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A Little Exposure to Radon

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Abstract. Indoor air quality (IAQ) has recently been a subject of increased concern, because (1) indoor pollutant levels and exposures frequently exceed those encountered outdoors, (2) many new products are being introduced into the indoor environment that provide increased levels of exposure and (3) energy conservation measures that reduce ventilation rates can elevate indoor pollutant concentrations. The indoor pollutant which has attracted the greatest public attention to date is radon. This paper provides information on potential sources of radon, typical indoor levels, the relationship of energy-efficient construction to these levels, the potential health effects from exposures to radon progeny and effective control strategies to mitigate indoor radon levels in residences. In addition, this paper addresses how government and other organizations have responded to concerns about indoor radon exposures.

Key words and phrases: Radon, indoor air quality, energy conservation, environmental health effects, air pollution, low-dose radiation exposure.

INTRODUCTION

Within the last decade, concern about the quality of indoor air has become a major environmental factor in the design, construction and operation of buildings. Indoor air quality (IAQ) has become a subject of increased concern because (1) indoor pollutant levels and exposures frequently exceed those encountered outdoors, (2) many new products are being introduced into the indoor environment that provide increased levels of exposure and (3) energy conservation measures that reduce ventilation rates can elevate indoor pollutant concentrations. As the need to maintain acceptable indoor air quality has become a public issue, policymakers have had to develop strategies to address this need based upon the best available information.

Radon is the indoor pollutant which has attracted the greatest public attention to date. This paper provides the following information about radon: (1) potential sources; (2) typical indoor levels; (3) the relationship of energy-efficient construction to indoor levels; (4) potential health effects and (5) effective control strategies to mitigate indoor levels in residences. In addition, this paper addresses how government and other organizations have responded to concerns about indoor radon exposures.

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RADON SOURCES AND INDOOR LEVELS

Radon-222, commonly called radon, is a naturally occurring radioactive gas created in all earth materials by the decay of trace quantities of uranium. The primary source of indoor radon is the infiltration of radon-bearing soil gas into dwellings from surrounding soil. Water is a secondary source, which can be significant when water requirements are met from radon-contaminated private water supplies.

Radon is transferred through the pores of rock and soil and infiltrates into houses in response to pressure differences between the inside of a house and its surrounding soil. Primary entry sites for radon include below-grade cracks in the building envelope, construction joints at walls and floors, loose-fitting pipe penetrations and sump pump wells.

Indoor radon levels are primarily determined by the rate of entry of radon from surrounding soil; the influence of ventilation (achieved by infiltration in most residences) on indoor radon levels is significant but secondary (Nero, Boegel, Hollowell, Ingersoll and Nazaroff, 1983).

Radon entry rates are determined by the concentration of radium (the precursor of radon) in the soil, the soil permeability and house characteristics (e.g., construction type—basement, crawl space, etc.). Therefore, the probability of a given home having a high indoor radon level is greatest in geographic locations with radium-rich, highly permeable soils. In addition, *it cannot be generalized that tight* (*i.e., low infiltration rate*), *energy-efficient houses will have high indoor radon levels and loose, less energy-efficient homes will not.*

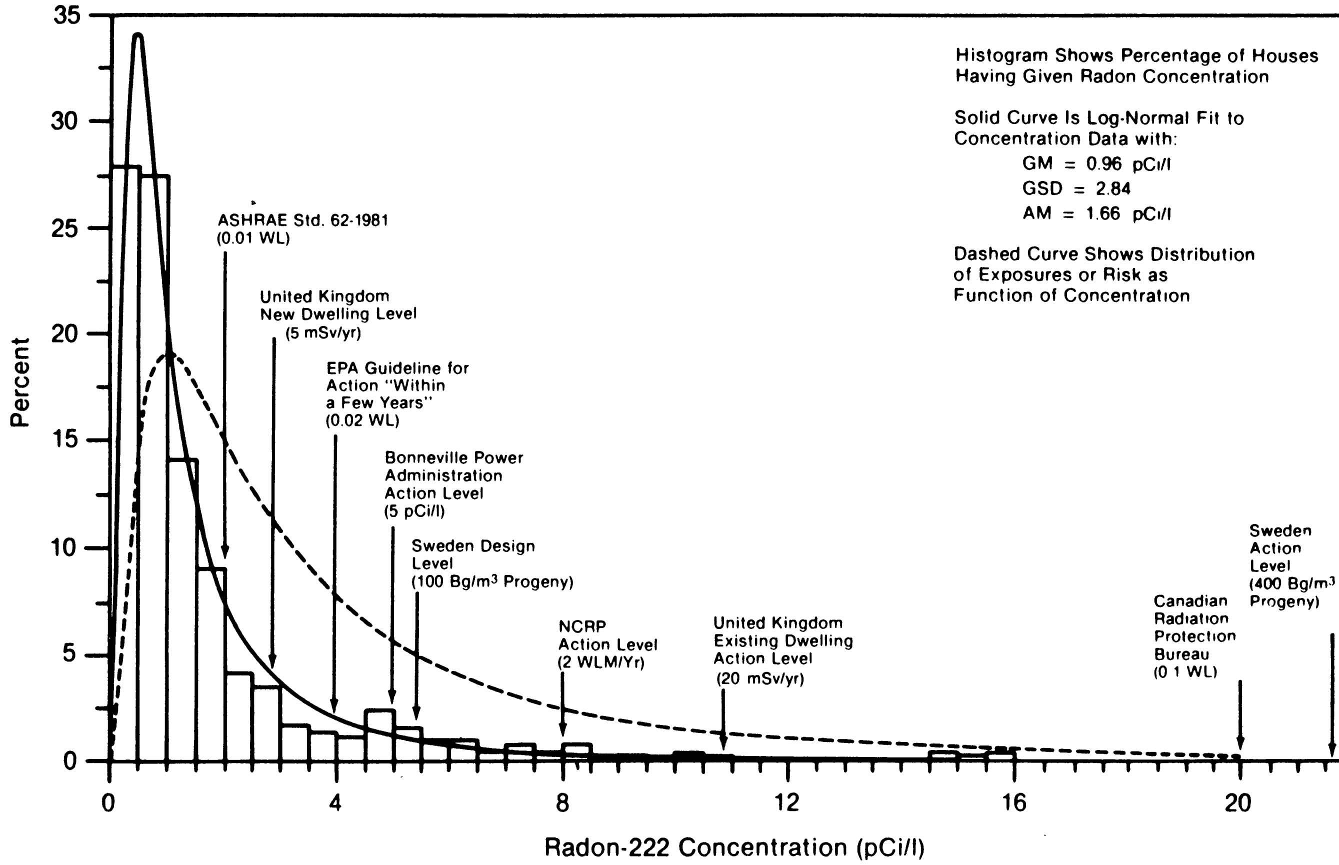

FIG. 1. *Frequency distribution of* ^{222}Rn *concentrations in* 552 *homes in the United States.*

Nero (1986) estimated the frequency distribution of radon levels across the United States by combining the results of unbiased radon field studies. The resulting frequency distribution curve is shown in Figure 1.

POTENTIAL HEALTH EFFECTS

The four immediate decay products of radon-222, commonly called radon progeny or daughters, are radioactive isotopes with short half-lives. Two of the radon progeny decay by emitting alpha particles. Some of the radon progeny attach to other small particles in the indoor air, giving rise to the terms "attached" and "unattached" fractions, and resulting in a radioactive aerosol. When this radioactive aerosol is inhaled, radon progeny can be deposited and retained in the respiratory tract, causing the epithelial cells to be irradiated by alpha particles. The potential effect of this irradiation of the lung is the induction of lung cancer.

Concern for indoor radon exposures stems from epidemiologic evidence of excess lung cancer among uranium and other miners who were exposed to high concentrations of radon progeny at work, levels usually higher than those experienced in dwellings. In addition, there is also evidence that radon and smoking interact in the induction and promotion of lung cancer, potentially in a multiplicative manner. Experimental exposure of animals to radon progeny support these results. Finally, small epidemiologic studies of groups of persons exposed to elevated concentrations of radon progeny in dwellings are indicative of excess lung cancer, but not conclusively so.

To determine the risk per unit of exposure to radon progeny from the miner epidemiologic data, it is appropriate (i.e., the best guess) to adopt the conventional assumption of a linear relationship, without threshold (i.e., radiation exposures contribute cumulatively to risk). Alternatively, the dose equivalent to lung tissue per unit of exposure may be determined from a model of the deposition and retention of radon progeny in the lung and then translated into risk. Both approaches yield fairly congruent results (National Radiological Protection Board (NRPB), 1987).

MITIGATION TECHNIQUES

The United States Department of Energy (DOE) and Environmental Protection Agency (EPA) are among the organizations conducting research to identify and evaluate mitigation technologies to reduce indoor radon levels. These research efforts are investigating both source control techniques to minimize radon entry and ventilation strategies to dilute indoor radon levels. Although source control is the preferred technique whenever feasible, in some instances, increased ventilation is the easiest and most cost-effective mitigation approach.

Research devoted to radon mitigation is studying the following mitigation strategies: sealing cracks and holes at below-grade building envelope surfaces, house ventilation with heat recovery, substructure ventilation, basement pressurization and crawl space sealing and ventilation. Preliminary results indicate that all of these techniques, properly applied, are capable of reducing indoor radon levels (Turk, Prill, Fisk, Grimsrud, Moed and Sextro, 1986; Henschel and Scott, 1986). For additional information, readers are referred to EPA's technical guidance document on radon reduction techniques (EPA, 1986a).

SUMMARY

The primary source of indoor radon is known to be from surrounding soil, and the potential health consequence is lung cancer. Relying upon the frequency distribution curve shown in Figure 1 and extrapolating from uranium miner data, the percentage of the United States population exposed to a given indoor radon level or higher can be estimated, as can the accompanying risk. For example, approximately 2% of houses in the United States are at a level of 8 pCu/liter or higher, and the associated lifetime risk of inducing lung cancer from exposures to this level is estimated to be about 2%. The risk is nonvoluntary, imposed by natural phenomena and apparently occurs primarily in residential and low-rise buildings. Effective indoor radon mitigation strategies do exist, although further research is needed both to ensure the reliability and reduce the costs for these techniques.

How have government and other organizations responded to concerns about indoor radon exposures? The EPA and the United Kingdom Department of the Environment have responded, in part, with public information pamphlets (EPA, 1986b,c; United Kingdom Department of the Environment, 1987). The United States DOE and the EPA have increased their coordinated research efforts devoted to radon. Finally, numerous organizations, including both federal and state governments, have adopted or proposed various limitation schemes to reduce radon exposures.

Some of these guidelines, standards, recommended action levels, etc. are indicated in Figure 1 (NRPB, 1987; EPA 1986b; ASHRAE, 1981; Bonneville Power Administration, 1984; National Council on Radiation Protection and Measurements, 1984). Figure 1 indicates both the unit of choice and the relative picoCuries per liter value for each of the various limitation schemes, using generally accepted conversion factors. These units are, respectively, abbreviated: Working Levels (WL); milliSieverts per year (mSv/yr); Becquerels per cubic meter (Bq/m^3); and Working Level Months per year (WLM/yr). It is important to note that *the choice of a recommended indoor radon action level dramatically affects the percentage of homes, and hence populations, identified at risk.*

In conclusion, in response to concerns about indoor radon exposures, policymakers have, using the best available information, developed a full spectrum of alternative policy responses ranging from no action to standards. Although all were developed for the same indoor pollutant, these responses are nonuniform in their approach, choice of acceptable levels and impact on affected populations.

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