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Measurement of radioactivity in the environment — Air — Radon 220: Integrated measurement methods for the determination of the average activity concentration using passive solid-state nuclear track detectors

Mesurafge de la radioactivité dans l'environnement — Air — Radon 220: Méthode de mesure intégrée pour la détermination de l'activité volumique moyenne avec des détecteurs passifs solides de traces nucléaires

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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.

ISO 16641 was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

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 considered to be the main source of human exposure to natural radiation. The UNSCEAR (2006) report [2] suggests that, at the international level, radon accounts for around 52% of the global average exposure to natural radiation. Isotope 222 (48%) is far more significant than isotope 220 (4%), while isotope 219 is considered negligible.

Recent studies on indoor radon-222 and lung cancer in Europe, North America and Asia provide strong evidence that radon-222 causes a substantial number of lung cancers in the general population. Current estimates of the proportion of lung cancers attributable to radon-222 range from 3 to 14%, depending on the average radon-222 concentration in the country concerned and the calculation methods.

Indoor radon-222 concentration is mainly measured by passive detectors that may measure both radon-222 and radon-220 signals. If the readings are overestimated, the lung cancer risk is given as a biased estimate when epidemiological studies are carried out. Experiences from field work indicate that there is no correlation among radon-222 and radon-220 and its decay products concentrations. This implies that one parameter cannot be estimated from the other. Therefore, specific measurements of radon-220 and its decay products are justified as radon-222 measurement standards cannot be applied.

There are many ways of measuring the activity concentration of radon-220 and its decay products. The measuring technique proposed is an integrated measurement method only for radon-220.

Measurement of radioactivity in the environment — Air — Radon 220: Integrated measurement methods for the determination of the average activity concentration using passive solid-state nuclear track detectors

1 Scope

This document covers integrated measurement techniques for radon-220 with passive sampling only. It provides information on measuring the average activity concentration of radon-220 in the air, based on easy-to-use and low-cost passive sampling, and the conditions of use for the measuring devices.

This standard covers samples taken without interruption over periods varying from a few months to one year.

This type of measurement is applicable for determination of both radon-220 and radon-222 activity.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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, *Nuclear energy — Measurement of radioactivity in the environment — Air — Part 1: Radon-222 and its short-lived decay products in an atmospheric environment: Their origins and measurement methods*

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

ISO 11929, *Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for ionizing-radiation measurements — Fundamentals and application*

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 following terms and definitions apply.

3.1.1
activity
number of spontaneous nuclear disintegrations occurring in a given quantity of material over a reasonably short time interval, divided by this time interval

[Source: ISO 921]

Activity is expressed by the relationship:

$$A = \lambda \cdot N \qquad (1)$$

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

$$\lambda = \frac{\text{Ln}\,2}{\text{T}} \qquad (2)$$

3.1.2
activity concentration
activity per unit volume

[Source: IEC 61577-1]

3.1.3
average activity concentration
exposure to activity concentration divided by the sampling duration

3.1.4
radon exposure
integral with respect to time of radon activity concentration accumulated during the exposure time

Exposure to radon is expressed by Equation (3):

$$\text{e} = \int_0^t C dt \qquad (3)$$

3.1.5
integrated measurement
measurement obtained by accumulating over time physical variables (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

3.1.6
measurand
particular quantity subject to measurement (VIM)

3.1.7
passive sampling
sampling using no active device like pumps for sampling the atmosphere

Note1 to entry: In this case, the sampling is in most instruments mainly made by diffusion

[Source: IEC 61577-1]

3.1.8
primary standard
standard designed or widely acknowledged as having the highest metrological qualities and whose value is accepted without reference to other standards of the same quantity

[Source: IEC 61577-1]

Note 1 to entry: The concept of primary standard is equally valid for base quantities and derived quantities.

3.1.9
reference atmosphere
radioactive atmosphere in which the influencing parameters (aerosols, radioactivity, climatic conditions, etc.) are sufficiently well-known or controlled to allow its use in a testing procedure for thoron or its decay products measuring instruments.

Note 1 to entry: The parameter values concerned shall be traceable to recognized standards

[Source: IEC 61577-1]

3.1.10
reference source
radioactive secondary standard source for use in the calibration of the measuring instruments

[Source: IEC 61577-1]

3.1.11
sampling duration
time interval between the installation and removal of the sampling device at a given point

3.1.12
sampling plan
precise protocol that, depending on the application of the principles of the strategy adopted, defines the spatial and temporal dimensions of sampling, the frequency, the sample number, the quantities sampled, etc., and the human resources to be used for the sampling operation

3.1.13
sampling strategy
set of technical principles that aim to resolve, depending on the objectives and site considered, the two main issues which are the sampling density and the spatial distribution of the sampling areas

Note 1 to entry: The sampling strategy provides the set of technical options that will be required in the sampling plan.

3.1.14
radon-220 decay products
decay products of radon-220 disintegration such as polonium-216 (^{216}Po), lead-212 (^{212}Pb), bismuth-212 (^{212}Bi), polonium-212 (^{212}Po) and thallium-208 (^{208}Tl) (see Figure A.1)

3.2 Symbols

For the purposes of this document, the following symbols apply.

λ_i	Decay constant of the nuclide i, in per second
$\overline{C}$	Average activity concentration, in becquerel per cubic metre
t	Sampling duration, in hours
e	Exposure to radon, in becquerel per cubic metre hour
$u(\ )$	Standard uncertainty associated with the measurement result
U	Expanded uncertainty calculated by $U = k \cdot u(\ )$ with k = 2
$\overline{C}^{*}$	Decision threshold of the average activity concentration, in becquerel per cubic metre
$\overline{C}^{\#}$	Detection limit of the average activity concentration, in becquerel per cubic metre
$\overline{C}^{\triangleleft}, \overline{C}^{\triangleright}$	lower and upper limit of the confidence interval, respectively, of the average activity concentration, in becquerel per cubic metre

μ	Quantity of the accumulated physical variable
μ_0	Quantity due to the background effect
ω	Correction factor linked to the calibration factor and the sampling duration
d_L	Track density for low air-exchange rate chamber in tracks per square centimetre
d_H	Track density for high air-exchange rate chamber in tracks per square centimetre
$\bar{b}$	Track density due to background in tracks per square centimetre
f_{Tn1}	Calibration factor for radon-220 in a low air-exchange rate chamber in (tracks per square centimetre per hour) per (becquerel per cubic metre)
f_{Tn2}	Calibration factor for radon-220 in a low air-exchange rate chamber in (tracks per square centimetre per hour) per (becquerel per cubic metre)
f_{Rn1}	Calibration factor for radon-222 in a high air-exchange rate chamber in (tracks per square centimetre per hour) per (becquerel per cubic metre)
f_{Rn2}	Calibration factor for radon-222 in a high air-exchange rate chamber in (tracks per square centimetre per hour) per (becquerel per cubic metre)

4 Principle of the measurement method

The integrated measurement of the average radon-220 activity concentration using a sold-state nuclear track detector (SSNTD) is based on:

— passive sampling using two chambers with different air-exchange rates during which the alpha particles, including those produced by the disintegration of radon-220, radon-222 and their decay products, transfer their energy by ionising or exciting the atoms in the polymer or plastic. This energy transferred to the medium leaves areas of damage called “latent tracks”. Because of their different half-lives, radon-222 and radon-220 can be separated using these two chambers. In the high air-exchange rate chamber, both isotopes are detected. In the low air-exchange rate chamber, however, radon–222 is mainly detected with only a small quantity of radon-220 (See Figure 1);

— transport of the exposed detectors to the laboratory for the appropriate chemical processing which transforms the latent tracks into "visible tracks" counted via an optical system. The number of these visible tracks per unit surface area is linked to the exposure value of the radon-220 and/or its decay products by the calibration coefficient defined for detectors in the same batch processed chemically and counted under the same conditions;

— determination of the average activity concentration from the radon-220 exposure value and the sampling period.