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THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL STRATEGY FOR RADON REMEDIATION

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ABSTRACT

During the past 10 years the U.S. Environmental Protection Agency (EPA) has pursued a national strategy to address radon remediation in buildings to meet its goals of radon risk reduction. Initially the approach developed and demonstrated remediation methods and techniques in existing residences with specific attention to the effect of regional climate variations and the differences in housing construction. A number of studies and demonstrations were undertaken to accurately characterize and evaluate the effectiveness of several remediation methods and techniques. This knowledge was then later expanded through research on radon control for newly constructed houses with the subsequent development of model standards and techniques. Additionally, other research was initiated to gain a better understanding of remediation approaches in existing and newly constructed non-residential buildings such as schools, commercial office buildings, and hospitals. This paper provides an historical summary of the evolution of EPA's national strategy for indoor radon remediation, recent developments, and anticipated future directions.

KEYWORDS

Radon, mitigation, research, soil gas, technology

BACKGROUND

Indoor radon is recognized as one of the most significant environmental health problems in the United States. Radon is the main source of exposure of individuals to ionizing radiation. The EPA predicts that 1 in 15 U.S. houses may have elevated radon levels, and exposure to increased levels of radon is believed to cause between 7,000 and 30,000 deaths per year in the U.S. (USEPA, 1992a). EPA's risk estimates for indoor radon are based on extensive epidemiological evidence from 20 different studies of lung cancer in occupationally exposed miners. This evidence is among the strongest that has been assembled on the carcinogenicity of an environmental contaminant. EPA's risk estimates are also based on the work of the National Academy of Sciences and have been peer reviewed by the Agency's Science Advisory Board. Independent evaluations by the International Agency for Research on Cancer, the International Commission on Radiological Protection, and the National Council on Radiation Protection and Measurement have reached comparable conclusions on the significance of the indoor radon problem (Marcinowski and Napolitano, 1993).

Indoor radon drew national attention when, in December 1984, a house in northeastern Pennsylvania was discovered to have indoor radon levels in excess of 74,000 Bq m^{-3}. Investigators attributed the high indoor radon concentration to the uranium-rich soil and rock on which the house was built. In 1986 the U.S. Congress authorized EPA to conduct surveys to determine the extent of the hazard, and to develop and demonstrate measurement and mitigation technologies. Legislation followed in 1988 with the Indoor Radon Abatement Act (IRAA) which further expanded the efforts to include development of technologies to achieve indoor radon levels as low as the ambient air outside of buildings for existing houses, new houses, schools, and day care centers. Proposed legislation, if passed, would require disclosure of radon information during a real estate transaction, accelerate the adoption of radon-resistant building codes, and create a mandatory certification program for radon measurement and mitigation contractors.

Development of radon mitigation technology has been a coordinated effort between two EPA organizations, the Office of Research and Development (ORD) and the Office of Radiation and Indoor Air (ORIA). ORD has focused on development and demonstration of mitigation technologies, including fundamental studies and innovative mitigation technology development. ORIA has complemented these efforts by demonstrating field applicability of various mitigation techniques, as well as providing policy guidance to states and to homeowners based on research findings. EPA's research efforts are also augmented by the U.S. Department of Energy which is conducting basic research in radon fundamentals.

PROGRAM RESULTS

EPA's initial efforts in radon mitigation targeted existing residential construction. Mitigation techniques were demonstrated in numerous houses with varying radon levels, foundation types, and architectural designs. Since the application of radon mitigation techniques by homeowners is largely voluntary (except when required by a real estate transaction), the EPA targeted mitigation technologies that were reliable, durable, and low in cost. This effort resulted in development of soil depressurization techniques that have effectively lowered radon levels to below the EPA action level of 148 Bq m^{-3} in a variety of residential structures. The most commonly applied radon reduction method in existing U.S. houses is the active soil depressurization (ASD) system. EPA has found ASD to be the most consistently effective radon reduction method in existing houses, and it is the technique most widely used by commercial mitigators (Henschel, 1993). Radon mitigation techniques for existing houses have been found to be very effective, reducing indoor radon levels to below 148 Bq m^{-3} in 97 percent of houses and to below 74 Bq m^{-3} in about 70 percent of houses studied (Hoornbeek and Lago, 1991). The cost of a subslab depressurization system will range between \$500 and \$2,500 (US) (USEPA, 1992b).

In 1987 EPA began to develop model standards for the construction of radon-resistant housing. By working directly with the housing industry, EPA was able to develop methods to prevent the entry of radon into a new house based on construction practices that are common to U.S. builders. These methods are based on a passive subslab depressurization system which enables the radon to be vented from under the slab and exhausted above the roof line of a house. The passive system relies on natural air currents to assist in drawing the radon from underneath the slab. If, after construction, the house is found to have radon levels above 148 Bq m^{-3}, a fan can be easily installed to upgrade the passive system to an active one, thereby ensuring that radon levels stay below EPA's action level. The cost of including a passive radon control system in a new house is between \$350 and \$500 (US) (USEPA, 1992c).

Elevated radon levels have been found in a number of U.S. school buildings, and a national survey of schools released in 1991 predicted that about 19 percent of U.S. public schools may have elevated radon levels (above 148 Bq m^{-3}) in one or more classrooms (USEPA, 1993). Development and demonstration of radon mitigation technologies for schools began in 1988 with existing school buildings. Initially, research in schools focused on ASD since it was the most successful radon control technique in houses. In a follow-up study of 14 schools conducted in 1992, it was found that ASD systems were effective in maintaining low radon levels in the schools, with only 4 percent of the 409 tested locations exceeding 148 Bq m^{-3} (Dehmel, *et al.*, 1993). A study of the cost of mitigating existing school buildings found the average cost to be about \$5.40 per m^2 (1991 US dollars) (Leovic, *et al.*,1992).

Complicated subslab structures and subslab fill materials can make ASD expensive to install because of an increased number of suction points, so EPA concentrated part of its research efforts in schools on the use of the heating, ventilating, and air-conditioning (HVAC) system for radon reduction. Research found that a school's HVAC system could be used to control radon levels if it allowed for the introduction of sufficient amounts of outdoor air. If the HVAC system could provide sufficient outdoor air, pre-mitigation radon levels below 370 Bq m^{-3} could be reduced successfully. In most of the 40 schools visited by researchers, the HVAC systems were found to be operating improperly, often the result of neglect and poor maintenance practices. In some cases the introduction of outdoor air had been compromised. Researchers also measured carbon dioxide concentrations in 15 of the schools and found 14 of them with levels above 1,000 parts per million (Ligman, 1994).

Low cost and effective radon mitigation technology has been demonstrated in the construction of large buildings, including schools. An ASD system for inclusion in large building construction has been designed and demonstrated by EPA. This system consists of a 1.2 x 1.2 x 0.2 m void area created by a wire cage placed centrally underneath the poured slab. ASTM #5 crushed aggregate (ASTM, 1986) is recommended for the subslab . A suction pipe is routed from the wire cage to the rooftop, where a blower is installed to activate the system. In demonstrations of this pit design, slab areas as large as 5,574 m^2 have been successfully mitigated with one suction pit and a suction fan rated for 240 L s^{-1} (at no head pressure), using a 15 cm diameter vent pipe. Radon levels were lowered from 1,950 Bq m^{-3} (highest reading) to levels that were not measurable with open faced charcoal canisters. The construction cost of this ASD system was around \$0.90 per m^2 (1991 US dollars) (Craig, *et al.*, 1993).

A variety of technology transfer products have been generated by EPA that directly impact the public and the radon mitigation industry, including a number of public information booklets and brochures that cover such topics as basic information on radon to aid consumers in their quest to mitigate their homes. EPA has also produced technical manuals, brochures, special reports, articles in peer reviewed journals, and unique information pieces for selected audiences. 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 for labor and resources.

PROGRAM PLANS

The future of EPA's research program includes the development of the next generation of radon mitigation technologies capable of lowering indoor concentrations to near-ambient levels. A program of innovative research focused on achieving ambient levels of radon has been undertaken at EPA. This research will emphasize unique barrier technologies to prevent the entry of soil gas into houses and the feasibility of using removal techniques to lower the dose from radon progeny. EPA also plans to direct more future mitigation research to multi-story buildings since these buildings pose unique mitigation challenges and may require innovative mitigation approaches more dependent on HVAC control to prevent the entry of radon (via pressurization of the building interior) and to dilute radon and other indoor air pollutants.

There is a continued need to further refine known mitigation techniques, and to make them more efficient, less costly, and more durable. New techniques need to be demonstrated for reducing radon levels in large, multi-story buildings. We should look for opportunities to share research experiences with other indoor air investigators and continue technology transfer of information that is useful to homeowners, mitigators, and researchers around the world.

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