Australian Standard®

Methods for sampling and analysis of indoor air

Method 4: Determination of radon

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee CH/19 on Methods for Examination of Air. It is one of a series for the sampling and analysis of indoor air.

The objective of this Standard is to provide those involved in the sampling and analysis of indoor air with standardized methods for determination of the radon content of indoor air or reference methods against which other measurement methods can be calibrated or compared.

This Standard is the result of a consensus among representatives on the Joint Committee to produce it as an Australian Standard.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

CONTENTS

Page

FOREWORD

The term 'radon' strictly applies to any one of the isotopes of the element with atomic number 86. These isotopes are colourless, odourless, chemically inert, radioactive gases. The principal isotope, which occurs naturally as a member of the ^{238}U radioactive decay series, is ^{222}Rn (historically known as 'radon'), which has a half-life of 3.82 d. ^{220}Rn (historically known as 'thoron') is produced from the radioactive decay of ^{232}Th, and has a half-life of 55 s. The third naturally occurring isotope, ^{219}Rn, is called 'actinon' and originates from the radioactive decay of ^{235}U; because the half-life of ^{235}U is much smaller than that of either ^{238}U and ^{232}Th and also because the half-life of ^{219}Rn is small (19 s), ^{219}Rn occurs naturally in negligibly small quantities. For simplicity, throughout the remainder of this document the historical names 'radon' and 'thoron' will refer to ^{222}Rn and ^{220}Rn respectively.

NOTE: A summary of the ^{238}U decay series is given in Appendix A.

^{226}Ra (radium) has a half-life of 1602 years. Since this is much longer than the half-life of any subsequent uranium progeny such as radon, ^{226}Ra can be regarded as a fixed-rate generator of ^{222}Rn, which has a half-life of 3.82 d. Radioactive equilibrium between radon progeny ^{218}Po(RaA), ^{214}Pb(RaB) and ^{214}Bi(RaC) is achieved after approximately three hours (in the absence of processes which compete with the radioactive decay of the nuclides. After a ^{214}Bi(RaC) decay (half-life of 19.7 min), the ^{214}Po(RaC′) decays almost immediately (164 μs) to ^{210}Pb(RaD), which has a 22-year half-life, effectively blocking the decay chain for normal measurement periods. Since ^{214}Po and ^{214}Bi are always in radioactive equilibrium, the relatively high energy 7.69 MeV alpha particle radiated from ^{214}Po is normally used when measuring ^{214}Bi. The mobility of the radon gas and the relatively short decay times for the subsequent radon progeny leads to a natural division between the radon decay chain and the rest of the uranium decay series. This applies both to measurement methods and to the associated health risk. The half-lives of thoron and its progeny combine to produce a much lesser hazard than that from radon and its progeny in most circumstances. The rest of this discussion is therefore based on radon. However, the same general principles can be applied to the thoron decay series.

Inhalation of elevated concentrations of radon progeny increases the risk of cancer occurring in the respiratory tract, because the biological half-lives of the radon progeny in the respiratory tract are longer than their radioactive half-lives. Most of the inhaled radon progeny therefore decay in the respiratory tract, emitting gamma radiation, beta particles and the more damaging high energy alpha particles. Since these alpha particles are readily stopped in tissue, most of their energy will be deposited in respiratory tract tissue; this has the potential to cause respiratory tract cancer.

Under normal atmospheric conditions, the dose to the lung can be determined from the measurement of the potential alpha energy concentration (PAEC) of the three radon progeny ^{218}Po, ^{214}Bi and ^{214}Pb. The historical unit of measurement of PAEC for radon progeny is the radon working level (WL). The WL(Rn) is defined as any combination of the short-lived decay products of radon in one litre of air which results in the ultimate emission of 1.3×10^5 MeV of alpha particle energy. In terms of the individual number concentrations N_A, N_B and N_C of the radon progeny ^{218}Po(RaA), ^{214}Pb(RaB) and ^{214}Bi(RaC) respectively, the radon working level is given by the following equation:

$$WL = (13.69N_A + 7.69N_B + 7.69N_C)/1.3 \times 10^5 \quad \ldots (1)$$

In terms of the activity concentrations, this equation converts to the following:

$$WL = (0.0278C_A + 0.1370C_B + 0.1008C_C)/1000 \quad \ldots (2)$$

where C_A, C_B and C_C for ^{218}Po, ^{214}Pb and ^{214}Bi respectively are activity concentrations in becquerels per cubic metre (Bq/m^3).

The preferred SI unit for PAEC is now joules per cubic metre (J/m^3) and one WL equals 2.08×10^{-5} J/m^3. The PAEC in joules per cubic metre is thus given by the following equation:

$$PAEC = (5.79C_A + 28.6C_B + 21.0C_C) \times 10^{-10} \quad \ldots (3)$$

where C_A, C_B and C_C are as previously defined.

When radon and thoron are formed they can diffuse through soil and rock pore spaces and can escape to the atmosphere if the diffusion time to the solid/air interface is no more than a few half-lives of the isotope. As ^{238}U and ^{226}Ra are widely distributed in trace concentrations in many types of rock and soil, radon is being continuously released to become a trace constituent of the 'soil gas' which exists in soils and dissolves to some extent in underground water. The 'soil gas' diffuses into the atmosphere, and enters houses and buildings of which the lowest levels or basements are within or in close proximity to the ground (including the 'pier and crawl-space' type of house commonly constructed in Australia).

The concentration of radon which accumulates in buildings or houses is governed by the radium content of the underlying soil, the porosity of the soil and channelling produced by geological structures, the availability and dimensions of cracks or other openings between the house interior and the soil, the pressure differential between the soil gas and the interior of the building, and the ventilation rate of the building. Where surveys have been conducted it has been found that the radon content of the atmosphere in the building is higher than that of the atmosphere outside the building, frequently by as much as one or even two orders of magnitude (and in rare instances by more than three orders of magnitude).

The International Commission on Radiological Protection (ICRP) has suggested* advisory levels to limit dosages of indoor radon (20 mSv per year as an action level, and 10 mSv per year for new construction); these figures represent an annual exposure to an average radon concentration on 228 Bq/m^3 and 114 Bq/m^3 respectively)†. The Radiation Health Committee of the National Health and Medical Research Council (NHMRC) have suggested an advisory exposure level of 200 Bq/m^3 for Australian homes. An Australia-wide survey‡ has shown that the average level of radon in Australian homes is approximately 12 Bq/m^3, and that 0.1 percent of the homes surveyed have radon levels above the advisory level recommended by the Radiation Health Committee.

---

* INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. *Lung cancer risk from indoor exposures to radon daughters*. Oxford: Pergamon Press ICRP Publication 50 Ann. ICRP, Vol. 17, No.1, 1987, p.1-60.

† IBID, sec 3.3.

‡ LANGROO, M.K., WISE, K.N., DUGGLEBY, J.C. and KOTLER, L.H. *A nation-wide survey of radon and gamma radiation in Australian homes.* Australian Radiation Laboratory Technical Report ARL/TR090 (ISSN 0157-1400), April 1990.

METHOD

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out three methods for the determination of the radon content of indoor air. The methods are as follows:

(a) *Collection in scintillation cells and measurement of alpha activity (Method A)** Applicable for grab samples (sampling times of a few seconds) and providing a rapid means of obtaining a radon concentration at a particular time. Its detection limit is dependent on the background count rate. For a background count rate of 1 count/min and a counting period of 60 min, the lower detection limit is 40 Bq/m^3. For a scintillation cell with a sampling volume of 140cm^3, the sensitivity of the method is approximately 0.019 counts/min per Bq/m^3 in air.†

(b) *Passive adsorption onto activated charcoal and measurement of gamma radiation (Method B)* Applicable for short term sampling (between 1 d and 7 d). The detection limit is approximately 15 Bq/m^3 for an exposure period of 4 d and counting period of 60 min.

(c) *Solid-state nuclear track monitoring (Method C)* Applicable for sampling periods from one week to one year. The detection limit is 3 Bq/m^3 for an exposure period of one year and a counting area of 1.5 cm^2.

Methods for the determination of the concentrations of certain radon progeny, by membrane filter collection and measurement of alpha activity, and estimation of the total potential alpha energy concentration (PAEC) of radon progeny in indoor air are included in Appendix B. A sampling period of 5 min is used and, for the count intervals specified, this method should give a lower detection limit of $2.5 \times 10^{-8} J/m^3$ for the PAEC of the radon progeny.‡

NOTES:

1 The recommended advisory level for radon in dwellings is expressed as a radon concentration in air, in becquerel per cubic metre, while actual radiation doses are calculated from the measurement of the concentration of the radon progeny in the air. The methods in Appendix B have been included for use in situations where measured radon concentrations are high enough to warrant further investigation.

2 The detection limits for each method have been estimated using the procedure given by Currie (published in *Analytical Chemistry*§)

1.2 PRINCIPLE

1.2.1 Method A An instantaneous sample of air equal to the volume of the scintillation cell is collected when a previously evacuated cell is opened to the atmosphere. The alpha particles from the decay of radon and radon progeny produce scintillations through interaction with the phosphor coating on the inner surfaces of the cell. Following a

---

* LUCAS, H.F. Improved low-level alpha scintillation counter for radon. *Review of Scientific Instruments*, Vol. 28, 1957, p. 680-683.

† GAN, T.H., SOLOMON, S.B., and PEGGIE, J.R. Standardization of Rn-222 at the Australian Radiation Laboratory. *Journal of Research of the National Institute of Standards and Technology*, No. 95, 1990, p. 171-175.

‡ NAZAROFF, W.W. Optimising the total-alpha three-count technique for measuring concentrations of radon progeny in residences. *Health Physics*. No. 46, 1984, p. 395-404.

§ CURRIE, L.A. Limits for qualitative detection and quantitative determination. *Analytical Chemistry*, Vol. 40, 1968, p. 586-593.