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

Part 8: Methodologies for initial and additional investigations in buildings

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

Partie 8: Méthodologies appliquées aux investigations initiales et complémentaires dans les bâtiments

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Contents

Page

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.

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 11665-8:2012), 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 of ISO 11665-1:2019 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 of ISO 11665-1:2019). 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 should establish national reference levels for indoor radon activity concentrations. The reference levels for the annual average activity concentration in air should 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 assessment of the radon activity concentration of the atmosphere in a building is based on a step-by-step procedure with two measuring stages: the initial investigation, to estimate the annual average value of the radon activity concentration in the building, and, when needed, additional investigations.

When it is decided that the radon activity concentration in a building has to be reduced, mitigation techniques are adapted to each individual case[8][9][10]. The impact of the mitigation is assessed using new radon measurements in the building.

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

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

Part 8: Methodologies for initial and additional investigations in buildings

1 Scope

This document specifies requirements for the determination of the activity concentration of radon in all types of buildings. The buildings can be single family houses, public buildings, industrial buildings, underground buildings, etc.

This document describes the measurement methods used to assess, during the initial investigation phase, the average annual activity concentration of radon in buildings. It also deals with investigations needed to identify the source, entry routes and transfer pathways of the radon in the building (additional investigations).

Finally, this document outlines the applicable requirements for the immediate post-mitigation testing of the implemented mitigation techniques, monitoring of their effectiveness and testing of the sustainability of the building's behaviour towards radon.

This document does not address the technical building diagnostic or the prescription of mitigation work.

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 6707-1, *Building and civil engineering — Vocabulary — Part 1: General terms*

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 11665-4, *Measurement of radioactivity in the environment — Air: Radon 222 — Part 4: Integrated measurement methods for determining average activity concentration using passive sampling and delayed analysis*

ISO 11665-7, *Measurement of radioactivity in the environment — Air: radon-222 — Part 7: Accumulation method for estimating surface exhalation rate*

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 ISO 6707-1 and the following 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/

3.1.1
additional investigations
stage of actions, including measurements, when identifying the sources of radon and its entry routes and transfer pathways in a building

3.1.2
building
anything that is constructed or results from construction operations, usually partially or totally enclosed and designed to stand permanently in one place, and whose main purpose is to provide shelter for its occupants and contents

Note 1 to entry: In this document, a building is considered as underground if its roof is partly or entirely underground (see Figure A.1).

Note 2 to entry: The buried levels of a building are those with their ceiling entirely below the ground level (see Figure A.2).

3.1.3
building mapping
spatial presentation of measurement results showing the distribution of radon activity concentration data in the different spaces of the building in order to identify those where radon activity concentration is the highest

Note 1 to entry: The measurements carried out for the building mapping are representative of the prevailing conditions at the time of sampling and thus cannot be used to establish the annual average activity concentrations.

3.1.4
homogeneous zone
zone including one or more adjacent volumes inside the building that share identical or very close characteristics (type of walls, floors, basement, foundations, building level, water supply, water usage patterns, ventilation, openings, temperature, etc.) with a homogeneous activity concentration of radon

Note 1 to entry: A homogeneous zone is defined based on the following main criteria:

— same type of soil-building interface;

— same ventilation conditions (no ventilation system, natural ventilation, mechanical ventilation, etc.);

— same temperature level.

Note 2 to entry: In cases where water can be a potential source of radon, the following additional criteria apply:

— same mode of water supply (direct, indirect, continuous, recycled);

— same type of water usage patterns (washing, showering, therapeutic care).

3.1.5
initial investigation
first stage of actions, including measurements, when determining the annual average activity concentration of radon in a building

3.1.6
mitigation techniques
technical means implemented in an existing building in order to reduce the activity concentration of radon

3.1.7
occupied volume
volume regularly occupied with a residence time justifying an interest with regard to the radon exposure risk

EXAMPLE Living-room, workshop, office, classroom, etc.

3.1.8
radon entry routes
passages and vectors (air or water) that permit radon to penetrate the building

Note 1 to entry: Radon does not enter uniformly across the entire envelope of the building. The preferred entry routes are cracks in the soil-building interface, piping runs, etc.

3.1.9
radon source
origin of radon present in the building

Note 1 to entry: The main source of radon in buildings is usually the underlying soil. In some cases, building materials, the outdoor air, water (inflow water, supply water, thermal water, etc.) and even city gas are additional sources that can increase the radon activity concentration.

3.1.10
radon transfer pathways
passages and vectors (air or water) that permit radon to move from one volume in the building to another

Note 1 to entry: Radon transfer pathways commonly include piping runs, staircases, doorways, etc.

3.1.11
soil-building interface
contact surface between the soil and the building

Note 1 to entry: The soil-building interface can, for example, be formed by:

— a beaten-earth floor;

— an earthen floor;

— a slab or floor on a crawl space, technical space, basement or cellar;

— buried or semi-buried walls in contact with the ground;

— etc.

3.1.12
technical building diagnostic
investigation operations conducted to identify the causes of the presence of radon detected in a building during the initial investigation, and to provide the data and information needed to choose appropriate long-lasting mitigation techniques

3.1.13
value of interest
pre-fixed value of the annual average radon activity concentration, from which actions shall be taken to reduce the annual average activity concentration in a building[11]

Note 1 to entry: The values of interest, also referred to as reference levels, are fixed by regulations issued by the competent administrative national authority or agreed contractually by the parties involved.

3.1.14
volume
closed space in a building

EXAMPLE Room, corridor, box room, workshop, office, classroom, crawl space, cellar, etc.

3.2 Symbols

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

$\bar{C}$ average annual radon activity concentration, in becquerels per cubic metre

$\bar{C}_I$ value of interest of the radon activity concentration, in becquerels per cubic metre

4 Organization of the measuring stages

The assessment of the radon activity concentration of the atmosphere in a building is based on a step-by-step procedure with different measuring stages:

— The presence of radon in a building shall be demonstrated through an initial investigation in accordance with the requirements described in Clause 5. The aim of this stage is to obtain measurement data with which to assess the annual average activity concentration of radon that is compared to the value of interest.

— If the initial investigation demonstrates that the radon activity concentration is lower than any values of interest, the sustainability of the building's behaviour towards radon is monitored in accordance with the requirements set out in Clause 9. If changes in the building can alter its sustainability, the initial investigation shall be performed again in accordance with the requirements set out in Clause 5.

— If the initial investigation demonstrates that the radon activity concentration is higher than any values of interest, investigations shall be performed in order to identify the causes of the presence of radon at this level in the building (technical building diagnostic, etc.). Depending on the type of building involved, and particularly for large-footprint buildings with complex structure configurations, additional investigations may be carried out to help identify the sources of radon (soil, building materials and water) and its entry routes and transfer pathways in the building. These additional investigations shall be carried out in accordance with the requirements set out in Clause 6.

— If mitigation techniques (simple actions such as power on ventilation, building works, etc.) are implemented, immediate post-mitigation testing may be performed using short-term radon measurements that are not representative of the annual average value (see Clause 7). The effectiveness and the sustainability of these mitigation techniques shall be monitored in accordance with the requirements set out in Clauses 8 and 9.

NOTE An example of the organization of the different stages is given in Annex B.

5 Initial investigations

5.1 Objective

The aim of the initial investigation is to determine whether a building or part of a building shows an annual average value of radon activity concentration above any values of interest.

5.2 Methodology followed during the initial investigation

The initial investigation shall be performed following the time sequence described below:

— selection of measuring devices;

— location of the measuring points in the building;

— installation and removal of measuring devices;

— processing of measuring devices;

— data analysis of measurement results obtained for each homogeneous zone;

— initial investigation report drafting.

5.3 Selection of measuring devices

The measurement method used to approximate the annual average activity concentration shall be the long-term integrated measurement method in accordance with ISO 11665-4.

Several types of measuring device complying with the requirements of ISO 11665-4 may be used during the initial investigation. However, to facilitate the data analysis and the interpretation of the measurement results, the same type of measuring device shall be used per building.

For a specific atmosphere with a high variable equilibrium factor (dusty atmosphere, high humidity, highly ventilated, etc.), a passive measuring device in so-called "closed configuration" shall be used.

5.4 Location of the measuring points

5.4.1 General

The installation of the measuring devices follows a three-stage protocol which determines:

— the homogeneous zones in the building under investigation;

— the number of devices per homogeneous zone required to take the representative measurements;

— the locations of the measuring points in the homogeneous zones.

5.4.2 Determination and selection of the homogeneous zones

Homogeneous zones are determined from the lowest floor upwards in order to progressively select a total surface of occupied homogeneous zone that is at least equal to the ground level area of the building. This approach is expected to select the homogeneous zones with the highest activity concentration of radon.

This approach is performed following two steps:

— the determination of homogeneous zones is based on:

  — the following main criteria:

    — same type of soil-building interface;

    — same ventilation conditions (no ventilation system, natural ventilation, mechanical ventilation, etc.);

    — same temperature level;

  — the following additional criteria when water can be a potential source of radon:

    — same mode of water supply (direct, indirect, continuous, recycled);

    — same type of water usage patterns (washing, showering, therapeutic care);

— the selection of homogeneous zones shall comprise at least one occupied room.

In specific cases where specific sources other than soil (water and/or building materials) have been identified, this approach is performed for each building floor concerned.

For buried levels of a building, this approach is performed for each floor that is below ground-level, and each homogeneous zone that is occupied is selected.

For underground buildings, this approach is performed for each building floor.