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PAPER 6

HUMAN EXPOSURE TO RADON DECAY PRODUCTS IN THE SOUTH WEST

First Edition May 1986

Published for the South West Energy Group by Devon County Council

ACKNOWLEDGEMENTS

The paper is based on published research and also on advice from the following whom I thank:

Dr A Wrixon (National Radiological Protection Board)
Dr P Warren (Building Research Establishment)
Mr A Webb (Consultant)
Dr E Durrance and Mr R Gregory (Exeter University Department of Geology).

I am particularly grateful to Mr Gregory for the time spent explaining to me the uranium geology of the South West. The opinions expressed are of course my own and no endorsement by the individuals or institutions listed is implied.

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1. INTRODUCTION

Human exposure to radioactivity associated with radon gas occurring naturally inside buildings in the South West has recently been highlighted in the press (1). This is because recently published work by the National Radiological Protection Board (NRPB) indicates that higher than average levels of exposure due to radon do occur in the region (2). West Devon District Council has decided to undertake its own survey on radon concentrations and to see whether these can be associated with lung cancer incidence (3).

The control of radon gas is likely to have implications for building structure and ventilation. There is a potential conflict between the desirability of increasing ventilation to cut radon levels on the one hand and reducing air infiltration to save energy on the other. This briefing paper reviews the NRPB's published results and other relevant information about radon.

2. BACKGROUND INFORMATION

Radon is a radioactive gas slowly released by materials containing radium. Radium in turn is produced by the radioactive decay of uranium. Uranium is present throughout the earth's crust but usually at very low concentrations of about three parts per million. In the granites of the South West the concentration is higher, typically between 10 and 12 parts per million (4). This increases the radium concentration and therefore the radon production rate.

Technically the main biological effect of radon comes not from the radioactivity of the gas itself but from that of further radioactive elements produced when radon atoms decay. This is the main part of what his loosely referred to as radon exposure. The principal biological effect of radon exposure is to increase the risk of lung cancer.

Solid granite is practically impermeable and so the radon will only be able to escape at faults or discontinuities. Therefore high levels of exposure are likely near the margins of the granite bosses of the south west peninsula. However the granite bosses themselves are extensively fractured and so radon enhancement may also occur well within the granite areas and underground hydrothermal circulation may carry uranium mineralisation some miles away from the granite itself (5). High radon levels in buildings are also possible where mine spoil (or other broken rock with relatively high uranium content) used as infill has produced radon-permeable ground (9).

In short, high radon concentrations are to be anticipated:

on or within a km or so of the granite bosses themselves, off the granite where there is likely uranium mineralisation and faulting,

on or off the granite where broken rock with high uranium content has been used as infill.

These criteria help the identification of potential high radon districts in Devon and Cornwall (see 3.2). It does not follow that all buildings within such areas will have very high indoor radon levels, but statistically speaking high radon concentrations will be more likely.

The air inside buildings almost invariably contains more radon than the outside air. This enhancement, typically by a factor of about 10, comes mainly from the building materials themselves and the ground the building stands on (6). Building materials emit radon if they are derived from crustal materials and therefore contain uranium at low concentrations. However, most indoor radon in the South West comes not from building materials, but from the subsoil. This will probably be the main source of the gas even if the building has granite walls. This is because the granite wall blocks will be solid and therefore not permit the release of radon in appreciable quantities.

3. LEVELS OF EXPOSURE AND BIOLOGICAL EFFECTS

Although a positive correlation between lung cancer incidence and radon exposure in uranium miners is firmly established (7), there seem to have been no detailed epidemiological studies of a potential link between lung cancer and radon related exposure in buildings. A significant risk may nevertheless exist in some cases.

3.1 COUNTY AVERAGES

There is no observed excess of lung cancer in the two south western counties (8). For women, the age standardised mortality rate for lung cancer in Devon and Cornwall during the decade 1968-1978 was not significantly different from the national average. For men the rate was significantly below average over most of the peninsula. The 1968-1978 figures provide no evidence, down to the geographical resolution provided by the sixteen local authority districts in Devon and Cornwall, of relatively higher rates of lung cancer in the potentially high radon areas of the South West.

The NRPB has undertaken national and regional surveys of radon concentrations in houses in the UK (2). The national survey took data from 2,000 houses in different parts of the country. The households initially approached were selected at random from the postal directory (9) and so they should form a fairly representative sample although there is the possibility of some social bias introduced by the willingness to take part in the survey. The national survey included fifty houses in Devon and Cornwall. Although this is not a very large sample, the results suggest that the radon concentrations inside houses in the two counties are typically three times the UK average.

This average level of exposure is consistent with the absence of a lung cancer excess, at least at the county level. The NRPB's figures (2) imply that a lifetime's exposure to domestic radon concentration three times the UK national average would entail an additional lung cancer risk of about 10^{-3} (1 in 1000). By contrast the average UK citizen runs a risk of about 5×10^{-2} (1 in 20) of dying from lung cancer. In comparison with this the incremental risk of 1 in 1,000 is not significant. The highest incidences of lung cancer is the UK are associated with extensive urbanisation. It appears that, so far as the average inhabitant of Devon and Cornwall is concerned, the reduced risk of lung cancer derived from living remote from the great conurbations more than outweighs any additional risk due to domestic radon exposure.

The calculation based on average domestic radon levels is over simplified because it fails to distinguish between smokers and non-smokers who have a much lower background lung cancer rate.

US data (7) gathered before smoking became widespread suggests that in a non-smoking (and non passive-smoking) population the lifetime cancer risk might be about 1 in 1,000. A significant part of the background risk to non-smokers may well be due to radon exposure and clearly non-smokers in Devon and Cornwall have on average a radon-related lung cancer risk about three times the mean UK radon-related lung cancer risk. However, we are still talking about risks of the order 10^{-3}, nothing like the lung cancer risk run by smokers. In addition, even non-smokers in cities are likely to suffer an increased lung cancer risk due to the generally higher levels of atmospheric pollution, and they too will benefit from the cleaner air of a rural environment.

3.2 HIGH RADON AREAS

There are some districts in Devon and Cornwall where radon concentrations are higher than the average for the two counties.

Criteria for identifying potentially high radon areas were identified in Section 2 above. Geological information on the distribution of granite and associated mineralisation (10) may be used as a guide to which parts of the sixteen local authority districts in Devon and Cornwall are likely to contain high radon areas. They would seem to include the following:

Carrick, Penwith and Kerrier, west of Truro and excepting the southern half of the Lizard peninsula,

Carrick and Restmoral, along the Perranporth-Pentewan line,

Restmoral, on and around the St Austell granite, particularly in the east,

Caradon and North Cornwall on and around Bodmin Moor,

Caradon, North Cornwall and West Devon between Bodmin Moor and Dartmoor,

West Devon, South Hams, Teignbridge and a small part of Mid-Devon on and around Dartmoor.

These areas would be expected to have statistically higher radon levels inside buildings and within them the maximum regional indoor radon concentrations would be anticipated.

The NRPB's regional survey measured indoor radon concentrations in areas of high radon concentration. Separately averaged over 150 houses in Devon and 329 in Cornwall, provisional results indicate radon concentrations respectively 9 and 16 times the national average. These levels are averaged over houses specifically chosen for likely high radon concentration and do not represent overall averages for the areas listed above. In the Cornish group concentrations more than 100 times the national average were observed in a few cases.

The average exposures just quoted for the 150 houses in Devon and 329 in Cornwall imply additional lifetime lung cancer risks of 3×10^{-3} (3 in 1,000) and 6×10^{-3} (6 in 1,000) respectively. These figures are respectively 1/16 and 1/8 of the national average lung cancer risk.

Given the relatively small number of houses likely to have very high radon levels, the beneficial effects of a rural environment, coupled with the fact that not everybody resident in a high radon area will remain so for his or her lifetime, it is not too surprising that no excess of lung cancer over the national average rate is observed in any of the local authority districts of Devon and Cornwall.

There is as yet no detailed epidemiological study relating radon decay product exposure to lung cancer incidence in the South West. However such an investigation would be very difficult to undertake, because of the relatively small number of houses with very high radon levels, the problems of people moving house, the effects of smoking, etc.

A lifetime's exposure to domestic radon at the highest levels recorded in Cornwall would, on the NRPB's estimates, incur a lung cancer risk of the order 0.1 (1 in 10), say twice the national average. Effectively this would double or triple the lung cancer risk of a person smoking ten cigarettes a day and produce in a true non-smoker a risk about double that of an average UK ten-a-day smoker. Moreover, the highest observed indoor radon concentrations are likely to cause exposures in excess of the standard set for occupational exposure to radon decay products. On the best estimate available (9) the number of houses in the South West with radon levels in excess of the occupational limit may be of the order of 1,000, although the figure is very uncertain at present.

3.4 RISK ESTIMATES

The radiological risk estimates used above derive from the recommendations of the International Commission on Radiological Protection (11). These are generally accepted by governments and those responsible for the regulation of the nuclear industry. However there is evidence that the ICRP risk estimates may be too low (12). The average or below average lung cancer incidence even in high radon districts of the South West does not provide a sensitive test of the ICRP figures however. Given the epidemiological advantage, with respect to lung cancer, of rural location the radon risk factor could be increased appreciably without the expectation of raising the South West lung cancer rate above the national average.

4. RADON CONTROL

It is possible that central government will introduce standards for domestic radon control, as the governments of other countries have done. If the recommendations of NRPB staff are followed (2, 6), these would initially try to ensure that radon levels in existing dwellings do not produce levels of exposure in excess of the occupational standard. On the ICRP risk factor this would correspond to a lung cancer risk from a lifetime's exposure of about 2×10^{-2} (2 in 100), appreciably less than the national average risk (1 in 20) but much greater than the risk run by true non-smokers (of the order 10^{-3}). For new buildings the standard might be set at one-fifth that for existing buildings. Recommendations made by the Royal Commission on Environmental Pollution (15) are in accordance with these suggestions. These or other standards would have to be backed up by measurements, possibly using the same techniques employed for the NRPB's national and regional surveys.

It remains unclear whether the government will implement such measures. However it is possible to make some assessment of the methods of control which might be adopted and to make one or two suggestions for practical steps which can be taken now.

In principle one can control radon either by inhibiting its entry into a building or by removing it, once it has entered, by increased ventilation.*

Most houses have ventilation rates in the range 0.5 to 2 air changes an hour. This range, other things being equal, could by itself be responsible for a variation of 8 to 1 in radon related exposure.

The existing observations suggest however that the highest levels of radon exposure in the South West are not correlated with low ventilation rates (9). Nevertheless houses on or close to granite areas should not be allowed to maintain very low ventilation rates (less than say 0.3 ac/h). It is unlikely that older buildings without modern or draught-stripped window and doors will be as airtight as this especially if there are unblocked chimneys open or ventilated to the inside. In more airtight buildings a small amount of window or ventilator opening should always be used. Purpose built ventilators and air-bricks should not be blocked, especially those ventilating the underfloor space.

However simply increasing ventilation rates is not a general solution to radon control. Natural ventilation, used in almost all UK houses, is unpredictable and does not allow heat recovery. Increasing ventilation will eventually raise heating costs to unacceptable levels and the heating plant will at some point be unable to meet the extra demand. In the longer term therefore the preferred solution to radon control must be to inhibit the entry of the gas. For this it will often be sufficient to reduce the permeability of the floor slab to radon. In solid floors this can be done by caulking any cracks, for example round pipes and drains, which might allow the soil gas access to the building. Swedish research suggests that this could reduce cross-floor radon infiltration by 90% (13). For suspended

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* As previously mentioned, it is the radon decay products and not radon itself which delivers most of the lung tissue dose. A third possible means of control is to remove the decay products, which became attached to particles in the air, using electrostatic precipitators. This method has disadvantages however, for example it increases ozone levels in the air.

floors it might be necessary to install a mechanical sub-floor ventilation system to keep the air pressure below the floor less than that in the house. Mechanical sub-floor ventilation systems can also be effective with solid floors. In Sweden radon reductions of the order 90% have been achieved with a system that reduces the sub-floor soil gas pressure by sucking air from a system of interconnected holes excavated below the slab (13). Where there are suspended wooden floors an immediate measure is to ensure that sub-floor ventilators are not blocked.

In the UK research on reducing radon infiltration has been undertaken by the NRPB with part funding and technical assistance from the Building Research Establishment and results of this work should be available in 1986 (14).

5. CONCLUSIONS

None of the sixteen local authority districts in Devon and Cornwall has a lung cancer rate significantly above the national average. However lung cancer statistics are dominated by the effects of smoking. The impact of radon exposure may therefore be masked. At the highest levels of exposure encountered in the region non-smokers may be experiencing a radon-induced lung cancer risk of the same order of magnitude as that run by smokers but the number of houses where this is the case is likely to be small.

It is possible that central government will introduce standards intended to ensure that nobody in the region would run a lifetime lung cancer risk in excess of about 10^{-2} as calculated on the risk estimates currently advocated by the International Commission on Radiological Protection. A standard set at about one fifth of this level may be used for new buildings. In order to meet these or other standards it will be necessary to inhibit the transfer of radon across the floors of some buildings in high radon areas. This will probably involve caulking cracks in existing floor slabs and inclusion of an impermeable layer in new ones. Suspended floors may need mechanical sub-floor ventilators although efficient natural sub-floor ventilation can be effective, so in existing buildings with suspended floors sub-floor ventilation should be unblocked. Mechanical sub-floor ventilation, using a system of suck-holes, can also be effective with solid floors. Increasing ventilation may reduce radon concentrations but is not a satisfactory general solution because of difficulties with heating.

REFERENCES

1 Western Morning News, 12 September: Survey Finds High Level of Radon Gas; ibid, 12 September End the Secrecy (Editorial).

2 A D Wrixon, 1985: Human Exposure to Radon Decay Products. Paper presented to the 52nd Conference of the National Society for Clean Air, Scarborough, 14-17 October 1985.

3 Western Morning News, 23 October: Council to Check Radon Danger; ibid, 23 October: Radon Probe (Editorial).

4 E M Durrance, private communication.

5 R Gregory, private communication.

6 M C O'Riordan, A C James, S Rae and A D Wrixon: Human Exposure to Radon Decay Products Inside Dwellings in the United Kingdom. Report R152, National Radiological Protection Board, Chilton, Didcot, Oxon.

7 R D Evans, J M Harley, W Jacobi, A S McLean, W A Mills, C G Stewart: Estimate of Risk from Environmental Exposure to Radon-222 and its Decay Products. Nature, 290, 98-100,1981.

8 M J Gardner, P D Winter, C P Taylor and E D Acheson: Atlas of Cancer Mortality in England and Wales 1968-1978. Wiley, Chichester, 1983.

9 A D Wrixon, private communication.

10 M Stone and C S Exley, High Heat Production Granites of South West England and their Associated Mineralisation: a Review, Proc. St Austell Conference on High Heat Production Granites, Hydrothermal Circulation and Ore Genesis organised by Institute of Mining and Metallurgy, September 1985.

11 Recommendations of the International Commission on Radiological Protection, Oxford, Pergammon Press (ICRP publication 26, Ann. ICRP 1, no 3).

12 R H Nussbaum, Survivor Studies and Radiation Standards. Bulletin of the Atomic Scientists, 41, 7, 68-71, 1985. (Short review).

13 S O Ericson, H Schmied and B Clavensjo: Modified Technology in New Constructions, and Cost Effective Remedial Actions in Existing Structures to Prevent Infiltration of Soil Gas Carrying Radon. 3rd International Conference on Indoor Air Quality and Climate, 1984.

14 P R Warren, private communication.

15 Royal Commission on Environmental Pollution, Tenth Report, HMSO, London 1984.