Natural radiation

How to live with radon

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'As safe as houses' is not a sound simile. Mortality statistics for accidents in homes show that one death in a hundred is from fumes, falls or fires. If potential deaths from indoor exposure to radon are included, home seems even less a haven. Participants at a recent meeting* agreed that radon is the most serious cause of human irradiation, attempted to quantify the consequences for health and explored the developing controls on domestic exposure. It is clear that an important advance is occurring in radiation protection — the extension of dose limitation from artificial to natural sources.

The risks from radon are as real as those from any other radiation, and doses received by the public can be much higher than from artificial sources; excessive exposures are, moreover, readily avoidable. These facts should be reflected in a rational approach to radiation protection, but public perception determines otherwise, and effort is perforce diverted to less serious sources. It was encouraging to learn at the meeting that the imbalance is being corrected.

Human exposure to terrestrial gamma rays, cosmic rays and natural radionuclides in diet is appreciable but not too variable. The annual dose from these sources of radiation, which has been called basic background, is on average about 1 mSv (millisievert), this quantity being the effective dose equivalent. It is important to establish the magnitude of this dose, as it is a convincing criterion of the acceptability of the annual limit of 1 mSv set by the International Commission on Radiological Protection (ICRP) for prolonged exposure to artificial sources of radiation.

Variability

The chief characteristic of indoor radon levels, however, is their variability. On average, the concentration in temperate latitudes is about 15 Bq m^{-3} (becquerels per cubic metre of air), the equilibrium equivalent concentration of radon-222. The value of this quantity can range from an order of magnitude below to three orders of magnitude above for otherwise ordinary houses.

Dosimetric models for the human lung lead to a conversion coefficient of 10 Bq m^{-3} = 1 mSv yr^{-1} between the annual average concentration and the annual effective dose equivalent (Anthony James, National Radiological Protection Board, Chilton), and there are corroboratory results from studies of the rat lung (Naomi Harley, New York University School of Medicine). Annual doses, therefore, run from 1 mSv or less through an average of 1.5 mSv to 1,000 mSv or more. The gravity of this circumstance has not escaped notice, and enlightened authorities are following the recommendations of the ICRP by intervening to remedy and prevent the highest indoor exposures.

The high indoor levels are caused by the forced flow of radon-laden soil gas into buildings. The entire process is described by a 'four-p' mnemonic: production of radon from the trace quantities of radium in the ground; permeability of the ground to air; perforations or other gaps in floors; pressure differential between houses and the atmosphere, which is usually negative (Anthony Nero, University of California, Berkeley).

The four immediate decay products, or daughters, of radon-222 are radioactive isotopes of solid elements with short half-lives, two of which transform by emitting alpha particles. The daughters create a radioactive aerosol with small particles in room air. When inhaled, some daughters are deposited and retained in the respiratory tract, where the alpha particles irradiate epithelial cells, particularly in the bronchial region; the potential effect is the induction of lung cancer. Radon gas itself delivers only a very small dose.

Radon reference data from the ICRP

Radon parameter	EEC (Bq m^{-3})	Lifetime risk Relative	Lifetime risk Absolute (per cent)
Average value	15	0.1	0.25
Upper bound	100	0.5	1.3
Action level	200	1.0	2.5

Radon parameters are the prevailing, prevention and remedial levels for houses. EEC implies lifelong exposure at equilibrium equivalent concentration. The absolute value of lifetime risk is for a population with 2.5 per cent prevailing risk of lung cancer.

To date, there is no conclusive evidence of excess lung cancers among households exposed to high levels of radon daughters, but more epidemiological investigations are being conducted in Sweden, Norway, Britain and the United States, and others are being planned. Case-control studies preponderate, each requiring the establishment of past exposure to radon and allowance for cigarette smoking. There is, however, determinative evidence from epidemiological studies of miners who received large doses underground, supported by the results of inhalation studies on animals (Frederick Cross, Pacific Northwest Laboratory, Richland). A relative risk model with a multiplicative influence of smoking has been used by the ICRP, after appropriate adjustment, to translate the lifetime risk of lung cancer from mining to domestic exposure (Wolfgang Jacobi, GSF Institut für Strahlenschutz, Munich). In the table, the model is applied at the average, design and action levels for indoor radon recommended by the ICRP. Lifelong exposure at 200 Bq m^{-3}, for example, implies a doubling of the prevailing risk, which is 2.5 per cent for the reference population, but which varies from country to country.

Programmes

The Committee on the Biological Effects of Ionizing Radiation (William Ellett, National Research Council, Washington DC) also used a multiplicative model of smoking and radon exposure in a modified relative risk analysis of the data for miners, but assumed that the results are best applied without adjustment to domestic exposure. The outcome is a greater estimated risk than that of the ICRP; the difference is within the uncertainties of the models.

Programmes to determine and limit indoor exposure to radon are being pursued by Nordic, US and British authorities, and the Commission of the European Communities is teetering on the edge of a decision (James McLaughlin, University College Dublin). None of the limitation criteria coincides with the ICRP recommendations for new and old houses, but they are generally congruent. Sweden is the most advanced country in Europe: measurements have been made in 60,000 or so houses, about 2,000 have been remedied, and preventive measures are effective in almost 95 per cent of cases (Gun Astri Swedjemark, National Institute of Radiation Protection, Stockholm). But the most dramatic advances have occurred in the United States, where a partnership is being forged between the public and private sectors to tackle radon (Richard Guimond, Environmental Protection Agency, Washington DC). Federal expenditure on radon reached $10 million in 1987 and is likely to increase: the main objectives of the programme are to discover the scale of the problem, develop both remedial and preventive measures, and disseminate helpful information. Fundamental research on radon effects is supported, expenditure by states is also substantial, more than 250,000 householders have tested their homes, and a few thousand have remedied high levels. □

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