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The U.S. EPA Office of Research and Development Overview of Current Radon Research

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ABSTRACT

The Air and Energy Engineering Research Laboratory (AEERL) of EPA began a research program to develop and demonstrate radon mitigation alternatives in 1984. This program grew significantly in 1986 with the addition of a Congressional funding supplement. In 1989 a separate Radon Mitigation Branch was established within the Pollution Control Division of AEERL. Radon mitigation research within EPA has evolved since 1984 from a program initially focused on houses with severely elevated radon levels in Boyertown (Pennsylvania) and Clinton (New Jersey) to the multi-faceted program currently concerned with reducing radon to near-ambient levels in existing houses, new houses, schools, and other large buildings.

This direction of EPA's Indoor Radon Program recognizes the successes achieved by EPA and others in demonstrating mitigation options capable of reducing radon to below 4 pCi L^{-1} in the majority of houses. However, these options: 1) fail to achieve the ambient radon goal established by the Indoor Radon Abatement Act of 1988 (IRAA-88), 2) are too expensive for general homeowner acceptance, and 3) have only limited development and demonstration for schools and other large complex structures. To address these needs, emphasis is being placed on research of low radon level houses, directed at low-cost solutions for lower radon houses in order to have significant impact on the estimated 16,000 to 20,000 radon-induced lung cancer deaths each year.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

BACKGROUND

In recent years, indoor radon has received recognition as an environmental health problem for a large portion of the population. The current notoriety of radon comes from the value attributed to its effective dose in indoor air. Radon is considered the main source of exposure of individuals to ionizing radiation (Figure 1) (1). The average lifetime risk of radon-caused lung cancer for individuals in the U. S. population is approximately 1 in 10,000 (2). This assessment of risk is the result of improvements both in the knowledge of radon concentrations in houses throughout the U. S. and in the dosimetric models. The main source of high radon concentrations indoors is the exhalation of radon from the soil.

Successful mitigation systems and strategies have been developed by EPA and others; however, there exist obvious shortcomings in the state-of-the-art. In most cases, current mitigation strategies: 1) fail to achieve the new ambient radon goal established by Congress (IRAA-88) (3), 2) are too expensive for general homeowner acceptance, and 3) have only limited development and demonstration in schools and other large, complex structures. Moreover, the bulk of radon exposure to the population exists in low radon level (less than 4 pCi L^{-1}) houses (4) (Figure 2)(4); thus a program emphasis directed at low-cost solutions for lower radon houses is being implemented to have a significant impact on the estimated 16,000 to 20,000 (2,4,5) annual radon-induced lung cancer deaths. In turn, the lower levels achieved by new mitigation technology will lower individual risk.

EPA's Radon Mitigation Program is attempting to develop and demonstrate technology that can achieve indoor air quality that is as free of radon as the ambient outdoor air. This technology is being developed for application to existing and new houses, schools, and other large buildings (residential, commercial, and industrial). This technology will also address all substructure types built in the variety of geologies found throughout the U.S. Efforts are being made to achieve this technology at low cost, with features acceptable to builders and occupants and with proven long-term durability.

AEERL's Radon Mitigation Branch is currently structured into five Strategic Program Areas: I. Innovative and Supporting Studies, II. Existing Houses, III. New House Construction, IV. Schools and Other Large Buildings, and V. Technology Transfer. The concepts developed in Program Area I (Innovative and Supporting Studies) will be demonstrated in Areas II, III, and/or IV. The products from each effort in Areas I-IV will be refined in Program Area V (Technology Transfer) to ensure an adequate level of information exchange. Knowledge obtained from demonstration efforts in Areas II, III, and IV will be shared to minimize duplication of efforts between areas within EPA's Indoor Radon Program. The emphases of the planned program are 1) an increased emphasis on developing new and improved radon reduction methods through a better understanding of fundamentals, 2) a deemphasis on demonstration of currently available radon mitigation technology in existing and new houses, 3) an increased emphasis on mitigation system durability assessments and operating cost analyses, 4) a continued major effort to identify, develop, and demonstrate radon mitigation operations for schools and other large buildings, and 5) a greater variety of more audience specific technology transfer products.

STRATEGIC PROGRAM AREAS

PROGRAM AREA I: INNOVATIVE AND SUPPORTING STUDIES

The primary issue that challenges radon mitigation research is the limited understanding of processes that influence radon entry and its prevention or removal. To address this issue, EPA is using research houses, as well as bench and pilot scale simulations, to perform controlled experiments in an effort to understand the roles of the four important phenomena: 1) radon production and transport in the soil, 2) radon entry paths into the house, 3) driving forces inducing radon entry, and 4) radon removal processes through decay, dilution, and plate out of progeny.

Among the questions that this research will address, will be: 1) the relative importance of aggregate and surrounding soil to radon entry, 2) the feasibility of providing pressure breaks or barriers between the house foundation and the soil, 3) the potential of radon barriers as mitigation/prevention options, 4) the effect of air cleaners on lung dose, and 5) the identity of materials with potential to absorb and retain radon until it decays.

To develop the needed understanding of the physical mechanisms affecting indoor radon levels, controlled experiments are required. Previous research was performed primarily in occupied houses. Consequently, the ability to control or even change many of the important parameters was very limited. The new recommended approach is to conduct research in unoccupied houses where construction details have been documented. The ideal approach is to construct the "test" house on well characterized soil with sensors placed under the house. The house should be carefully constructed in stages with the ability to control certain features (such as adjustable, quantified openings) designed into the structure. Only by varying important parameters in a controlled manner while properly monitoring the response variables can cause and effect be demonstrated.

Because some parameters, such as weather effects, cannot be individually controlled even in unoccupied research houses, it is important to supplement these studies with small scale structures that can be better controlled. Some of these studies can be in laboratory sized units (1/200 of full scale) and some in pilot sized units (1/20 of full scale). Some major advantages of the small structures are: 1) better control of study variables, 2) less time required to design and perform experiments, 3) less costly to build, modify, and operate, and 4) many different soils, climates, and building features can be simulated.

By better understanding the relative contributions of the individual mechanisms to the indoor radon level, it will be possible to develop improved mitigation methods at reduced installation and operation costs. This knowledge will also allow individual reduction methods (such as sealing, pressurization, and active soil depressurization) to be combined into a single system in an optimum manner.

PROGRAM AREA II: EXISTING HOUSES

Some major issues that pertain to improving mitigation options for existing houses are: 1) the reduction potential of active soil depressurization in moderate to low radon houses built with a variety of substructures, 2) the durability and failure rates of currently applied mitigation systems, 3) the potential for developing innovative mitigation system designs, 4) the most significant factors that influence radon mitigation cost, and 5) conditions under which grade-level exhaust is satisfactory compared to roof-level exhaust.

To address these issues EPA will evaluate the existing mitigation data base of premitigated 4-10 pCi L^{-1} houses and supplement these data with limited field testing in additional houses to define the difficulties in achieving 1 pCi L^{-1} and less using active soil depressurization in slightly to moderately elevated houses. In addition, EPA plans to continue a systematic program to monitor the reliability and durability of existing mitigation systems. EPA also plans to evaluate alternative configurations of active soil depressurization exhaust systems to reduce re-entrainment and overall exposure and to make the installation costs less expensive. As alternatives to active soil depressurization are developed, EPA plans to demonstrate these in appropriate applications.

New, low cost technology must be developed to meet the IRAA-88 ambient level goals for indoor radon concentrations. The emphasis to date has been on mitigating houses with initial indoor radon levels greater than 4 pCi $L^{-1}$to get them below 4 pCi L^{-1}. While it has been demonstrated that this is achievable, the bulk of the radon risk to the U.S. public still remains in houses with levels less than 4 pCi L^{-1} (Figure 2). Cost can be a barrier to implementation even for high level houses, thus the AEERL program, in consultation with the Office of Radiation Programs, has shifted emphasis to low cost innovative techniques for all houses, but especially those less than 10 pCi L^{-1},to achieve low radon levels of less than 1 pCi L^{-1}.

The reduction techniques must be reliable, durable, and low in cost because the application of these techniques by homeowners is largely voluntary (except when required by a real estate transaction). Cost becomes increasingly important when the pre-mitigation radon level in the house is low, since there is then less incentive for a homeowner to install mitigation. Also, increased reliability and durability will reduce the possibility that occupants of mitigated houses will be exposed to higher radon levels, since the owner may be unaware of the system failure or slow in implementing repairs. The private sector often lacks the resources, especially under current market conditions, to undertake studies of durability or of innovative ways to reduce system costs. This is another area where AEERL can provide a significant added value.

PROGRAM AREA III: NEW HOUSE CONSTRUCTION

Some of the issues that are important in the area of radon-resistant new construction are: 1) definition of the ability of active soil depressurization systems to consistently achieve < 1 pCi L^{-1} given the lack of consistent quality control that is common in the residential construction industry, 2) identification of alternative mitigation strategies that are less intrusive and more acceptable to builders and homeowners, 3) determination and quantification of potential detrimental impacts of mitigation systems on the house structure, and 4) cost of radon-resistant design options. To address these issues, EPA is measuring radon levels in pre- and post-occupied houses built with and without radon mitigation systems. Pressure control as a mitigation option is also being studied. In addition, structural components, pesticide treatments, and energy consumption will be studied in mitigated houses.

EPA's Office of Radiation Programs (ORP) has developed model standards and techniques for radon-resistant residential new construction as required by IRAA-88. This model incorporates active sub-slab depressurization for houses built in radon prone areas. Building code organizations throughout the U. S. are being encouraged by EPA to incorporate these model standards and techniques into building codes. Efforts are needed to evaluate the ultimate effectiveness of the model standards and techniques in achieving near-ambient radon levels especially considering the house depressurization stresses that occupants ultimately place on these houses. The question also remains whether active subslab depressurization systems are really the best strategy for new houses, especially in mild climates and non-basement construction. If active soil depressurization is generally applied, its potential detrimental effects on foundation integrity, pesticide treatment, indoor pressures, and energy consumption will also be determined. A study is in progress that will determine if planned mechanical ventilation systems are practical and feasible alternatives for radon control when considered during construction. A near-term goal of the new construction program is to develop and demonstrate a passively mitigated new house.

PROGRAM AREA IV: SCHOOLS AND OTHER LARGE BUILDINGS

A bill that would require testing for radon in schools is currently under consideration in the Congress (Senate Bill S792). If passed, it would require local education authorities to measure radon levels in schools that are located within areas that are designated as "hot spots" by the EPA, with testing to be completed by September 30, 1993. It is essential that EPA be well prepared with demonstrated, cost-effective, and durable radon reduction techniques for schools with elevated levels of radon. Even if this bill does not pass, it is evident that many schools already have tested or are planning to test for radon this year, and it is important that technology be in place to reduce elevated levels of radon in these buildings as soon as possible. Also, with a relatively small additional effort, the information learned in radon mitigation of existing schools can be cost-effectively applied to develop specific guidance for radon-resistant new school construction.

Issues of importance in the school and large building radon mitigation program are: 1) the development and demonstration of both active soil depressurization and heating, ventilation, and air-conditioning (HVAC) control systems as radon mitigation options, 2) the determination of optional designs for new radon-resistant school construction, 3) the development of a better data base on school and other large building characteristics, 4) a method to determine whether active soil depressurization or HVAC control is the preferred mitigation option in a given school, and 5) whether non-residential child-care facilities have unique features that merit specific mitigation studies. In addressing these issues, EPA is expanding the demonstration of active soil depressurization and HVAC control system modification in school buildings that represent varied construction types, geologies, and climatic conditions. Experience with existing school mitigation systems is also being applied to the actual construction of new schools. A profile of school building characteristics is being assembled on a subsample of approximately 100 schools from ORP's National School Radon Survey (NSRS). Detailed structural and HVAC system characteristics are being collected during site visits to schools in 24 randomly selected areas. Approximately half of the sites will be visited during the current fiscal year (1991), and the remaining schools will be visited next year. Results will provide a perspective on the prevalence of various school building characteristics, including building size, population, foundation construction features, and HVAC system configurations. Active soil depressurization and the operation of HVAC systems are also being compared in the same schools, including comparisons of radon reductions achieved, costs, durability factors, and long-term effectiveness.

This program focuses on radon reduction in school buildings and non-residential child-care facilities since both types of buildings are addressed in IRAA-88. Commercial buildings are also included as an initiative.

PROGRAM AREA V: TECHNOLOGY TRANSFER

A variety of technology transfer products are planned to disseminate research information to the public. These include: 1) updated technical manuals and brochures, 2) radon symposia, 3) R&D status reports, 4) special reports, 5) articles in peer reviewed journals, 6) articles in "general public" publications, and 7) unique information pieces to selected audiences. Some of these technology transfer approaches (symposia and R&D status reports) offer the opportunity for feedback that could greatly expand the knowledge base and help the Agency identify new problem areas and more practical application techniques. Articles in general public publications increase the overall public awareness of the radon problem. Specially prepared information to selected audiences such as lending institutions guarantees that the correct information is getting to the people who need it and in a format that is usable by them.

The regular development and distribution of these technology transfer products keeps the variety of users aware of the latest developments in radon mitigation technology and allows them to achieve long term maximum radon reductions at minimum cost of labor and resources.

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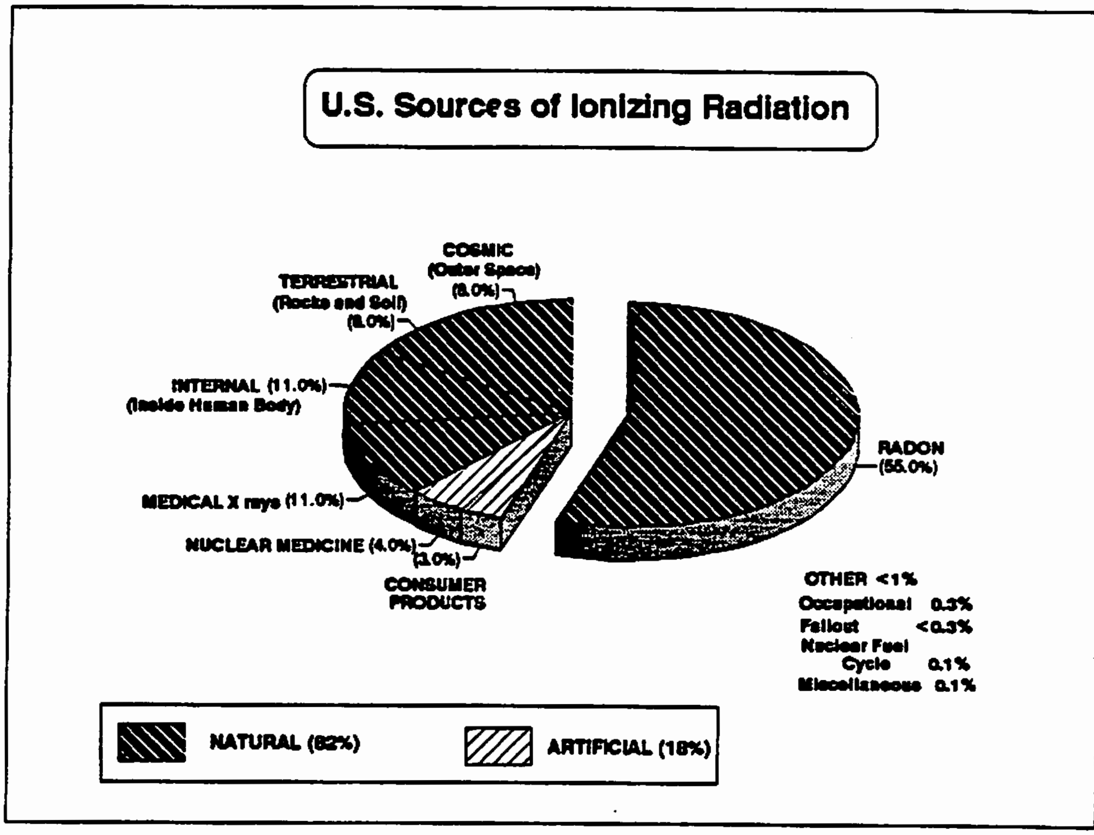

Figure 1. The greatest exposure to ionizing radiation comes from natural sources (1).

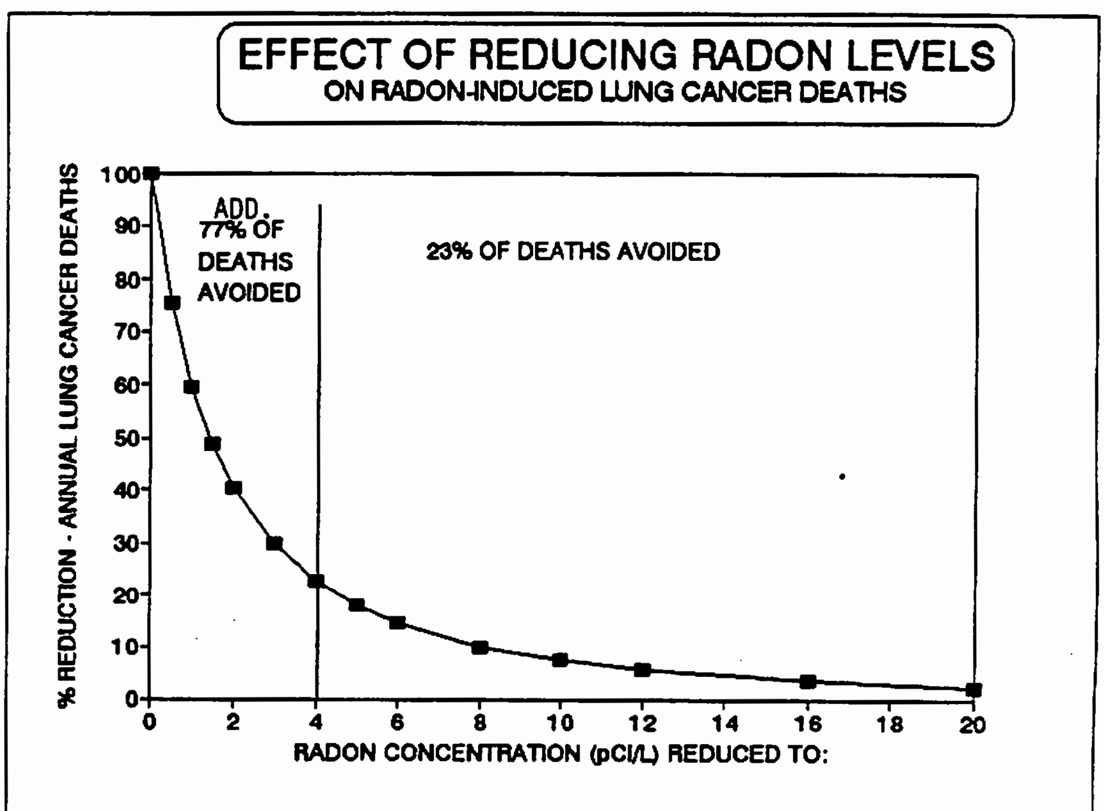

Figure 2. Current goals of 4 pCi L' have a relatively small effect on reducing radon-caused lung cancer deaths in the U.S. population (4).