CZ0129241

BGS RADON PROTECTIVE MEASURES GIS

Don Appleton & Keith Adlam, British Geological Survey, Keyworth, Nottingham NG12 5GG, England

Introduction

The accurate delineation of those areas in which radon exceeds reference levels in buildings is crucially important to the radon policies of many governments. Accurate mapping of radon-prone areas will help to ensure that the health of occupants of new and existing dwellings and workplaces is adequately protected. Radon potential maps have important applications, particularly in the control of radon through planning, building control and environmental health legislation (Appleton & Ball, 1995; in press). Radon potential maps are used (i) to assess whether radon protective measures may be required in new buildings; (ii) for the cost-effective targeting of radon monitoring in existing dwellings and workplaces; and (iii) to provide a radon assessment for homebuyers and sellers. It is important, however, to realise that radon levels often vary widely between adjacent buildings due to differences in the radon potential of the underlying ground as well as differences in construction style and use. Whereas a radon potential map can indicate the relative radon risk for a building in a particular locality, it can not predict the radon risk for an individual building.

Identification of development sites where radon protection required in new dwellings

Potential options for targeting radon protective measures in new dwellings through the Building Control (BC) system include:

BC-1: Universal application of radon protective measures.
BC-2: Mapping defines need for protective measures.
BC-3: Mapping defines need for protective measures. Site investigation may be used to permit relaxation of regulation if the developer wishes to use this option.
BC-4: Universal site investigation defines the need for protective measures.

Whereas it might be considered that Option BC-1 would involve unnecessary expenditure in much of England and Wales, blanket installation of a radon barrier would actually involve minimal additional cost to new dwellings (about 50-100) and would result in benefits to the development other than radon protection. Universal application of radon protective measures would assist in securing the health of people in new buildings and at the same time reduce the risk of blight and undue personal anxiety. It should be noted, however, that although cost is a consideration in the assessment of regulatory proposals, it is not the deciding factor.

Options BC-2 and BC-3 both require maps that can be readily used by Building control bodies, developers and others concerned with radon protective measures. In the UK, practical options currently available for identifying areas or sites where new development requires protection include (a) National Radiological Protection Board (NRPB) grid square radon potential maps (Lomas et al., 1996), (b) geological radon potential maps, (c) a combination of NRPB grid square and geological radon potential maps and (d) site investigation.

In Option BC-3, which applied to the 1996 interim guidance for new dwellings in England and Wales, the developer had the option of applying for relaxation of the requirement for measures based on the results of a geological site investigation (incorporating desk studies, ground investigations and soil gas radon measurements). The site investigation and report would have needed to be executed by a suitably qualified geologist. Technical protocols for soil gas radon measurements and assessment of results were not clearly defined in the interim guidance. Indeed, the reliability of radon site investigations was uncertain at that time. In most cases it is impractical to assess the severity of a radon problem on a particular site accurately until the building has been constructed and occupied, therefore precautions should be taken in areas where high radon levels have been predicted by the mapping programme. In the UK, radon site investigation techniques are not yet reliable enough to be incorporated into guidance (BGS, 2000a). In the interim guidance, it was also noted that the use of the site investigation option to obtain relaxation of requirement for measures is unlikely to be a cost-effective option unless the development is for more than 10-20 dwellings.
In the UK it has been concluded that a requirement for a radon site investigation to be carried out on all new development sites (Option BC-4), as is currently required in Sweden, for example, would lead to unnecessary expenditure for both developers and Building Control authorities (BGS, 2000a,b).

Mapping radon potential on the basis of house radon and geology.

In the UK radon potential maps generally indicate the probability that new or existing houses will exceed a radon reference level, which in the UK is termed the radon Action Level (200 Bq m^{-3}). In other countries, geological radon potential maps predict the average indoor radon (e.g. Gundersen et al. 1992) or give a more qualitative indication of radon risk (e.g. Kemski et al. 1996). However, since the purpose of radon potential maps in the UK is to indicate radon levels in buildings, maps based on actual measurements of radon in buildings are preferable to those based on radiometric, geochemical or pedological data. It is also relatively inexpensive to map by this method as passive radon detectors can be distributed by post (Miles 1994). Radon potential maps based on indoor radon data grouped by geological unit have the capacity to accurately estimate the percentage of dwellings affected together with the spatial detail and precision conferred by the geological map data (Miles & Ball 1996; BGS, 2000a).

A detailed evaluation was carried out of the relative advantages and disadvantages of using grid square radon potential mapping and geological radon potential mapping to designate areas where radon protective measures are required (BGS, 2000a). Recommendations for the production of a radon potential maps for use by building control and planning systems in England and Wales have evolved from an evaluation of mapping options in areas with many house radon measurements (Derbyshire and Northamptonshire) and also in selected areas with relatively few house radon measurements (BGS, 2000a). This research demonstrated that the maps in *Radon: guidance for radon protective measures in new dwellings* (BR211, BRE 1991 as revised 1992) have limitations that could result in radon protection not being installed where required and vice versa. It was concluded that geological radon potential mapping in general provides the best spatial detail and accuracy as this method relates radon risk to geology - identified as the most important overall control on the concentration of radon in dwellings (Appleton and Ball, 1995). A geological radon potential mapping exercise for England and Wales was carried out using the new BGS 1:250,000 scale lithostratigraphic

(bed rock) and the 1:625,000 scale drift digital map data which became available in November 1998.

In the UK, the BGS and the NRPB have devised a procedure to correlate radon levels in dwellings with geology without prejudicing the confidentiality undertakings given to householders and the DETR. Lognormal modelling of the indoor radon data (Miles 1998) produces estimates of the percentage of the housing stock above the UK Action Level for each combination of bedrock (solid geology) and drift (unconsolidated deposits, such as glacial sand and gravel, till, etc.) within a map sheet, grid square or administrative district. The influence of artificial features, such as worked out areas and landslips, may also be assessed in some areas.

The following methodology was used to produce 1:250,000 scale geological radon potential maps covering the whole of England and Wales and twenty 1:50,000 scale geological radon potential maps of some of the most radon prone areas of England.

- Using *Bentley Geographics* running as an addition to *Bentley Microstation 95*, a point topology was built using the dwelling geographical co-ordinates. Area topologies were built using BGS solid and drift geological polygons. The point-in-polygon overlay process was used to add solid and drift geological codes to each dwelling location point and the co-ordinates, geological codes and map sheet numbers were loaded back to an *Access* database.

- The National Radiological Protection Board (NRPB) added house radon data and removed location co-ordinates from the file to preserve confidentiality. Lognormal modelling (Miles, 1998; Miles and Ball, 1996) was then carried out by BGS on the house radon data using *dBase* and *Excel* macros. This process produced an estimate of the percentage of homes with radon exceeding the Action Level for each combination of solid, drift and artificial codes within a map sheet and 5-km grid square. In general, the accuracy of these estimates is proportional to the number of radon measurements.

- Solid, drift and artificial topologies were built together using *Bentley Microstation 95* and attributed with radon potential values grouped using the following class limits: 3-5%, 5-10%, 10-30% and >30% probability of being above the Action Level.

Radon Protective Measures GIS

The BGS Radon Protective Measures Geographical Information System (RPM GIS) has been developed to provide Geological Assessments (RPM site reports) as part of the revised guidance for dealing with radon in new dwellings (BRE, 1999). The RPM GIS currently comprises 1:250,000 scale geological radon potential data with more detailed information for twenty 1:50,000 scale geological map sheets covering the most radon-prone parts of England and Wales (Figure 1). The GIS runs under *Arcview* and is being upgraded to 1:50,000 scale as new digital maps become available through the BGS DIGIMAP programme.

Radon site reports

A new service to provide advisory reports on the requirement for radon protective measures in new dwellings and extensions has been launched by the British Geological Survey (http://www.bgs.ac.uk/radon.). These reports fulfil the requirements of the Stage 2 Geological Assessment outlined in revised guidance on the protection of new dwellings from radon gas (BRE, 1999). The revised guidance brings together the best practice for protecting new homes against radon. It updates previously published guidance, details measures that must be incorporated in new dwellings and defines the geographical areas in England and Wales where radon protection is necessary. In addition to Cornwall and Devon and parts of Somerset, Northamptonshire and Derbyshire - which were covered in previous guidance - the guidance identifies new areas where radon protection will be needed. These are parts of the Yorkshire Dales; parts of Wales and the Welsh Border; North Oxfordshire; parts of the Midlands adjacent to the currently delineated areas in Derbyshire; Northamptonshire; parts of Gloucestershire, the Lake District and Northumberland. There are also a few scattered areas in south-east England where these measures need to be applied.

There is a flow chart in BR 211(BRE, 1999) that sets out a two-stage procedure to help determine the level of radon protection required in new dwellings. In Stage 1, the 5 km grid square radon potential maps produced by the National Radiological Protection Board (NRPB) are used to make the primary determination of the level of radon protection needed. In Stage 2, a second series of maps produced by the BGS is used to decide whether it is necessary to consider upgrading the requirement for protection indicated by Stage 1. This has the objective of avoiding cases of underprotection that might occur had the guidance depended solely on the average radon level in the 5 km grid square indicated by the NRPB maps. The BGS maps show those 5 km grid that are underlain, completely or in part, by geological units that require either basic or full protection to be installed in new dwellings.

A geological assessment may need to be carried out where the site falls within a shaded grid square on the BGS map (Figure 1). The GIS generates automatically a radon site report after the site location details (based on National Grid co-ordinates) have been entered. The GIS checks whether a site is on or close to a geological unit which potentially exceeds the action levels for either basic or full radon protection. The search area (circle or rectangle) for a site is increased by a buffer zone of 50 m in areas with 1:50,000 scale data and 500m in areas with 1:250,000 scale data. This is to allow for potential inaccuracies in the position of the geological boundaries. The advisory report indicates the highest level of protection required within the buffered search area. An abstract from a BGS Radon Protective Measures Site Report is given in the Appendix to this paper.

Consideration must be given to installing basic or full radon protection if the geological assessment shows that this is indicated. If a site falls within one of the shaded squares (Figure 1), it does not necessarily mean that it must have radon protection. This is because some of the grid squares contain bed rocks and unconsolidated (drift) deposits with lower radon potential than the maximum levels shown on the map. In many cases the geological radon potential varies considerably within a grid square. In other cases, only a very small area (sometimes only a few hundred square metres) with a radon potential exceeding the thresholds for basic or full protection occurs within the shaded grid square. The level of protection that might be required is thus site specific, and can be determined by reference to the relevant radon potential map in BR211 (BRE, 1999) followed by a geological assessment of the site.

Follow-up radon protective measures site reports

For most parts of the UK, a higher resolution assessment of radon protective measures requirements can be provided by the BGS. This comprises:

i. Assessment by a qualified geologist of the relevant 10,000, 1:10,560 or 1:50,000 scale geological map(s) covering the total search area from BGS archives.
ii. Precise identification of the level of radon protective measures indicated for all geological units encountered within the site and the immediately surrounding area.
iii. A map extract displaying the required radon protective measures in relation to the original site area and buffer, and any site plan provided by the client.

References

Appleton, J.D. & T.K. Ball (1995). Radon and background radioactivity from natural sources: characteristics, extent, and relevance to planning and development in Great Britain. *British Geological Survey Technical Report*, WP/95/2.

Appleton, J.D. & T.K. Ball (in press). Geological radon potential mapping. In P. Bobrowsky (ed.) *Geoenvironment mapping: methods, theory and practice.* Rotterdam: Balkema.

BGS, 2000a. Evaluation of mapping and site investigation methods for targeting areas where new development requires installation of radon protective measures. *British Geological Survey Research Report* (in preparation).

BGS, 2000b. Dealing with radon emissions in new development: Summary report and recommended framework for guidance. *British Geological Survey Research Report* RR/00/7.

BRE (Building Research Establishment) 1991. Radon: guidance on protective measures for new dwellings. *Building Research Establishment Report* BR 211.

BRE (Building Research Establishment) 1999. Radon: guidance on protective measures for new dwellings. *Building Research Establishment Report* BR 211.

Gundersen, L.C.S., E.R. Schumann, J.K. Otton, R.F. Dubief, D.E. Owen & K.E. Dickenson 1992. Geology of radon in the United States. In A.E. Gates & L.C.S. Gundersen (eds.), *Geologic Controls on Radon* Geol. Soc. Am. Special Paper 271: 1.16.

Kemski, J., R. Klingel & A. Siehl 1996. Classification and mapping of radon-affected areas in Germany. *Environment International* 22 (Suppl. 1): 789-798.

Lomas, P.R., B.M.R. Green, J.C.H. Miles & G.M. Kendall 1996. Radon Atlas of England. *National Radiological Protection Board*, Chilton. NRPB-R290.

Miles, J.C.H. 1994. Mapping the proportion of the housing stock exceeding a radon reference level. *Radiation Protection Dosimetry* 56: 207-210.

Miles, J.C.H. 1998. Mapping radon-prone areas by log-normal modelling of house radon data. *Health Physics*. 74(3): 370-378.

Miles, J.C.H. & T.K. Ball 1996. Mapping radon-prone areas using house radon data and geological boundaries. *Environment International.* 22 (Suppl. 1): 779-782.

Acknowledgements

Some of the information in this paper is derived from the results of a number of research projects carried out for the UK Department of the Environment, Transport and the Regions (DETR) by the BGS in collaboration with Chris Scivyer (Building Research Establishment

Ltd.), Philip Smith (Land Use Consultants) and Jon Miles (National Radiological Protection Board). This paper is published with the permission of the Director, British Geological Survey (NERC)

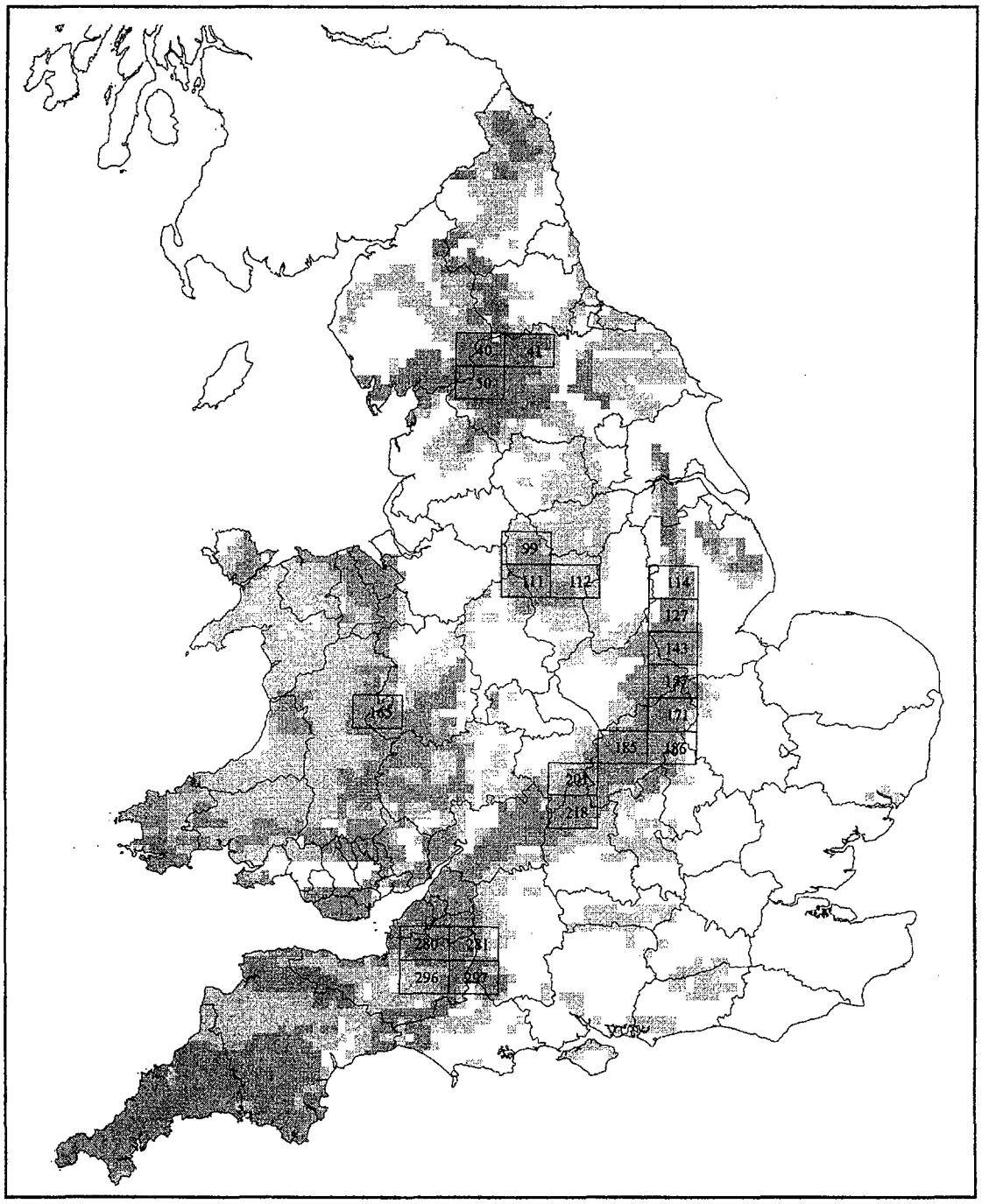
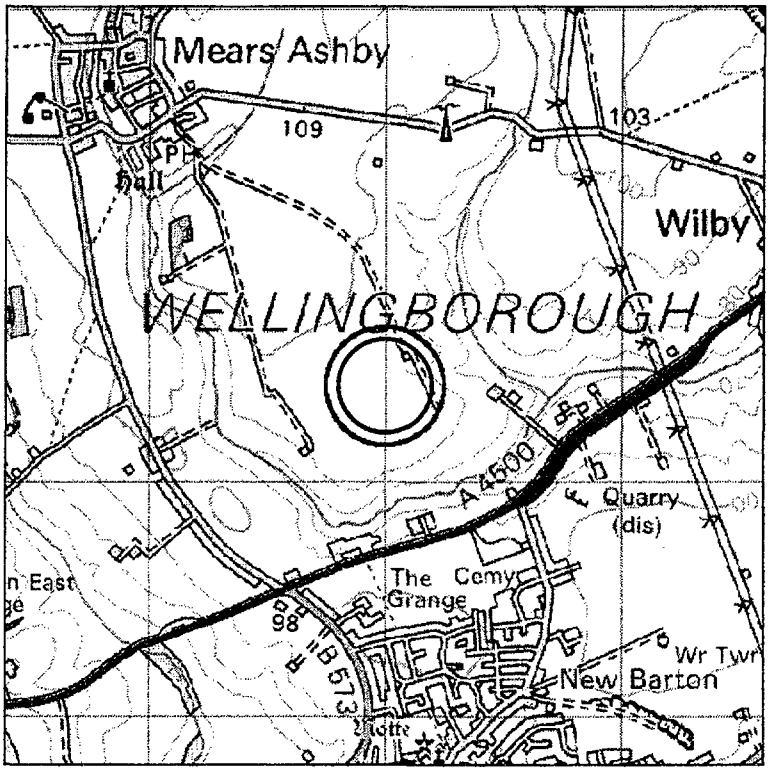


Figure 1 Areas where a geological assessment may need to be carried out to determine whether radon protective measures are required in new dwellings (adapted from Map 2, Annex B, BR211 (BRE, 1999); basic radon protection may be required if site is in a pale shaded square; full or basic radon protection may be required if site is in a dark shaded square). Also shown are the twenty map sheets for which 1:50,000 scale geological radon potential data is currently incorporated in the GIS. County boundaries reproduced with permission from the Ordnance Survey (Licence No. GD27219/1999).

APPENDIX: Abstract of Radon Protective Measures Site Report

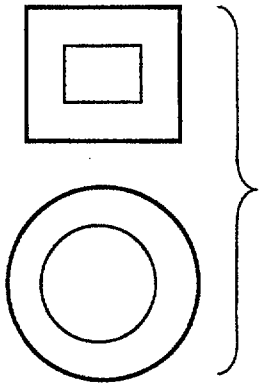
SECTION 1: LOCATION AND EXTENT OF REPORT AREA

Area centred at: *485000, 265400*
Radius of site area: *200 metres*



Topography based on the latest 1:50,000 scale Ordnance Survey Maps with the permission of The Controller of Her majesty's Stationery Office, Crown Copyright. Ordnance Survey licence number GD272191/2000. Display scale may vary.

KEY:



INNER RECTANGLE or CIRCLE defines site area (details provided by client).

OUTER LINE shows extent of TOTAL SEARCH AREA comprising the site area and automatically generated buffer zone. The requirement for radon protective measures indicated in Section 2 is based on a geological assessment of the Total Search Area.

Section 4 explains how the search is carried out

Section 2: Requirement for radon protective measures

The RPM GIS has determined that:
FULL RADON PROTECTIVE MEASURES ARE REQUIRED FOR THE REPORT AREA.

This assessment was derived from 1:50,000 scale data. In some cases a developer, property owner or their agent may consider that a more detailed geological assessment of the requirement for radon protective measures will be of value (see Section 5 for details).
Where protective measures are indicated, guidance can be found in BR211(1999) *Radon: guidance on protective measures for new dwellings.*

Section 4 explains how the assessment is carried out

Section 3: Geological units within the search area

Below is a listing, if available, of the possible combinations of Solid Geology units and overlying Drift (Superficial) Geology units within the total search area.

These have been derived (as indicated) from searches of either:
a) Combined 1:250,000 Solid and 1:625,000 Drift geology maps
b) 1:50,000 Solid, Drift and Artificial geology maps

1:50,000 data
1. Northampton Sand Formation; No drift; Not disturbed
2. Whitby Mudstone Formation; No drift; Not disturbed