THE PRESENT STATUS OF THE RADON PROGRAM IN THE UNITED STATES OF AMERICA

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The indoor radon program in the US. started in the early 1970's in response to Congressional Hearings that recommended the initiation of radon measurements in certain parts of the united States where enhanced radon caused by contaminated uranium and radium tailings was suspect. In the mid 1970's, the Department of Energy (DOE), Environmental Measurements Laboratory (EML), conducted the first indoor radon survey in the New York City Metropolitan area. The two year study recommended that radon surveys should be expanded throughout the US. for better assessment of the radiation exposure of the general public to radon and its decay products. In 1984, well documented findings of very high concentrations of radon in homes located on the Reading Prong in Pennsylvania generated public interest in radon measurements and prompted the Environmental Protection Agency (EPA), to initiate a program to address the newly discovered public health problem. In 1988, EPA was assigned the task to implement the Indoor Radon Abatement Act (IRAA), which established a long-term national goal to reduce indoor levels to those found outdoors. In the 1980's, DOE funded many radon research projects on the health effects of environmental radon, instrument development and measurement quality. Unfortunately by the end of fiscal year 1998, DOE, the principal radon research agency stopped funding radon projects.

The expanded role of EPA resulted in a very extensive voluntary program which was designed to (1) evaluate the effectiveness of measurement and mitigation methods; (2) establish regional radon training centers and the National Radon Proficiency Program (NRPP); (3) assess the potential for radon contamination in schools; (4) develop radon resistant standards in new construction; and (5) provide grants for State radon programs. As of September 30, 1998, EPA ceased operation of its NRPP, due to the agency's limited resources.

Today, radon testing is primarily conducted in real estate transactions, in family relocations, in schools, government buildings and private homes of concerned citizens. Radon mitigation has accelerated to the point that by the year 2005 it is estimated that more than 700,000 homes will be mitigated at an average cost of $1,000 per home. Radon resistant techniques applied by architects and builders are incorporated in about 200,000 homes per year.

Key words: radon, real estate, relocations, radon resistant, mitigation.

INTRODUCTION

The radon program in the US. started in the fall of 1967 after Congressional Hearings recommended characterization of uranium mine atmospheres for possible link with the high incidence of lung cancer among uranium miners. The indoor radon program was initiated in the early 1970's in response to Congressional Hearings that recommended the initiation of indoor radon measurements in certain parts of the United States such as areas of enhanced radon caused by contaminated uranium or radium tailings waste, and in areas that are geologically rich in uranium deposits near the surface. Both the
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Department of Energy (DOE), formerly Atomic Energy Commission (AEC) and the newly created United States Environmental Protection Agency (EPA), through a Congressional resolution began to characterize radon areas such as Grand Junction Colorado, Lewiston New York, Canonsburg Pennsylvania and the phosphate region in Central Florida. In the late 1970's, DOE conducted the first radon survey in the NYC Metropolitan area [1] and recommended that indoor radon measurements be extended to other areas of the United States to get a reliable estimate of the radon concentration level in residential buildings.

In 1984, very high radon levels in some houses in Pennsylvania and the discovery of elevated radon concentrations throughout most of the US, prompted EPA and other federal, state, and local agencies and private individuals to test for radon. The high concentrations found in some regions helped to locate areas referred to as "hot spots" and to promote testing by a wider section of the general population. In 1988, EPA and the Surgeon General's Office held a joint press conference recommending that all homes and schools be tested for radon. As a result, the increased interest in measuring radon or radon decay products has stimulated instrument research and development for short-term (screening purposes) and long-term measurements.

DOE's role in the government radon program was mainly research in the health effects of radon on uranium miners and subsequently on the risk to the general public from environmental levels of radon. A substantial effort was directed to develop instruments and to establish measurement quality. In the 1980's and early 1990's more than sixty research contracts were awarded to universities and other research institutions by DOE. At the end of fiscal 1998 year, DOE stopped funding the radon program. However, to meet the needs of an emerging "new biology", DOE will fund $15 million in research at five of its laboratories and thirteen universities and research institutions. The research will take a new look on the health effects of radiation by seeking to develop methods to sequence microbial genomes and to explore the rich biomedical potential of microbes for producing and using energy or helping clean up the environment. Other current DOE projects will deal with the exploration of biological and genomic information in model organisms such as mice, yeasts and flies for better understanding of the organization, function and control of the human genome, understanding the health effects of exposures to low doses and low dose rates of energy-related materials and by-products. The last project may deal in a small scale with the effects of low dose alpha irradiation that may use radon decay products as the source of radiation.

THE STATUS OF THE RADON PROGRAM

EPA, the federal regulatory agency authorized by the 1986 Indoor Radon Abatement Act (IRAA), undertook a more extensive role in the radon program and developed a voluntary program (1) to evaluate the effectiveness of measurement and mitigation devices and methods; (2) to establish radon regional training centers; (3) to assess the potential for radon contamination in schools; (4) to develop radon resistant standards for new construction; and (5) to provide grants for State radon programs. The main objective of the radon program is to reduce human exposure and risk by reducing elevated radon concentrations in existing buildings and to encourage good practices in building design and construction siting that will reduce risks in the future.
To identify areas of the US. that have the potential to produce elevated levels of radon, EPA in cooperation with the US. Geological Survey (USGS) and the Association of American State Geologists (AASG), produced several documents and maps of radon zones depicting on a county- by-county basis the radon potential [2]. In all, 3,141 counties were examined by assessing indoor radon measurements, geology, aerial radioactivity, soil parameters and foundation types all known to be important indicators of radon potential. The survey found that approximately 6 million homes in the US. have annual radon averages equal or greater than 150 Bq m\(^{-3}\) (the EPA action level), and they are likely to be found in Zone 1. Homes with moderate variable radon levels between 75 - 150 Bq m\(^{-3}\) are likely to be found in Zone 2, and homes with radon levels <75 Bq m\(^{-3}\) are likely to be found in Zone 3. The availability of the maps of radon zones assists national and state and local governments and organizations to target their radon program activities and resources and to help building code officials to determine areas that are the highest priority for adapting radon resistant new construction. The radon maps are very useful guides but they are not used as a substitute for indoor radon testing because elevated indoor radon levels have been found in every State and in low radon zones.. The prudent thing to do, is to have all homes tested for radon at least once.

In response to the Congressional mandate and recommendations, EPA established the Residential Measurement Service Provider and the Residential Mitigation Service Provider, components of the Radon Proficiency Program (RPP) to evaluate the providers' proficiency. Although, the EPA RPP is voluntary, some States and local governments adopted legislation requiring EPA RPP listing or State certification. Many States require participants to complete the EPA or State requirements before providing services in their jurisdiction. The elements that help to ensure the proficiency of radon measurement and mitigation contractors are training and the national examination.

Training for radon technician or radon measurement operator

The training courses were designed by EPA to address the most important aspects of the radon program. The 16 -24 hour training course that is presently required consists of the following topics.

1. Radiation physics , radon fundamentals and health risks.
2. Radon sources, entry and behavior in the indoor environment (pressure and temperature induced differentials, wind and rain effects).
3. Radon and radon decay product measurement methods and measurement devices (principles of detection, specific applications and device protocols)
4. Protocols for radon and radon decay product measurement in homes, schools, and large buildings, measurement options interpretation of results, Quality Assurance (QA), and Quality Control (QC).
5. Building investigation and diagnostics.
6. Overview of radon reduction, mitigation strategies, control techniques and mitigation design criteria to reduce the impact of radon from the soil or from water.
7. New construction and implementation of radon resistant techniques.
8. Radiation and general safety at work.

To meet these training needs, EPA established four National Radon Training Centers in which over five hundred programs were conducted for more than ten thousand participants in its first five years of
operation. Today there are several private organizations in addition to the training centers, offering the required courses for certification and continuing education credits to maintain certification.

National examination

EPA and many States require measurement service providers to take an examination which is designed to test and evaluate their overall knowledge of radon and radon decay product measurement. Passing the examination is the primary requirement for acceptance into the program and inclusion on an official proficiency listing. The examination consists of 100 questions covering all aspects of the radon program as outlined in the previous section on training. As of 1998, there are more than 1200 measurement service providers participating in the EPA RPP program.

Continuing education

To maintain continued listing for measurement proficiency, service providers must accumulate continuing education credits. Beginning in 1996, all participants have the option of completing continuing education requirements every two years. This can be accomplished by taking approved courses given by authorized course providers by attending seminars and workshops by taking video based courses.

Training to be a radon technologist for mitigation

This course examines the major aspects of radon mitigation from diagnosis to implementing and evaluating a mitigation plan. Participants must take a four day course that addresses theoretical and practical aspects of designing and installing radon mitigation systems. The course must be offered by an EPA approved service provider. The first 16 hours of classroom instruction addresses:

1) radon occurrence and health effects; 2) radon entry and behavior in the indoor environment; 3) radon and radon decay product measurement methods and techniques; 4) building investigation and diagnostics; 5) mitigation techniques and procedures and guidelines; 6) radon resistant new construction; and 7) worker radiation and general safety. Another 16 hours are devoted to hands-on training in a laboratory type setting or in a field situation.

National examination for mitigation service

The mitigation exam consists of 150 questions and is designed to evaluate mitigation specialists and their knowledge of radon measurements, diagnostics radon reduction strategies, system design mitigation standards and communication skills to the consumer. The test can be administered by an EPA recommended trainer or other approved agencies. Presently approximately 410 contractors have passed the mitigation exam and are listed on the proficiency list for mitigation service.

Continuing education

Every two years mitigation service providers must complete 16 hours of continuing education consisting of formal classroom lecture courses, hands-on courses, correspondence courses, video based courses and approved activities such as conference and radon workshop attendance, presentations and publications of technical papers and public outreach presentations.
As of September 30, 1998 EPA ceased operation of its RPP, due to the Agency's limited resources. However, EPA's position on the risk to radon remains unchanged and will continue to encourage testing and mitigation of homes that exceed EPA's action level of 150 Bq m$^{-3}$. This position is strengthened by the BEIR VI Report that radon causes between 15,000 to 22,000 lung cancer deaths annually.

**Radon action week**

The National Radon Action Week (NRAW), began in 1990 as a Congressional Resolution which urged Americans to test for radon. It usually takes place in the third week in October. The purpose of the activities of the week is to draw attention to radon as a serious public health issue. The week is highlighted by media coverage and is the kickoff week of an entire year of activities designed to increase awareness of radon's serious health effects. The theme of the October 18 -24, 1998 week is "Take the Test". Public Service Announcements in local communities connect with local media, business and civic groups. States host seminars and pursue other public service activities such as television and radio coverage to reach the maximum number of listeners. In its effort to increase public awareness and promote testing for radon, EPA published the Citizen's Guide to Radon [3], the Home Buyer's and Seller's Guide to Radon [4] and the guide Radon Prevention in the Design and Construction of Schools and Other Large Buildings [5].

According to a 1996 survey by the Conference of Radiation Control Program Directors (CRCPD), awareness about radon in the US. among adults is very high. In 1996, about 70% have heard of radon. About 83% of college graduates and 63% of high school graduates are aware of radon. Awareness is 82% among upper income citizens earning over $50,000 per year and 50% among those earning less than $12,000 per year. Only 16% of those that know about radon have tested, while 83% have not. Nationally, testing increased from 9% in 1992 /93 to 11% in 1996.

**Who tests for radon**

Because consumers are becoming increasingly knowledgeable about radon, they are requesting that houses they are considering purchasing be tested for radon as part of, or in addition to a regular home inspection. Members of the American Society of Home Inspectors (ASHI), claim that most of the radon tests they conduct are in homes purchased by families who are relocating. Many inspectors now advertise radon as part of their home inspection service. Also, increased public and corporate awareness about the dangers of radon, and legislation at the State and county level involving real estate transactions, and potential of liability, have resulted in increased radon testing. The public interest in radon is especially high during real estate transactions. In many cases, mortgage lending institutions and home relocation firms require radon testing prior to loan approval. If radon levels are above 150 Bq m$^{-3}$, mitigation may be required before approval of financing. According to a 1994 survey of 443 corporate members by the Employee Relocation Council only half of the relocations involve radon testing. It is estimated that about 800,000 relocations take place annually. If 50% of them involve radon testing, there is a substantial market for the radon test industry.

Today, in the US. about 4 million real estate transactions take place, a very large market to explore. It is estimated that 25% of these transactions involve radon testing.
In many States, the trend is to include radon testing along with other home inspection services. At present, a large number of candidates that take the EPA approved radon training courses are home inspectors who prepare for certification in anticipation of accelerated radon testing and mitigation. Realtors make information on radon testing available to their clients and some even offer radon testing services. In the most recent radon course which I taught, there were some real estate brokers in attendance.

Volume of radon testing and the magnitude of the radon problem

Radon testing reached a new plateau, with a growing number of measurements involving real estate transactions. Radon testing varies from State to State. For example, in New York State, with a very active radon program in place, more than 120,000 documented radon tests were performed between 1987-1996. Of these tests 82,000 were short-term measurements in basements of homes and over 35,000 long-term measurements in the first floor of a home. Radon test results from 40,000 short-term measurements in 58 Counties, show a radon average value of 210 Bq m\(^{-3}\) with a geometric mean of 93 Bq m\(^{-3}\) with 35% and 2.5% of the homes having radon levels >150 Bq m\(^{-3}\) and >720 Bq m\(^{-3}\) respectively. Simultaneous first floor measurements were typically about half the basement radon level. From a pool of 12,000 radon measurements in the first floor, the average radon value and the geometric mean were 85 and 41 Bq m\(^{-3}\) respectively. In the State of New Jersey another State with a very active radon program about 221,000 homes were tested for radon and about 50,000 (23%) were found to have radon levels >150 Bq m\(^{-3}\). Since 1988, more than 13 million homes have been tested for radon accounting only about 15% of the US. housing stock. EPA estimates about 6% of the measurements to be above 150 Bq m\(^{-3}\), about 1 million or 1% above 300 Bq m\(^{-3}\) and 60,000 above 740 Bq m\(^{-3}\).

The State Indoor Radon Grant (SIRG), established by EPA, provides about $8.5 million assistance to States for education, training, mitigation and to promote radon resistant new construction techniques with home builders. According to Radon Testing Corporation of America (RTCA), there are some States that still support free or low cost radon testing in surveying thousands of homes and some schools in areas of potentially high radon levels. Another large testing effort is at several Indian Reservations (EPA funding for Indian Tribes) and at some Federal Buildings occupied by US Armed Forces personnel (Air Force and Naval Bases). The US Postal Service is developing a radon testing program intended to survey about 12,000 postal service buildings and complexes. However, there is no indication that the plan will be implemented soon due to lack of test protocols for large buildings.

Privatization of the radon proficiency program.

The privatization of the RPP, is beginning to materialize through a pilot program administered by the National Environmental Health Association (NEHA) of Colorado Springs, Colorado. A second organization the National Radon Safety Board (NRSB) has also developed a private RPP, as an alternative to the NEHA program. Another area of great importance is the establishment of the Radon Chamber Qualification (RCQ) Proficiency Program that is intended to meet the needs of Radon Measurement Proficiency participants when testing and calibrating the instruments and equipment that measure radon and radon decay products. EPA, drafted a manual for the Radon Chamber Qualification
Proficiency Program [6]. This manual is similar to the one drafted for the International Radon Metrology Program (IRMP), under the auspices of the International Atomic Energy Agency (IAEA), with the title "Design Criteria and Operational Characteristics of Radon and Thoron Chambers". As with the RPP, the RCQ will be privatized under the guidance of EPA, exercising control, authority and oversight over the program.

With the privatization of the EPA RPP, individual States will undertake a more active role to ensure the proficiency of individuals that operate within their jurisdiction and perform radon testing and mitigation. With the diminished role of EPA, State agencies have become the primary sponsors and promoters of radon testing and mitigation. Radon testing in real estate transactions has become one of the most important part of the radon program and I believe that is where the future of radon testing lies. It appears that radon testing in real estate transactions will become routine in the next few years.

Many States have very rigid regulations concerning radon testing in real estate transactions. EPA or State testing protocols must be adhered to during a real estate radon test with legal consequences if the test was tampered with or was done improperly. Of the 50 States, 37 have laws, policies and regulations reflecting considerable activity in the State legislatures and State agencies regarding radon. In 20 States, there are laws that require certification of radon professionals. Of the 50 States 37 require disclosure of known radon test levels during a real estate transaction and in some of these States laws establish programs to educate the public about radon, provide financial assistance for radon testing and mitigation and adapt model construction standards and techniques for controlling radon levels in new buildings.

Usually, agencies such as the Department of Health, Public Health, Health Services, Office of Radiation Control, Human Resources, Nuclear Safety, Environmental Protection, Environmental Resources and Radiation Protection Division are the ones that address radon issues in their respective States. Of the 37 States that have some regulations regarding radon, California, Florida, Illinois, Iowa, New Jersey, New York, Ohio and Pennsylvania have very strong and regulated radon programs. With EPA's reduced role, many other States are likely to adopt similar programs and in the near future we may see a more unified and standardized radon program.

**RADON MITIGATION**

In 1991, EPA published Radon Mitigation Standards (RMS) to establish protocols for the design, installation and performance of mitigation systems and evaluate the performance of radon mitigation contractors [7]. Over the past few years, the effectiveness of the basic radon mitigation techniques has been validated in field applications throughout the US. The acquired experience served as the basis for the latest Radon Mitigation Standards which are applicable throughout the country. According to EPA, by the year 2005, more than 700,000 homes will be mitigated with an average cost of about $1,000 per home. In the State of New Jersey of the 50,000 homes that were found with radon levels >150 Bq m⁻³, only 16,500 or one third have been mitigated. If we assume that 6% of the homes tested for radon in the US need to be mitigated, there is a potential of over 5 million homes that eventually have to be mitigated. Since, about 75% of the homes in the US. have not been tested for radon there exists a large market for radon testing and mitigation. In high radon areas only about 2% tend to mitigate.
RADON RESISTANT CONSTRUCTION

In 1994, EPA published model standards and techniques for control of radon in new construction which provided the basis for the application of radon resistant techniques for new homes [8,9]. The experience gained by EPA and mitigation contractors in the control of radon in residential buildings, provided additional innovations to enhance the original EPA approach. The result is a cooperative design guidance document for use by architects and builders to guide radon resistant construction in new buildings. The most popular and affordable radon resistant techniques are (1) a layer of aggregate (gravel) beneath the slab; (2) A loop of perforated pipe in the soil beneath the slab. Both methods improve soil gas lateral movement and collection beneath slabs which can be drawn outdoors by either passive or active depressurization techniques. The gravel technique is the attractive choice if it is of local origin. The advantage of radon resistant construction is that it is aesthetically more acceptable and less costly than if you have to install a mitigation system on an existing building. According to the National Association of Home Builders Research Center Survey, the estimated number of homes built radon resistant from 1990 to 1997 is 1,396,000, averaging about 175,000 homes per year. Table 1, lists the results of the survey over a period of eight years [10]. In 1997, of 958,900 newly built single family detached homes, 184,100 homes had radon resistant features (personal communication). The Middle Atlantic and New England States had the highest usage of radon resistant techniques. According to EPA, about 200,000 new homes per year will feature radon resistant features a number close to that estimated by the NAHB.

RADON IN DRINKING WATER

If the EPA maximum contaminant level (MCL) for radon in drinking water of 11 Bq L\(^{-1}\) or (300 pCi L\(^{-1}\)) is accepted, it will affect about 27,000 public well water systems that supply about 19 million people. To mitigate these systems is estimated it will cost about $270 million. The National Academy of Science (NAS), was funded by EPA to prepare a risk assessment for radon in water and to publish a health risk reduction and cost analysis for various MCL options for public comment by August 1999 [11] Based on information gathered by NAS the recommended MCL for radon in drinking water is likely to be set at 150 Bq L\(^{-1}\) or (4,000 pCi L\(^{-1}\)). The new MCL is proposed in light of new information provided by the National Research Council committee panel, suggesting that only 160 deaths or 0.8% of the total lung cancer deaths result from inhaling radon released from household water. The number of stomach cancers from drinking water containing radon is estimated at 20 from a total of 13,000 stomach cancers from all causes or <0.2%.

THE BEIR VI REPORT

The findings of the 1998 report of the Biological Effects of Ionizing Radiation (BEIR) [12], differ very little from the 1991 BEIR report [13]. However, the new report is based on much more extensive research and much richer data base. The main findings of the report are; (1) radon is the second leading
cause of lung cancer and it is a serious public health problem; (2) 12% of the lung cancer deaths in the US. are linked to radon. Of the 157,400 total lung cancer deaths recorded in 1995 (95,400 men and 62,000 women), between 15,000 to 22,000 are caused by radon. EPA estimates 14,000 annual lung cancer deaths due to radon. The NRC Committee spent 4 years to prepare the BEIR report examining 11 epidemiological studies of underground miners that included 68,000 men of whom 2,700 have died of lung cancer and from new data on lung cancer in the general population and from the latest biological data on cancer and alpha radiation.

The Committee used the information from miners and supplemented it with information from laboratory studies, measurements of radon levels indoors and with facts about the US. population. The radiation dose to mine workers was calculated using the particle sizes that DOE obtained in 1971-72 in four large underground working uranium mines. The data were chosen because they represented working conditions in the mines.

CONCLUSIONS

Radon testing in the US. reached a new level with most testing involving real estate transactions and relocations. The active role of EPA in the RPP, is becoming somewhat limited due to budgetary limitations. However, because of EPA's claim that radon is a serious public health problem, will maintain a supportive role on the radon program. and will continue to provide guidance and recommendations through its several documents on measurement, mitigation, radon resistant construction and on the assessment of the health risk from radon and its decay products. EPA will exercise control, authority and oversight over the performance of the RPP that has been assigned to the private sector. EPA is getting set up to provide radon and radon decay product measurement traceability, through one of its radon chamber facilities.

Installation of mitigation systems is on the increase with an average cost of about $1,000. Construction of radon resistant homes is estimated to be about 200,000 or 18% of the total number of homes built. The MCL for radon in water, is likely to be set higher in light of new information on the lower risk from radon released from domestic water.

The latest BEIR report considers radon to be the second leading cause of lung cancer causing about 12% of the lung cancer deaths in the US.

REFERENCES


Table 1: Estimated total number of single family homes built radon resistant

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