PUBLIC EXPOSURE TO RADON DAUGHTERS

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INTRODUCTION

Two surveys of indoor exposure to natural radiation in the UK have been carried out, a representative national survey and a selective survey of regions where above average radon concentrations were expected (1). Doses from both gamma rays and radon daughters were determined. Complementary studies were also made of the doses received outdoors. The focus here however is on indoor exposure to radon daughters.

NATIONAL SURVEY

This survey was carried out to determine the general distribution of radiation levels in dwellings, to search for correlations with the factors that might influence them and to improve the estimates of exposure of the population. The dwellings were selected systematically from the UK housing stock. The survey was conducted by post, measurements of radon concentrations in the living area and main bedroom being made with etched-track detectors (CR-39 detector elements) over a whole year. Information on the characteristics of the dwelling and relevant living habits of the occupants were obtained by use of a questionnaire. Of about 5,000 householders invited to take part, 54% agreed to participate. Of these, 88% (more than 2,000) completed the survey. This is a small fraction of the 20 million or so residences in the UK but was regarded as adequate if corrections could be made to any biases in the responses.

The distribution of radon concentrations for each dwelling weighted according to the average occupancy of different rooms (45% of time at home in the living area and 55% in the bedroom) is given in Figure 1. The distribution is approximately log-normal. The arithmetic mean, corrected for bias in the sample, was 20.5 Bq m^{-3} and the median about 13.6 Bq m^{-3}. The highest concentration found was 50 times the mean. The concentrations were strongly related to the local geology. Dwellings on clay had the lowest whereas those on more permeable sedimentary rock were higher. The highest concentrations were found in southwest England generally on or near granite.

The wide spread of results caused problems in analysing the data in relation to dwelling characteristics because the presence of one dwelling with high levels could unduly distort the analysis. To overcome this, the analysis was based on a restricted data set including only those dwellings with radon concentrations within two geometric standard deviations of the median.

About two-thirds of the dwellings surveyed were two-storey houses with the living area on the ground floor and bedroom upstairs. On average, the radon concentrations in such bedrooms were about 65% of those in living areas. About one in eight dwellings were bungalows: in these cases, the mean concentrations in bedrooms were only slightly less, at 90%, than the living areas. Flats and maisonettes above ground-floor level had lower concentrations than ground-floor rooms. These results confirm the view that the ground is generally the main source of radon in dwellings. There was no correlation between the main building material of the exterior walls and the radon concentrations.

Measures taken to reduce heat losses in dwellings, such as secondary glazing and draught proofing, achieve their success, at least partly, by reducing the ventilation rate. The analysis of the data showed that dwellings with either double glazing or draught-proofing around doors and windows in general had higher radon concentrations than those without. This effect can be clearly seen with the data for 2-storey dwellings where, after subtraction of the contribution from outdoor radon (4 Bq m^{-3}), partial double glazing leads to an increase in radon levels of indoor origin (the ground and building materials) by about 30%; complete double glazing leads to an increase by about 60%. The majority (about 60%) of the dwellings in the survey were of the 2-storey type. For other types of dwellings, such as bungalows, for which smaller sample sizes were available for the analysis, the uncertainties on the data became larger. Nevertheless, a similar, albeit less pronounced trend, was also observed for bungalows.

In most cases, an analysis of the data with respect to window opening habits showed no clear trends. The only detectable trend was in the case of dwellings where the living room window was left open at night. Here the radon concentrations in the living rooms were on average 20% lower than those for the survey as a whole.

Several factors that might be expected to influence radon concentrations showed little or no effect. These included: the type of heating used; the presence of an air brick above floor level; the use of extractor fans; the presence of a chimney or flue and the type of floor (suspended wood or solid concrete).

REGIONAL SURVEY

This survey was carried out to determine the magnitude of individual exposures, the results from which indicated the need for standards in the UK. The regions were selected from a study of the literature on metal mining and uranium mineralisation and in consultation with geologists. No attempt was made to obtain a representative sample for each area but rather to obtain dwellings in locations where above average radon levels might be expected. Over 700 householders, the majority in southwest England, completed the survey.

The distribution of radon concentrations in the dwellings in southwest England, the most interesting of the regions studied, is shown in Figure 2. The values have been weighted as in the analysis of the national survey results by average occupancy of different rooms. The mean radon concentration is about 300 Bq m^{-3}, that is, about 15 times the national average. About 20% of the dwellings surveyed were above the NRPB action level of 400 Bq m^{-3} (2,3). The highest value was about 8,000 Bq m^{-3}. In the Pennine areas of Derbyshire and North Yorkshire, the mean concentration was 100 Bq m^{-3}, with 5% of dwellings exceeding the action level. In the selected areas of Scotland, the mean radon concentration was 70 Bq m^{-3} with only 2% exceeding the action level. These last two sets of results are of some interest. In the former, it is thought that the substantial fracturing of the limestone which allows the relatively free movement of soil gas into dwellings is largely responsible for the higher than average levels. In the other case, although the regions surveyed were predominantly granite, the contrast to the results obtained in southwest England is marked. The absence of widespread mineralisation and fracturing of the granite is thought to explain the substantially lower levels of radon.

RADIATION DOSE

The national and regional surveys together provide a complementary indication of the exposure of the UK population to radon daughters in dwellings. The conversion coefficient from time-integrated radon concentration to effective dose equivalent now used is about 7 nSv per Bq h m^{-3} (3). This leads to a mean effective dose equivalent of about 1 mSv per annum from exposure to radon daughters in the home. An analysis of the time spent in indoor locations has revealed that, on average, 77% of time is spent indoors in residential accommodation and a further 15% in other buildings (1). On the reasonable assumption that radon concentrations in other buildings are the same as in dwellings, the average person in the UK would receive another 0.2 mSv per annum in these locations. Exposure out of doors (average radon concentration 4 Bq m^{-3}) would contribute a further 0.02 mSv per annum, giving a rounded total of 1.2 mSv per annum. The present evidence suggests that individual doses range from 0.4 to 400 mSv per annum in the UK.

Measurements of the concentrations of thoron decay products were made in 150 or so dwellings in the central uplands of England. A mean value of 0.3 Bq m^{-3} equilibrium equivalent thoron concentration was found. The effective dose equivalent due to indoor exposure was calculated to be 0.09 mSv per annum. Inclusion of a contribution from exposure outdoors leads to a total rounded dose of 0.1 mSv per annum.

These values may be compared with the mean annual effective dose equivalent from terrestrial gamma rays of 0.35 mSv with a range of individual doses from about 0.12 to 1.2 mSv, on the evidence from the surveys. The dose from cosmic rays is about 0.3 mSv per annum with only about a 10% variation throughout the country.

CONCLUSIONS

The surveys of exposure to natural radiation have provided firmer estimates than previously of the exposure of the UK population and have also indicated the range of exposures to radon daughters. These findings have led to an NRPB recommendation and Government agreement that action be taken to reduce high radon concentrations in existing dwellings and that measures be introduced to prevent high levels in new dwellings (2,3). The action level for existing dwellings is 20 mSv per annum (effective dose equivalent) which corresponds to a radon concentration of 400 Bq m^{-3}. The upper bound for new dwellings is 5 mSv per annum corresponding to 100 Bq m^{-3}. It is estimated that about 20,000 dwellings, mostly but not exclusively in southwest England, exceed the action level and that 3,000 houses are being built each year which are likely to exceed the recommended upper bound, again mostly in the southwest.

REFERENCES

(1) A D Wrixon, et al. NRPB-R190 (1987), London, HMSO.
(2) NRPB, ASP(10), London, HMSO.
(3) NRPB, NRPB-GS6 (1987), London, HMSO.

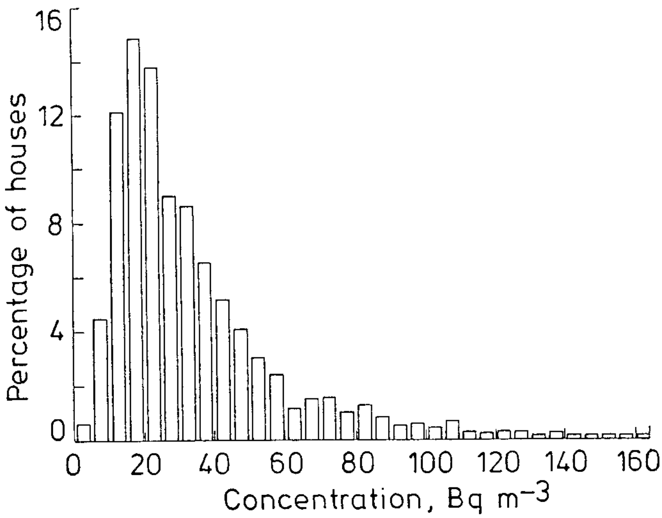

Figure 1: Distribution of radon concentrations in UK dwellings

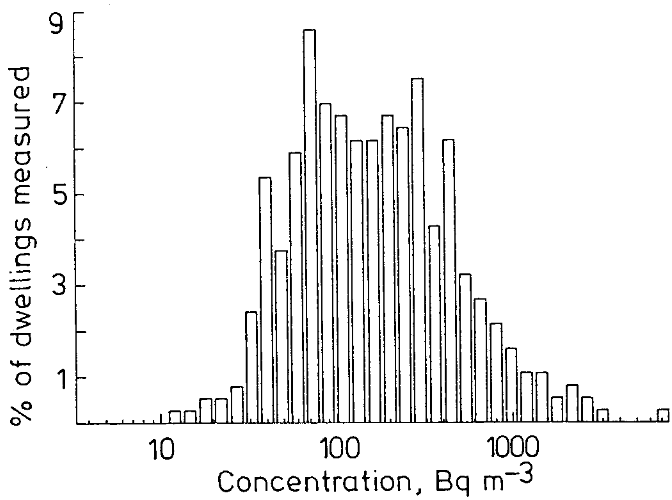

Figure 2: Distribution of radon concentrations in dwellings measured in the south west regional survey