Health Risks due to Exposure to Radon in Homes in Ireland

The Implications of Recently Published Data

Joint Statement by the Radiological Protection Institute of Ireland and National Cancer Registry of Ireland

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Radiological Protection Institute of Ireland
An Institiúid Éireannach um Chosaint Raideolaíoch

National Cancer Registry Ireland

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Executive Summary

This document summarises the evidence that links exposure to radon in homes with an increased risk of lung cancer. Using the most recent risk estimates derived from epidemiological studies carried out abroad, the risk associated with radon exposure in homes in Ireland is derived. The relationship between exposure to radon and cigarette smoking is also discussed.

On the basis of studies of uranium and other underground miners occupationally exposed to radon, it was previously estimated that 150-200 lung cancer deaths each year in Ireland could be linked to radon. This equates to 10% to 15% of all lung cancer deaths.

Recently, the results of a joint analysis of 13 individual epidemiological studies of residential radon exposure in nine European countries was published. The principal conclusion reached is that, while the underlying lung cancer risk for active smokers was considerably higher than for lifelong non-smokers, the risk to both groups increased by approximately 16% for every 100 Bq/m^3 of radon exposure in the home. In addition, this risk seems to apply even at low radon concentrations, typically below the Reference Levels that apply in a number of countries. The risk to active smokers from radon was observed to be approximately 25 times greater than the risk to lifelong non-smokers.

When applied to Ireland, the risk estimates from this European study provide a best estimate value of approximately 13% of all lung cancer deaths every year in Ireland being caused by radon. This corresponds to 195 lung cancer deaths, of which 91.5% (178) would be observed in active and ex-smokers and 8.5% (17) in lifelong non-smokers. Thus the majority of all lung cancers will be observed in people whose lungs have been damaged by tobacco smoke. This includes ex smokers, who remain at increased risk from radon for a number of years after they have stopped smoking.

The Institute considered if, in light of the most recent scientific evidence, there was a need to reduce the national Reference Level of 200 Bq/m^3 for radon exposure in the home. It found no justification to revise the national Reference Level as it represented a level of risk to the population as a whole comparable to other everyday hazards. A diversion of resources to identifying and remediating those homes with radon concentrations in the range 100 to 200 Bq/m^3 is unlikely to be justified.

Background

1. Radon is a naturally occurring radioactive gas. It is colourless, odourless and tasteless. Radon is formed in the ground by the radioactive decay of uranium, which is present in small quantities in all rocks and soils. Because it is a gas, radon can move freely through soil enabling it to enter the atmosphere or seep into buildings. Radon which surfaces in the open air is quickly diluted to harmless concentrations, but it can build up to unacceptably high concentrations indoors.

2. In many countries exposure in the home to radon gas represents the largest proportion of the radiation dose received by the general public[1]. In Ireland, radon accounts for over 60% of the total radiation dose received.

3. Once radon enters a building it quickly decays to produce radioactive particles, some of which remain suspended in the air. When inhaled, these particles can be deposited in the airways and attach themselves to lung tissue. These then give a radiation dose that may eventually lead to lung cancer.

4. Many environmental pollutants are classified as cancer-causing solely on the basis of laboratory studies using either animals or cell cultures. In the case of radon, there is direct evidence from human studies of a link between exposure to radon and lung cancer. For this reason radon has been classified by the International Agency for Research on Cancer, a part of the World Health Organisation, as a Group 1 carcinogen. This places radon in the same group of carcinogens as asbestos and tobacco smoke as a cause of lung cancer.

5. In 1990 the Government set a national Reference Level of 200 becquerels per cubic metre (Bq/m^3)[2] for radon exposure in the home. Based on an assumed occupancy of 7000 hours per year, this equates to an annual radiation dose of 5 millisievert (mSv)[3]. In Ireland, the average annual radiation dose is 3.62 mSv, of which 2.25 mSv is due to radon[4].

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[1] United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionising Radiation. UNSCEAR 2000 Report to the General Assembly with Scientific Annexes Vol. 1. United Nations, 2000.

[2] The becquerel is the unit of radioactivity, equivalent to one radioactive disintegration per second.

[3] The sievert is the unit of radiation dose. The millisievert is one thousandth part of a sievert.

[4] Colgan, P.A. *et al.* (2004) Current status of programmes to measure and reduce radon exposure in Irish workplaces. Journal of Radiological Protection 24: 121-129.

6. A Reference Level is not a rigid boundary between safety and danger. It represents a level at which one should consider taking action to reduce the radon concentration. The Reference Level for homes represents a level of risk for the general population similar to everyday risks such as fatal accidents on the road or deaths from accidental falls. It is estimated that approximately 91,000 homes, representing 7% of the national housing stock, have radon concentrations in excess of the national Reference Level[5], while about 0.06% exceed 1,000 Bq/m^3.

Estimating Risks from Radon Exposure

7. One source of data for estimating the risks to human health associated with exposure to radon is the Life Span Study of the survivors of Hiroshima and Nagasaki. The risk estimates based on the Japanese data are derived from a once-off exposure to high external radiation levels i.e. the radiation dose was delivered from outside the body and over a short timescale. This is different to the situation involving exposure to radon, where the source of radiation is inside the body, the radiation levels are normally lower and exposure extends over several years, or even decades.

8. Data also exist on the radiation exposure of the lung of patients undergoing medical treatment. These relate to radiation doses administered from outside the body as well as internal exposure from administered radioactivity. As with the Japanese data, all of the radiation doses are received over a relatively short period of time. It is therefore more desirable to base estimates of the risk from radon on population groups directly exposed.

9. Several studies[6] have been conducted on uranium and other miners who were occupationally exposed to radon, primarily in Canada, Czechoslovakia, Sweden and the United States. One of the largest of these, involving over 2,700 lung cancer deaths in 68,000 miners who between them had accumulated 1.2 million person-years of exposure, was published in the 1990s[7]. The study concluded that, on the assumption that these data could be applied directly to radon exposure in the home,

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[5] Fennell S.G. *et al.* (2002) Radon in Dwellings. The Irish national radon survey. Radiological Protection Institute of Ireland, Dublin. Report RPII-02/1.

[6] ICRP (1993) Protection against radon-222 at home and at work. International Commission on Radiological Protection. Publication 65. Annals of the ICRP. Pergamon Press, Oxford.

[7] Lubin, J.H. *et al.* (1994) Radon and lung cancer risk: a joint analysis of 11 underground miners studies. National Institute of Health. United States Department of Health and Human Services. Report NIH 94-3644.

radon could be responsible for approximately 9% of all lung cancer deaths in the United States.

10. In attempting to apply the risk estimates from the miners' studies to the general population, several differences between the two groups have to be considered. These include differences in age and sex distributions, the longer period of time over which members of the public are likely to be exposed and differences in the physical environment between mines and buildings. While the miners' data proved conclusively that long term exposure to radon increases the risk of lung cancer, these and other differences between miners and the general population could influence the risk factors for both groups.

11. Several case-control studies[8] have been conducted to quantify the risk following exposure to radon in the home[9,10,11]. A number of these studies were of low statistical power and, as a result, the calculated risk factors had large uncertainties. However, the risk factors derived were still broadly consistent with the miners' data. In 1999, an extensive study by the US National Research Council estimated that 10-15% of all lung cancers in the United States were caused by radon[12].

12. A number of geographical correlation studies[13,14] have also investigated the relationship between the risk of lung cancer and exposure to radon in the home. These studies compare exposure to radon and the incidence of lung cancer across large groups of the population and assume that the same risk relationship exists at the individual level. With this approach it is almost impossible to properly account for confounding factors that could

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[8] A case-control study is based on individual measurement and individual risk i.e. the exposure to radon of each individual in the study group is either measured or estimated.

[9] Letourneau *et al.* (1994) Case-control study of residential radon and lung cancer in Winnipeg, Manitoba, Canada. American Journal of Epidemiology 140: 310-322.

[10] Lubin, J.H. and Boice Jnr., J.H. (1997) Lung cancer risk from residential radon: meta-analysis of eight epidemiologic studies. Journal of the National Cancer Institute 89: 49-57.

[11] Samet, J.M. and Eradze, G.R. (2000) Radon and lung cancer risk: taking stock at the millennium. Environmental Health Perspective 108: 635-641.

[12] National Research Council (1999) Committee on the Biological Effects of Ionising Radiation (BEIR 4). Committee on Health Risks of Exposure to Radon. National Research Council, Washington, D.C. National Academy Press.

[13] Cohen, B. L. (1995) Test of the linear-no-threshold theory of radiation carcinogenesis for inhaled radon decay products. Health Physics 68: 157-174.

[14] Etherington, D. J. *et al.* (1996) An ecological study of cancer incidence and radon levels in South West England. European Journal of Cancer 32: 1189-1197.

influence the observed incidence of lung cancer. The most important confounding factor is smoking which can also show significant geographical variation and it is impossible to separate risk due to smoking from that due to radon unless the smoking status of each affected individual is known. For this reason these types of studies are normally not considered to provide useful information on the risks associated with exposure to radon[15].

13. In December 2004, the results of a joint analysis of 13 individual studies of residential radon exposure in nine European countries were published[16]. The studies had been carried out in Austria, the Czech Republic, Finland (2), France, Germany (2), Italy, Spain, Sweden (3) and the United Kingdom. The size of each of these studies on its own was too small to provide statistically significant results, but together they add up to the largest study of the risks of radon exposure in the home ever undertaken.

14. The study analysed 7,148 lung cancer cases and 14,208 controls. The principal conclusion reached was that, while the underlying lung cancer risk for active smokers was considerably higher than for lifelong non-smokers, the risk to both groups increased by approximately 16% for every 100 Bq/m^3 of radon exposure in the home. In addition, this risk seems to apply even at low radon concentrations, typically below the Reference Levels that apply in a number of countries. In early 2005, a comparable study undertaken in the United States reported similar results[17].

15. It is known that at high radiation doses a linear relationship exists between radiation exposure and risk of developing cancer. If the radon dose is doubled then the risk of developing cancer is also doubled. For radiation protection purposes, it is assumed that the linear relationship also applies at much lower doses. This is called the Linear-No-Threshold (or LNT) Hypothesis. The recent European study found that, in the case of radon, the LNT Hypothesis appears to hold down to about 150 Bq/m^3. Below this concentration, there is no conclusive evidence either way. However it is important to note that, as in all other fields of radiation protection, if the LNT Hypothesis does not hold and/or there is a threshold below which there is no risk, this could significantly affect the estimated risks.

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[15] Stidley, C.A. and Samet, J.M. (1993) A review of ecologic studies of lung cancer and indoor radon. Health Physics 65: 234-251.

[16] Darby S., *et al.* (2004) Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case studies. British Medical Journal 330: 223-228.

[17] Krewski D. *et al.* (2005) Residential radon and risk of lung cancer: a combined analysis of seven North American case-control studies. Epidemiology 16: 137-145.

Links between Radon and Smoking

16. It is generally accepted that radon is the second most important cause of lung cancer after tobacco smoking. It has previously been shown[18,19] that the relationship between exposure to radon and tobacco is greater than the sum of the individual risks, but less than multiplicative. These data were derived from studies of miners exposed to radon and until now no study of radon exposure in the home provided definitive information on the risks from radon in combination with smoking.

17. The recent European study recorded detailed smoking histories for all individuals and that allowed the relationship between smoking and radon to be examined. The study found that, on average, the risks of contracting lung cancer before age 75 at radon concentrations of 0, 100, 200 and 400 Bq/m^3 for lifelong non-smokers are 0.41%, 0.47%, 0.55% and 0.67% respectively. For active smokers, the corresponding rounded values are 10%, 12%, 13% and 16%. Ex-smokers were also found to be at significant risk from radon for a number of years after they had stopped smoking.

18. These data can be used to calculate the 'excess' risk due to radon alone, defined as the risk at a specified radon concentration less the risk at zero radon concentration. This is approximately 1 in 30 for active smokers and 1 in 700 for lifelong non-smokers at a radon concentration of 200 Bq/m^3. Therefore the risk to active smokers from radon is approximately 25 times greater than the risk to lifelong non-smokers. This suggests that the majority of lung cancers due to radon will be observed in people (active smokers but also ex-smokers) whose lungs have been damaged by tobacco smoke.

Risks in Ireland

19. Ireland has an average radon concentration of 91 Bq/m^3 compared with a European average of 59 Bq/m^3. To derive the risks from radon in Ireland, this value needs to be applied to the risk estimates discussed in paragraphs 16 to 18 above in combination with the national smoking habits of the 1990s (which are relevant to the current incidence of lung cancer). Statistical analysis leads to the conclusion that radon alone causes approximately 13% of all lung cancer deaths every year in Ireland. This corresponds to 195 lung cancer deaths, of which 91.5% (178) would be observed in active and ex-smokers and 8.5% (17) in lifelong non-smokers.

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[18] Doll, R. (1992) Risks from radon. Radiation Protection Dosimetry. 42: 149-153.

[19] Lubin, J.H. (1988) Models for the analysis of radon-exposed populations. Yale Journal of Biology and Medicine. 61: 195-214.

20. These are best estimate values and in any calculation of this nature there is some inherent uncertainty. This needs to be borne in mind when the numbers are being quoted. The RPII has previously estimated 10-15% of the approximately 1,500 lung cancer deaths in Ireland each year can be linked to radon. This equates to 150 to 200 lung cancer deaths annually. The RPII figure was based on the international risk estimates from the miners' studies and this is now confirmed by the recent European study of radon exposure in the home.

21. There is wide variability in the radiation dose received by individuals within the Irish population. This is influenced not only by the radon concentration present but also by the amount of time spent indoors. The longer a person remains indoors, the higher their exposure to radon. To date, the RPII has completed radon measurements in approximately 27,000 Irish homes of which around 3,400 have radon concentrations above 200 Bq/m^3 and 200 exceed 1,000 Bq/m^3. The highest concentration recorded to date is 49,000 Bq/m^3. Thus the residents of many Irish homes are at a much higher risk from radon than indicated by calculations made for exposure at either the average radon concentration in Irish homes or at the national Reference Level.

22. Lung cancer has a latency period of about 10 to 15 years. Therefore the incidence of lung cancer at any given time is principally dependent on the smoking habits of the population up to 15 years previously. The current trend in Ireland is of an overall reduction in smoking[20]. In 1970 some 46% of adults smoked. This dropped to approximately 30% in 1990 and to 27% in 2003.

23. At the individual level, the risks will be influenced by the number of cigarettes smoked per day, the number of years since smoking ceased and the extent of exposure to passive smoking. Because of the increased risk from radon to smokers, as the prevalence of cigarette smoking falls the number of lung cancer deaths due to radon in smokers will also fall, as will the number of lung cancer deaths generally. The much smaller number of radon induced lung cancers in non-smokers will remain the same over the next few years, but will increase marginally as the number of non- smokers increases.

24. While there are significant differences in the risks from radon between lifelong non-smokers, active smokers and ex-smokers, the overall risk is still significant. For example, accidents on the road account for approximately 300 fatalities annually, while cancer of the cervix kills around 70 women every year in Ireland. In 2003 there were 67 deaths following accidents in the workplace and 17 deaths caused by meningitis.

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[20] Organisation for Economic Co-operation and Development (2005) OECD Health Data 2005, June 2005. www.oecd.org/health/healthdata.

Implications for the national Reference Level

25. Given that there is a proven risk at the current Reference Level of 200 Bq/m^3, one needs to consider whether or not there is any justification for this to be reduced. If, for example, the Reference Level were to be set at 100 Bq/m^3, the risk to active smokers at the Reference Level from radon would be reduced to approximately 1 in 60 and that for lifelong non-smokers to about 1 in 1600.

26. Reducing the Reference Level by half to 100 Bq/m^3 would significantly increase the number of homes with radon concentrations above the Reference Level. Results from the National Radon Survey indicate that there are approximately 300,000 homes with radon concentrations above 100 Bq/m^3, compared with 91,000 above 200 Bq/m^3. The identification of those homes with radon concentrations between 100 and 200 Bq/m^3 is likely to require considerable resources and, once identified, their remediation will result in a smaller saving in radiation exposure than in the case of homes with higher radon concentrations.

27. Also to be considered is the fact that, at 200 Bq/m^3, the individual risks are similar to other everyday risks such as fatal accidents on the road and death due to accidental falls. As a society we tend to target the sub-groups such as those who drive at speed or under the influence of alcohol in an effort to reduce the number of deaths i.e. we target those at greatest individual risk. If the same approach is applied to radon, then the priority should be to identify the homes with highest radon concentrations rather than concentrating on a much larger number of homes with lower radon concentrations.

28. The vast majority of lung cancer deaths, including those deaths that are linked to radon, are among people who smoke, and non-smokers are at a low risk of contracting the disease. Programmes aimed at smoking cessation would help to maintain this fall in smoking rates among adults and will give rise to a significant reduction in the lung cancer deaths in future years far outweighing the benefit that may accrue from reducing the Reference Level.

29. Taking all these factors into account, it would appear that at this time reducing the national Reference Level for radon in homes to below the current value of 200 Bq/m^3 would result in a diversion of resources and effort to a section of the population at very low risk, and that the priority should be to continue with the identification and remediation of homes with higher concentrations of radon.

Conclusions

30. In conclusion, the most recent scientific information provides strong evidence that the risk estimates derived from occupational exposure to radon in underground mines can also be applied to radon exposure in the home. The previous estimate of 150-200 lung cancer deaths in Ireland every year due to radon remains unchanged. On that basis, the Institute does not believe that the Reference Level of 200 Bq/m^3 for exposure to radon in the home needs to be revised.

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