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Radon in Dwellings - The National Radon Survey

Galway and Mayo

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Abstract

This report presents the results of the final phase of the National Radon Survey carried out by the Radiological Protection Institute of Ireland. The counties included in this phase are Galway and Mayo. The average radon concentrations for the houses measured in these counties were 112 Bq/m^3 and 100 Bq/m^3, respectively. The measurement data were grouped on the basis of the 10 km grid squares of the Irish National Grid System and used to predict the percentage of dwellings in each grid square which exceeds the Reference Level of 200 Bq/m^3. Grid squares where this percentage is predicted to be 10% or higher are designated High Radon Areas. The health effects of exposure to high radon levels are discussed and recommendations are made regarding both new and existing dwellings.

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1. Introduction

It is accepted that long-term exposure to radon, a naturally occurring radioactive gas, can cause lung cancer. In a minority of homes and other buildings in Ireland, elevated radon concentrations occur which constitute a significant lung cancer risk for the occupants. When a building with a high radon level is identified, measures are available whereby the level can be substantially reduced.

In 1990, the Government adopted an annual average radon concentration of 200 becquerels per cubic metre (Bq/m^3) as the national Reference Level above which remedial action to reduce the indoor radon level in a dwelling should be considered. Results of a population-weighted radon survey carried out by the Experimental Physics Department of University College Dublin (UCD) between 1985 and 1989 estimated that 4% of the national housing stock have radon concentrations above this Reference Level [McLaughlin and Wasiolek, 1988]. In particular, the UCD survey indicated that the probability of finding a house with elevated indoor radon levels was greatest in the western counties, although houses with elevated radon concentrations were identified in most counties in Ireland.

Following this survey, the Institute undertook follow-up surveys in some of the identified potentially high radon areas including areas in counties Mayo, Galway, Clare and Kerry. More intensive surveys were carried out in selected areas in Co. Galway and Cork city. The results of these surveys are published in a previous report [Madden *et al.*, 1994].

To assist in identifying areas at greatest risk of high indoor radon levels, the Institute in 1992 initiated a national geographically-based radon survey. The results of this survey will allow the classification of the whole country on the basis of the predicted percentage of dwellings in each area which are above the Reference Level. Areas in which this value is 10% or greater will be designated High Radon Areas.

Reports detailing the results of the first four phases of the National Survey covering counties Cavan, Dublin, Louth, Monaghan and Wicklow [Duffy *et al.*, 1996]; Carlow, Donegal, Kildare, Kilkenny, Laois, Leitrim, Longford, Meath, Offaly, Roscommon, Sligo, Waterford, Westmeath and Wexford [McGarry *et al.*, 1997]; Cork and Kerry [McGarry *et al.*, 1998(a)] and Clare, Limerick and Tipperary [McGarry *et al.*, 1998(b)] have already been published. This report presents the results of the final phase of the survey which covers counties Galway and Mayo. Details are given of the percentages of dwellings in these counties estimated to exceed the Reference Level and High Radon Areas are identified.

2. Radon Sources and Health Effects

Radon is a naturally occurring radioactive gas. It is part of the radioactive decay series of uranium, which is present in variable amounts in all rocks and soils. Although radon itself has a relatively short half-life of 3.82 days, it is continually produced from its parent, radium-226, which has a half-life of 1600 years. Radon decays through a series of short lived decay products to stable lead.

Because it is an inert gas, radon can move freely through porous media such as rocks or soil, although only a small fraction of that produced in the ground rises to the surface and enters the atmosphere or seeps into buildings. Radon which surfaces in the open air is quickly diluted. Typical outdoor concentrations are between 4 and 15 Bq/m^3 [NCRP, 1988] and are relatively harmless.

A problem can arise, however, when radon from the ground enters an enclosed space such as a house. There it may reach unacceptably high concentrations as dispersion is restricted. Domestic water and gas supplies, in addition to building materials and infiltration of outdoor air, also contribute to the radon level in a dwelling, but in most cases these are considered minor sources relative to the ground on which the dwelling is constructed [Nero *et al.*, 1983].

The most significant mechanisms by which radon can enter a house are concentration-driven diffusion and pressure-driven flow from the ground beneath the house. The higher temperature indoors and the effect of wind on a dwelling combine to reduce the pressure indoors relative to that in the ground. The pressure difference is usually small, but sufficient to induce a flow of soil gas with radon into the dwelling if the ground is fairly permeable and an easy path for flow exists. Such paths include cracks in the floor or the walls, construction joints or gaps around pipes or cables. In most dwellings with high radon concentrations pressure-driven flow is recognised as the dominant mechanism of influx [Nazaroff *et al.*, 1988].

Two of the short-lived decay products of radon (polonium-218 and polonium-214) emit alpha particle radiation. It is these decay products which, following inhalation and deposition in the lung, deliver the radiation dose that is implicated in the induction of lung cancer [ICRP, 1977].

3. Survey Methodology

The primary objective of the survey was to determine, in detail, the geographical distribution of radon levels in dwellings in Ireland. In order to obtain a good geographical spread the survey was based on small area units; in this case, the 10 km grid squares of the Irish National Grid System. Radon measurements were carried out in selected dwellings and the data were used to predict the percentage of dwellings in each grid square with radon concentrations above the Reference Level. Grid squares where the predicted percentage of dwellings with radon concentrations above 200 Bq/m^3 is 10% or greater are designated High Radon Areas.

It has been shown that the distribution of radon levels in dwellings approximates a log-normal distribution [CEC, 1987] and that such a log-normal approximation appears to hold whether a whole country, or a smaller area such as a 10 km grid square, is considered [NRPB, 1990]. Modelling the distribution of indoor radon concentrations therefore allows the percentage of dwellings exceeding a reference concentration to be estimated [Miles, 1994]. The statistical procedure used in this survey is described by Daly [1994] and is based on the approach of Liberman and Resnikoff [1955].

Although in a truly random survey, a valid prediction can be made based on a sample size of only three dwellings per grid square, a minimum sample size of five dwellings was chosen for this survey. In order to ensure a sufficient sample size, about 70 householders per grid square were invited to participate. The householders' names and addresses were randomly selected from the Register of Electors by the Economic and Social Research Institute (ESRI). As the Register of Electors is not available on a grid square basis, the names and addresses were selected from the Register for each District Electoral Division (DED). There are, on average, six DEDs per grid square and so a minimum of eleven householders were selected from each DED.

The householders were then invited by letter to participate in the survey. When agreeing to participate the householders were asked to locate, as accurately as possible, the locations of their homes on the county map provided. This information was then used to assist in assigning the measurement for each dwelling to the correct grid square.

Each participant was issued with two radon detectors, one to be placed in the main living area and the second in an occupied bedroom. The detectors used were of the passive alpha track type and were left in place for a period of twelve months. On return to the Institute, the detectors were processed and the annual average radon concentration for each dwelling was calculated by averaging the results of the two measurements. The householders were individually notified of their measurement results and, where appropriate, recommendations were made regarding the necessity for remedial action.

The survey was carried out on a county by county basis and phased to match the available resources. In grid squares where there are less than five valid measurements, predictions will be made using data from surrounding grid squares. These predictions, together with the survey results for each county, is being published as a map entitled "Radon in Irish Dwellings". For grid squares which overlay the border between two or more counties, the percentage of dwellings above the Reference Level was predicted using all of the available data.

4. Results and Discussion

4.1 <u>County Surveys</u>

Radon measurements were completed in 1,213 dwellings in Co. Galway and 1,184 dwellings in Co. Mayo. For the majority of grid squares, the number of valid measurements exceeded ten per grid square. A summary of the results of these measurements is presented in Table 1. The mean annual indoor radon concentration for the dwellings measured was 112 Bq/m^3 in Galway and 100 Bq/m^3 in Mayo. The maximum value of 1,881 Bq/m^3 was measured in a house in Co. Galway.

Table 1. Summary of Survey Data

County	Number of Houses Measured	Measured Average Radon Concentration (Bq/m^3)	Measured Maximum Annual Radon Concentration (Bq/m^3)	Measured Number of Dwellings above Reference Level
Galway	1213	112	1881	181
Mayo	1184	100	1214	152

A total of 333 of the dwellings surveyed had radon concentrations in excess of the Reference Level of 200 Bq/m^3. The number of these dwellings, expressed as a percentage of the total number measured in each county, was 15% and 13%, respectively. These values are towards the upper end of the range of values determined for other counties in Ireland which have already been surveyed (i.e. 3% - 20%).

In the earlier surveys, 215 dwellings were measured in parts of Co. Galway and 151 dwellings were measured in Co. Mayo. A further 442 dwellings were measured in localised areas in Co. Galway; 235 in Moycullen, 160 in Salthill and 47 on Inis Mór. The percentage of dwellings surveyed which had radon concentrations in excess of the Reference Level was 15% in Co. Galway and 9% in Co. Mayo. In Salthill on the outskirts of Galway City, 31% of the dwellings measured had radon concentrations in excess of 200 Bq/m^3.

4.2 High Radon Areas

The radon measurement data presented in Table 1 were used to predict the percentage of dwellings with radon concentrations in excess of 200 Bq/m^3 in each grid square of counties Galway and Mayo according to the method described in Section 3. The results are presented in Figures 1 and 2. The figures are colour coded with each colour corresponding to a percentage band i.e. <1%, 1-5%, 5-10%, 10-20% and >20%. The two percentage bands 10-20% and >20% delimit the High Radon Areas.

From the figures it is evident that there is considerable geographical variation in indoor radon concentrations in both counties. In the eastern half of both counties, a wide band of grid squares running from north to south is designated a High Radon Area. In most of the grid squares in the western half of each county, less than 1% of houses are predicted to have radon concentrations above the Reference Level.

In County Galway, the High Radon Areas include Galway City, Salthill, Oughterard, Athenry, Tuam and Loughrea. In County Mayo, Ballina, Claremorris, Swinford, Ballinrobe and Ballycastle are designated as High Radon Areas.

The predictions for counties Galway and Mayo based on the National Survey now supersede those of the earlier surveys as the best estimate of the percentage of dwellings above the Reference Level in each grid square. In the National Survey an improved measurement protocol, better geographical distribution of measured dwellings and an improved statistical procedure for modelling the distribution of indoor radon levels were used.

In estimating the scale of the radon problem in any county, it must be borne in mind that this will depend on the housing density in the county as well as on the extent of High Radon Areas within the county.

5. Doses and Risk Estimates

The epidemiological evidence for the induction of fatal lung cancer by radon decay products has been derived both for miners exposed to radon at work and for persons exposed at home. In this report, estimates of risk from long-term exposure to radon are based on the lifetime fatality coefficient recommended in the latest relevant report of the International Commission on Radiological Protection [ICRP, 1994]. The observed lifetime risk of lung cancer from all causes for the whole population of Ireland is 3%. For a person living in a house with a radon concentration of 200 Bq/m^3, the additional lung cancer risk due to radon is a further 2%. At higher radon concentrations, the additional risk is proportionately greater. It is also of interest to note that for people who smoke, there is growing evidence that the risk from radon is considerably greater than these figures, while for non-smokers the risk from radon is less than the average figure for the population as a whole.

To allow comparison with radiation doses arising from other sources, the radiation dose due to radon exposure can be calculated using an exposure-dose conversion factor of 1 millisievert (mSv) annual radiation dose per 40 Bq/m^3 radon concentration in a dwelling. The derivation of this factor is detailed elsewhere [Madden *et al.*, 1994]. Annual exposure in the home to a radon concentration of 200 Bq/m^3 would therefore give rise to a radiation dose of 5 mSv.

When compared with the estimated average annual radiation dose of approximately 3 mSv per year in Ireland from all sources, the data show that radon exposure in the home is the major source of human exposure to ionising radiation in Ireland. It is also an extremely variable source, with exposures in individual homes in the counties reported here ranging from less than 1 mSv to about 47 mSv per year.

6. Conclusions and Recommendations

The results of the National Radon Survey reported here show that there is significant geographical variation in indoor radon concentrations in counties Galway and Mayo. Most of the eastern halves of both counties are designated High Radon Areas. In all High Radon Areas, the Institute would encourage householders to have radon measurements made in their homes in order to identify the individual dwellings with elevated indoor radon levels. Where high radon levels are found, householders are encouraged to take the necessary action to reduce the risks to themselves and their families. While the High Radon Areas can, by definition, be expected to have a higher proportion of homes with high radon levels, it cannot be inferred that elevated indoor radon concentrations do not occur in homes in other areas that are not designated High Radon Areas.

The Technical Guidance Documents (1997 edition) [DOE, 1997] which provide guidance on compliance with the requirements of the Building Regulations now require that the foundations in all new dwellings incorporate a potential means of extracting radon from the sub-structure. In addition, new dwellings in High Radon Areas must be fitted with a sealed membrane of low permeability. Advice on the most appropriate measure to be taken in either new or existing dwellings is available in the publication "Radon in Buildings" [Ryan and Finn, 1995], which is available from the Government Publications Sale Office.

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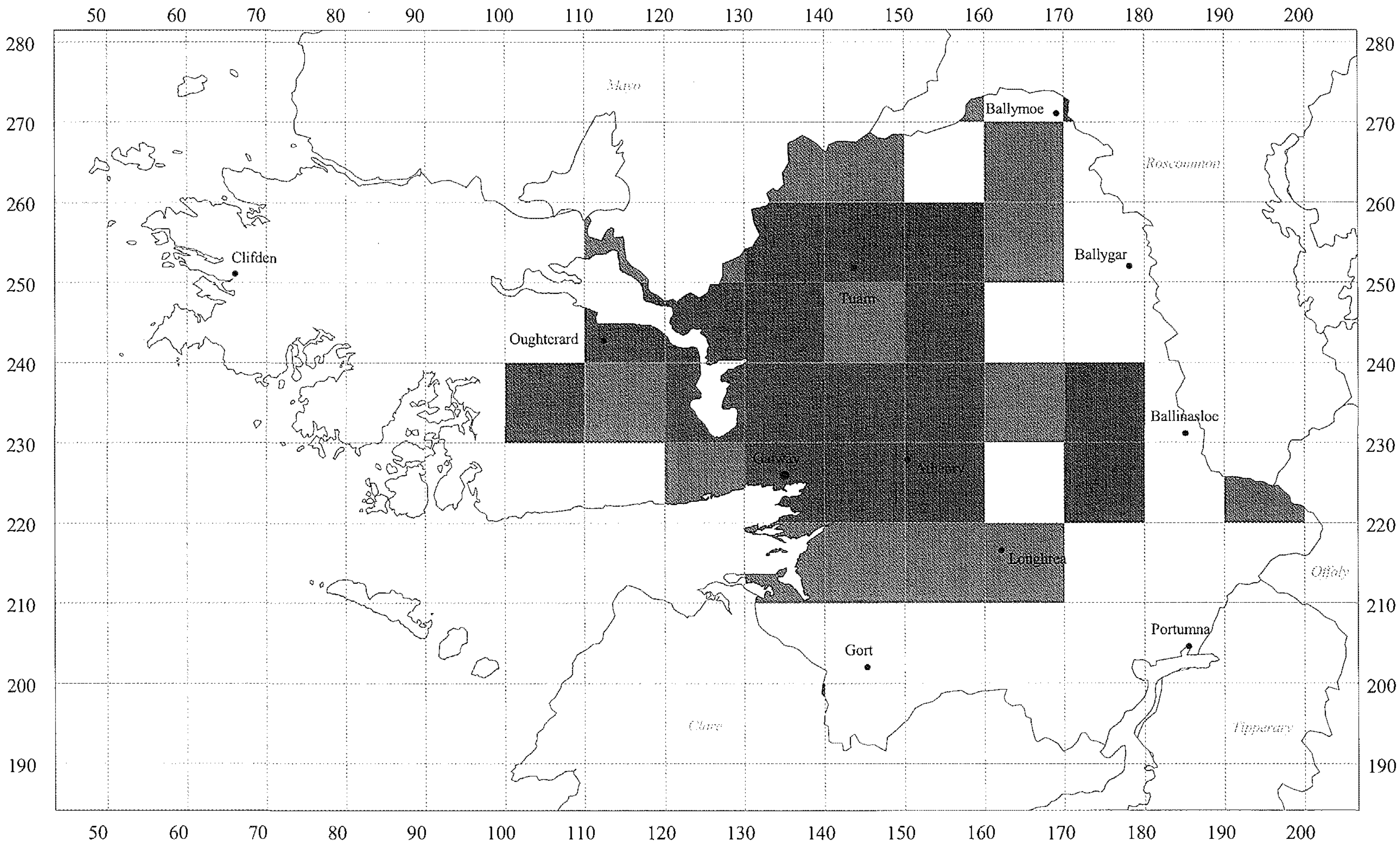


Grid: Irish National Grid

Legend

- > 20%
- 10 - 20%
- 5 - 10%
- 1 - 5%
- < 1%
- Insufficient Data

Map of County Galway

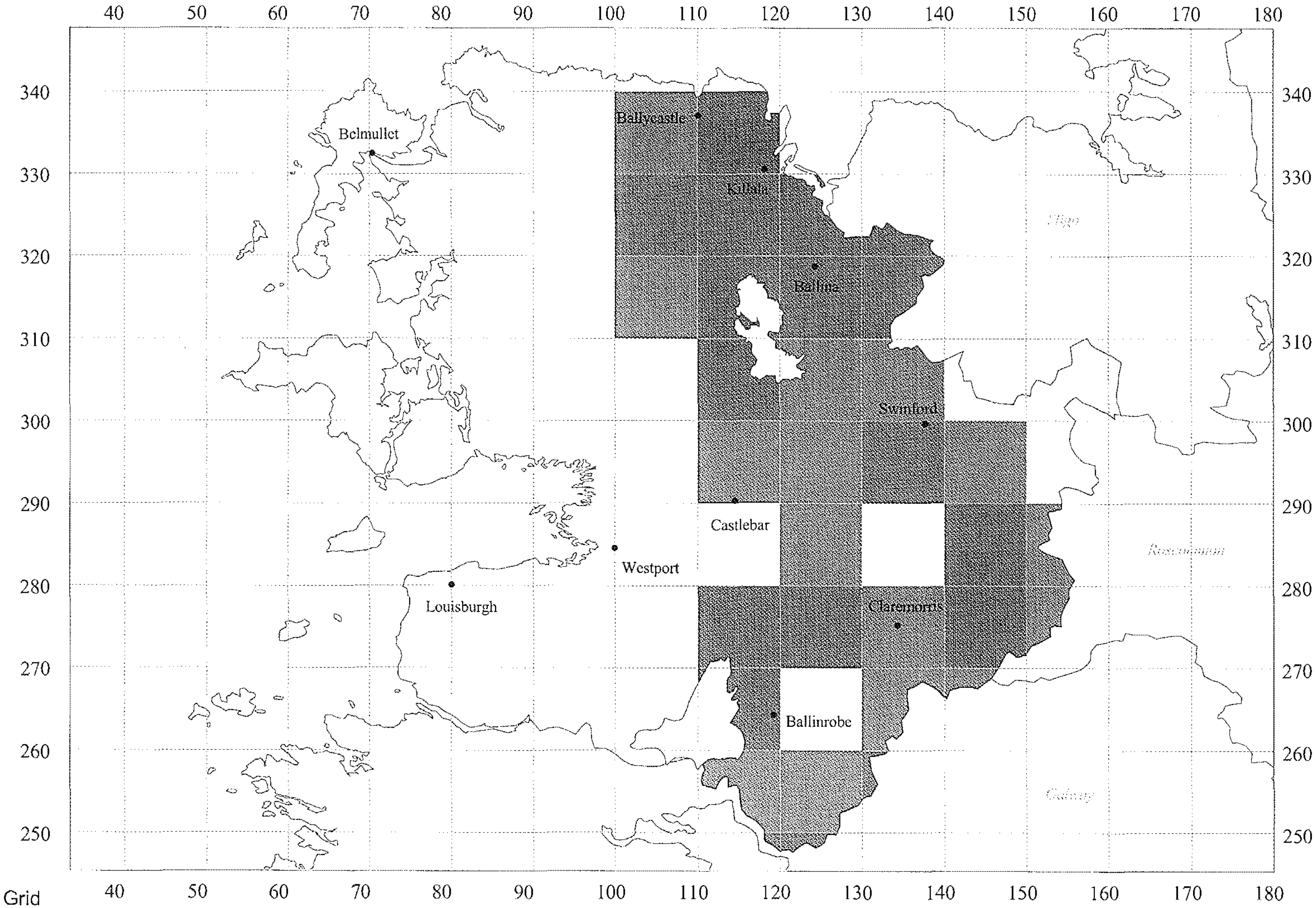
showing the percentage of dwellings predicted to exceed 200 Bq/m^3 in each 10 km grid square

5 0 5 10 15 Kilometers

5 0 5 10 Miles

Scale 1:800000

Figure 1.



Grid: Irish National Grid

Legend

- > 20%
- 10 - 20%
- 5 - 10%
- 1 - 5%
- < 1%
- Insufficient Data

Map of County Mayo

showing the percentage of dwellings predicted to exceed 200 Bq/m³ in each 10 km grid square

5 0 5 10 15 Kilometers

5 0 5 10 Miles

Scale 1:800000

Figure 2.

Glossary of Terms

Radon Concentration - the activity concentration of radon gas in terms of activity per unit volume of air. Activity is given in units of becquerel (Bq), with activity concentration given in becquerels per cubic metre (Bq/m^3). A becquerel is equal to one nuclear transformation per second.

Half-life - the time taken for the activity of a radionuclide to lose half its value by decay.

Lifetime Fatality Coefficient - the risk of death associated with exposure to radon and its decay products over a lifetime of 70 years.

Radiation Dose - a general term for the biological effect of radiation. It takes account of the type of radiation, the tissues exposed and their sensitivity to radiation. Dose is given in units of sievert (Sv). One Sv produces the same biological effect irrespective of the type of radiation.