PENNSYLVANIA RADON REMEDIATION RESEARCH AND DEMONSTRATION PROJECT

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ABSTRACT

In response to growing awareness that indoor radon was a serious problem in parts of Pennsylvania, the General Assembly in its 1986 session enacted the Radon Gas Demonstration Project and Home Improvement Loan Act. The primary purpose of the $1,000,000 Radon Demonstration Project carried out by the Department of Environmental Resources Bureau of Radiation Protection was to develop standards for radon remediation methods and materials to be used by contractors and homeowners to reduce radon levels and exposure. Other provisions of the Act required the development of experimental and prototypic radon remediation systems and the development of guidance to homeowners on avoiding unscrupulous or unqualified contractors. This paper details the Bureau's efforts to fulfill its legislative mandates in radon remediation research. It includes discussion of the diagnostic processes, remediation system design and installation and the reductions achieved. The results of this radon remediation demonstration project are important not only as a sizeable contribution to the growing body of radon research but also as a practical guide for the radon industry.

INTRODUCTION

BACKGROUND

In December of 1984, the Department of Environmental Resources (DER) responded to the discovery of an Eastern Pennsylvania home containing the highest ambient levels of radon progeny yet reported. The Bureau launched an unprecedented campaign of radon monitoring and public awareness aimed at determining the extent and severity of the indoor radon problem and encouraging homeowners to cooperate in the Bureau's free radon screening

program. By November of 1986, over 18,000 homes on and around the uranium rich geologic formation known as the Reading Prong, had been screened. However, despite the high level of publicity given to indoor radon in this region, less than thirty percent of the housing stock had been screened. The results of these screening tests indicated that 59% of the homes tested contained radon concentrations above .02 Working Levels (WL). Bureau staff concluded that one of the reasons more residents did not take advantage of the free screening program was their fear that their homes would be found to contain elevated radon concentrations and that there would be no reliable way to reduce the radon.

LEGISLATION

To increase confidence in remedial methods and systems and the contractors who install them, the Pennsylvania General Assembly in its 1986 session enacted the Radon Gas Demonstration Project and Home Improvement Loan Act. The Radon Demonstration Project (RDP) provisions of the Act charged the Department with:

developing, installing and evaluating methods of remedial action to reduce unsafe levels of radon in at least 100 residential buildings

establishing minimum standards for materials used and craftsmanship applied by radon remediation contractors

developing experimental and prototypic radon remediation methods

providing guidance to homeowners on avoiding unscrupulous or unqualified remediation contractors

It was expected that the development and successful demonstration of radon remediation methods and materials when publicized would reduce resident reluctance to test their homes for the presence of radon. Other expected benefits of the RDP were the increased competence and growth of the radon remediation industry. The Act provided $1,000,000 and one year beginning July 1, 1986, to complete the RDP House Evaluation Program.

THE REQUEST FOR PROPOSALS(RFP)

To fulfill the legislative mandates, it was decided to enlist contractor support to manage the RDP. The RFP was developed by an interdepartmental committee and published for competitive bid. It consisted of four primary tasks.

Task one called for the development of specifications for materials and standards of craftsmanship. The RFP required the contractor to develop a preliminary set of specifications and standards for material and craftsmanship before beginning any installations. These specifications and standards could then be modified as experience and knowledge of their effectiveness was gained as the project progressed. Although not specified in the RFP, it was always the DER intent that these material specifications

and craftsmanship standards be catalogued for use as a radon industry reference.

Task two required the contractor to examine the material specifications and particularly the standards of craftsmanship to identify categories of tradesmen that possessed the needed skills to install radon remediation systems. This list of trades was to provide the pool from which subcontractors would be solicited to participate in the RDP as radon remediation system installers. It was the intent of the RFP that as many subcontractors as possible be used and trained in the RDP to bolster the ranks of qualified remediation contractors.

A subtask under Task 2 was the development of a pamphlet written for the general public that would help them identify and avoid being victimized by the unscrupulous or unqualified radon remediation contractor.

Task 3 contained the bulk of the contractors responsibilities for managing the installation of remedial research systems in participating residences. Major elements of this task were house diagnostics and remedial systems design, the selection, supervision and administration of subcontractor; and the inclusion of at least 100 homes in the RDP. The DER was responsible for house selection and pre- and post-mitigation radon measurements.

Task four required the submission of a report detailing the work performed and results achieved for each participating house and the completion of a summary report containing a discussion of project organization and chronology, remediation system effectiveness and solutions for correcting problems encountered with remediation systems.

HOUSE EVALUATION PROGRAM

About the same time that a request for proposals was being developed for contractor support of the RDP, the Department was solicited by the U.S. Environmental Protection Agency (EPA) to participate in its House Evaluation Program (HEP). Under the HEP, the EPA would provide contracted radon diagnostic service and remediation design reports for up to 80 homes that met certain radon concentration and construction design parameters. For its part, the DER would solicit homeowner participation from its database and obtain written homeowner agreements. The decision was made to marry the RDP with the HEP to save money on diagnostics and remediation design so that more homes could participate in the demonstration. Sixty-nine (69) of the 80 homes for which the EPA provided HEP diagnostic and design services subsequently participated in the 106 home RDP.

RADON RESEARCH DEMONSTRATION PROJECT

PROJECT SCHEDULE

The one-year demonstration project period alloted by the legislation proved impossible to meet. Although the legislated project start date was July 1, 1986, the project management contract with Roy F. Weston, Inc., was

not finalized until February, 1987. This delay was compounded by late HEP diagnostic/remediation design reports, the last of which were received in August of 1987. We were able to obtain a six month administrative extension to December 31, 1987. However, this was not enough. Continued delays in recruiting and managing local remediation subcontractor participation left over $440,000 unspent and only 74 homes remediated by December 31. A new sole source contract was entered into with Roy F. Weston, Inc., to complete the demonstration project by June 30, 1988. By limiting the participation of local subcontractors, this deadline was met. The RDP included 106 homes most with multiple system installations.

PROJECT ORGANIZATION

Figure 1 represents the project flow. Responsibilities for the project execution were split between the DER and its consultant, Roy F. Weston, Inc. Weston was, in turn, assisted by its subcontractors, R.F. Simon Company and Radon Detection Services, Inc.

The DER developed the home selection criteria, performed the initial home radon screening test and obtained the agreements for mitigation work with the homeowners. Following these preliminary tests and administrative actions, the Weston team performed various radon diagnostic tests, prepared house-specific mitigation system design specifications, selected contractors, supervised and trained (on-site) the contractors, and performed interim post-mitigation radon measurements.

Finally, the DER performed post-remediation tests. The completion of the mitigation work was followed by the preparation of a comprehensive report for each remediated house.

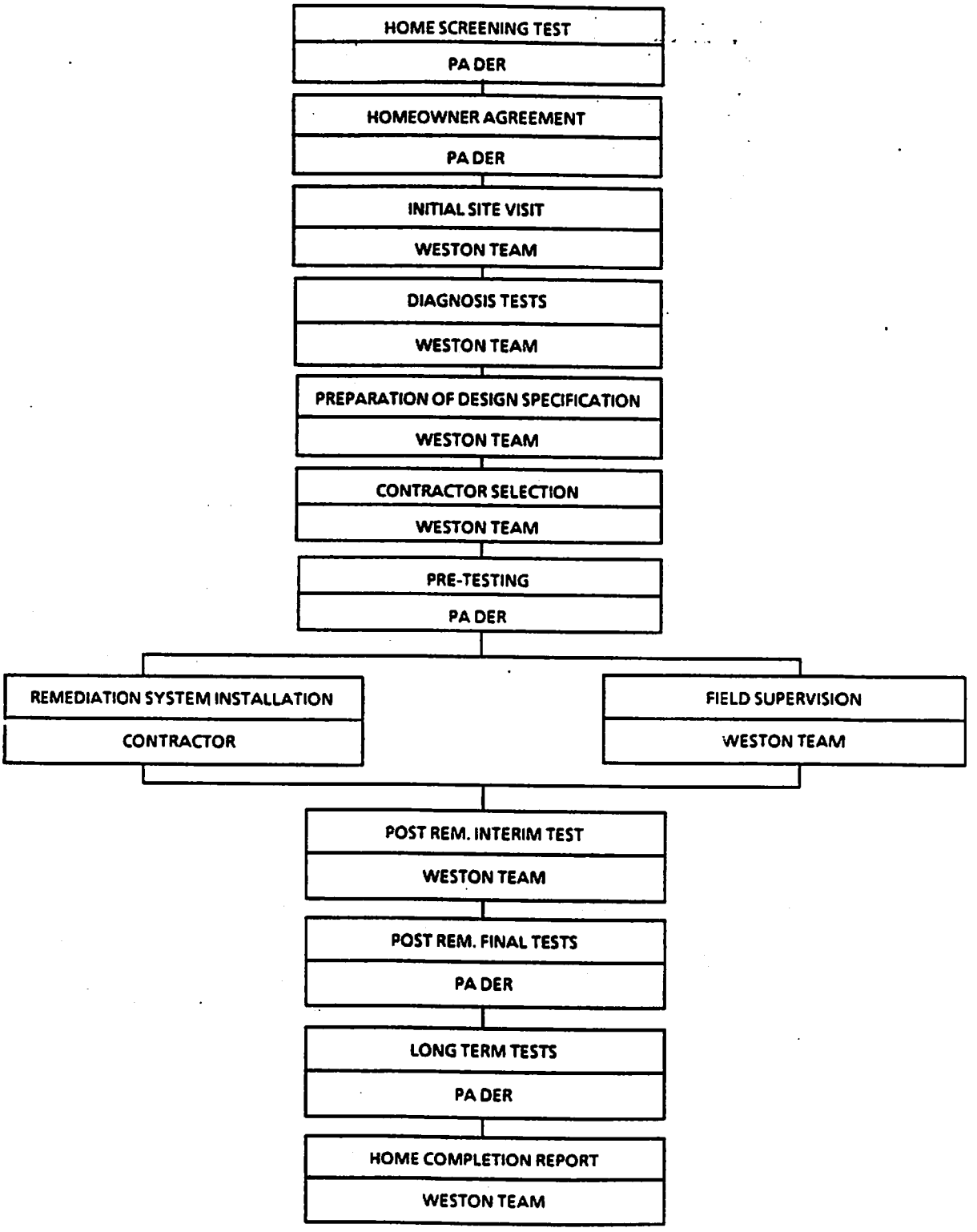

Figure 1. Project Flow Chart

HOME SELECTION PROCESS

Both the HEP and the Demonstration Project were in agreement that participating homes include a variety of representative housing construction types, e.g., basement, crawl space, and slab-on-grade foundation; single and multiple levels; and frame and masonry construction. Figure 2 shows breakout of participating houses by construction type. Figure 3 shows foundation types under living areas.

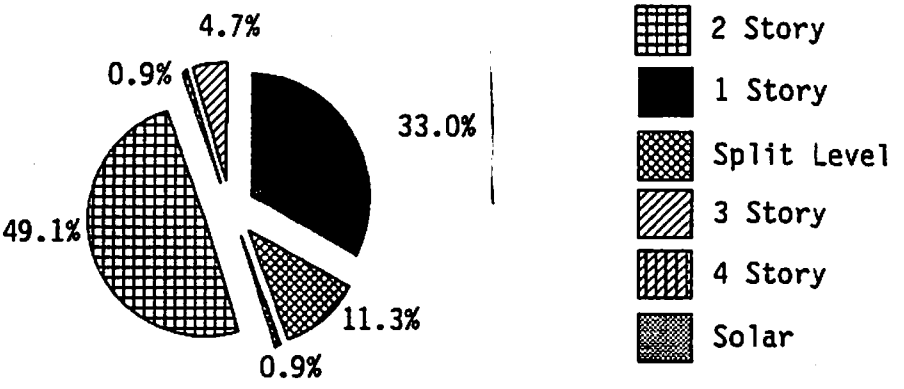

Figure 2. Construction Types

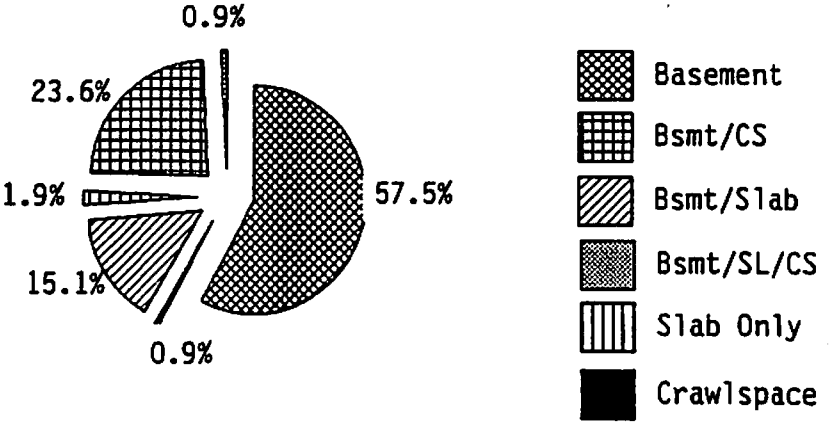

Figure 3 .Foundation Types Under Living Areas

For the sake of research and broad applicability of results, homes selected for participation in both projects represented a wide range of radon levels. Since the HEP was designed more to benefit the majority of homes that would be found to have radon problems, it required a higher participation of homes with low to moderately elevated radon levels. However, it was the intent of the RDP to also provide relief to residents exposed to extremely high (greater than 1 WL) radon concentrations. As a result, those 69 homes that participated both in the HEP diagnostic and design and the RDP represented a wider range of radon levels while most of the remaining 37 houses selected contained radon levels greater than 1 WL. A breakout of participating houses by pre-mitigation level range is found in Figures 4 and 5.

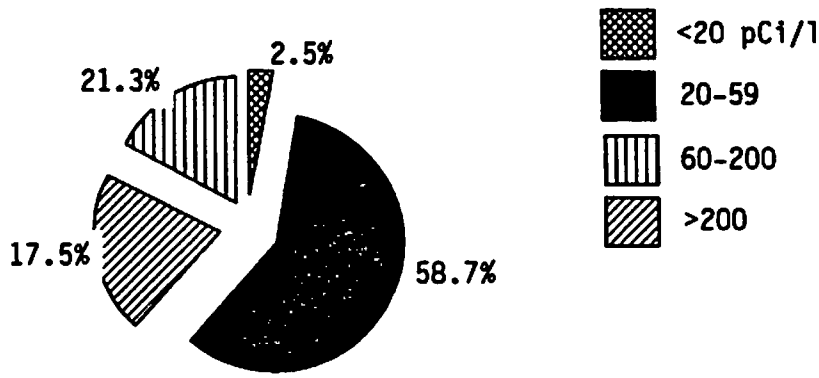

Figure 4 Pre-Mitigation Radon Level Ranges in RDP Houses That Also Participated in U.S. EPA HEP

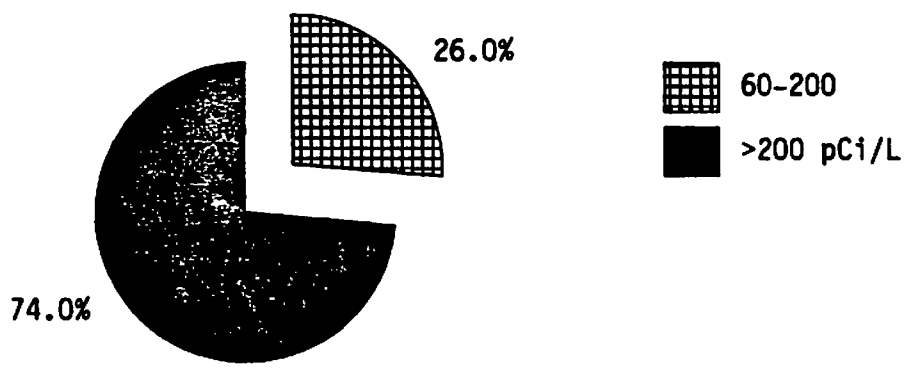

Figure 5 Pre-Mitigation Radon Level Ranges in RDP Houses That Were Not Part of the U.S. EPA HEP

HOMEOWNER AGREEMENT PROCESS

The HEP and RDP each required the execution of a legally binding homeowner agreement that clearly identified the parties to the agreement, explained the program and its intentions, stipulated homeowner and DER responsibilities and limited Commonwealth and Federal liability.

In general, the homeowners who agreed to participate in the HEP and/or the RDP were receptive yet cautious of our offer. In the end their fears of negative publicity, loss of property value and invasion of privacy were overcome by health concerns and the economic incentive of free remediation. Although not guaranteed, homeowners were assured that efforts would be made to keep their identities confidential.

SUBCONTRACTORS SOLICITATION EFFORTS AND PROBLEMS

The remediation of such a large number of homes presented an excellent training opportunity for local contractors. A major objective of the RDP was to train as many local contractors as possible in radon mitigation technology.

The list of contractors was developed from several sources. Announcements were made in local newspapers and trade journals, describing the project and inviting contractors to submit a letter of interest and a statement of their qualifications. Individual mailings were also used to notify contractors on pre-existing DER lists. In addition, a series of local meetings was held to describe the projects and solicit local contractor participation. House remediation design specifications were bid in groups of no more than five. An attempt was made to have homes that were bid together located in the same area. Bid solicitations were sent only to prequalified contractors.

Contractors were selected on the basis of bids submitted for the installation of house-specific remediation systems. In all, thirty-two contractor submitted bids and twenty-five were selected to install mitigation systems.

The participation of local contractor was not as high as expected. This may be attributed to several reasons:

- competition from routine business
- reluctance to travel outside normal work area
- lack of needed skilled personnel in some areas
- apprehensive of a new technology
- burdensome administrative/contractual process
- difficulty in obtaining liability insurance.

DIAGNOSTICS

To obtain information needed to design, install and fine tune a remediation system for each house, a combination of radon diagnostic tests from Table 1 were performed.

Table 1. Diagnostic Methods

Method	Information Obtained
Homeowner Interview	House Construction details, plans, photos
Visual Inspection	Radon entry routes, remediation system limitations
Sub-slab Vacuum with Freon or Smoke	Sub-slab Permeability
Freon Introduction	Remediation System Leaks
Radon Sniffer	Sub-slab Radon Concentrations
Chemical Smoke	Above vs. Below Slab Pressure Differential (qualitative) Remediation System Leaks
Manometer	Above vs. Below Slab Pressure Differential (quantitative)

RADON MEASUREMENT

All pretesting and post-testing of the project homes were performed as follows:

Duplicate two-day (48 hour) charcoal canisters were placed in the lowest level of the house, generally in the basement where the initial screening was performed. A Pylon AB-5 unit with a Passive Radon Detector (PRD-1) attachment was also placed next to the duplicate charcoal canisters and programmed to take continuous readings every hour for the same 48 hour period. All testing was done under closed house conditions as stated in the "EPA Protocols for Screening and Follow-up Radon and Radon Decay Product Measurements".

Pre-tests and Post-Tests were carried out in the same areas as much as possible for comparison. In addition to the charcoal canisters and continuous radon monitor, a 1 year Alpha Track Detector (ATD) was also placed on the first floor living area during the post-test visit.

As another follow-up post-test, each mitigated home was mailed two (2) additional ATD's to be placed in the basement and on the first floor for 90 days during the '87 - '88 heating season. However, due to scheduling and varying completion dates, not all homeowners could participate in this phase of post-testing. As a result, only 58% participated in the full 90+ day test. The others were either monitored for a minimum of 30 days (usually 60 days) or not at all.

In order to post-test all of the homes when the mitigation systems are under the most stress and during the same time of the year, two (2) additional ATD's will be mailed to each participant again this November 1988 to monitor the basement (lowest potential living area) and the first floor living area for a period of 90 days during the 1988-1989 heating season. Duplicate ATD's will be sent to 5% of the homes for quality control.

REMEDIATION DESIGN

The remediation design developed for each house resulted from a four step process. For the 69 HEP participant homes, the first step was to review the HEP report to become familiar with previous radon measurements, diagnostic test results, the house layout and recommended remediation design options. The second step was a visit to the house to conduct additional diagnostic tests and select a specific remediation design. Next, the selected remediation design was discussed with the homeowner to explain the basis for the design selection, how and why it was expected to work and what it would look like. On the whole, this step was more involved than expected. Homeowners, while not antagonistic, took a keen interest in the remedial design proposed for their homes. After obtaining homeowner concurrence, specifications for design implementation and materials to be used were drawn up to be included in the bid package.

MITIGATION INSTALLATION

A primary objective of the RDP was the evaluation of a variety of remediation methods, Table 2 lists the types of remediation methods used in the RDP and the number and percentage of homes to which they were applied. Remediation methods were usually installed in combination. Only in a few homes where remediation methods were installed incrementally were we able to attribute radon reductions to certain methods.

Table 2. Remediation Methods Distribution

Remediation Types	Number Installed in Project Homes	
	Number of Houses	Percentage of Houses
1. Sub-slab Depressurization:	92	86.80
OF THESE:		
a. Floor Penetration	72	67.90
b. Pit Cut-out	19	17.90
c. Deep probe	1	.94
2. Slab-on-Grade Depressurization	19	17.90
3. Sealing:	93	88.00
4. Isolation:	12	11.30
5. Depressurization with Captive Membrane	10	9.40
6. Pressurization:	4	3.80
7. Ventilation	11	10.40
OF THESE:		
a. Forced	3	2.80
b. Passive	8	7.50
8. Barrier Membrane with Floor Replacement:	5	4.70
9. Air Exchange:	1	0.94
10. Wall Depressurization:	10	9.40
OF THESE:		
a. Trough Suction	4	3.80
b. Individual Point Suction	6	5.70
11. Water Treatment: Aeration	4	3.80
12. Passive depressurization:	2	1.90
13. Perimeter Floor Ventilation:	1	0.94
14. Pressure Neutralization:	3	2.80
15. Outside Perimeter Ventilation:	1	0.94

Table 3. Remediation Methods Distribution

Remediation Types	Number Installed in Project Homes	
	Number of Houses	Percentage of Houses
1. Sub-slab Depressurization:	90	86.80
OF THESE:		
a. Floor Penetration	72	67.90
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c. Deep probe	1	.94
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EXPERIMENTAL/PROTOTYPICAL SYSTEMS

With the exception of the granular activated charcoal (GAC) and aeration water treatment systems installed in five houses, experimentation in remediation design and installation was confined to variations of known remediation methods.

The radon reductions achieved thorugh radon removal from residential water are shown in Figures 6 and 7.

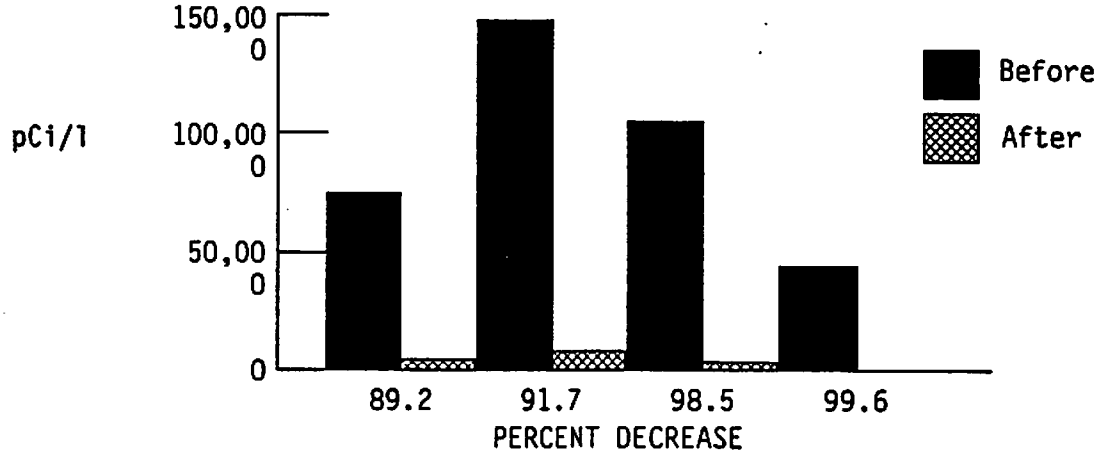

Figure 6. Radon Reduction in Household Water from Aeration Treatment

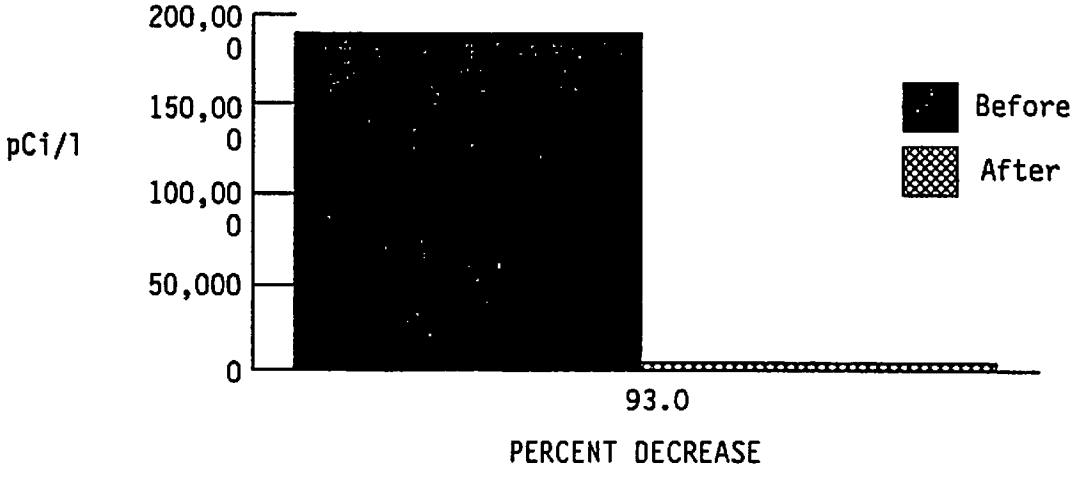

Figure 7. Radon Reduction in Household Water from GAC Treatment

PROJECT RESULTS

RADON REDUCTION

While we do not yet know the long-term effectiveness of the remediation systems that were installed under the RDP, post-mitigation charoal canister results indicate early success. These results show average reductions of 96.25% in basements and 94.76% in first floor areas of participating RDP houses with 73% of the basement areas and 84% of the first floors having radon levels below the 4 pCi/l target.

MITIGATION MANUAL

The final RDP summary report is designed to be used as a ready reference manual for radon remediation contractors. Chapter 2 contains a thorough discussion of diagnostic methods and equipment. Chapter 3 provides step by step instructions for applying and installing the list of remediation methods used in this project. Chapter 3 also includes itemized equipment and materials lists for each remediation method. Chapter 4 is devoted to detailed case studies that lead the reader thorugh the diagnostics and remediation performed in sample houses. In addition, Chapter 4 includes a discussion of difficult to remediate houses. The Appendix contains photographs and descriptions of properly and improperly installed radon remediation systems.

HOMEOWNER GUIDANCE

The Radon Certification Act of 1987 and its implementing regulations have done much to quell concerns about unqualified and dishonest radon contractors. By establishing minimum standards for proficiency, training and experience and by requiring the reporting of radon measurement and remediation results, this law reduces the likelihood of ineffective remediation and bolsters public confidence in the remediation industry.

To supplement this major protective measure, the Guide to Radon Contractor Selection was developed as an element of the RDP. This pamphlet provides the reader with easy-to-understand advice on checking out a contractor's performance record, comparing remediation cost estimates, entering into a remediation work agreement and filing a contractor complaint with the DER. Copies of the report and pamphlet will be sent to each state and the EPA when available.

MEASUREMENT OF SUCCESS

Table 2 provides a report card for the DER in fulfilling the mandate and intent of Act 62 through the RDP. Each of the specified and implied tasks have been assigned an indication of success. While admittedly biased, the report card does identify some RDP shortcomings. For example, although the RDP concluded on time, it did so only after two reprieves. There were no

truly experimental/prototypical remediation systems developed or tested during the RDP; however, there were new variations of existing methods employed. Local subcontractor participation was slow to evolve and had to be dropped for the last 32 homes remediated to maximize the number of homes with extremely high radon levels included in the RDP. But these shortfalls are minor in comparision to the benefits derived from the RDP not only by the homeowners, subcontractors and researchers directly involved with the project, but also by the radon industry and effected public who can be assured that documented and reproducible radon remediation methods are available to them.

TABLE 3. RDP REPORT CARD

Category	Grade
No. of Homes Participating (106)	+
Representative Housing Construction Included	+
Wide Range of Pre-Mitigation Radon Levels	+
Radon Reductions Achieved (95%)	+
Standards for Mitigation Craftsmanship Developed	+
Specifications for Mitigation Materials Developed	√
Wide Variety of Mitigation Methods	√
Experimental/Prototypic Methods Developed and Evaluated	√
No. of Local Contractors Participating	√
Mitigation Manual Developed	+
Contractor Selection Guidance Developed	+
Homeowner Relations	+
House Reports (106)	+
Completed within Budget	+
Completed on Time	√

√ Satisfactory
+ Well Done