Public Health England

Protecting and improving the nation's health

Validation scheme for organisations making measurements of radon in UK buildings: 2018 revision

About Public Health England

Public Health England exists to protect and improve the nation's health and wellbeing, and reduce health inequalities. We do this through world-leading science, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. We are an executive agency of the Department of Health and Social Care, and a distinct delivery organisation with operational autonomy to advise and support government, local authorities and the NHS in a professionally independent manner.

Public Health England
133–155 Waterloo Road
Wellington House
London SE1 8UG
T: 020 7654 8000

www.gov.uk/phe
Twitter: @PHE_uk
Facebook: www.facebook.com/PublicHealthEngland

Any enquiries regarding this publication should be sent to: CRCEDirectorsOffice@phe.gov.uk

Published: September 2018
PHE publications gateway number: 2018308

Validation Scheme for Organisations Making Measurements of Radon in UK Buildings: 2018 Revision

Z Daraktchieva, C B Howarth, T D Gooding, E J Bradley and N Hutt

Abstract

A revised scheme is described for the approval of suppliers of passive radon detectors for the measurement of radon in dwellings and workplace buildings, and the interpretation of results. This 'Validation Scheme' applies to long-term measurements for estimating the annual average of the radon concentration indoors and comparing it to the prevailing Action Level for homes and regulatory threshold for workplaces. The Scheme deals with the physical and administrative requirements for validation and specifies the procedures to be followed and the performance to be achieved. Suppliers engaged in such work are invited to participate.

Centre for Radiation, Chemical and Environmental Hazards
Public Health England
Chilton, Didcot
Oxfordshire OX11 0RQ

Approval: Month Year
Publication: Month Year

Executive summary

This document sets out a ‘Validation Scheme’ by which suppliers of passive radon detectors can demonstrate competence in the measurement of radon levels in UK buildings and in the interpretation of those results. The Scheme includes a review of the procedures used by each supplier, to ensure that an adequate quality system is in place, together with practical tests that assess their ability to measure radon by exposing detectors to known quantities of radon.

The aim of the Validation Scheme is not only to ensure good laboratory practice, but also to address issues such as data protection, record keeping and dealing with complaints from customers.

Because radon levels are highly variable on all timescales, the scheme only applies to long term measurements (3 months or longer). Shorter measurements, and especially those of less than a month, may be useful for screening purposes where time is short, but give a less accurate assessment of the annual average radon concentration and therefore are not covered by this scheme.

Contents

1 INTRODUCTION

1.1 Indoor radon concentrations display diurnal, monthly and seasonal variations (Miles and Algar, 1988). Therefore, the length of the measurements and the season will affect the estimation of the annual average radon concentration. To enable an adequate quality of measurement, the PHE Radon Group operates the Validation Scheme described in this document.

1.2 To estimate the annual average radon concentrations for comparison with radon reference levels measurements should ideally be made over periods of 12 months. However, such measurements have been impractical because of a long delay for the results. Measurements of 3 months have been used as an alternative by employing normalisation factors called 'seasonal correction factors'. Long-term measurement of the average radon concentration using passive radon detectors, such as etched-track detectors, is the most suitable technique for identifying dwellings where the radon concentration is above the Action Level recommended by Public Health England (PHE) (NRPB, 1990, McColl et al 2010). Long-term radon measurement is also the accepted practice for determining whether the Ionising Radiations Regulations 2017 (IRR17, HSE 2017) apply in workplaces. The seasonal correction factors can only be applied to radon measurements in buildings and are not appropriate for use in underground workplaces such as mines and caves, or any location where there is a known, additional radon source; radon measurements in such workplaces are not covered by this Validation Scheme.

1.3 Short-term measurements, which here are defined as measurements between 7 and 30 days, are proven to be less accurate in predicting annual average radon concentrations due to radon variability and measurement uncertainty which are higher for shorter exposure periods (ICRU report 88). Comparison between short-term measurements and one year tests showed that the short-term tests can deviate significantly from the actual annual values (Steck, 2005; Miles 2001, Hansen 2014). Taking into account the above findings, short-term measurements are not covered by this Validation Scheme since they cannot reliably predict the annual average radon concentration and are therefore not recommended for identifying buildings above the UK Action Level (see Section 12.3) or workplaces that exceed the IRR17 threshold (see Section 12.13).

This Validation Scheme applies to measurements undertaken using passive integrating detectors. Numerous electronic detectors are now available for measuring radon in air concentrations, however, the performance and ability of these types of detector to determine the annual average radon concentration is the subject of ongoing PHE research.

1.4 Application of the criteria below for successful validation is intended to provide suppliers and clients with confidence in the quality of the radon measurements and in the ability of laboratories to provide a sound interpretation of the measurements.

1.5 This document replaces HPA-RPD-047, *Validation Scheme for Laboratories Making Measurements of Radon in Dwellings: 2008 Revision* (Howarth and Miles, 2008). Changes have been made for 5 principal reasons:

(1) to review the initial and performance test parameters

(2) to reflect any changes needed following publication of 2013 EU BSS (EURATOM, 2013) and IRR 2017 (HSE, 2017)

(3) to include workplace measurements in the scope of the scheme

(4) to reflect the most recent estimates of seasonal correction factors

(5) to reflect the most recent findings for UK occupancy factors

2 EXPLANATION OF TERMS

2.1 Client

A Client is any person or organisation for whom the Supplier carries out radon monitoring.

2.2 Employer

An Employer is a person or organisation that employs people.

2.3 Processing Laboratory

A Processing Laboratory is an organisation that produces and analyses detectors used for the measurement of radon in air. A Processing Laboratory may be part of the same organisation as the Supplier, or a separate entity.

2.4 Performance Tests

Performance Tests are those laid down by the Validation Authority as necessary to determine that the Processing Laboratory meets the criteria of acceptable uncertainty in determining the radon exposure in dwellings, both on initial application for validation and on a continuing basis to maintain validated status.

2.5 Radon

Radon in this document refers to the principal isotope, radon-222, of the gas.

2.6 Radon concentration

The radon concentration is the activity of radon per unit volume of air, expressed as Bq m^{-3} (becquerels per cubic metre).

2.7 Radon exposure

Radon exposure is the time-integrated concentration of radon, expressed in kBq h m^{-3}.

2.7 Supplier

A Supplier is a party seeking to be validated, or already validated, for the measurement and interpretation of the results of radon exposure in the air of dwellings. The Supplier may be an independent organisation, part of another organisation, or a supplier of detectors originating with a third party.

2.8 Validation

Validation is formal recognition by the Validation Authority that the supplier is competent to carry out measurements of radon exposure in buildings and also competent to interpret such measurements in a manner consistent with the national policy on radon in dwellings (NRPB, 1990 and McColl et al 2010) and/or the IRR17 for workplaces, as appropriate.

2.9 Validation Authority

The Validation Authority will be the Radon Group of the Public Health England Centre for Radiation, Chemical and Environmental Hazards acting in support of the national programme for reducing exposure to radon. It will operate the Validation Scheme and determine whether a Supplier meets the validation requirements.

3 APPLICATION FOR VALIDATION

3.1 Applications should be made to the Validation Authority and should be accompanied by a Validation Manual giving details of the devices and procedures for which validation is sought and information concerning the Supplier's organisation, resources, personnel and methods. The Supplier should state whether validation is sought for radon measurements in dwellings only, workplaces only, or both.

3.2 The Validation Authority will maintain confidentiality about the information disclosed in the Validation Manual, and will not use it for any purpose other than validation of the laboratory.

3.3 A Supplier shall be Validated for the provision of radon measurements using a particular type of detector with appropriate processing and reporting procedures if:

(a) the Validation Manual is deemed acceptable by the Validation Authority;
(b) the initial performance tests are completed successfully;

(c) the Supplier participates satisfactorily in continuing performance tests.

3.4 Where a Supplier has been validated for the provision of measurements based on the use of a particular device and set of procedures and wishes to introduce other measurements based on a different device or procedures, the Laboratory must not claim to be validated for the new measurements until an appropriate application has been submitted to and successfully processed by the Validation Authority.

3.5 Where a Supplier provides radon detectors for the purpose of short-term screening measurements, that is measurements with a duration of less than 3 months, the Supplier shall not imply, directly or otherwise, that it is validated for the provision of such measurements.

3.6 Where a Laboratory provides radon measurements for purposes other than the determination of radon concentrations in dwellings or workplace buildings, or using procedures other than those for which successful application has been made to the Validation Authority, the Supplier shall not imply, directly or otherwise, that it is validated for the provision of such measurements.

3.7 The Validation Authority shall maintain an up-to-date list of validated suppliers which will be available on demand and published in an appropriate manner, including on the PHE radon website (www.ukradon.org/resources).

3.8 The Validation Authority will make such charges as are necessary to cover the costs of operating the Validation Scheme and performing and administering the tests. These may be varied from time to time.

4 VALIDATION MANUAL

A model manual is given in Appendix A. The manual shall contain, for each type of detector, method of assessment and application for which Validation is sought:

4.1 A brief description of the radon detector.

4.2 A brief description of the procedure for assessing radon exposure from the detector.

4.3 Details of the intended application of the measurement.

4.4 Point-by-point confirmation that the laboratory meets the requirements 5.1 – 12.21 (as appropriate) with documentary evidence where appropriate.

5 ORGANISATION AND MANAGEMENT

5.1 The Processing Laboratory manager and their appointed deputy, responsible for the day-to-day operation of the radon monitoring service, should be suitably qualified and experienced. In particular, these persons should understand:

a) the physical principles on which the monitoring device is based and its limitations;

b) the requirements for handling the devices before and after deployment;

c) the requirements for processing and for maintaining the stability of the processing equipment; and

d) the interpretation of the results obtained.

5.2 The Processing Laboratory and Supplier shall be organised so that members of staff shall not be subject to any influence that might adversely affect their judgement or the outcome of their work. Commercial involvement with organisations undertaking radon remedial (mitigation) or preventive work shall be made clear to the Client.

5.3 Responsibility for preparing and signing radon measurement reports shall be given only to members of staff that meet the relevant requirements of the scheme.

6 STAFF RECORDS

6.1 For each task to be performed, the Supplier or Processing Laboratory shall use competent members of staff who have an appropriate combination of academic qualifications, training, skill and experience. The use of persons undergoing training is acceptable provided they are supervised and that the number of staff undergoing training does not adversely affect the quality of the work undertaken.

6.2 The Supplier and Processing Laboratory shall have documented policy and procedures to ensure that existing and new staff have and maintain the relevant competence in radon measurements.

6.3 The Supplier and Processing Laboratory shall maintain up-to-date records of the relevant competence of all such members of staff, which shall be available to the Supplier or Processing Laboratory manager and, on request, to the Validation Authority.

7 QUALITY SYSTEMS

7.1 All aspects of relevant operations and responsibilities shall be documented to the extent necessary to ensure the adequate and consistent quality of the measurement

procedures. Members of staff shall have ready access to all documents on the handling of monitoring devices prior to issue, on receipt after exposure, and during processing.

7.2 All amendments to such documents shall be subject to management control, and the Supplier or Processing Laboratory shall have procedures clearly defining responsibility for the generation and distribution of amendments. Alterations to existing documents shall be clearly legible and indelible.

7.3 The Supplier or Processing Laboratory shall have procedures to be followed where departures from documented policies and procedures, for any reason, have been found. Where such departures may have affected the quality of reported results of radon measurements, these procedures shall require that work is halted immediately and that all necessary investigations and corrective actions are undertaken before further work is performed.

7.4 Departure from documented policies and procedures may be permitted where it can be shown that there are valid technical reasons for doing so and the quality of measurements is not adversely affected. The justification for the departure, with endorsement by management, shall be noted in the relevant records.

8 PROCESSING LABORATORY EQUIPMENT AND ENVIRONMENT

8.1 The Processing Laboratory shall utilise suitable equipment for all stages in the radon measurement process, including data storage and manipulation.

8.2 Equipment shall be protected as far as possible from deterioration and abuse. Where applicable, the manufacturer's instructions shall be available and followed. All equipment in service shall be checked regularly to ensure that operation is within specification, and records shall be kept.

8.3 Each item of equipment used by the Processing Laboratory shall, where appropriate, be uniquely identified.

8.4 For equipment requiring calibration, a record shall be kept comprising a full up-to-date history of performance, including calibration data.

8.5 Any item of equipment which suffers damage from mishandling, or gives suspect results, or malfunctions, or is shown by tests to be defective or unfit for use, shall be immediately withdrawn from service. It shall be segregated and prominently marked and shall not be returned to service until it has been repaired, re-commissioned and re-calibrated as appropriate. See also point 7.3 above.

8.6 Where computers or other automated equipment are used for the collection, manipulation, recording, reporting, storage or retrieval of measurement data, the Processing Laboratory shall ensure that, where applicable, the preceding requirements of this section are met. The Processing Laboratory shall, wherever possible, ensure that computer software is documented and tested before use.

8.7 The Processing Laboratory should be based in accommodation which is not subject to adverse influences of a mechanical, thermal, or other nature, and should have concentrations of radon in air that are sufficiently low as to cause negligible adventitious exposure of detectors while in the accommodation. Environmental control must be sufficiently stringent to ensure that no equipment or detector material is subject to conditions likely to affect its performance.

9 HANDLING OF DETECTORS

9.1 The Supplier shall have an effective, documented system for identifying radon detectors. It shall be designed and operated so as to ensure that detectors cannot be confused physically or in records or other documents.

9.2 The identification systems shall permit ready cross-reference to be made between the identifiers for each detector and any other identifier associated with the use of that detector (such as the Client's identifier, order number, or report number).

9.3 Each detector shall be assigned a unique identifying number. Labelling or some equivalent method shall be used to ensure that the assigned identifier is associated with the detector until the final report of the result is issued.

9.4 Where detectors are re-usable, each use of the detector should have a unique identifier, which distinguishes it and the particular issue number.

9.5 Upon receipt of a detector for processing, any departure from its normal condition shall be noted and recorded. Where there are any resulting doubts as to the validity of the result, the Client must be informed in a clear and unambiguous manner.

10 RECORDS OF OPERATION

10.1 The Processing Laboratory and Supplier shall have and maintain a systematic and documented record of all information of relevance to the validated radon measurements it makes. The records shall be designed and maintained so as to facilitate identification of any sources of error.

10.2 The Processing Laboratory and Supplier must maintain an appropriate degree of confidentiality, and where necessary, comply with relevant data protection legislation.

10.3 The record for each detector shall include:

(a) the complete address, with postcode, of the dwelling or workplace in which it was placed, including the name of the occupier or Client;

(b) the location within the dwelling or workplace where the detector was placed;

(c) the date of start of the measurement;

(d) the duration of the measurement;

(e) the radon exposure in kBq h m^{-3}, or the average radon concentration during the period of measurement in Bq m^{-3}.

10.4 The record for each dwelling shall also include, with an indication of the methods of derivation:

(a) the occupancy-weighted average radon concentration;

(b) the seasonally-corrected value of the foregoing parameter.

10.5 The record for each workplace shall also include, with an indication of the methods of derivation:

(a) the average radon concentration for each detector during the period of measurement

(b) the seasonally-corrected value of the foregoing parameter.

11 COMPLAINTS AND ANOMALIES

11.1 The Supplier shall have documented policy and procedures for the resolution of complaints from Clients. A record shall be maintained of all complaints and of the actions taken by the Supplier.

11.2 Where a complaint or any other circumstance raises doubt about compliance with any element of this Validation Scheme, the matter must be promptly investigated. Should the investigation indicate that the Supplier or Processing Laboratory has been operating in an invalid manner, it must endeavour to correct the matter, if appropriate, and undergo a continuing performance test as soon as possible.

11.3 If the need arises, the Validation Authority shall be given reasonable access to the record of complaints.

12 MEASUREMENT PROTOCOL AND REPORTING PROCEDURES

12.1 The Processing Laboratory and Supplier shall follow a measurement protocol appropriate to the purpose of estimating the annual average of the radon gas concentration for comparison with the Action Level or IRR17 threshold as appropriate.

12.2 All validated measurements shall take place over a period of at least 3 months and maximum of 12 months.

Dwellings

12.3 Two detectors are to be exposed at the same time. One detector will be used in the main living area and one in an occupied bedroom. It is important that the tests in each of the rooms are carried out simultaneously to eliminate additional variations caused by short-term fluctuations in radon levels within the property. Any additional monitors placed in other rooms will not be used to calculate the average radon concentration in the dwelling. In some dwellings, such as studio flats it may not be appropriate to place two detectors. In these and similar cases the supplier should adopt a pragmatic approach.

12.4 Measurements to test the efficacy of remedial measures shall take place in the same living area and occupied bedroom as the measurements made before the installation of remedial measures.

12.5 The dynamic range of the detector shall cover at least the range 50 - 1000 Bq m^{-3} for a 3 month exposure. If the dynamic range of the detector is too small to cover the range 50 - 1000 Bq m^{-3} for a 3 month exposure, the Supplier may report to the Client that the radon concentration is greater than a particular value. It shall then offer a repeat measurement to determine the concentration with greater accuracy. This repeat measurement shall be carried out at the expense of the Supplier.

12.6 The detector casing/holder shall be of a design that excludes radon decay products.

12.7 The householder shall be provided with appropriate instructions for placing and returning the detectors. Suggested model placement instructions are provided in Appendix B.

12.8 All radon concentrations must be reported in units of becquerels per cubic metre of air (Bq m^{-3}).

12.9 The estimate of the annual average radon concentration in a dwelling shall be calculated as follows:

Take a weighted mean of living room and bedroom radon concentrations, using weights of 0.42 and 0.58 respectively.

Calculate the estimated annual mean radon concentration in the dwelling. This may be done by multiplying the weighted mean concentration by the appropriate seasonal correction factor from Table 1. An example calculation is provided in Appendix C.

If, due to loss/ damage of a detector, only one result is available for a house, the house average may be estimated by multiplying the seasonally corrected individual detector result by the corresponding factor given in Table 2.

In this event, the householder should be informed that estimating on the basis of a single result is less accurate than estimating on the basis of a pair of results.
An example calculation is provided in Appendix C.

12.10 The Supplier shall advise the Client of the estimated annual average radon concentration for the dwelling. If the Supplier chooses, they may also report the average concentrations of radon actually measured by each detector, but should clearly distinguish these from the estimated annual average.

12.11 The advice to be offered to the Client should be on the basis of the estimated annual average radon concentration and shall be in accordance with that shown in Table 3.

12.12 In cases where the measurement is not intended to estimate the annual mean radon concentration in a dwelling (and is therefore not described as validated), other values may be reported instead, such as the actual mean radon concentration during the measurement.

Workplaces

12.13 Workplaces vary greatly in terms of internal area and floor plan. Employers shall use as many radon detectors as are needed to characterise the occupied areas; the recommended minimum monitoring densities for a variety of workplaces are given in Appendix D. This should enable the employer to undertake the suitable and sufficient risk assessment described in The Management of Health and Safety at Work Regulations 1999 (HSE, 1999).

12.14 Measurements to test the efficacy of remedial measures, confirm the location(s) of the radon concentrations that exceed the IRR17 threshold prior to remediation, or provide information for risk assessments shall take place over a period of 3 months. Radon monitoring should avoid times when the building will be unoccupied for extended periods, eg school summer holidays. Measurements to confirm radon concentrations prior to remediation shall include the same rooms that exceeded the IRR17 threshold initially.

12.15 As for paragraph 12.5.

12.16 As for paragraph 12.6.

12.17 The employer shall be provided with appropriate instructions for placing and returning the detectors. Suggested model placement instructions are provided in Appendix B1.

12.18 As for paragraph 12.8.

12.19 The estimates of annual average radon concentrations in a workplace building shall be calculated by multiplying with the appropriate seasonal correction factor in Table 1.

12.20 All the individual, seasonally corrected radon concentrations will be reported. The Supplier should also report the average concentrations of radon actually measured, but should clearly distinguish these from the seasonally corrected radon concentration.

12.21 The advice offered to the Client about the course to take on the basis of the highest annual average radon concentration within each building shall be in accordance with Table 4.

The Supplier and Client must be made aware that this advice does not constitute a consultation with a Radiation Protection Adviser (RPA) unless the Supplier is an appropriately qualified, experienced and certificated RPA (individual or corporate) and this is explicitly stated in the report.

13 PERFORMANCE TESTS

13.1 In the case of an initial performance test, the Supplier shall submit 55 detectors to the Validation Authority. Of these, 5 will be stored in a radon-free atmosphere and the remainder subjected to radon exposures in the range 100 to 3000 kBq h m^{-3}. The detectors will be returned to the Supplier for processing and the Supplier shall report the calculated exposure for each detector to the Validation Authority for assessment.

13.2 For a continuing performance test, the Supplier shall submit 35 detectors to the Validation Authority. Of these, 5 will be stored in a low radon atmosphere and the remainder subjected to radon exposures in the range 100 to 3000 kBq h m^{-3}. The detectors will be returned to the Supplier for processing and the Supplier shall report the calculated exposure for each individual detector to the Validation Authority for assessment. The interval between continuing performance tests shall not exceed 12 months. Participation in an Intercomparison exercise could be considered as a suitable performance test if the Supplier provides the results for its participation to the Validation Authority.

13.3 If a Supplier uses a detector with a dynamic range of response too small to cover the range of exposures given in 13.1 and 13.2, it may report results as greater than a particular value. It shall then supply to the Validating Authority replacement detectors for retesting.

13.4 The Validating Authority shall estimate radon exposures in performance tests using techniques traceable to national standards. The exposures so estimated shall be designated 'nominal exposures'.

13.5 The performance test shall consist of 2 parts. A Supplier shall be deemed to have passed the first part of a performance test if the total uncertainty for exposed detectors does not exceed the following limits:

(a) 25% in the exposure range 100 to 300 kBq h m^{-3};

(b) 15% in the exposure range 300 to 1000 kBq h m^{-3};

(c) 25% in the exposure range 1000 to 3000 kBq h m^{-3}.

These limits have been set to require maximum accuracy at exposures equivalent to a 3 month exposure at both the domestic and occupational Action Levels.

Total uncertainty for the purposes of validation is defined in terms of the mean percentage difference between the reported result and the nominal radon exposure (D), and the percentage standard deviation of the reported result (S), using the following equation:

$$\text{Total uncertainty} = \sqrt{D^2 + S^2}$$

A Supplier shall be deemed to have passed the second part of the performance test if the mean integrated exposure of the transit detectors is less than 45 kBq h m^{-3}. This is equivalent to a 3 month exposure at the average UK radon level of 20 Bq m^{-3}, and 10% of the UK domestic Action Level.

13.6 Should a validated Supplier fail a continuing performance test, it must discover the causes of failure and rectify them as soon as possible. If it does not submit to and successfully complete an initial performance test within 30 days of being notified of its failure in the continuing performance test, it must halt the issuing and processing of detectors until it has successfully completed an initial performance test or indicate that measurements are not validated.

13.7 Quality checks such as blind tests and dummy customers could be used by the Validation Authority for additional performance checks of the Supplier without prior notice.

14 REFERENCES

Daraktchieva Z (2017). New correction factors based on seasonal variability of outdoor temperature for estimating annual radon concentrations in UK, Rad. Prot. Dosimetry 175-1: (65-74).

Daraktchieva Z (2017-2). Private communication, July 2017.

EURATOM (2013). Council Directive 2013/59/EURATOM of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, Official Journal of the European Union L13/1.

Hansen MF, Moss GR, Fews AP, Henshaw DI (2014). Improving on short-term radon measurements using PADC detectors. Rad. Prot. Dosimetry 160(1-3): 181-183.

Howarth and Miles (2008). Validation Scheme for Laboratories Making Measurements of Radon in Dwellings: 2008 Revision HPA-RPD-047.

HSE (1999). The Management of Health and Safety at Work Regulations 1999. SI 3242/1999, HMSO, London.

HSE (2017). The Ionising Radiations Regulations 2017. SI 1075/2017, HMSO, London.

ICRU Report 88 (2012). Measurement and Reporting of Radon Exposures, Journal of the ICRU Vol 12 No 2, Oxford University Press 2015.

McColl NP, Miles JCH, Green BMR, Dixon DW, Fey R, Meara JR, Harrison JD and Cooper JR (2010). RCE-15: Limitation of Human Exposure to Radon. Chilton. HPA-CRCE.

Miles JCH and Algar RA (1988) Variations in radon-222 concentrations. Journal of Radiological Protection 8 (2), 103-106.

Miles JCH (2001). Temporal variation of radon levels in houses and implications for radon measurement strategies. Rad. Prot. Dosimetry 93 (4), 369–375.

NRPB (1990). Board Statement on limitation of human exposure to radon in houses. Docs NRPB, Vol 1, No. 1, 15-16.

Steck DJ (2005) Residential Radon Risk Assessment: How well is it working in a high radon region? AARST Proceedings of the 15TH International Radon Simposium, 1-13, Fletcher, NC

Table 1: Seasonal correction factors for derivation of annual average radon concentration

Start month	Duration (months):										
	1	2	3	4	5	6	7	8	9	10	11
January	0.73	0.73	0.75	0.79	0.85	0.91	0.97	1.02	1.04	1.05	1.03
February	0.74	0.77	0.82	0.88	0.96	1.03	1.08	1.10	1.10	1.07	1.04
March	0.81	0.87	0.95	1.03	1.11	1.17	1.19	1.17	1.13	1.08	1.03
April	0.94	1.04	1.14	1.23	1.28	1.29	1.25	1.19	1.12	1.06	1.02
May	1.16	1.28	1.37	1.41	1.39	1.32	1.24	1.15	1.08	1.03	1.01
June	1.42	1.51	1.52	1.47	1.36	1.25	1.15	1.07	1.02	0.99	0.99
July	1.61	1.58	1.48	1.35	1.22	1.11	1.03	0.98	0.96	0.96	0.97
August	1.56	1.43	1.28	1.15	1.05	0.98	0.93	0.91	0.92	0.94	0.97
September	1.32	1.18	1.06	0.97	0.91	0.87	0.86	0.87	0.90	0.93	0.97
October	1.06	0.96	0.89	0.84	0.82	0.82	0.83	0.86	0.90	0.94	0.98
November	0.88	0.82	0.79	0.77	0.78	0.80	0.84	0.89	0.93	0.97	0.99
December	0.77	0.75	0.74	0.76	0.79	0.83	0.89	0.94	0.98	1.01	1.01

Daraktchieva Z (2017)

To derive the seasonally corrected average multiply the occupancy weighted mean for a dwelling by the factors based on the month in which the measurement started and the duration of the measurement, rounded to the nearest month.

Example:

A 97-day measurement starting on May 5th, measured average radon concentration 46 Bq m^{-3}

Start Month = May

Duration = 3 months

Seasonal correction factor = 1.37

Seasonally corrected radon level = 46 x 1.37 = 63 Bq m^{-3}

Table 2: Factors to apply when calculating annual average radon concentrations in dwellings with single results

Living area and bedroom situated on	Only living room result	Only bedroom result
Different floors	0.79	1.25
Same floor	0.95	1.04

Daraktchieva Z (2017-2)

Table 3: Initial advice to be given to householders on the basis of the estimated annual average radon concentration in a dwelling

Estimated annual average radon concentration	Advice
Less than 100 Bq m^{-3}	Remedial measures not required
100 - 200 Bq m^{-3}	Consider installing remedial measures If remedial measures installed, then retest to check effectiveness
Greater than or equal to 200 Bq m^{-3}	Install remedial measures and retest to check effectiveness

McColl et al (2010)

Table 4: Advice to be supplied to employers on the basis of the highest annual average radon concentration in the building

Annual average radon concentration	Advice
Less than or equal to 300 Bq m^{-3}	IRR17 do not apply. No radon controls are required.
Greater than 300 Bq m^{-3}	IRR17 apply. Action is required to reduce radon levels or manage exposures You must also notify HSE of these results

Appendix A Model validation manual

RADON VALIDATION SCHEME MANUAL FOR SUPPLIER X

This document describes how Supplier X meets the requirements for validation of suppliers making measurements of radon in dwellings as set out in PHE-CRCE-xxx.

Paragraph numbering follows that in the report.

Appendices attached:

1.	Description of detector and its use	Published paper
2.	Preparation and handling	protocol QA AB/16
3.	Acceptance criteria	protocol QA AB/17
4.	Production	protocol QA AB/18
5.	Reception, dismantling	protocol QA AB/19
6.	Etching	protocol QA AB/20
7.	Counting	protocol QA AB/21
8.	Calibration	protocol QA AB/22
9.	Calculation and reporting	protocol QA AB/23
10.	Records of competence of staff	protocol QA AB/24
11.	Complaints and anomalies	protocol QA AB/25

Description of detector: See appendix 1.

Description of procedure for assessing radon exposure: See appendix 1.

Intended application: Measurements of radon in dwellings and workplaces.

Paragraph 5: Organisation and management

5.1 Standard procedures ensure that this requirement is met. The laboratory manager is A, and the deputy is B.

5.2 Standard procedures ensure that this requirement is met.

5.3 Standard procedures ensure that this requirement is met.

Paragraph 6: Staff records

6.1 Standard procedures ensure that this requirement is met.

6.2 The appendices attached fully document the procedures used. Staff are required to follow these procedures. New staff are trained in the procedures before handling detectors used in buildings.

6.3 Standard procedures ensure that this requirement is met. See appendix 10.

Paragraph 7. Quality systems

7.1 Standard procedures ensure that this requirement is met. See appendices.

7.2 Standard procedures ensure that this requirement is met.

7.3 Standard procedures ensure that this requirement is met. Departures from standard procedures are reported to the manager or their deputy for a decision on action.

7.4 Standard procedures ensure that this requirement is met.

Paragraph 8. Laboratory equipment and environment

8.1 Standard procedures ensure that this requirement is met.

8.2 Standard procedures ensure that this requirement is met.

8.3 Standard procedures ensure that this requirement is met.

8.4 Standard procedures ensure that this requirement is met.

8.5 Standard procedures ensure that this requirement is met.

8.6 Standard procedures ensure that this requirement is met.

8.7 Standard procedures ensure that this requirement is met.

Paragraph 9. Handling of detectors

9.1 Standard procedures ensure that this requirement is met. Detectors are uniquely coded with a dot code, and records of their placement are kept on a computer database which is backed up each day.

9.2 Standard procedures ensure that this requirement is met.

9.3 Standard procedures ensure that this requirement is met.

9.4 Detectors are not re-used.

9.5 Standard procedures ensure that this requirement is met.

Paragraph 10. Records of operation

10.1 Standard procedures ensure that this requirement is met.

10.2 Standard procedures ensure that this requirement is met.

10.3 Standard procedures ensure that this requirement is met.

10.4 Standard procedures ensure that this requirement is met.

10.5 Standard procedures ensure that this requirement is met.

Paragraph 11. Complaints and anomalies

11.1 Standard procedures ensure that this requirement is met.
See appendix 11.

11.2 Standard procedures ensure that this requirement is met.

11.3 Standard procedures ensure that this requirement is met.

Paragraph 12. Measurement protocols and reporting procedures

12.1 Standard procedures ensure that this requirement is met.

12.2 Standard procedures ensure that this requirement is met.

Dwellings

12.3 Standard procedures ensure that this requirement is met.

12.4 Standard procedures ensure that this requirement is met.

12.5 Standard procedures ensure that this requirement is met.

12.6 Standard procedures ensure that this requirement is met.

12.7 Standard procedures ensure that this requirement is met.

12.8 Standard procedures ensure that this requirement is met.

12.9 Standard procedures ensure that this requirement is met.

12.10 Standard procedures ensure that this requirement is met.

12.11 Standard procedures ensure that this requirement is met.

12.12 Standard procedures ensure that this requirement is met.

Workplaces

12.13 Standard procedures ensure that this requirement is met.

12.14 Standard procedures ensure that this requirement is met.

12.15 Standard procedures ensure that this requirement is met.

12.16 Standard procedures ensure that this requirement is met.

12.17 Standard procedures ensure that this requirement is met.

12.18 Standard procedures ensure that this requirement is met.

12.19 Standard procedures ensure that this requirement is met.

12.20 Standard procedures ensure that this requirement is met.

12.21 Standard procedures ensure that this requirement is met.

Date (Signed) Manager

Appendix B Model placement instructions for radon detectors in dwellings

Do

- Read the position on the flat side of each detector to ensure that they are placed correctly in the Living Area and Bedroom locations
- Put them in their correct position as soon as you receive them
- Place them at around breathing height (1 to 2 metres off the ground)
- Place them on a shelf, noticeboard, bedside table or similar location
- Hang them from their loop if convenient
- Place them any way up
- Use the placement sheet to record the date they were placed and removed
- Leave the detectors in position until the specified removal date

Don't

- Place the detectors:
    - on the floor
    - in draughts, for example window sills or mantle shelves
    - near sources of heat or tied to hot pipes, for example radiator covers
    - inside cupboards or drawers
    - in direct sunlight
    - in close contact with water, for example by a sink
    - on top of electrical equipment or radiators, for example the TV
- Leave them in their packaging
- Attempt to open the detectors
- Remove the barcode labels
- Use adhesive pads or BluTack™ to hold the detectors in place
- Move the detectors to another location during the measurement period

Appendix C Model placement instructions for radon detectors in workplaces

Do

- Read the position on the flat side of each detector to ensure that they are placed in the correct locations
- Put them in their correct position as soon as you receive them
- Place them at around breathing height (1 to 2 metres off the ground)
- Place them on a shelf or noticeboard
- Hang them from their loop if convenient (eg use cable ties to secure them to racking)
- Place them any way up
- Use the placement sheet to record which detector went in which position (with extra details as required), use room numbers, avoid using occupant names
- Use the placement sheet to record the date they were placed and removed
- Leave the detectors in position until the specified removal date
- Consider using 'Do Not Move' labels if there is a risk of displacement

Don't

- Place the detectors:
    - on the floor
    - in ceiling voids, pipes, drains or ducts
    - in draughts
    - near sources of heat or tied to hot pipes
    - inside cupboards or drawers
    - in direct sunlight
    - in close contact with water
    - on top of electrical equipment or radiators
- Leave them in their packaging (unless a special, water-resistant bag has been supplied)
- Attempt to open the detectors
- Remove the barcode labels

- Use adhesive pads or BluTack™ to hold the detectors in place
- Move the detectors to another position during the measurement period

Appendix D Example calculations of the annual average radon concentration in a dwelling

The estimate of the annual average radon concentration for a dwelling uses the result for each individual detector seasonally corrected and weighted to give the result in Bq m^{-3} for the annual average exposure of the occupant of the dwelling. An example is given below.

Living area radon result: **L** Bq m^{-3} (Becquerel per cubic metre of air)

Bedroom result: **B** Bq m^{-3} (Becquerel per cubic metre of air)

Seasonal correction factor from Table 1: **S**

Occupancy factor for homes[1] is defined as 42% of the time spent in the living area and 58% of the time spent in the bedroom.

Annual average radon concentration: ((L x S) x 0.42) + ((B x S) x 0.58) Bq m^{-3}

Where a single detector result only is available, the calculation is modified. See below:

Living area result only

Living area radon result: **L** Bq m^{-3} (Becquerel per cubic metre of air)

Bedroom result: **not available** Seasonal correction factor from Table 1: **S**

Single result correction factor from Table 2: **R_{SING}**

Annual average radon concentration: ((L x S) x R_{SING}) Bq m^{-3}

Bedroom result only

Bedroom result: **B** Bq m^{-3} (Becquerel per cubic metre of air)

Living area radon result: **not available**

Seasonal correction factor from Table 1: **S**

Single result correction factor from Table 2: **R_{SING}**

Annual average radon concentration: ((B x S) x R_{SING}) Bq m^{-3}

1. Daraktchieva Z. Review and Update of Occupancy Factors for UK homes, CRCE report, Manuscript submitted for publication.

Appendix E Placement protocols for non-domestic situations

Use the following table to decide how many detectors are required under each circumstance for workplace testing:

Table 1: Radon monitoring density for different types of workplace

Workplace type*	Number of monitors	Examples
Office (individual or small), classrooms	One per 100 m^2, generally corresponds to between a half and third of all ground floor rooms	Banks, small shops, professional practice (solicitors, etc), residential homes, schools
Open plan office, and retail or workshop up to about 1000 m^2, also public access areas	One per 250 m^2	Administrative and call centres, light industry, hotels, libraries
As above, up to 5000 m^2	One per 500 m^2	Large retail, etc
Very large areas of several thousand m^2	One for each distinct area with obviously different environmental conditions, not less than 1 per 1000 m^2.	Manufacturing or process plant, warehouses
Basements	One in each separate room, section or area irrespective of size, if occupied more than 50 hours per year	Retail, bank and professional storage areas
Wholly underground*	As a guide at least one in each main working area, and other normally occupied areas, but seek specialist advice	Water industry, mines and caves, tunnels

* Underground workplaces are not covered by the Validation Scheme.