

## Do radon-proof membranes reduce radon levels adequately in new houses?

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**Abstract.** Current UK Building Regulations specify the installation of radon-proofing, typically by means of an impermeable membrane, in new homes constructed in Radon Affected Areas. Radon levels were measured in 64 recently-constructed dwellings in the village of Brixworth, Northamptonshire, an area designated as a Radon Affected Area in 1992, all of which were known to have had radon-proof membranes installed during construction. 11% of the dwellings surveyed were found to have radon levels in excess of the Action Level, compared with the 17% average for all homes in the area, radon-proofed or not. The results suggest that, in some 60% of the homes surveyed, installation of a membrane has not resulted in reduction of mean annual radon concentrations to below the Action Level. It is recommended that mandatory testing be introduced for all new homes in Affected Areas.

### 1. INTRODUCTION

Radon is a naturally occurring radioactive gas, which can concentrate in the built environment, including domestic properties, and which contributes around 50% to the average background radiation dose received by the UK population [1]. At high levels in uranium mines, radon has been shown to be associated with increased risk of lung cancers in miners. Radon has a variable occurrence, and extrapolation from the miners' data has suggested that residents of high-radon areas are similarly at increased risk from lung cancer [2]. A meta-analysis of eight national epidemiological studies by Lubin and Boice [3], a case-control study in the South West of England [4] and, most recently, extensive collaborative analyses of individual data from 13 European [5] and from 7 North American case-control studies [6], all support this view.

In the UK, the National Radiological Protection Board (NRPB) has established an Action Level of 200 Bq m<sup>-3</sup> for domestic properties. The NRPB has also declared a number of Radon Affected Areas, where study indicates that over 1% of the housing stock would have radon levels greater than the Action Level. Northamptonshire is such an area [7].

Successive iterations of the UK Building Regulations governing the construction of new dwellings [8] require that "precautions shall be taken to avoid danger to health and safety caused by substances found on or in the ground to be covered by the building". Geographical areas requiring provision of protective measures against radon, and recommended technical solutions, are discussed in documentation published by the UK Building Research Establishment (BRE) [9], and since 1992, all new houses in such areas must be built with radon protection. Secondary protection, appropriate to areas of moderate radon levels, comprises the use of a radon-proof membrane as the damp-proof course, modified by the inclusion of a cavity tray, to which the membrane is sealed, and "weep-holes" for drainage at the base of the cavity wall.

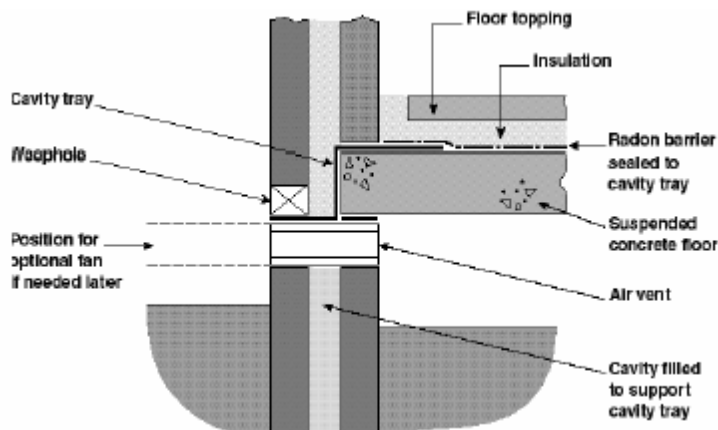


Figure 1: Possible working detail for full radon protection in a suspended concrete floor, showing positioning of membrane (BRE) [9].

In high radon areas, full protection, comprising a membrane supplemented with additional de-pressurisation measures such as a sump (without a pump) or air-bricks, is required. Figure 1 shows a constructional suggestion for full radon protection in a building with a suspended concrete floor [9]. Published guidance from BRE indicates that the minimum specification for the radon-proof membrane is 300  $\mu\text{m}$  polythene sheet.

UK practice does not require a radon test in newly constructed homes, and property developers rarely have an effective procedure that informs buyers that the area is radon affected, or that radon preventative measures have been taken [10]. This study assesses whether radon-proof membranes provide sufficient radon reduction, and whether post-construction testing is required.

## 2. METHODOLOGY

Brixworth, a large village in Northamptonshire situated in postcode area NN6 9, is an area where BRE guidance mandates the provision of full radon protection, and studies by the UK National Radiological Protection Board (NRPB) [11] show that 17.7% of houses have radon levels above the action level. Since 1992, a large development comprising 444 new houses has been built in Brixworth by three large-scale speculative builders. In compliance with current legislation, all of these were constructed with radon-proof membranes. Considerable development of the village had also occurred before 1992, with similar housing built by the same builders, but without protective membranes.

As a result of extensive contact with residents in this development, 105 householders expressed interest in participating in the programme and in receiving free radon tests in their properties. However, following counselling on the implications of the programme, 37 householders declined to proceed, leaving a population of 68 properties for testing.

Houses were monitored for radon using track-etch detectors deployed in accordance with the NRPB Measurement Protocol [12]. This uses two track-etch detectors, exposed for nominal three-month periods, one in the bedroom, one in the main living area. The protocol calculates a weighted average of the two readings, the bedroom being assigned a weighting of 0.55, the living room 0.45, reflecting the relative occupancies. In practice, all tests had an exposure time of  $90 \pm 2$  days. The weighted average of the two measurements was seasonally corrected and compared to the Action Level.

In previous work during April and May 2000, the occupants of 100 new homes on the same estates had been asked to complete a structured questionnaire on their knowledge of the risks of radon. 73 householders were interviewed (73%).

## 3. RESULTS

68 households returned detectors, of which 4 were spoiled, leaving 64 usable results. As shown in Figure 2, the results have a highly lognormal distribution ( $r = 0.83$ ), showing that the sample is not biased. 7 houses (11%) had radon levels above the Action Level.

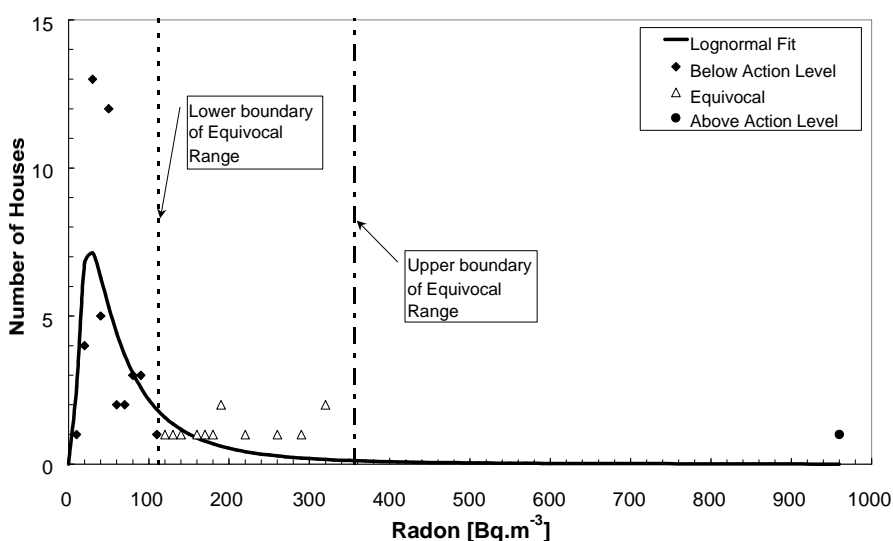


Figure 2: Distribution of radon levels found in Brixworth, with fitted lognormal distribution

A recent detailed study by our group [13] has shown that, where 3-month track-etch detector exposures are used to assess whether houses are above or below the domestic Action Level of  $200 \text{ Bq}\cdot\text{m}^{-3}$ , results between  $112 \text{ Bq}\cdot\text{m}^{-3}$  and  $356 \text{ Bq}\cdot\text{m}^{-3}$  must be regarded as equivocal and the measurement should be

repeated. For indicated radon levels in excess of  $356 \text{ Bq}\cdot\text{m}^{-3}$ , the house has radon levels that are definitely abnormal; for indicated levels below  $112 \text{ Bq}\cdot\text{m}^{-3}$  the radon levels are definitely low. In this study, 57 (73%) of the houses were below  $112 \text{ Bq}\cdot\text{m}^{-3}$ , and consequently safe. 16 houses (25%) returned results within the equivocal range and would therefore, in practice, be repeated, while one house (1.6%) returned a radon level that was definitely abnormal.

Analysis of the questionnaire results showed that 53 of 64 respondents (83%) had not been informed by their property developer, either of the radon issue or that their house had been built with radon precautions. Although 41 of 73 (56%) were aware of the health risks of radon, a large minority, 34 of 71 (48%), did not know that Northamptonshire was a designated Radon Affected Area. 34 respondents had moved to Brixworth from outside the county, although not all were unaware of the radon issue. Finally, despite living in a Radon Affected Area, 60 of 72 respondents (83%) had not tested their house for radon. These results, summarised in Table 1, showed little difference from a similar survey of 133 householders in new homes in East Northamptonshire conducted a year earlier [10]. The results suggest that there is limited awareness of the radon issue.

Table 1: Questionnaire administered to occupants of new homes in Brixworth, Northamptonshire and in East Northamptonshire District

	Brixworth 2000 (%)			East Northamptonshire 1999 (%)		
	Yes	No	Don't Know	Yes	No	Don't Know
Is radon gas a health risk?	56	15	29	68	23	9
Is radon a problem in your part of Northamptonshire?	42	10	48	33	8	59
Has your house been tested for radon?	17	83	0	9	91	0
Were you clearly informed by the developers about the radon protection measures in your house?	15	83	2	13	87	0

#### 4. DISCUSSION

The nature of the study meant that it was not possible to make direct comparison with a control group of houses, constructed in the same location but without membranes. However, NRPB studies showed that 17.7% of the existing houses in the local area (Brixworth and some adjoining villages) would be expected to exhibit radon levels in excess of the Action Level [7], and this figure was adopted as an alternative reference level.

If a radon-proof membrane installed during construction were fully effective, then all radon results would be expected to be below the Action Level. However, as seen above, the present study indicates that 11 % of houses constructed with anti-radon membranes have mean annual radon concentrations above the Action Level, suggesting that the membranes provide inadequate protection in around 60% of cases. These results suggest that a total of 27 of the 444 new homes in Brixworth might have radon concentrations above the Action Level. In Northamptonshire as a whole, where 6.3% of existing homes are over the Action Level, 3196 new houses were built in 2002/3, with similar numbers in preceding years. Applying the results found here, around 120 of the houses built in 2002/3, and around 1500 of those built since 1992, will have radon concentrations over the Action Level.

Synnott *et al.* [14] performed a comparable study in two separate areas in the Irish Republic, where Building Regulations require houses commenced after July 1998 to have an inactive radon sump [15]. In High Radon Areas this has to be supplemented by installation of a BBA Accredited Membrane across the entire footprint of the house. Their results were similar to those obtained from this study, with 11 out of 90 houses with membranes (12%) being over the Action Level in an area where 27% of existing dwellings overall exceeded this figure, and 9 houses out of 44 with membranes (20%) in an area where 45% of dwellings exceeded the Action Level. In each case, the most likely cause of these results is damage to the membrane during building construction, but may also be due to alterations to the house after a completion, or settling of the house.

The questionnaire results suggest that occupiers of these new homes have limited awareness of the radon issue and, in consequence, are unlikely to test their homes.

The current measurement protocol in the UK uses track-etch detectors with a three-month exposure period. This does not provide a sufficiently rapid response to be used by the builder prior to the sale and occupation of the house. Our group has recently evaluated the accuracy of seven-day measurements using a variety of different short-term detector technologies, and has shown that use of these is realistic, although they have a higher variance and a larger equivocal range. The results of this work [13, 16] suggests that these short-

term techniques are suitable to be adopted as a mandatory assessment by the builder, prior to releasing the house to the purchaser.

However, radon levels have been shown to be significantly different in an occupied home than in one that is unoccupied [17], and it may therefore be more appropriate to wait until shortly after the house-holder moves in before making a measurement. In this case, the National Housing Builders Council (NHBC) guarantee should ensure that the cost of any remediation (such as fitting a pump in the sump) is borne by the builder, and not the occupier.

The membrane also acts as a damp-proof course and prevents access of spores present in the underlying ground, which can cause asthma and other health-related problems. Therefore, poorly-installed or absent membranes can also result in other health issues.

UK Building Regulations are enforced by local council Building Inspectors, who should visit the site to assess compliance during the various stages of construction. There is some evidence, which this pilot study did not assess, that this inspection process is inconsistent across the UK and that it can, on occasions, be inadequate or non-existent [18]. It could, therefore, be argued that a stricter inspection regime would improve the success rate of radon-proof membrane installation, and would address other building issues.

In November 2004, the Housing Health and Safety Rating System was introduced in the UK [19]. This addresses a range of issues, including radon, and gives the Environmental Health Inspectors powers to inspect premises and assess the health risks from any identified hazards. At present, this system is being applied to rented accommodation and Housing Association properties. The associated guidance [20] specifies the requirement that "all new buildings in radon-affected areas should be constructed to achieve radon levels as low as possible", and notes that "and, as radon levels can vary widely between apparently identical dwellings, the only way to determine whether or not there is a threat to health is by measurement." However, it falls short of specifically requiring such measurements in new homes.

## **5. CONCLUSIONS**

This pilot study suggests that the radon-proof membranes currently incorporated in new houses constructed in the UK do not always provide adequate radon protection. Although the fraction of houses with radon concentrations in excess of the Action Level was reduced relative to that found in existing housing without radon precautions, the proportion is still around 50%, consistent with the findings of an Irish study assessing two geographically separated areas.

An improved inspection regime may reduce the percentage of failed membranes but, although affected houses can only be identified by measuring radon levels, the UK currently has no requirement to test radon levels in newly-constructed houses. However, the questionnaire results show that householders occupying newly-constructed homes in designated Radon Affected Areas have limited awareness of the radon issue, and have not tested their homes. It is therefore incumbent on the developers to test the property as fit for purpose before handing it over.

This study indicates that there is strong evidence to support the case for radon measurements in new houses once construction is complete in order to identify those where the membrane provides inadequate protection. It is therefore recommended that before releasing a newly-constructed house, its builders should be required to perform a 7-day radon measurement, once the house is completed and with the central heating operative, using an approved protocol, to confirm that it has low radon levels.

Since there is a large inventory of homes constructed in Radon Affected Areas since 1992 and therefore incorporating protective membranes, the present results highlight the need to test these retrospectively, to identify those in which the membrane is ineffective.

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