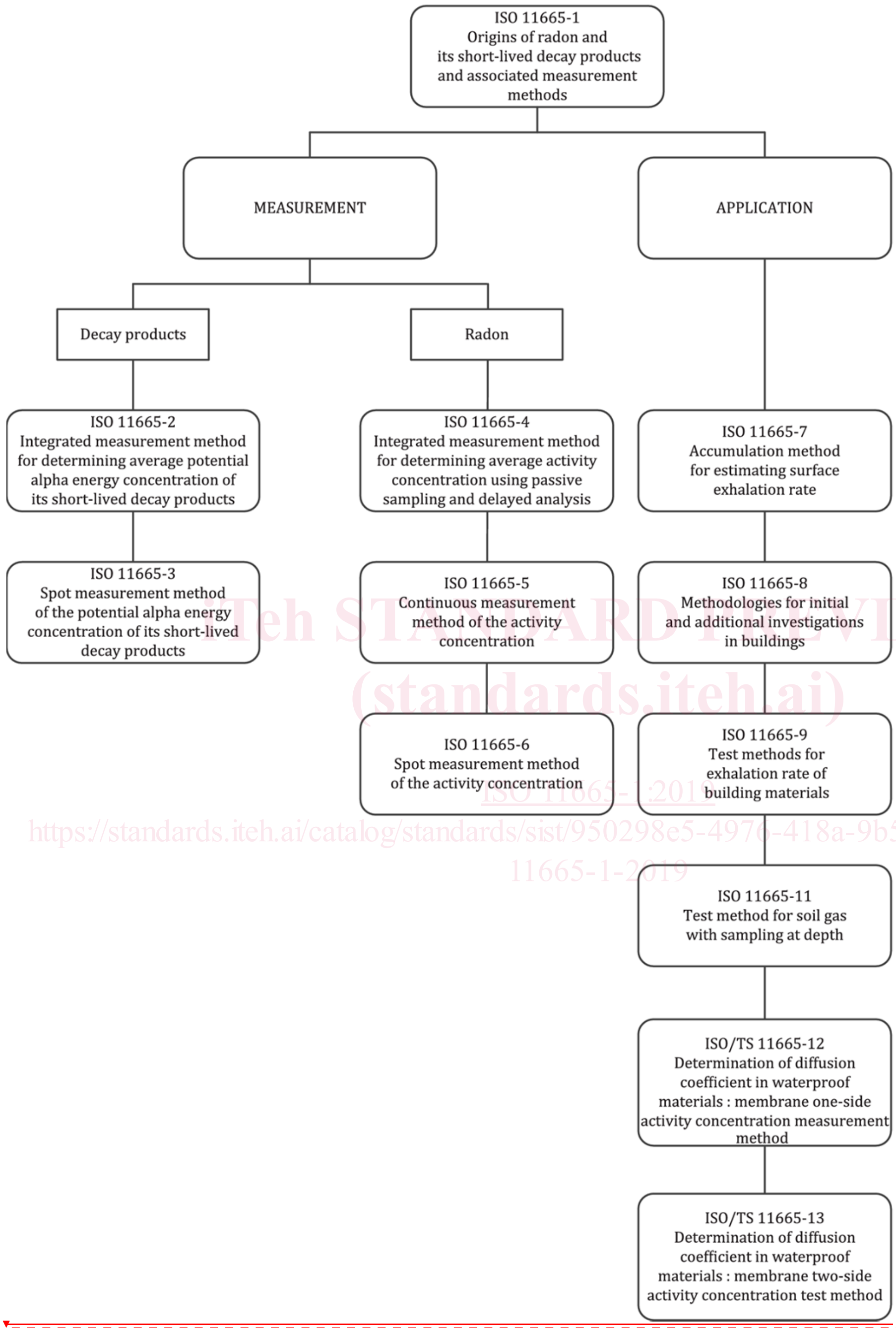

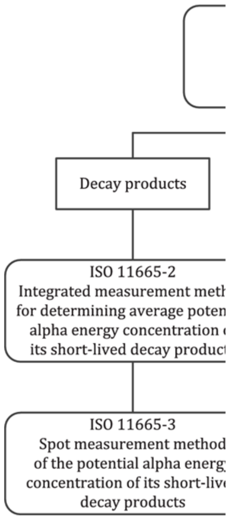

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Figure 1 — Structure of the ISO 11665 series

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

1 Scope

This document outlines guidance for measuring radon-222 activity concentration and the potential alpha energy concentration of its short-lived decay products in the air.

The measurement methods fall into three categories:

a) spot measurement methods;

b) continuous measurement methods;

c) integrated measurement methods.

This document provides several methods commonly used for measuring radon-222 and its short-lived decay products in air.

This document also provides guidance on the determination of the inherent uncertainty linked to the measurement methods described in its different parts.

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/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* ^{222}*Rn and* ^{220}*Rn measuring instruments*

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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 following terms and definitions 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

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

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3.1.1
active sampling
sampling using active devices like pumps for sampling the atmosphere

[SOURCE: IEC 61577-1:2006, 3.2.22]

3.1.2
activity
disintegration rate
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

Note 1 to entry: Activity, A, is expressed by the relationship given in Formula (1):

$$A = \lambda \cdot N$$

where

λ is the decay constant per second;

N is the number of atoms.

Note 2 to entry: The decay constant is linked to the radioactive half-life by the relationship:

$$\lambda = \frac{\ln 2}{T_{1/2}}$$

where

$T_{1/2}$ is the radioactive half-life, in seconds.

3.1.3
activity concentration
activity per unit volume

[SOURCE: IEC 61577-1:2006, 3.1.2]

3.1.4
attached fraction
fraction of the potential alpha energy concentration of short-lived decay products that is attached to the ambient aerosol

[SOURCE: IEC 61577-1:2006, 3.2.15, modified]

Note 1 to entry: The sizes of the carrier aerosol to which most of the short-lived decay products are attached are generally in the 0,1 µm to 0,3 µm range of median values.

3.1.5
average activity concentration
exposure to activity concentration divided by the sampling duration

3.1.6
average potential alpha energy concentration
exposure to potential alpha energy concentration divided by the sampling duration

3.1.7
background noise
signals caused by something other than the radiation to be detected

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Note 1 to entry: A distinction can be made between signals caused by radiation from sources inside or outside the detector other than those targeted for the measurements and signals caused by defects in the detection system electronic circuits and their electrical power supply.

3.1.8
continuous measurement
measurement obtained by taking a sample continuously (or at integration intervals typically in range of 1 min to 120 min) with simultaneous or slightly delayed analysis

Note 1 to entry: The sampling duration shall be adapted to the dynamics of the phenomenon studied to monitor the evolution of radon activity concentration over time.

Note 2 to entry: See Annex B for further information.

3.1.9
diffusion length
distance crossed by an atom due to diffusion forces before decaying

Note 1 to entry: Diffusion length, l, is expressed by the relationship given in Formula (3):

$$l = \left(\frac{D}{\lambda}\right)^{1/2}$$

where

D is the diffusion coefficient, in square metres per second;

λ is the decay constant per second.

3.1.10
equilibrium factor
ratio of the potential alpha energy concentration of short-lived radon decay products in a given volume of air to the potential alpha energy concentration of these decay products if these are in radioactive equilibrium with radon in the same volume of air

Note 1 to entry: The short-lived ^{222}Rn decay products present in an atmosphere are very rarely in radioactive equilibrium with their parent (through being trapped on the walls or eliminated by an air renewal system, for example) and the equilibrium factor is used to qualify this state of "non-equilibrium".

Note 2 to entry: The equilibrium factor is between 0 and 1. The equilibrium factor in buildings typically varies between 0,1 and 0,9, with an average value equal to 0,4[4][6].

Note 3 to entry: The equilibrium factor, F_{eq}, is expressed by Formula (4):

$$F_{eq} = \frac{E_{PAEC,222_{Rn}}}{5{,}57 \cdot 10^{-9} \times C_{222_{Rn}}}$$

where

$E_{PAEC,222_{Rn}}$ is the potential alpha energy concentration of ^{222}Rn, in joules per cubic metre;

$5{,}57 \times 10^{-9}$ is the potential alpha energy concentration of the short-lived ^{222}Rn decay products for 1 Bq of ^{222}Rn in equilibrium with its short-lived decay products, in joules per becquerel;

$C_{222_{Rn}}$ is the activity concentration of ^{222}Rn, in becquerels per cubic metre.

3.1.11
grab sampling

collection of a sample (i.e of air containing radon or aerosol particles) during a period considered short compared with the fluctuations of the quantity under study (i.e volume activity of air)

[SOURCE: IEC 61577-1:2006, 3.2.18]

3.1.12
guideline value
value which corresponds to scientific, legal or other requirements with regard to the detection capability and which is intended to be assessed by the measurement procedure by comparison with the detection limit

Note 1 to entry: The guideline value can be given, for example, as an activity, a specific activity or an activity concentration, a surface activity or a dose rate.

Note 2 to entry: The comparison of the detection limit with a guideline value allows a decision on whether or not the measurement procedure satisfies the requirements set forth by the guideline value and is therefore suitable for the intended measurement purpose. The measurement procedure satisfies the requirement if the detection limit is smaller than the guideline value.

Note 3 to entry: The guideline value shall not be confused with other values stipulated as conformity requests or as regulatory limits.

[SOURCE: ISO 11929:2019, 3.18]

3.1.13
integrated measurement
measurement performed by continuous sampling of a volume of air which, over time, is accumulating physical quantities (number of nuclear tracks, number of electric charges, etc.) linked to the disintegration of radon and/or its decay products, followed by analysis at the end of the accumulation period

Note 1 to entry: See Annex B for further information.

3.1.14
long-term measurement
measurement based on an air sample collected within a period greater than one month

3.1.15
measurand
quantity intended to be measured

[SOURCE: ISO/IEC Guide 99:2007, 2.3]

3.1.16
measuring system
set of one or more measuring instruments and often other devices, including any reagent and supply, assembled and adapted to give information used to generate measured quantity values within specified intervals for quantities of specified kinds

[SOURCE: ISO/IEC Guide 99:2007, 3.2]

3.1.17
passive sampling
sampling using no active devices such as pumps for sampling the atmosphere, whereby in most instruments sampling is performed mainly by diffusion

[IEC 61577-1:2006, 3.2.21 modified]

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3.1.18
potential alpha energy of short-lived radon decay products
total alpha energy emitted during the decay of atoms of short-lived radon decay products along the decay chain through to ^{210}Pb for the decay chains of the ^{222}Rn

Note 1 to entry: The potential alpha energy of short-lived ^{222}Rn decay products, $E_{\text{PAE},222_{\text{Rn}}}$, is expressed by Formula (5):

$$E_{\text{PAE},222_{\text{Rn}}} = \left[\begin{array}{l} \left(E_{\text{AE},218_{\text{Po}}} + E_{\text{AE},214_{\text{Po}}}\right) \cdot \left(N_{218_{\text{Po}}}\right) \\ + E_{\text{AE},214_{\text{Po}}} \cdot \left(N_{214_{\text{Pb}}} + N_{214_{\text{Bi}}}\right) + E_{\text{AE},214_{\text{Po}}} \cdot \left(N_{214_{\text{Po}}}\right) \end{array} \right]$$

where

$E_{\text{AE},218_{\text{Po}}}$	is the alpha particle energy produced by the disintegration of ^{218}Po, in joules;
$E_{\text{AE},214_{\text{Po}}}$	is the alpha particle energy produced by the disintegration of ^{214}Po, in joules;
$N_{218_{\text{Po}}}$	is the number of atoms of ^{218}Po;
$N_{214_{\text{Pb}}}$	is the number of atoms of ^{214}Pb;
$N_{214_{\text{Bi}}}$	is the number of atoms of ^{214}Bi;
$N_{214_{\text{Po}}}$	is the number of atoms of ^{214}Po.

Note 2 to entry: The total alpha energy emitted during the decay of atoms of short-lived radon decay products along the decay chain through to ^{208}Pb for the decay chains of the ^{220}Rn is expressed by Formula (6):

$$E_{\text{PAE},220_{\text{Rn}}} = \left[\begin{array}{l} \left(E_{\text{AE},216_{\text{Po}}} + 0{,}36 \cdot E_{\text{AE},212_{\text{Bi}}} + 0{,}64 \cdot E_{\text{AE},212_{\text{Po}}}\right) \cdot \left(N_{216_{\text{Po}}}\right) \\ + \left(0{,}36 \cdot E_{\text{AE},212_{\text{Bi}}} + 0{,}64 \cdot E_{\text{AE},212_{\text{Po}}}\right) \cdot \left(N_{212_{\text{Pb}}} + N_{212_{\text{Bi}}}\right) + E_{\text{AE},212_{\text{Po}}} \cdot \left(N_{212_{\text{Po}}}\right) \end{array} \right]$$

where

$E_{\text{PAE},220_{\text{Rn}}}$	is the potential alpha energy of ^{220}Rn, in joules;
$E_{\text{AE},216_{\text{Po}}}$	is the alpha particle energy produced by the disintegration of ^{216}Po, in joules;
$E_{\text{AE},212_{\text{Bi}}}$	is the alpha particle energy produced by the disintegration of ^{212}Bi, in joules;
$E_{\text{AE},212_{\text{Po}}}$	is the alpha particle energy produced by the disintegration of ^{212}Po, in joules;
$N_{212_{\text{Pb}}}$	is the number of atoms of ^{212}Pb;
$N_{212_{\text{Bi}}}$	is the number of atoms of ^{212}Bi;
$N_{212_{\text{Po}}}$	is the number of atoms of ^{212}Po.

3.1.19
potential alpha energy concentration of short-lived radon decay products
concentration of any mixture of short-lived radon decay products in air in terms of the alpha energy released during complete decay through ^{210}Pb and/or ^{208}Pb respectively

[SOURCE: IEC 61577-1:2006, 3.2.2, modified]

Note 1 to entry: The potential alpha energy concentration of the nuclide i, $E_{\text{PAEC},i}$, is expressed by Formula (7):