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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

Mesurage 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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is 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, 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.[3]

Indoor radon-222 concentration is mainly measured by passive detectors that can measure both radon-222 and radon-220 signals.[4] If the readings are overestimated, the lung cancer risk is given as a biased estimate when epidemiological studies are carried out. Radon-222 and radon-220 parallel measurements have been carried out in several countries[4]-[11] (See Table A.1). 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. Unless radon-220 activity concentration is measured, a correct radon-222 concentration cannot be given with a single use of radon-222 measuring device. Therefore, a specific measurement of radon-220 is justified.

Due to its short half-life, radon-220 disappears very rapidly in the atmosphere. An activity concentration gradient is observed from the walls or grounds to the inner space of the room. Depending on the objective of the measurement (building characteristics, construction material characterization, etc.), the sampling location is to be chosen after taking into account this gradient.

Due to a highest level of radon-222 in air, radon-220 is very difficult to measure alone. This International Standard proposes a measuring method of radon-220 activity concentration using a dual system considering radon-222 and radon-220.

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 for radon-220 only.

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

This type of measurement is also applicable for determination of radon-222 activity concentration.

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 11665-1:2012, *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 11929, *Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation — Fundamentals and application*

ISO/IEC 17025:2005, *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 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 921:1997, 23]

Note 1 to entry: Activity is expressed by the relationship:

$$A = \lambda \times N$$

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

$$\lambda = \frac{\ln 2}{T}$$

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

Note 1 to entry: Exposure to radon is expressed by:

$$e = \int_0^t C \mathrm{d}t$$

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

[SOURCE: ISO/IEC Guide 99]

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

[SOURCE: IEC 61577-1]

Note 1 to entry: In this case, the sampling is in most instruments mainly made by diffusion.

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

[SOURCE: IEC 61577-1]

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

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 are required in the sampling plan.

3.1.14
radon-220 decay products
polonium-216 (^{216}Po), lead-212 (^{212}Pb), bismuth-212 (^{212}Bi), polonium-212 (^{212}Po), and thallium-208 (^{208}Tl)

Note 1 to entry: See Figure A.1.

3.2 Symbols

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

λ	decay constant of the nuclide i, in per second
$\bar{C}$	average activity concentration, in becquerel per cubic metre (e.g. $\overline{C_{Tn}}$ radon-220 activity concentration)
$\tilde{C}$	true value of the average activity concentration
t	sampling duration, in hours
e	exposure to radon, in becquerel per cubic metre hour
$\tilde{u}$	standard uncertainty of the estimator of the true value $\tilde{C}$
$u()$	standard uncertainty associated with the measurement result
U	expanded uncertainty calculated by $U = k \times u()$ with $k = 2$
$\bar{C}^*$	decision threshold of the average activity concentration, in becquerel per cubic metre
$\bar{C}^\#$	detection limit of the average activity concentration, in becquerel per cubic metre
$\bar{C}^\triangleleft, \bar{C}^\triangleright$	lower and upper limit of the confidence interval, respectively, of the average activity concentration, in becquerel per cubic metre

ω_1 factor linked to the calibration factor f_{Tn2} and the sampling duration

ω_2 factor linked to the calibration factor f_{Tn1} and the sampling duration

ω_3 factor linked to the calibration factor f_{Rn1} and the sampling duration

ω_4 factor linked to the calibration factor f_{Rn2} 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 high 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 low 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 solid-state nuclear track detector (SSNTD) is based on the following:[12]

— 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 ionizing 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);

  The high air-exchange rate should be set as high as possible so that the calibration factor of radon-220 is ideally the same as that of radon-222. On the contrary, the low air-exchange rate should be set as low as possible with a high diffusion barrier.

— 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 its decay products by the calibration factor defined for detectors in the same batch processed chemically and counted under the same conditions;

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

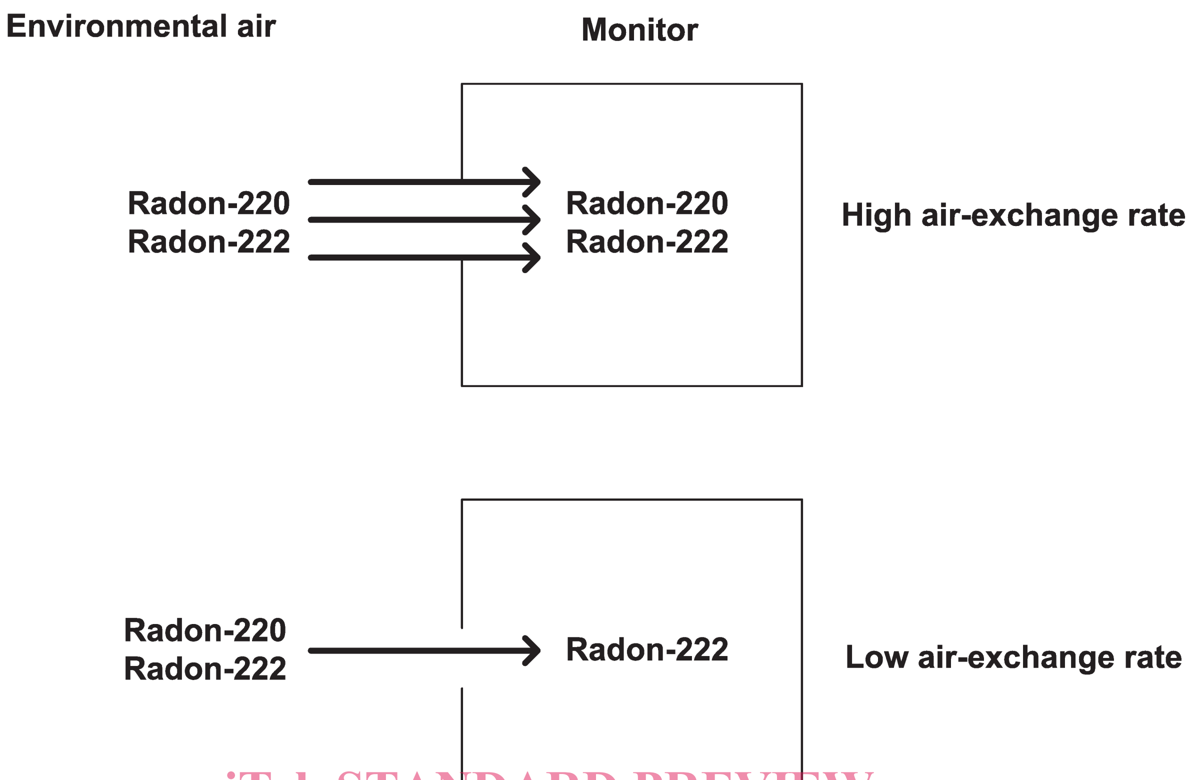

Figure 1 — Principle of radon-thoron separation technique

5 Equipment

The apparatus includes the following.

5.1 A device composed of two closed accumulation chambers with different air-exchange rates.

Each of them is associated with a solid state nuclear track detector. Each closed accumulation chamber has a filter through which the radon-220 and radon-222 diffuse. This filter is set to prevent access of the aerosols present in the air at the time of sampling, especially the solid radon-220 and radon-222 decay products (see Figure 2).

The SSNTD shall come from the same sheet of plastic to avoid different results. Nevertheless each SSNTD batch is calibrated.

5.2 The equipment and suitable chemical reagents for etching the detector.

See ISO 11665-4.

5.3 An optical microscope and associated equipment, for scanning and counting the etched tracks.