20. Modelling in-house radon potential using Tellus data and geology to supplement in-house radon measurements

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It is well known that naturally occurring radon gas rising from the ground and accumulating in dwellings and workplaces is a cause of lung cancer, particularly among smokers. In the UK and Ireland, campaigns to measure and suppress radon in buildings have been proceeding for several years. This chapter considers how additional data from geological mapping and data from the Tellus surveys can improve our estimation of in-house radon potential. In the Republic of Ireland radon potential mapping has hitherto been based solely on indoor radon measurements, while in Northern Ireland indoor radon readings are supplemented with geological data. New radon modelling with Tellus airborne gamma-ray spectrometry and soil geochemistry, in combination with geological data and indoor radon measurements, has in some settings produced maps with more detailed spatial resolution. The process has identified some differences between the Tellus modelled maps and the current indoor radon maps. These should be validated with additional radon measurements, especially where the Tellus maps indicate higher radon potential and where in-house radon measurements are sparse. The Tellus-based radon maps should be used as an aid in future in-house radon measurement campaigns.

INTRODUCTION

Radon in the environment

Radon is produced by the radioactive decay of radium (^{226}Ra), which in turn is derived from the radioactive decay of the uranium isotope ^{238}U. Uranium is found in small quantities in all soils and rocks, although the amount varies from place to place. The rate of release of radon from rocks and soils is largely controlled by their uranium and radium concentrations, grain size and the types of minerals in which the uranium occurs (Appleton, 2013).

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Radon can accumulate in buildings, where it provides about 50–55% of the total radiation dose to the average person in the UK and Ireland (Watson *et al.*, 2005; O'Connor *et al.*, 2014). The most important factors controlling the migration and accumulation of radon in buildings include:

- characteristics of the bedrock and soils that affect fluid transport, including porosity and permeability;
- the construction of the building, its use and ventilation;
- environmental factors such as temperature (increased heating in buildings during the colder months causes a chimney effect which draws soil gases including radon into the property), and wind speed and direction, which can increase the chimney effect.

Radon concentrations in outdoor air in the UK and Ireland are generally low, on average 4 to 6 Bq m^{-3}, while the population-weighted average in indoor air in Northern Ireland dwellings is 19 Bq m^{-3} (Green *et al.*, 2009). The average indoor radon concentration in Ireland is 89 Bq m^{-3} (Fennell *et al.*, 2002). An extreme concentration of 49,000 Bq m^{-3} was measured at a dwelling in County Kerry.

Managing health risks

Radon decays to form radioactive particles that can enter the body by inhalation. Inhalation of these short-lived decay products of radon has been linked to an increase in the risk of developing lung cancer. Breathing radon indoors is the second largest cause of lung cancer deaths after smoking. An estimated 1100 lung cancer deaths per year in the UK were caused by radon, representing 3.3% of total lung cancer deaths (HPA, 2009). Some of the highest indoor radon concentrations found anywhere in Europe have been found in homes and workplaces in Ireland, where it is estimated that radon is linked to 150–200 cancer deaths annually (RPII and HSE, 2010). Most radon-related deaths are caused by a combination of radon and smoking.

An Action Level (AL) for radon in homes of 200 Bq m^{-3} has been established in the UK. The same concentration is called the Reference Level (RL) in Ireland. Parts of the UK with 1% probability or more of homes being at or above 200 Bq m^{-3} are designated as radon Affected Areas.

Radon potential (RP) maps are produced in Northern Ireland (Daraktchieva *et al.*, 2015) and Ireland (Fennell *et al.*, 2002) that indicate the probability that new or existing houses will exceed the AL or RL of 200 Bq m^{-3}. The maps are used (a) to assess whether preventative (protective) measures need to be installed in new dwellings and other buildings (BRE, 2001; DEHLG, 2008); (b) for cost-effective targeting of radon monitoring in existing dwellings and workplaces in order to identify buildings that need to have radon remediation measures installed; and (c) to provide a radon risk assessment for homebuyers and sellers. An RP map can indicate the relative radon risk for a building in a particular locality, but it cannot predict the radon risk for an individual building. This can only be established by having the building tested, but RP maps are an important tool for prioritising or identifying areas in which buildings should be tested.

RP maps are based on measurements in homes, but they can be used to predict the likely extent of the local radon hazard in all buildings. The information is therefore relevant to employers in assessing workplace risks. For workplaces the Action or Reference Level is 400 Bq m^{-3}, which takes into account that most people spend much more time at home than at work. Employers' responsibilities are set out for Northern Ireland in the Health and Safety at Work Regulations (HSENI, 2000) and for Ireland in the Safety, Health and Welfare at Work Act 2005 (HSA, 2005). Guidance on how to apply the radon maps in assessing workplace radon is available from the Health and Safety Executive Northern Ireland (HSENI) website, www.hseni.gov.uk. Equivalent guidance in Ireland is given by the EPA (RPII, 2008).

Data and methodology

In order to help prevent the public from having high exposures to radon, it is necessary to identify the areas most at risk. The potential for high indoor radon concentrations depends on multiple factors, including the amount of ^{226}Ra in the ground underneath buildings and the permeability of the ground. As a result, indoor radon tends to be correlated with local geology (Appleton and Miles, 2010). The probability of homes in Northern Ireland having radon concentrations above 200 Bq m^{-3} was until very recently estimated on the basis of the results of radon measurements in homes, grouped by 1 km squares where there are sufficient results in the square, or interpolated from the nearest measurements for squares where there are too few results (Green *et al.*, 2009). In Ireland, measurement data are grouped by 10 km grid squares (Fennell *et al.*, 2002). In the UK an integrated mapping method has been developed to use indoor radon results in conjunction with geological boundaries to map RP with greater accuracy and detail than is possible using the 1 km grid square RP map based solely on indoor radon measurements (Miles and Appleton, 2005; Appleton *et al.*, 2015; Daraktchieva *et al.*, 2015).

Uranium concentrations in surface rocks and soils, estimated by airborne surveys of gamma rays from ^{214}Bi, and referred to as eU (equivalent uranium), have been used to inform RP mapping in many countries. The geochemical and airborne radiometric results of the Tellus and Tellus Border Projects allow existing RP maps to be refined in Northern Ireland, the Border Region and the Tralee–Castleisland area (County Kerry). Modelling RP using the Tellus data in combination with indoor radon measurements is described below. Data collection and survey procedures are described in earlier chapters of this volume.

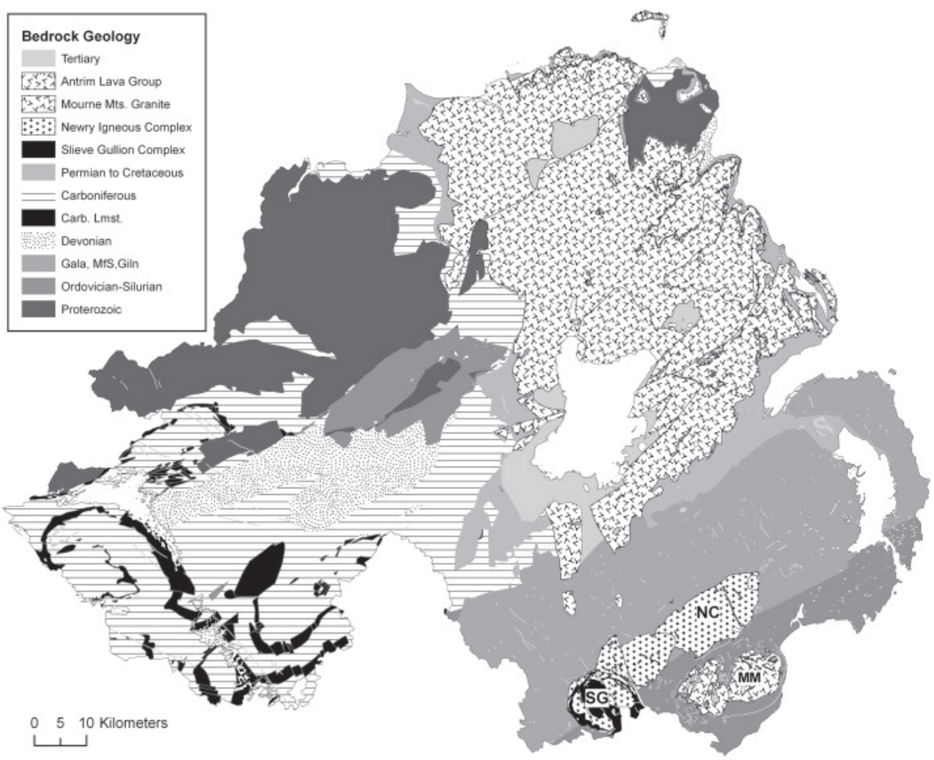

Figure 20.1. Simplified bedrock geology of Northern Ireland. MM, Mourne Mountains Granite; SG, Slieve Gullion Complex; NC, Newry Igneous Complex (BGS © NERC; Geological and topography data © Crown Copyright, 2011; Appleton *et al.* (2011a)).

Northern Ireland

Predictive modelling of relevant Tellus airborne and soil geochemical parameters (Appleton *et al.*, 2011a) was used in an attempt to refine the radon map based solely on indoor radon data and 1:250,000 scale geology (Figs 20.1 and 20.2) . National and terrain-specific linear regression models were statistically validated against the radon map based on indoor radon and geology in order to assess whether RP maps derived by predictive modelling of ground permeability, airborne gamma-ray spectrometry and soil geochemical data could usefully inform future indoor radon measurement programmes. Indoor radon measurements were available for approximately 23,000 dwellings, with accurate (±10 m) locations available for 90% of the dwellings. The average measurement density is 1.6 indoor radon measurements per km^2, although measurements are clustered both in urban areas and especially in known high-radon areas.

The RP map produced from Tellus data using separate linear regression models for different geological terrains provides the best visual and statistical agreement with the RP map based solely on indoor radon and geology (compare Figs 20.2 and 20.3). However, RP maps produced using the Tellus data appear to underestimate RP, especially where the highest RP is indicated on the indoor radon/geology RP map. For example, there are several areas underlain by Argyll Group metasediments, Gala Group greywackes, Hawick Group greywackes (e.g. Lecale peninsula), the Newry Granodiorite and Carboniferous

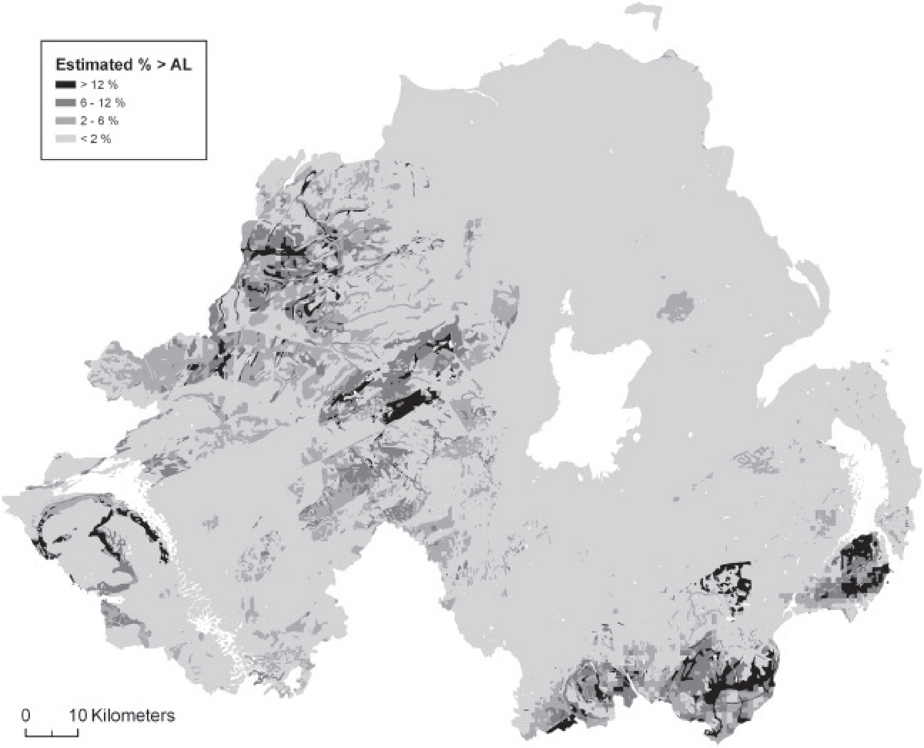

Figure 20.2. Radon potential (estimated % > AL) map based on 1:250,000 scale geology and indoor radon data (BGS © NERC; Geological and topography data © Crown Copyright, 2011; Appleton *et al.* (2011a)).

limestone where the RP estimated from the Tellus data is substantially less than that shown on the indoor radon/geology map (Figs 20.2 and 20.3). This underestimation may be because airborne eU values (calculated from ^{214}Bi, a daughter product of radon, ^{222}Rn) are in some cases reduced where the radon concentration is lower in the top 30 cm of the soil than at greater depth, as a result of the loss of radon from the surface rocks and soils to air. In Northern Ireland only 13% of the variation of indoor radon was explained by 1:250,000 scale geology, whereas geology explains 69% of the variation of airborne eU data and 83% of the variation of soil U data. So it is not entirely surprising that the agreement between the indoor radon/geology RP and RP modelled from the Tellus data in Northern Ireland is less than perfect. Subsequent to this study based on indoor radon data and 1:250,000 scale geology (Appleton *et al.*, 2011a), a new radon map has been published based on indoor radon data and more spatially accurate 1:10,000 scale digital geological data (Appleton *et al.*, 2015; Daraktchieva *et al.*, 2015).

TRALEE–CASTLEISLAND AND CAVAN AREAS, REPUBLIC OF IRELAND

Tellus Airborne gamma-ray spectrometer data for the Tralee–Castleisland area of County Kerry and part of County Cavan were compared statistically with in-house radon measurements in conjunction with geological and ground permeability data to establish linear regression models and produce RP maps (Appleton *et al.*, 2011b).

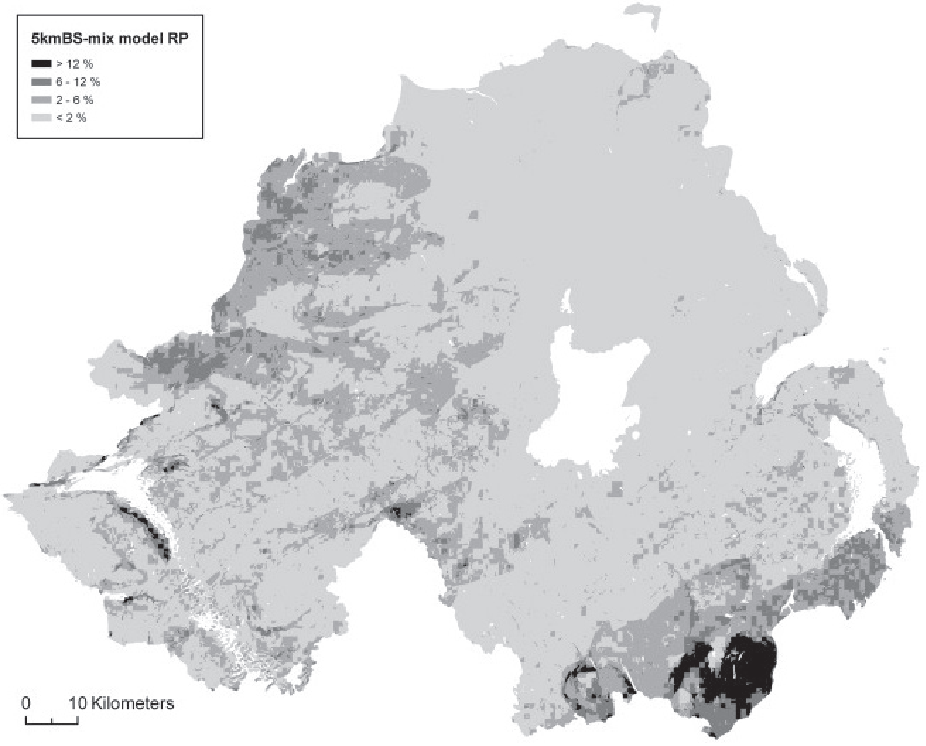

Figure 20.3. Radon potential (estimated % > AL) map modelled from eU and permeability using the 5kmBS-mix linear regression model (BGS © NERC; Geological and topography data © Crown Copyright, 2011; Appleton *et al.* (2011a)).

The best agreement between the percentage exceeding the RL (%>RL), estimated from indoor radon data and modelled RP for six townlands in the Tralee–Castleisland area is produced by models based on the Tellus eU data and ground permeability.

Different regression models were required for the four geological terrains in the Cavan area (Appleton *et al.*, 2011b). Reasonably close agreement was obtained between (a) the percentage of dwellings exceeding the RL, estimated from indoor radon data for seven townland areas and (b) modelled RP estimated from eU data using the terrain-specific models.

RP maps derived using the Tellus data show more spatial detail than the current RPII 10 km map in both Tralee–Castleisland (Figs 20.4a and 20.4b) and Cavan (see Figs 10 and 11 in Appleton *et al.*, 2011b).

THE BORDER REGION, REPUBLIC OF IRELAND

Multivariate linear regression analysis was used to determine the relationship between indoor radon probability data, airborne gamma-ray spectrometry, soil chemistry and geological parameters (Hodgson and Carey, 2013). All data were averaged within individual 1 km grid squares and correlated with indoor radon probability values expressed as a percentage exceeding the Reference Level. A subset of indoor radon measurements, not used in the model development, was used to validate the model. Modelling uncertainties

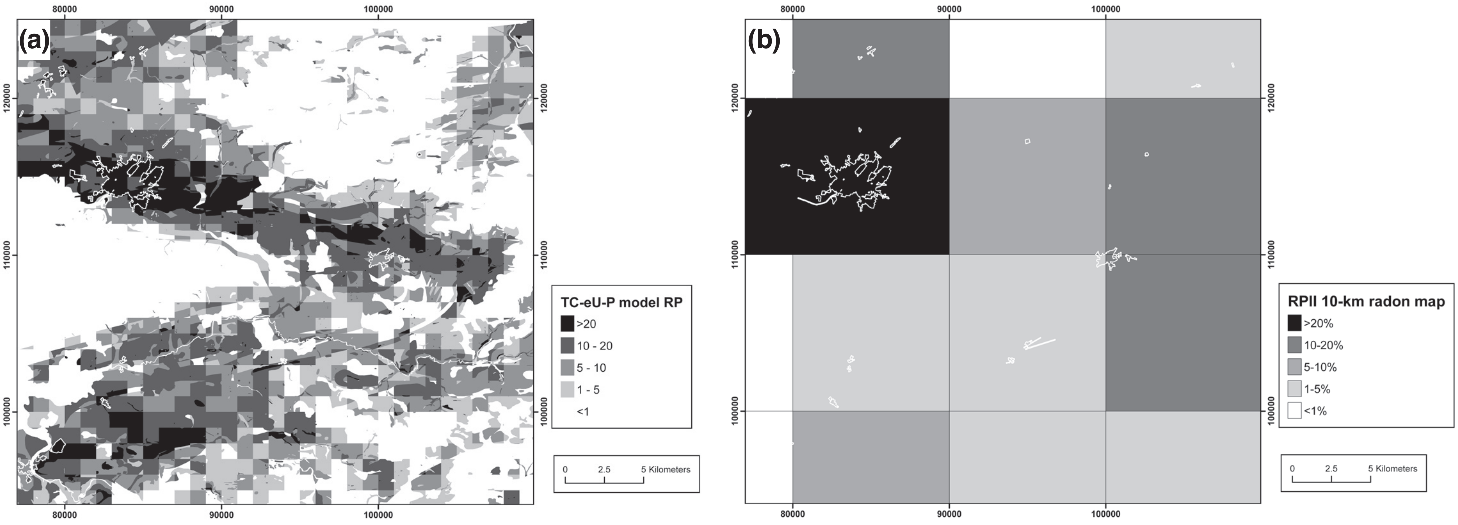

Figure 20.4 (a). Radon potential (%>RL) map of the Tralee–Castleisland area produced using the TC-eU-P linear regression model (urban areas outlined in white) (BGS © NERC; derived from geological data © GSI, 2011; some boundaries derived from data prepared by Spatial Analysis Group, TEAGASC, Kinsealy Research Centre, funded by NDP; Appleton *et al.* (2011b)). (b). RPII 10-km grid radon map of the Tralee–Castleisland area (main urban areas outlined in white; map redrawn from the data in Fennell *et al.* (2002)) (BGS © NERC; Appleton *et al.* (2011b)).

include the influence on the indoor radon measurements of (a) house type, method of construction and ventilation; (b) house location uncertainty; and (c) the small number of radon measurements. Indoor radon measurements were available for only 5010 dwellings and exact (±10 m) locations for only 10% of these.

Equivalent uranium, groundwater recharge coefficient and the degree of karstification of the mapped bedrock were identified as the only statistically significant independent variables for modelling RP using 1 km averaging. Groundwater recharge, calculated from soil thickness, permeability and the capacity of the underlying aquifer to accept recharge through fractures or porosity, was used as an indicator of total ground permeability (Hodgson and Carey, 2013). The linear regression model was applied to every grid square across the region to estimate RP (%>RL). Modelled %>RL shows generally good agreement with the RPII 10 km grid National Radon Map, but with more detailed spatial resolution.

The modelled RP map predicts a number of zones with high (>20) %>RL. Many of these agree with the existing national radon map of Ireland (Fig. 20.5), in particular with granite in Donegal (A in Fig. 20.6); Carboniferous limestones and uraniferous shales in southern Donegal, Sligo, Leitrim (B, C, D) and north County Meath (G), and finally granite and Lower Palaeozoic greywackes in northern Louth and the Cooley peninsula (F). However, previously unknown radon highs that do not correlate with the national radon map are predicted by the modelled RP map within central Sligo and Leitrim, southern Donegal and a band running through northern Monaghan (E in Fig. 20.6). These may be due to (a) the different scales of the modelled RP and national radon maps, (b) real but previously unidentified radon highs or (c) artefacts caused by high eU, karst and/or groundwater recharge values. These areas identified using the Tellus data warrant further investigation to eliminate the risk of unidentified high-risk radon areas.

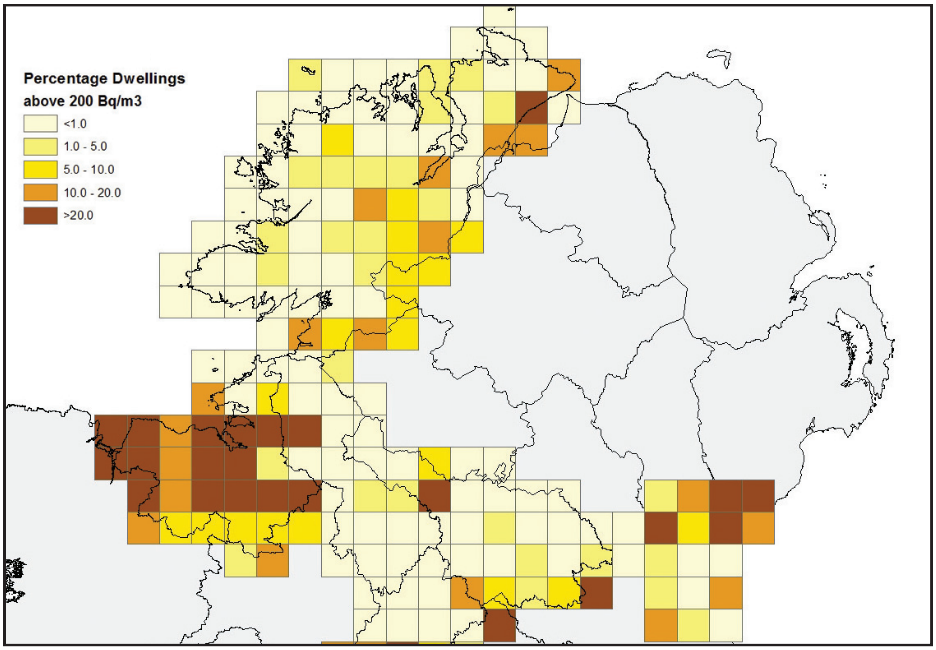

Figure 20.5. Extract for Border Region from 10 km grid National Radon Map of Ireland (© GSI, 2015; map redrawn from the data in Fennell *et al.* (2002)).

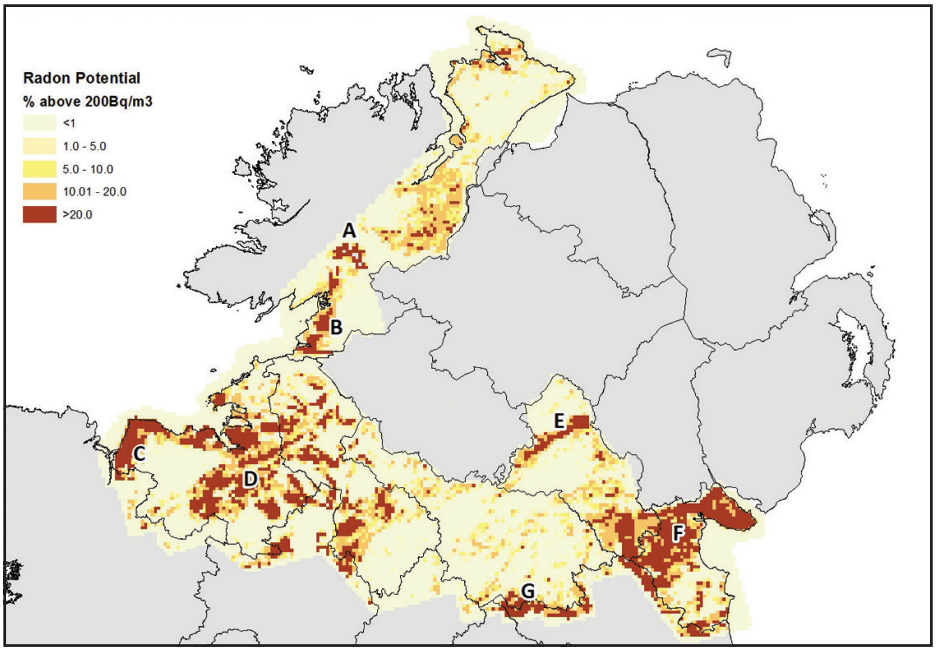

Figure 20.6 Output from model TB_RN_Mod10 for Border Region derived from eU, groundwater recharge and karst values, with anomalous zones labelled A-G; details within text (© GSI, 2015; adapted from Fig. 10, Hodgson and Carey, 2013))

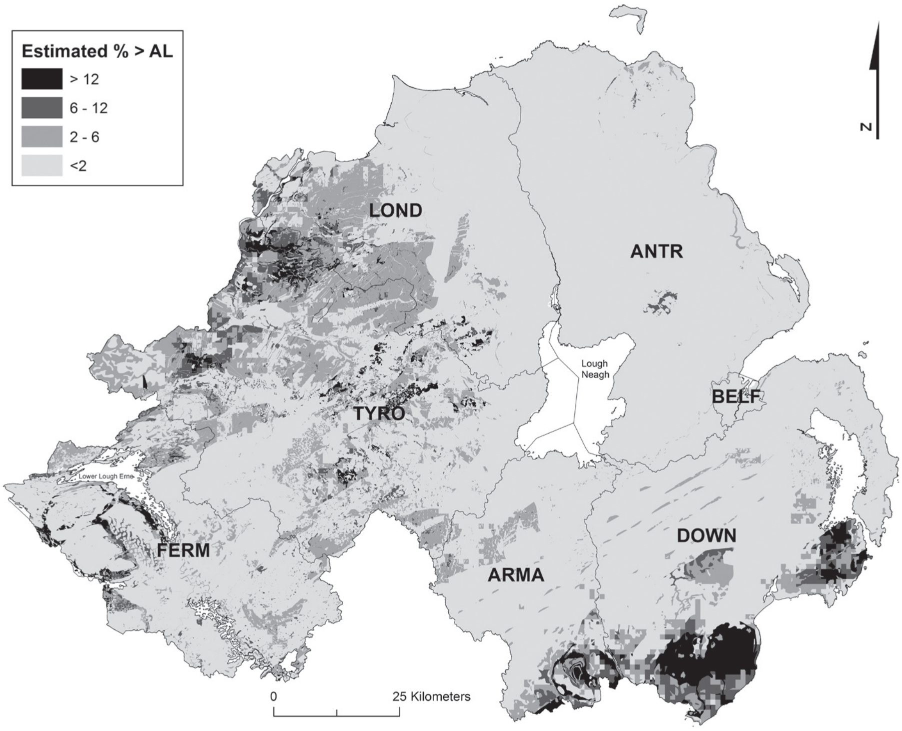

Figure 20.7. Joint HPE-BGS radon potential map of Northern Ireland showing the percentage of dwellings estimated to exceed the radon Action Level (ANTR = Antrim; ARMA = Armagh; BELF = Belfast; DOWN = Down; FERM = Fermanagh; LOND = Londonderry; TYRO = Tyrone) (BGS © NERC; Geological and topography data © Crown Copyright, 2011; Appleton *et al.* (2015)).

Disparities exist between the modelled RP (Fig. 20.6) and the new radon map for adjacent areas in Northern Ireland (Fig. 20.7). In most cases the modelled RP in Ireland is higher than the RP in Northern Ireland. This could be caused by the use of a regression model dominated by Carboniferous limestone data in the Border Region. This linear regression model may not be appropriate for other geological terrains, as previously demonstrated in Northern Ireland (Appleton *et al.*, 2011a) and in the Cavan area (Appleton *et al.*, 2011b).

Conclusions and recommendations

In Ireland, radon mapping is currently based solely on indoor radon measurements while in Northern Ireland indoor radon data are combined with geological data (Daraktchieva *et al.*, 2015). However, differences have been identified between the official maps and radon potential (RP) modelled from eU, karst and ground water recharge in the Border Region, and from eU and ground permeability in Northern Ireland, Cavan and the Tralee–Castleisland areas.

It is recommended that additional indoor measurements should be made where the official and RP maps modelled from eU and geology/soil variables disagree, especially in areas where (a) the modelled RP is higher and (b) there are few indoor radon measurements. In the Border Region, it is recommended that subsoil information and the accurately geo-referenced indoor radon data should be used to improve the models. The need for terrain-specific models should also be investigated using the combined Northern Ireland and Border Region data.

Radon mapping based on targeted in-house measurements is more cost-effective than using an airborne survey carried out only for the purpose of producing RP maps, although in Ireland mapping can be slower due to limited uptake of in-house measurements by home owners. As a consequence, airborne gamma-ray spectrometry data should be used for radon mapping only if the data are collected as part of a multidisciplinary, multi-detector survey such as the Tellus projects. Radon maps based on the data from such surveys are a valuable output that can be used to help target future in-house radon measurement campaigns designed to identify dwellings and other buildings with radon above the Action or Reference Level.

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References

Appleton, J.D., 2013 'Radon in air and water' in O. Selinus (ed.) *Essentials of Medical Geology* (revised edition), 239–78. Dordrecht. Springer. Available at http://nora.nerc.ac.uk/502215/. http://dx.doi.org/10.1007/978-94-007-4375-5_11.

Appleton J.D., Daraktchieva Z. and Young M.E., 2015 'Geological controls on radon potential in Northern Ireland', *Proceedings of the Geologists' Association*, 126, 3, 328–45. Available at http://nora.nerc.ac.uk/511253/. http://dx.doi.org/10.1016/j.pgeola.2014.07.001.

Appleton, J.D., Doyle, E., Fenton, D. and Organo, C., 2011b 'Radon potential mapping of the Tralee–Castleisland and Cavan areas (Ireland) based on airborne gamma-ray spectrometry and geology', *Journal of Radiological Protection*, 31, 211–35. Available at http://nora.nerc.ac.uk/14599/. http://iopscience.iop.org/0952-4746/31/2/002/.

Appleton, J.D. and Miles, J.C.H., 2010 'A statistical evaluation of the geogenic controls on indoor radon concentrations and radon risk', *Journal of Environmental Radioactivity*, 101, 10, 799–803. Available at http://nora.nerc.ac.uk/12853/. http://dx.doi.org/10.1016/j.jenvrad.2009.06.002.

Appleton, J.D., Miles, J.C.H. and Young, M.E., 2011a 'Comparison of Northern Ireland radon maps based on indoor radon measurements and geology with maps derived by predictive modelling of airborne radiometric and ground permeability data', *Science of the Total Environment*, 409, 1572–83. Available at http://nora.nerc.ac.uk/14598/. http://dx.doi.org/10.1016/j.scitotenv.2011.01.023

Building Research Establishment (BRE), 2001 *Radon: Guidance on Protective Measures for New Buildings in Northern Ireland*. Watford, UK. Building Research Establishment report BR-413.

Daraktchieva, Z., Appleton J.D., Rees D.M., Adlam K.A.M., Myers A.H., Hodgson S., McColl N.P., Wasson G.R. and Peake L.J., 2015 *Indicative Atlas of Radon in Northern Ireland*. Chilton, UK. Public Health England report PHE-CRCE-017. Available at http://www.ukradon.org/resources/.

Department of the Environment, Heritage and Local Government (DEHLG), 2008 *Technical Guidance Document C – Site Preparation and Resistance to Moisture*. Dublin. Stationery Office. Available at http://www.environ.ie/en/TGD/.

Fennell, S.G., Mackin, G.M., Madden, J.S., McGarry, A.T., Duffy, J.T., O'Colmain, M., Colgan, P.A. and Pollard D., 2002 *Radon in Dwellings: The Irish National Radon Survey*. Dublin. Radiological Protection Institute of Ireland.

Green, B.M.R., Larmour, R., Miles, J.C.H., Rees, D.M. and Ledgerwood, F.K., 2009 *Radon in Dwellings in Northern Ireland*. Chilton, UK. Health Protection Agency report HPA-RPD-061.

Health and Safety Authority (HSA), 2005 *Safety, Health and Welfare Act 2005 (No. 10 of 2005).* Dublin. Available at http://www.hsa.ie/eng/Legislation/Acts/Safety_Health_and_Welfare_at_Work/.

Health and Safety Executive of Northern Ireland (HSENI), 2000 *Management of Health and Safety at Work Regulations (Northern Ireland).* Belfast.

Health Protection Agency (HPA), 2009 *Radon and Public Health*. Report prepared by the Subgroup on Radon Epidemiology of the Independent Advisory Group on Ionising Radiation. Chilton, UK. Health Protection Agency Report HPA-RCE-11. Available at https://www.gov.uk/government/collections/radiation-hpa-rce-report-series.

Hodgson J. A. and Carey S., 2013 *Radon Risk Predictive Modelling Using Airborne Geophysical Data in the Border Region of Ireland*. Tellus Border Project Report TBGPH06, Geological Survey of Ireland and Geological Survey of Northern Ireland. Available at http://www.tellusborder.eu/Library.htm.

Miles, J.C.H. and Appleton, J.D., 2005 'Mapping variation in radon potential both between and within geological units', *Journal of Radiological Protection*, 25, 257–76. Available at http://nora.nerc.ac.uk/18361/. http://dx.doi.org/10.1088/0952-4746/25/3/003.

O'Connor, C., Currivan, L., Cunningham, N., Kelleher, K., Lewis, M., Long, S., McGinnity, P., Smith, V. and McMahon, C., 2014 *Radiation doses received by the Irish population*. Dublin. Radiological Protection Agency of Ireland, report RPII 14/02. Available at https://www.epa.ie/search/.

Radiological Protection Institute of Ireland (RPII), 2008 *Guidance Notes on the Actions an Employer May Take if High Radon Concentrations are Found in a Work Place*. Dublin. Radiological Protection Institute of Ireland. Available at https://www.epa.ie/search/.

Radiological Protection Institute of Ireland (RPII) & Health Service Executive (HSE), 2010 *Radon Gas in Ireland*. Joint position statement. Dublin. Available at https://www.epa.ie/search/.

Watson, S.J., Jones, A.L., Oatway, W.B. and Hughes, J.S., 2005 *Ionising Radiation Exposure of the UK Population: 2005 Review*. Chilton, UK. Health Protection Agency report HPA-RPD-001.

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