RADON IN DRINKING WATER IN COUNTY WICKLOW – A PILOT STUDY

Leo McKittrick, Savio Sequeira, Tom Ryan and Tony Colgan

Radiological Protection Institute of Ireland, 3 Clonskeagh Square, Clonskeagh Road, Dublin 14, Ireland. Email: rpii@rpii.ie

ABSTRACT

A pilot study of radon in drinking water has been carried out by the Radiological Protection Institute of Ireland (RPII) with the assistance of Wicklow County Council. County Wicklow was selected for the study primarily on the basis that the underlying geology is predominantly granite with known elevated concentrations of uranium, which ultimately decays to radon. Radon activity concentrations were measured in tap water from the private groundwater supplies of 166 houses in County Wicklow. Four houses had activity concentrations in excess of the recommended EC action level of 1,000 Bq/l for private drinking water supplies, 15 had activity concentrations between 500 and 1,000 Bq/l, 51 were between 100 and 500 Bq/l and 96 had activity concentrations below 100 Bq/l. Further studies were also carried out on the four houses with activity concentrations above 1,000 Bq/l, including additional measurements of radon in drinking water and radon in air measurements. An assessment of temporal trends in radon activity concentrations in one house was also carried out. Dose estimates based on measurements made in this study demonstrate that radon in drinking water may pose a significant additional health risk, in the longer term, to some consumers who depend on private groundwater supplies as their source of drinking water.

Keywords : Drinking water, Radon, Wicklow.

INTRODUCTION

Radon is a naturally occurring radioactive gas that is part of the uranium decay series. Its presence in the environment is associated mainly with trace amounts of uranium and its immediate parent, radium-226, in rocks and soil. Because of its gaseous nature, radon can move freely through porous media such as soil or fragmented rock. Radon may permeate from rocks and soil into buildings through cracks in floors or gaps around pipes or cables. The inhalation of radon in indoor air has been identified as the principal contributor to radiation dose in Ireland. The issue has been comprehensively studied and reported by the RPII (Fennell *et al*., 2002).

Where pores in rock and soil under the water table are saturated with water, radon can be dissolved into the water and transported with it. Consequently domestic water supplies may have elevated concentrations of dissolved radon. This can give rise to a radiation dose as a result of either inhalation or ingestion. Radon can be released from the water into the air and, when inhaled, results in radiation exposure of the lungs. The organ at greatest risk from the ingestion of water containing radon is considered to be the stomach (Khursheed, 2000).

Attention has been focused on the issue of radon in drinking water by a European Commission Recommendation (EC, 2001) proposing that surveys should be undertaken in Member States to determine the scale and nature of exposures caused by radon in domestic drinking water supplies. Considering both the ingestion and inhalation pathways, the annual effective dose caused by water containing 1,000 Bq/l of radon is comparable to that caused by an indoor radon concentration of 200 Bq/m^3. This is the current reference level in Ireland and several other EU Member States. The Commission thus recommends 1,000 Bq/l as the radon activity concentration in private drinking water supplies above which remedial action should be taken.

In light of this new recommendation, a pilot study of radon in drinking water was recently completed on private drinking water supplies in County Wicklow. The principal objectives of the study were to determine the distribution of radon activity concentrations in private drinking water supplies and to assess their dosimetric implications. County Wicklow was selected for the study primarily on the basis that the underlying geology is predominantly granite, with known elevated uranium content. In addition, there are an estimated 1,200 to 5,000 private drinking water supplies in use in the county. Furthermore, a nationwide study conducted by the RPII has predicted high indoor air radon activity concentrations in a significant number of dwellings in the county, consequently the radon present in the underlying rocks and soil may also become dissolved in the groundwater resulting in elevated radon activity concentrations in groundwater supplies.

METHODS

Drinking water from 166 houses in County Wicklow that use private boreholes as their primary supply was sampled and analysed in duplicate for radon (Ryan *et al*., 2003). For the purposes of standardisation and assessment of radon ingestion, water was sampled from the cold kitchen tap in each household. In order to prevent potential losses of radon, the water was sampled in an airtight container that was completely filled and tightly capped. The samples were analysed for radon as soon as possible after collection to minimise radioactive decay of radon and reduce uncertainties in the analysis. All measurements were decay corrected to the time of sampling. Linear regression analysis of the duplicate samples for each supply demonstrated excellent agreement (R^2=0.999).

Radon in water was measured by low-level liquid scintillation counting using a Packard TriCarb-2770 TR/SL, a counter with an alpha/beta separation facility, and a non-water miscible organic scintillant, Ultima Gold F (Sequeira *et al*., in press). Alpha/beta separation on this counter is achieved by pulse shape analysis. The counter was calibrated for radon measurements with a certified radium-226 standard which was allowed to reach secular equilibrium with radon after 28 days (at least 99% ingrowth). The uncertainty on each measurement was typically 10%.

RESULTS & DISCUSSION

Of the 166 supplies sampled, four had radon activity concentrations which exceeded 1,000 Bq/l (2.4%), 15 had activity concentrations between 500 and 1,000 Bq/l (9.0%), 51 were between 100 and 500 Bq/l (30.7%) and 96 had activity concentrations below 100 Bq/l (57.8%). The results are summarised in Figure 1.

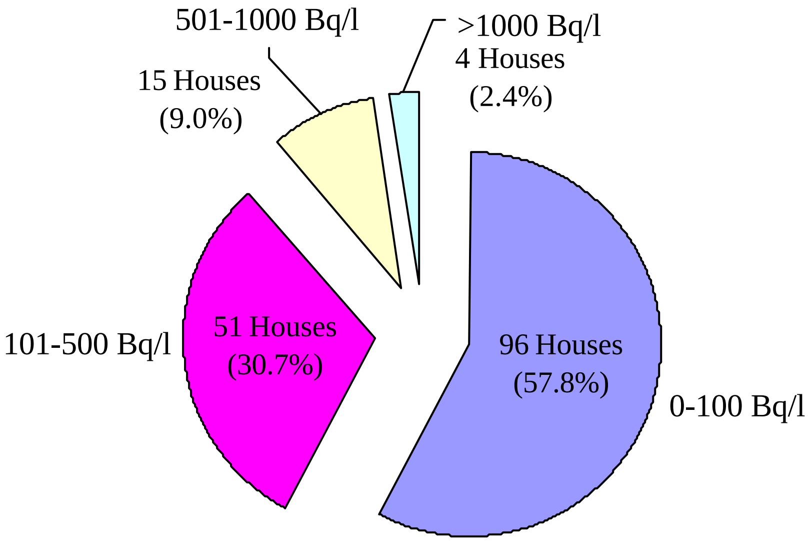

Figure 1: Radon in drinking water, County Wicklow

Further studies were subsequently carried out in the four houses which exceeded the 1,000 Bq/l reference level. A selection of water samples were taken for radon analysis from taps inside and outside the house for comparison with the original measurement. In addition, Cr-39 track-etch detectors, to measure the indoor air radon activity concentration, were placed in a number of rooms in each of the four houses for a three-month period. The results of these analyses are presented in Tables 1 and 2.

Table 1 Radon activity concentrations (Bq/l) in water from different taps in the houses above 1,000 Bq/l

House	Kitchen (Original)	Outside	Kitchen (Cold)	Kitchen (Hot)	Bathroom (Cold)	Bathroom (Hot)
1	5985 ± 599	5040 ± 504	5736 ± 574	2089 ± 209	3006 ± 301	nm
2	3316 ± 332	2877 ± 288	2887 ± 289	nm	2845 ± 285	1016 ± 103
3	1396 ± 140	905 ± 91	813 ± 82	nm	498 ± 50	411 ± 42
4	1720 ± 172	1901 ± 191	1835 ± 184	nm	1258 ± 126	970 ± 98

Note: nm = not measured

Table 2 Indoor air radon activity concentrations in the houses with water radon activity concentrations above 1,000 Bq/l

Indoor air radon activity concentrations (Bq/m^3)					
House	**House average**	**Kitchen**	**Bedroom**	**Bathroom**	**Living Room**
1	130	nm	97	110 (es: 197)	158
2	339	291	390	515	314
3	55	66	18	105	73
4	139	77	139	103 (es: 439)	65

Notes: es = ensuite, nm = not measured

Repeat measurements of radon in drinking water confirmed that radon activity concentrations in three of the four selected houses remained above 1,000 Bq/l. One house, which originally had a concentration of 1,396 Bq/l, was found to have a concentration of 813 Bq/l at the second analysis (Table 1).

The seasonally adjusted mean indoor radon air concentration in three of the houses was found to be significantly below 200 Bq/m^3, the national Reference Level at which remedial action to reduce radon activity concentrations is advised for private dwellings (Table 2). The fourth house had an indoor air radon concentration of 339 Bq/m^3. In all four cases, the highest concentration of radon in indoor air was found in a bathroom - this is most likely due to emanation of radon from water usage (showering, flushing, etc.).

Temporal trends in radon activity concentrations

Water from house No. 3 was sampled at regular intervals between December 2001 and May 2002 to study temporal trends (Figure 2). While only one house was used in the study and the study period was relatively short, a significant variation in the radon activity concentration was found. In this case the radon concentration was found to vary from 550 Bq/l (May 2002) to a high of 1,437 Bq/l (April 2002). Other studies have also found large variations in activity concentrations over time (Talbot *et al*., 2000). Further investigation is required to fully quantify this variability and its resultant implications. However, because of the large number of supplies measured as part of the survey, random or seasonal variability is unlikely to significantly affect the overall distribution of observed radon activity concentrations.

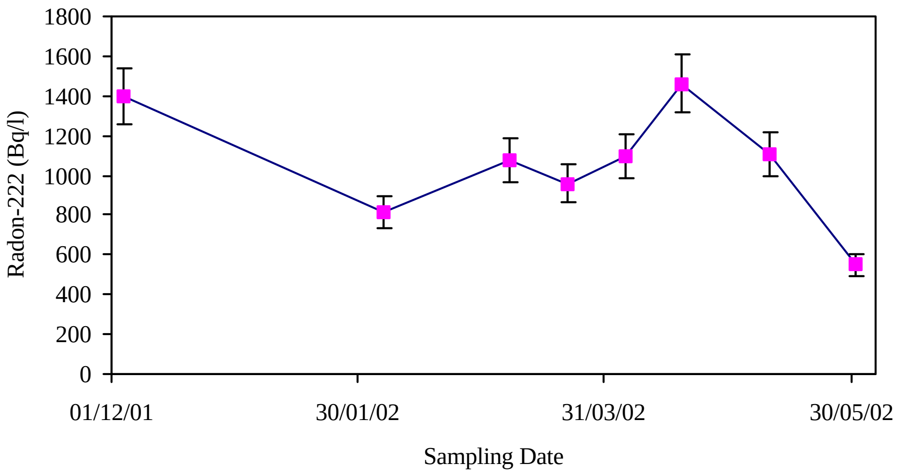

Figure 2: *Variations in radon activity concentration in water with time at a location in County Wicklow*

Doses from water consumption due to radon

The dosimetric implications of ingesting radon in water at different consumption rates were assessed by Ryan *et al* (2003) and are given in Table 3. Dose estimates may be significantly higher for children and infants (UNSCEAR, 1993). These doses may be compared to the annual average radiation dose of 3.62 mSv to a person in Ireland from all sources of radioactivity. For example, the consumption of 0.5 litre per day of tap water from house No. 4 would result in an additional annual dose approximately equal to that from all sources of radioactivity.

Table 3 Potential annual doses (mSv) to adults due to the consumption of water using a range of consumption rates

House	Activity Concentration (Bq/l)	Daily water consumption rates				
		0.1 l/d	**0.5 l/d**	**1.0 l/d**	**1.5 l/d**	**2.0 l/d**
		Doses to adults due to the consumption of water at above rates (mSv)[1]				
1	5985	2.18	10.9	21.8	32.8	43.7
2	3316	1.60	6.0	12.1	18.2	24.2
3	1396	0.50	2.5	5.0	7.5	10.0
4	1720	0.62	3.1	6.2	9.3	12.4

Note: (1) The dose conversion factor used was $1x10^{-8}$ Sv/Bq. It is assumed that all of the water consumed is unprocessed and directly from the tap without loss of radon.

CONCLUSION

The pilot study of radon in drinking water conducted in County Wicklow showed that, while the majority of houses tested had radon activity concentrations well below the recommended EC action level of 1,000 Bq/l, a small percentage (2.4%) exceeded this limit. Dose estimates based on measurements made in this study demonstrate that radon in drinking water may pose a significant additional health risk, in the longer term, to some consumers who depend on the supplies as their main source of drinking water. However, it should be noted that while significant doses have been estimated for radon ingestion in drinking water, it is expected that the number of people affected is small in comparison with the number of people likely to be affected as a consequence of exposure to radon in indoor air.

ACKNOWLEDGEMENTS

The co-operation and support of the staff of Wicklow County Council, all participating householders and RPII colleagues during this pilot study are gratefully acknowledged.

REFERENCES

EC, 2001. Commission recommendation of 20 December 2001 on the protection of the public against exposure to radon in drinking water supplies. Official Journal of the European Communities, L344, 85-88.

Fennell S.G., Mackin G.M., Madden J.S., McGarry A.T., Duffy J.T., O'Colmáin M., Colgan P.A. and Pollard D., 2002. Radon in Dwellings. The Irish National Radon Survey, Radiological Protection Institute of Ireland, Dublin, RPII-02/1.

Khursheed, A., 2000. Doses to systemic tissues from radon gas. Radiation Protection Dosimetry, 88 (2), 171-181.

Ryan T.P., Sequeira S., McKittrick L., Colgan P.A., 2003. Radon in Drinking Water in Co. Wicklow – a Pilot Study, Radiological Protection Institute of Ireland, Dublin.

Sequeira, S., McKittrick, L., Ryan, T.P. and Colgan, P.A., (in press). Investigation of a method for measuring radon in Irish domestic groundwater supplies. In: Proceedings of 9th International Symposium on Environmental Radiochemical Analysis, 18th – 20th September, 2002, Kent. UK: Royal Chemistry Society.

Talbot, D.J., Davis, J.R. and Rainey, M.P., 2000. Natural Radiation in Private Water Supplies in Devon. DETR Report – DETR/RAS/00.010, Department of the Environment, Transport and Regions, UK.

UNSCEAR, 1993. Sources and Effects of Ionizing Radiation. UNSCEAR 1993 Report to the General Assembly, with Scientific Annexes. New York: United Nations.