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The United Kingdom Perspective on Radon

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In the UK, high concentrations of radon in indoor air, both in homes and in workplaces, have been recognised for some years as significant hazards to health. In homes, the Government endorses an Action Level of 200 Bq m^{-3} for the annual average radon concentration, above which measures should be taken to reduce the level. In all workplaces, radon daughter exposures of workers are regulated where concentrations exceed 0.67 10^{-6} J m^{-3} (0.03 WL). Epidemiological studies are in progress in the region most affected by high indoor radon levels.

INTRODUCTION

The National Radiological Protection Board (NRPB)) was established(1) under the Radiological Protection Act 1970, and acts as adviser to the Government on matters relating to radiation protection. Members of staff recognised in the early 1970s that the most significant source of exposure to ionising radiation for the average member of the UK population was the inhalation of radon daughters in indoor air(2). It was not until the introduction of the concept of effective dose equivalent(3) by the International Commission on Radiological Protection (ICRP) in 1977, however, that exposures to radon daughters could be compared readily with other sources of exposure to ionising radiation. Surveys for radon concentrations in UK dwellings(4,5) have demonstrated that the range of annual effective dose equivalent (hereafter referred to simply as dose) received by the population from radon daughters indoors is much larger than that from any other natural source. The potential for very high doses from radon daughters in indoor air has led(6) to an Action Level, designed to limit exposures at home, being adopted by the Government, and for exposures at work to be controlled(7) under the Ionising Radiation Regulations 1985.

RADON IN DWELLINGS

A study of radon concentrations in about 90 dwellings(4) in England and Scotland was carried out in 1976. This study focussed mainly on the major population centres, which are situated predominantly in areas of sedimentary geology. Even so, a wide range of concentrations was found. There were reasons related to geology and mining history, however, that suggested higher concentrations of radon in indoor air might occur in regions of the UK that were sparsely populated and had not been included in this study.

It is the radon daughters in inhaled air that deliver essentially all the dose to lung tissue. For a given radon gas concentration, the dose increases with increasing equilibrium factor, F, and depends markedly(8) on the fraction, f_p, of the potential alpha energy concentration (PAEC) of the daughters that is not attached to the ambient aerosol. It has been shown(9) that, in homes, conditions leading to an increase in F are associated generally with a decrease in f_p, with the result that the average radon gas concentration is a much better indicator of dose than is any simple measurement of daughter concentration. In the UK, a single conversion coefficient(10) of 20 Bq m^{-3} of radon gas per mSv a^{-1} has been adopted for the typical occupancy factor(11) of 0.8 for dwellings.

The concentration of radon in indoor air exhibits large variations over short time intervals, and long-term integrating detectors are required to measure the annual average concentration. Etched-track detectors have been developed that provide a cheap and reliable method for determining average radon gas concentrations over periods from weeks to months(12,5) and allow studies to be conducted by mail.

Two substantial exploratory studies of radon in UK dwellings have been completed(5). One was a national representative survey (population density weighted) of 2100 or so dwellings, the other a regional survey of about 700 dwellings in areas where local conditions suggested that high radon levels might occur. In these surveys, the average radon gas concentration over a year was determined for both the living area and an occupied bedroom. The results for the national survey are shown in Figure 1, where the annual average radon concentration is occupancy-weighted(11) to reflect 55% of the time spent at home in the bedroom and 45% in the living area. The distribution is approximately log-normal with geometric mean 14.8 Bq m^{-3} and geometric standard deviation (GSD) 2.17: more high values occurred however than the values of these parameters predict. If the average value(5) of 4 Bq m^{-3} for radon concentration in outside air is subtracted from each result, a better fit to a log-normal distribution is obtained (personal communication, J C H Miles, NRPB); the geometric mean is then 7.8 Bq m^{-3} and GSD 3.50. The arithmetic mean radon concentration was 20.5 Bq m^{-3}, indicating an annual dose of 1 mSv. Apart from home, persons spend on average 15% of their time indoors elsewhere(11), and on the assumption that radon concentrations there are similar to those at home, the mean annual dose received by the UK population from indoor radon is about 1.2 mSv.

In the regional survey, parts of the counties of Cornwall and Devon in southwest England were found to be most affected by high radon levels; the results for this region are shown in Figure 2. The distribution is again approximately log-normal with geometric mean 159 Bq m^{-3}, GSD 3.6 and arithmetic mean 309 Bq m^{-3}.

Preliminary results from these surveys demonstrated that some members of the public were receiving annual doses from indoor radon that were by any standard unacceptable, and in 1982 members of staff of the NRPB considered(13) the possibility of controlling them. It was considered that annual doses in excess of 25 mSv would be difficult to defend, particularly as the implied lifetime risk of lung cancer was calculated to be comparable to that from all accidents. Consideration of actions to reduce indoor radon levels would need, however, to take into account the feasibility of doing so, the costs and the likely degree of success. It was acknowledged that some thought should be given also to the economic and social consequences of any proposed action.

In 1984, ICRP discussed(14) the principles for limiting exposure of the public to natural sources of radiation, in particular to radon daughters indoors. ICRP proposed different control levels for existing and future dwellings, as it was thought that the cost of incorporating radon preventive measures at the construction stage should be less than remedial action in occupied structures. Remedial action would also be disruptive and might cause distress to homeowners. An Upper Bound corresponding to an annual dose of 10 mSv was therefore proposed for future dwellings with a graded approach, in terms of severity of action, for existing homes starting at an Action Level of 20 mSv.

The Royal Commission on Environmental Pollution (RCEP) considered radon, among other things, and in its 1984 report(15) recommended action in existing dwellings where the annual dose exceeded 25 mSv. A value of 5 mSv for future dwellings was conditionally advocated. In its response(16) to the RCEP report, the Government indicated its intention to await the advice of the NRPB before considering what measures might be taken.

The first recommendations(17) of NRPB in 1987 took as their basis the scheme proposed by ICRP, recommending an Action Level of 20 mSv for existing homes above which homeowners should be advised to reduce radon levels. An Upper Bound of 5 mSv, however, was recommended for future homes. A temporal condition regarding the urgency with which remedial action should be taken was also introduced: priority should be given to the homes with the highest radon levels. In terms of annual average radon gas concentration, the Action Level and Upper Bound were deemed to correspond to 400 Bq m^{-3} and 100 Bq m^{-3} respectively. The Government accepted(18) the advice, making it clear that the advice would be kept under review and that further research to identify homes having high radon levels and to determine cost-effective remedial action would be funded by the exchequer. These studies are continuing and, by the end of 1991, it is estimated that radon measurements in some 25,000 homes in the UK will have been completed. This figure includes nearly 4000 homes studied by the Institution of Environmental Health Officers(19,20) and financed by local government.

Lifetime risk of contracting lung cancer is perhaps the most important consideration when recommending an Action Level. At the time of the initial advice to Government(17), the lifetime risk associated with an annual dose of 20 mSv from radon daughters was estimated to be about 2.5%, similar to the combined risk of death from accidents on the road and in the home. That the lifetime risk is considerably higher(21) than 2.5% follows from the re-evaluation by the BEIR IV committee of the data on miners exposed to radon daughters(22), and the assessment by ICRP(23) of the risk from exposure to radon daughters in the home. Increased risk, by a factor between 2 and 3, was also suggested(24) by health effects models developed by NRPB.

The assumption that radon resistant floors at the construction stage of dwellings would be considerably cheaper than remedying existing homes has proved not to be the case in practice. In addition, members of the public and the building professions could not appreciate the need for different standards for existing and future homes. Consequently, in January 1990, the NRPB advised the Government that its recommendations on radon in homes should be strengthened and simplified.

NRPB recommended(6,25), and the Government accepted(26), that the Action Level for existing homes should be reduced to an average radon concentration of 200 Bq m^{-3} and that future homes should be so constructed that radon concentrations are as low as reasonably practicable and at least below 200 Bq m^{-3}. It was recognised, as before, that homes with the highest radon levels require earlier action, and it was further recommended that action be taken as soon as reasonably practicable and at least before a further integrated exposure of 1500 Bq m^{-3} y is accumulated; this is approximately the life-time exposure at the average indoor radon level in the UK. Radon affected areas are to be defined as those where there is a 1% or greater probability of present homes, or of future homes without preventive measures, exceeding 200 Bq m^{-3}. Figure 3 indicates, on a county or regional basis, the percentage of homes in the UK estimated to exceed 200 Bq m^{-3}. The total number of homes exceeding 200 Bq m^{-3} is estimated(25) to be at least 75,000, of which about 2500 had been identified by March 1990.

Following initial acceptance(18) of the need for action, the Department of the Environment issued a booklet(27) for the general public providing general information about radon: it dealt with all aspects of the subject in a succinct yet informative way. It was also recognised that changes in building practice were required in areas where high indoor radon levels were common, and interim guidance on floor construction in these areas was issued as well(28). Both of these documents are being revised in the light of experience and the changed circumstances brought about by the revised NRPB recommendations.

RADON IN WORKPLACES.

Until the Ionising Radiation Regulations 1985 came into force(7), radon in workplaces was not subject to legislation in the UK. Radon levels in British coal mines had been studied in the nineteen sixties and found(29) generally to be low, but relatively high levels were found(30) in some metal mines. These findings prompted a wide-ranging survey(31) for radon levels in non-coal mines throughout the country. It was estimated that 42% of non-coal miners were receiving annual exposures exceeding 4 WLM (Working Level Months), the limit then in force for miners in the USA which is equivalent to 2520 kBq m^{-3} h equivalent equilibrium radon (EER) concentration. NRPB recommended that the occupational exposure of miners be limited to 4 WLM in a year, and that miners having exposure in excess of 1 WLM (630 kBq m^{-3} h EER) should be subject to programmes of radiological surveillance. A follow-up some years after these recommendations, indicated(32) that the exposures had been significantly reduced, with 28% exceeding the recommended annual limit.

The introduction of the Regulations imposed controls on radon daughter exposure for all workers, in above-ground workplaces as well as in mines. The Regulations are framed in terms of radon daughter concentration, but they apply only if the concentration averaged over any 8 hour working period exceeds 0.67 10^{-6} J m^{-3} (approximately 0.03 Working Level, WL). The geographical distributions of workplaces and homes with elevated radon daughter concentrations are similar; in many instances the buildings are comparable in size and construction. Thus, buildings such as schools, medical practices and libraries in some areas would be subject to the Regulations unless measures were taken to reduce radon levels. Certain regulatory requirements come into effect when the annual dose to workers exceeds 5 mSv, and preliminary studies(33) in southwest England indicate that in many buildings workers might receive annual doses from radon daughters well in excess of this value. In many cases, fortunately, substantial reductions in radon concentration can be achieved using techniques well known in North America and Scandinavia, such as underfloor depressurisation. Cornwall County Council, for example, has completed radon monitoring in some 500 public buildings, predominantly schools, and has identified about 80 to which the Regulations apply. Successful remedial action has been taken in 25 buildings with more action planned for the summer of 1990.

EPIDEMIOLOGY

A case control study(34) of lung cancer in southwest England is in progress, organised jointly by NRPB and the Imperial Cancer Research Fund. Six hundred lung cancer cases will be studied together with two control populations of similar size each matched to cases for age and smoking history. One control population will be drawn from persons admitted to hospital with respiratory complaints, but diagnosed as not suffering from lung cancer, the other from the general practitioner lists for the area. Radon measurements will be made in the current homes of cases and controls and in homes previously occupied during the period from 35 to 5 years before the study. Results should be available in 1994.

A cohort study, with about 13,000 participants, is at the planning stage. This would again be focussed on southwest England and be directed at the cause of death for occupants of homes in which radon measurements had been completed.

CONCLUSIONS

The problem of potentially high exposure to radon and its daughters has been recognised in the United Kingdom for two decades or so. Before recommendations for controlling these exposures could be developed, a clear understanding of the extent of the problem was required. Systematic and regional surveys of radon in dwellings defined the mean exposure and demonstrated the magnitude of some exposures.

Mines were first recognised as workplaces where high radon daughter exposures could occur; operators of some mines acted to reduce radon concentrations before there was a legal requirement to do so. Government recognised that high radon exposure at work could occur in circumstances other than mining and introduced legislation to control exposures in all workplaces.

Acting on early advice from NRPB, the Government accepted the need for action against high radon levels in homes, and acknowledged the need to limit individual risk by assigning the highest priority to those receiving the highest exposures. NRPB responded to revised risk estimates for the induction of lung cancer by advising that the level of radon in homes above which remedial measures were required should be reduced, with the result that the Action Level is now set at an annual average radon gas concentration of 200 Bq m^{-3}.

Studies to define the radon problem in the UK have been carried out in a deliberate manner. The risk from high radon levels in homes and at work are recognised, but there is no sense of panic in the community. Although much has been achieved, there is no sense of complacency, and studies to identify and remedy affected homes and workplaces will continue at a sensible level and with appropriate emphasis on the avoidance of risk and compliance with the law.

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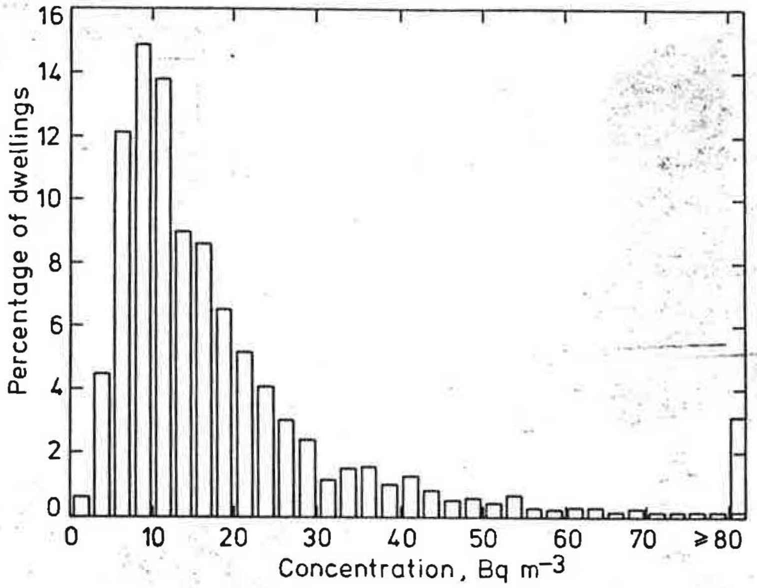

Figure 1 National survey distribution of indoor concentrations

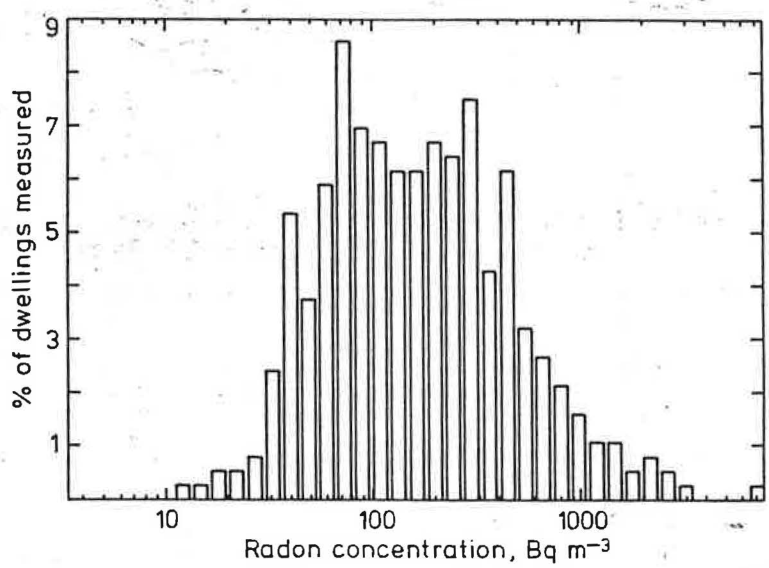

Figure 2 Distribution of radon concentrations in dwellings measured in the southwest England survey

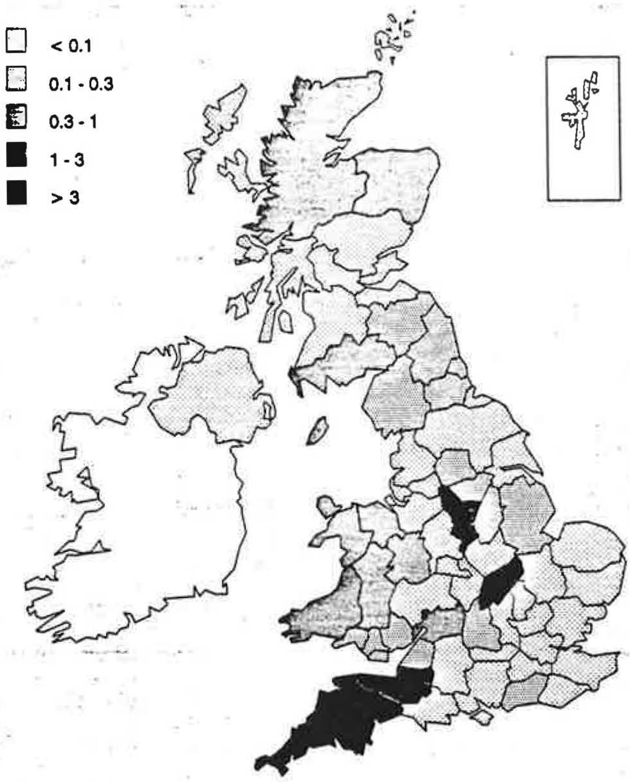

Figure 3 Percentage of homes in the UK with radon concentrations above 200 Bq m^{-3}