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

Part 7: **Accumulation method for estimating surface exhalation rate**

Mesurage de la radioactivité dans l'environnement — Air: radon 222 —
Partie 7:
Méthode d'estimation du flux surfacique d'exhalation par la méthode d'accumulation

Reference number
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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 11665-7 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].

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.

The radon-222 half-life (3,8 days) is long enough for it to migrate from the rock producing it, through the soil, to the air[3]. The radon atoms in the soil are produced by the disintegration of the radium-226 contained in the mineral grains in the medium. Some of these atoms reach the interstitial spaces between the grains: this is the phenomenon of emanation. Some of the atoms produced by emanation reach the soil's surface by diffusion and convection: this is the phenomenon of exhalation[3][4][5]. These mechanisms are also brought into play in materials (building materials, walls, etc.).

The quantity of radon-222 reaching the open air per unit of time and per unit of surface is called the radon-222 surface exhalation rate and depends on the physical characteristics of the soil and weather conditions. When the ground is covered in snow or a layer of water, or is frozen, this surface exhalation rate can become very weak.

Values of the radon-222 surface exhalation rate observed in France, for example, vary between 1 $mBq/m^2/s$ and about 100 $mBq/m^2/s$[6][7]. In uranium-bearing ground, radon-222 surface exhalation rates in the order of 50 000 $mBq/m^2/s$ can be observed. By way of comparison, the United Nations Scientific Committee estimates the average surface exhalation rate on the surface of the globe at 20 $mBq/m^2/s$[8].

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 7: Accumulation method for estimating surface exhalation rate

1 Scope

This part of ISO 11665 gives guidelines for estimating the radon-222 surface exhalation rate over a short period (a few hours), at a given place, at the interface of the medium (soil, rock, laid building material, walls, etc.) and the atmosphere. This estimation is based on measuring the radon activity concentration emanating from the surface under investigation and accumulated in a container of a known volume for a known duration.

This method is estimative only, as it is difficult to quantify the influence of many parameters in environmental conditions. This part of ISO 11665 is particularly applicable, however, in case of an investigation, a search for sources or a comparative study of exhalation rates at the same site. This part of ISO 11665 does not cover calibration conditions for the rate estimation devices.

The measurement method described is applicable for radon exhalation rates greater than 5 $mBq/m^2/s$.

NOTE The uncertainty relating to the estimation of the result obtained by applying this part of ISO 11665 cannot guarantee that the true flux value is included in the uncertainty domain.

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 11665-5, *Measurement of radioactivity in the environment — Air: radon-222 — Part 5: Continuous measurement method of the activity concentration*

ISO 11665-6, *Measurement of radioactivity in the environment — Air: radon-222 — Part 6: Spot measurement method of the activity concentration*

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*

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 and the following apply.

3.1.1
accumulation container
recipient with known geometric characteristics used to accumulate the radon, with one open face in contact with the surface under investigation

3.1.2
accumulation duration
time elapsed between installation of the container after air tightness is achieved and the end of sampling

3.1.3
back diffusion
mechanism responsible for the transport of radon from the accumulation container atmosphere into the material under investigation

3.1.4
effective surface
internal surface of the open face of the container that is in contact with the surface under investigation

3.1.5
effective volume
available internal volume for radon accumulation after the container is installed

3.2 Symbols

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

C	activity concentration in the accumulation container at time t, in becquerels per cubic metre
S	effective surface, in square metres
t	elapsed time since the start of the accumulation process, 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	effective volume, in cubic metres
λ_B	time constant of back diffusion, per second
λ_i	decay constant of the nuclide i, per second
λ_V	time constant of leakage, per second
ϕ	surface exhalation rate, in becquerels per square metre per second
ϕ^*	decision threshold of the surface exhalation rate, in becquerels per square metre per second
$\phi^\#$	detection limit of the surface exhalation rate, in becquerels per square metre per second
$\phi^\triangleleft$	lower limit of the confidence interval of the surface exhalation rate, in becquerels per square metre per second
$\phi^\triangleright$	upper limit of the confidence interval of the surface exhalation rate, in becquerels per square metre per second

4 Principle of the measurement method for estimating surface exhalation rate

The measurement method for estimating the radon surface exhalation rate is based on the following elements:

a) accumulating radon in a radon-free accumulation container applied to the surface under investigation for a known duration;

b) sampling a volume of air representative of the air contained in the accumulation container;

c) measuring the radon activity concentration in this air sample;

d) calculating the surface exhalation rate.

An estimate of the surface exhalation rate is calculated from the following elements:

— the variation in the radon activity concentration inside the accumulation container between two given moments;

— the effective surface of the accumulation container in contact with the surface under investigation;

— the effective volume of the accumulation container.

The radon activity concentration in the accumulation container increases over time depending on the surface-related exhalation rate, the volume of the accumulation container and influencing factors such as inadequate air tightness (leakage) and back diffusion.

The increase of radon activity concentration can be fitted with an exponential function:

$$C(t) = \frac{\phi \cdot S}{V \cdot \lambda} \cdot \left(1 - \mathrm{e}^{-\lambda t}\right) \tag{1}$$

where

$$\lambda = \lambda_{\mathrm{Rn222}} + \lambda_B + \lambda_V \tag{2}$$

Since the background radon activity concentration in the container is close to zero at the beginning of the accumulation process, the initial slope of the curve is independent of back diffusion[9][10]. Assuming that radon loss by leakage is negligible, the accumulation phase can be approximated by a linear increase of radon activity concentration in the accumulation container (see the example in Figure 1) as described by Formula (3):

$$C(t) = \frac{\phi \cdot S}{V} \cdot t \tag{3}$$

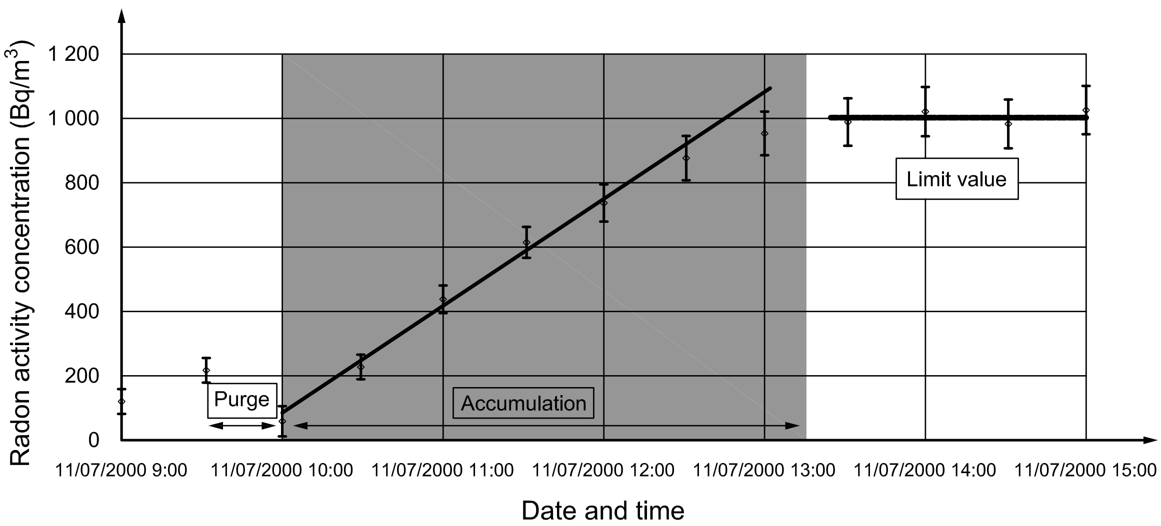


Figure 1 — Example of changes in radon activity concentration in the accumulation container

For outdoor measurements, the analysis of the measurement results can require detailed knowledge of climatic conditions. For example, the radon surface exhalation rate measurements carried out during snow or rain are only representative of these weather conditions.

For soil investigations, the surface area, topography, geology, pedology, vegetation, etc. all need to be taken into account. The humidity content of the ground at the time of sampling may be determined (see ISO 11465).

Several measurement methods meet the requirements of this part of ISO 11665. They can be distinguished by the way the air is sampled from the accumulation container.

5 Equipment

The apparatus shall include the following components.

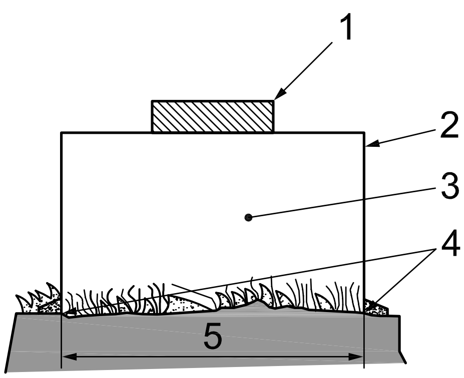
a) An accumulation container with known geometric characteristics (see Figure 2): The accumulation container characteristics shall be chosen so that any irregularities of the surface under investigation do not introduce an uncertainty of more than 10 % into the effective volume of the accumulation container. The effective surface of the accumulation container shall be selected to ensure that measurements are the most representative possible of the surface under investigation (i.e. the effective surface shall be appropriate for the surface area under investigation). The effective volume of the accumulation container shall be at least 10 times greater than the volume of air sampled from the accumulation container by the radon measuring device. The material used in the accumulation container shall not allow the radon to be diffused towards the outside of the container during the accumulation period. Neither the accumulation container material nor colour shall encourage a rise in temperature in the effective volume in the event of exposure to sunlight. The accumulation container shall have one or two orifices with a closing system for sampling purposes. When the accumulation container is placed on the material under investigation these orifices shall be open to prevent overpressure in the container.

b) A homogenization system in the accumulation container. Depending on its dimensions, the container may have a system to homogenize the entire volume of the container.

c) An air sampling device.

d) A measuring device adapted to the physical quantity to be measured.

The necessary equipment for specific measurement methods is specified in Annexes B and C.



Key

1 measuring device

2 accumulation container

3 effective volume

4 contact surface

5 effective surface

Figure 2 — Example set-up of apparatus

A single model of accumulation container shall be used when investigating a site in order to find the zones with the highest exhalation rates.

6 Accumulation of radon in a container

6.1 Accumulation characteristics

The open face of the accumulation container shall be positioned on the surface of the material under investigation (soil, rock, building material, etc.). The accumulation container geometry shall suit the surface under investigation. The contact surface shall be arranged so as to ensure uniform contact between the base of the accumulation container and the surface under investigation (weeds, pebbles, roots removed) (see Figure 2). Any alteration to the surface under investigation shall be recorded on the results sheet (see Annex A). Whenever possible, the surface under investigation shall be chosen so that its irregularities do not introduce an uncertainty of more than 10 % into the effective volume of the accumulation container.

After installing and before making the accumulation container air tight on the surface under investigation, the container shall be purged with radon-free air to ensure that the radon activity concentration is close to zero at the beginning of the accumulation process.

6.2 Accumulation duration

The experimental results show that accumulation takes between 1 h and 3 h depending on the volume of the accumulation container.

7 Sampling

7.1 Sampling objective

The sampling objective is to place an air sample representative of the air contained in the accumulation container in contact with the detector of the radon measuring device.

7.2 Sampling characteristics

7.2.1 General

Sampling may be either active via pumping or passive via natural diffusion. It shall not disturb the accumulation phenomenon.

Sampling characteristics depend on the measuring device used (see ISO 11665-5, ISO 11665-6 and Annexes B and C).

7.2.2 Grab sampling

When grab sampling is used, the sampling shall be carried out at the beginning and before the end of the accumulation phase. Sampling shall be carried out as specified in ISO 11665-6.

7.2.3 Continuous sampling

Continuous sampling may be

a) active, whereby the pump integrated in the radon activity concentration measuring device provides continuous air circulation between the measuring device and the accumulation container, or

b) passive by diffusion.

Sampling shall be carried out as specified in ISO 11665-5.

7.3 Sampling duration

The sampling duration depends on the measuring method used (see ISO 11665-5, ISO 11665-6 and Annexes B and C).

7.4 Volume of air sampled

The volume of air sampled depends on the measuring method used (see ISO 11665-5, ISO 11665-6 and Annexes B and C). It shall be determined accurately. To avoid alteration of the exhalation process in the case of grab sampling, the total volume of sampled air shall not exceed 10 % of the effective volume of the container.

8 Detection method

Various detection methods may be used to measure the radon activity concentration of the sampled air from the accumulation container.

For grab sampling, detection methods shall be in accordance with ISO 11665-6.

For continuous sampling, detection methods shall be in accordance with ISO 11665-5.

9 Measurement

9.1 Procedure

Measurement shall be carried out as follows.

a) Select and locate the measuring place.

b) Record the location of the measuring place.

c) Prepare the surface under investigation by removing rocks, roots, etc. if necessary.

d) Install the accumulation container on the surface of the material under investigation.

e) Purge the accumulation container with radon-free air.

f) Ensure the connection between the accumulation container and the surface under investigation is air tight.

g) Record the start time (date and hour) of the accumulation process.

h) Wait for the accumulation of radon in the container.

i) Take an air sample that is representative of the air of the container.

j) Record the time (date and hour) of sampling.

k) Measure the radon activity concentration of the sampled air. In the case of continuous sampling, measurement of the radon activity concentration shall be carried out during the accumulation process.

l) Determine the radon surface exhalation rate by calculation.

Interpretation of the results requires knowledge of the sampling and environmental conditions.

The measurement procedure for each measurement method, distinguished by the type of sampling, is specified in Annexes B and C.

