RADON REDUCTION EFFORTS IN NEW JERSEY

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ABSTRACT

This paper presents summary information on homeowner-funded radon reduction efforts compiled by the New Jersey Department of Environmental Protection (DEP). Data collected through a post-remediation testing program and from reports voluntarily submitted by radon mitigation firms include pre- and post-mitigation radon levels, mitigation method, mitigation installer and cost of mitigation for over 700 homes. Effectiveness of soil depressurization systems, sealing techniques and air to air exchangers was evaluated by comparison of short term pre- and post- mitigation radon measurements performed by DEP or reported by mitigation firms. A review of data compiled from the post-mitigation testing program indicates soil depressurization to be the predominant method employed by mitigation firms to reduce indoor radon levels. Pre-mitigation radon levels in dwellings remediated by homeowners were generally less than 20 pCi/l and generally greater than 20 pCi/l in homes remediated by mitigation firms. Lowest floor radon concentrations following mitigation exceeded 4 pCi/l in 64% of homes with 13% having levels greater than 20 pCi/l. The average cost of mitigation determined from reports submitted by mitigation firms was $1,300 with a range of $200 to $8,600.

INTRODUCTION

In recent years, a number of studies sponsored by State and Federal agencies have been conducted to develop and demonstrate effective radon reduction methods for existing homes. Techniques evaluated through such studies include soil ventilation, sealing, and forced house ventilation. This technology has been transferred to the public and private sectors of New Jersey through dissemination of U.S. Environmental Protection Agency (EPA) documents[1,2] which provide guidance on the selection, design and operation of radon reduction systems. Government sponsored mitigation training courses have been attended by many private sector mitigators in New Jersey. Phone consultations provided by DEP technical staff to New Jersey residents seeking advice on appropriate mitigation strategies also serve as a means of technology transfer.

The New Jersey Department of Environmental Protection (DEP) has compiled data on homeowner-funded radon reduction efforts for 716 homes in an attempt to determine (1) what mitigation methods are being selected by residents, (2) who is performing mitigation work, (3) the average cost of mitigation and, (4) the effectiveness of methods used by both homeowners and mitigation firms. The data compiled will be used by the DEP to gauge the success of the mitigation technology transfer process and to identify public and private sector information needs.

SOURCES OF DATA

The New Jersey Department of Environmental Protection (DEP) has in place a post-remediation testing program which permits tracking of homeowner-funded radon reduction efforts in the state. The major purposes of this program, which was established in January, 1986, are to provide homeowners with access to no cost radon testing to assess the effectiveness of control measures employed to reduce radon levels in their homes and to monitor the performance of the rapidly developing and currently unregulated mitigation industry in the state. Testing is conducted through field visits to remediated homes at which time two carbon canisters are placed on the two lowest floors and a survey form is completed. Information documented for each home includes identification of mitigation method, installer and pre- and post- mitigation radon levels. Effectiveness of mitigation installations is also evaluated through comparison of pre- and post-mitigation radon levels measured on the lowest "liveable" floor under closed house conditions. The review of data which follows has been derived from post-remediation surveys conducted in 716 homes by DEP from January, 1986 through March, 1988.

A second program through which mitigation activities of the private sector are monitored is a DEP voluntary mitigation certification program. Firms participating in this program are required to submit quarterly reports on mitigation work performed in New Jersey homes. Reports include information similar to that obtained through the post-remediation testing program. Cost of mitigation installations charged to clients is also included in these reports. Data has been compiled from firm reports submitted to DEP for 942 homes mitigated in 1987. Because interpretation of this data set relies heavily on the honesty and accuracy of firm reporting, it is used only for comparison with data from the post-remediation testing program. Unless otherwise indicated, the discussion and review of data which follows is based on information compiled from the post-mitigation testing program.

MITIGATION METHODS

Methods employed to reduce indoor radon levels in the 716 homes surveyed through the DEP post-remediation testing program have been grouped into 4 major categories which include (1) sealing only techniques, (2) soil depressurization methods, (3) forced ventilation with air to air exchangers and, (4) other methods.

Sealing only techniques most commonly observed were the covering or filling in of sump pump pits and french drains. Floor/wall crack sealing and the application of water resistant paints to basement walls, also included in the sealing only category, were less frequently employed. The extent to which sealing techniques were applied varied considerably and materials used were diverse. Rarely did methods conform to guidance provided in EPA documents. Cracks were almost never widened before applying sealants and in some cases ordinary mortar alone was used as the sealant material rather than silicone and urethane caulks recommended by EPA.

Soil depressurization methods observed in homes included active sub-slab, drain tile and block wall suction. Sub-slab suction was by far the most common soil depressurization method selected (90% of homes) and in most homes mitigated by DEP certified mitigation firms was accompanied by sealing of major radon entry routes. Homeowners who installed their own soil depressurization systems rarely did any sealing.

Air to air exchangers were either those with or without heat recovery. The classification of systems as air to air exchangers was based on claims by manufacturers or installers of systems. It was also noted that one particular unit was placed in 23 of 57 homes in which this technique was used and frequent failure of this system has raised questions about it's classification as an air to air exchanger.

Included in the "other" mitigation methods category were combinations of techniques, i.e., sub-slab suction/air to air exchanger, basement or sub-slab pressurization and passive house and sub-slab ventilation. These techniques were generally used either as temporary measures or when other systems installed had failed.

Selection and installation approaches of mitigation methods discussed above were influenced by who was performing the work. Homeowners with some knowledge of building construction or engineering or who wanted to minimize costs often performed their own mitigation work using mainly various sealing techniques. Most homeowners, however, engaged the services of certified mitigation firms. Non-certified firms is a third group which performed mitigation work in homes. These firms either elected not to participate in the DEP certification program or failed to meet minimum enrollment requirements. Also included in the non-certified firm group were those which installed air to air exchangers for purposes other than radon mitigation.

Table 1 indicates the number of homes mitigated for each of the 4 categories of methods discussed above. A further breakdown for 3 different groups of mitigators is provided. As shown, the dominant mitigation technique selected was soil depressurization (59% of homes). Sealing as a sole mitigation method was used in 28% of homes and air to air exchangers in 8% of homes. Homeowners performed a significant proportion (34%) of mitigation work and most often employed sealing techniques as a sole mitigation method. DEP certified firms installed systems in 53% of homes and soil depressurization was the most frequently used technique by this group, comprising 85% of all work which they performed. This is not surprising as soil depressurization is the method which

has been demonstrated through EPA sponsored studies to be the most effective in reducing indoor radon levels. The non-certified firm group performed only 13% of work in surveyed homes using primarily air to air exchangers and soil depressurization systems.

The influence of pre-mitigation radon levels on homeowner mitigation choices can be postulated from data summarized in Table 2. For homes with pre-mitigation radon levels in the 4 to 8 pCi/1, 45% of mitigation choices were sealing techniques. The use of this mitigation method decreased with each increasing range of radon levels. No homes with radon levels exceeding 200 pCi/1 were remediated by sealing alone. Soil depressurization was clearly the dominant mitigation choice for homes with initial radon levels greater than 8 pCi/1. Air to air exchangers were most often used in homes with levels less than 50 pCi/1. The data would appear to indicate that EPA guidance in selecting appropriate mitigation strategies based on pre-mitigation radon levels is, in general, being followed by New Jersey residents. This is evidenced by increased use of soil depressurization and limited use of sealing only techniques in homes with higher radon levels.

EFFECTIVENESS OF MITIGATION SYSTEMS

For the 716 homes surveyed through the DEP post-remediation testing program, the performance of mitigation systems was evaluated by computing percent reductions from short term pre- and post-mitigation radon levels measured by DEP. Because radon levels measured were not representative of annual averages, the data must, at best, be considered approximate. The results of this analysis are shown in Figure 1. Reductions calculated were averages for each mitigation technique and for each group of mitigators. The highest average reduction was achieved by certified firms using soil depressurization methods (80%). The lowest average reduction (27%) was achieved by homeowners who employed sealing techniques. For all mitigation techniques, certified firms achieved higher average reductions than did homeowners or non-certified firms. An exception is homeowner success in reducing radon levels using air to air exchangers. This data is based on only 4 installations and therefore should not be considered representative. For all mitigation techniques performance ranged from an increase in radon to 99% reduction.

The performance of mitigation installations in the 716 homes surveyed was also evaluated by determining the proportion of homes which had radon levels above 4 pCi/1 following remediation. (The EPA recommends remedial action in homes in which annual average radon levels exceed 4 pCi/1). Figure 2 shows the distributions of pre- and post- mitigation radon levels in homes remediated by all mitigators and for all mitigation methods. Pre-mitigation radon levels in the 716 homes surveyed ranged from 4 pCi/1 to 670 pCi/1. Again, it should be emphasized that measurements were short term and made on lowest floors of homes under closed house conditions and are therefore not representative of annual average concentrations. The distribution of post-mitigation radon levels shows that, in 64% of homes, levels exceeded 4 pCi/1 following remediation and in 36% of homes radon levels exceeded 8 pCi/1.

To further investigate the failure of mitigation systems to reduce lowest floor radon levels to below 4 pCi/l the distributions of pre- and post-mitigation radon levels in homes remediated by certified firms only was reviewed. It was thought that experienced mitigators would be more successful in reducing levels to below 4 pCi/l. This data is shown in Figure 3. Pre-mitigation radon levels were generally higher in homes remediated by this group. The performance of systems installed by certified firms was somewhat better than that achieved by all mitigators with 52% of homes having radon levels greater than 4 pCi/l following mitigation as compared to 64% for all mitigators. This is somewhat surprising in view of the fact that soil depressurization methods were employed in 85% of homes mitigated by certified firms and the data apparently conflicts with information on mitigation practices collected through an EPA pilot survey of private sector firms in New Jersey and a number of other states.[3] Firms participating in this survey reported that they achieve radon levels below the EPA's recommended level of 4 pCi/l in 90% of homes in which sub-slab ventilation systems are installed. Data available from an EPA mitigation demonstration program conducted in Pennsylvania appear to support DEP findings.[4] In 16 of 34 homes in which soil depressurization techniques were used, radon levels were equal to or exceeded 4 pCi/l following mitigation. Measurements in these homes were also short term and made in basements under closed house conditions.

An assessment of pre- and post-mitigation radon levels for each mitigation technique was also performed to identify mitigation methods least effective in reducing radon levels below 4 pCi/l. Distributions for sealing only and air to air exchanger methods are shown in Figure 4. Examination of post-remediation radon levels in homes in which sealing alone was used indicate that this method was not effective in reducing radon levels to below 4 pCi/l following mitigation. The failure of sealing could be attributed to inappropriate techniques by inexperienced homeowners, the group which most often selected this method.

Success in reducing levels to below 4 pCi/l using air to air exchangers was similar to that determined for sealing techniques with 77% of homes having levels greater than 4 pCi/l following mitigation.

Figure 5 shows the distributions of pre- and post-mitigation radon levels in homes in which soil depressurization systems and "other" methods were employed. Post-mitigation radon levels exceeded 4 pCi/l in 50% of homes in which soil depressurization techniques were used by all groups of mitigators. Pre-mitigation radon levels were generally higher in homes in which soil depressurization methods were employed than those in which sealing only or air to air exchangers were used.

The success of "other" methods was again similar to that achieved for sealing and air to air exchangers with 80% of homes having radon levels above 4 pCi/l following mitigation.

The effect of initial radon levels on the performance of mitigation systems was also evaluated. As shown in Table 3, the overall percent of homes with post-mitigation radon levels greater than 4 pCi/l increased from 55% to 72% as

initial radon levels increased. For all ranges of initial radon levels, soil depressurization was more effective in reducing levels to below 4 pCi/l than other methods. Evident from the data is the apparent difficulty in reducing radon levels on lowest floors of homes below 4 pCi/l for all ranges of initial radon levels.

Performance of mitigations systems installed by DEP certified firms evaluated from data compiled from the post-remediation testing program was compared to mitigation information derived from reports submitted to DEP by these same firms. This data is provided in Table 4. Average percent reductions determined for all mitigation methods reported by firms were in general, somewhat higher than those compiled from the follow-up testing program. The proportion of homes reported by firms to have radon levels greater than 4 pCi/l following mitigation is markedly conflicting with data compiled from the post-remediation testing program for all mitigation methods. Eleven percent of homes, on average, were reported by firms to have radon levels greater than 4 pCi/l following mitigation. Data derived from the post-remediation testing program indicated that 50% of homes surveyed had levels greater than 4 pCi/l following mitigation. Pre- and post-remediation radon levels reported by firms were measured using a variety of techniques and by numerous testing firms which may partially explain the discrepancy in the two data sets. DEP post-remediation testing was conducted from January, 1986 through March, 1988 while reports submitted by firms were from 1987. It could be that success of firms in reducing radon levels below 4 pCi/l was much lower in 1986 than in 1987, or that homes tested through the DEP program were those more difficult for certified firms to mitigate. Inaccuracy of firm reporting or failure of systems after post-mitigation testing by firms and before DEP testing may also be reasons for conflicting data. It could also be that firms were less likely to report failures in reducing levels below 4 pCi/l to the DEP.

AVERAGE COSTS OF MITIGATION

The average cost of radon mitigation work charged to homeowners by DEP certified firms was computed from information reported by firms in 1987. This data is provided in Table 5 and compared to average costs estimated by EPA and the New York State Energy Office (NYSEO) through surveys of radon mitigation firms in the eastern United States.[3,5] The overall average estimated by DEP was $1,300 and is at the upper end of the overall average range reported by EPA. With the exception of sealing only techniques, average mitigation costs charged by DEP certified firms were slightly higher than those estimated from the NYSEO survey. DEP cost estimates for sealing techniques were considerably lower than those reported by NYSEO but did fall within the range estimated by ORP. NYSEO estimates for this technique were based on sealing used as a sole mitigation technique or in conjunction with other methods whereas costs determined by DEP were based on sealing only methods which could explain why the former were lower than the latter. It should be noted that costs for radon mitigation performed by homeowners were not included in estimates.

CONCLUSIONS

Soil depressurization was the most common mitigation method employed by DEP certified firms to reduce indoor radon levels in 716 homes surveyed through a post-remediation testing program. Sealing was most often the choice of homeowners who performed their own mitigation work. Air to air exchangers were used less often than either sealing or soil depressurization.

While significant reductions in radon levels were achieved in the 716 homes included in the follow-up testing program, many homes still had lowest floor radon levels greater than 4 pCi/l following mitigation. Sealing and the use of air to air exchangers were found to be the least effective in reducing levels to below 4 pCi/l. About 80% of homes in which these techniques were used had levels greater than 4 pCi/l following mitigation. In 50% of homes in which soil depressurization was used post-mitigation radon levels exceeded 4 pCi/l.

Reports from firms participating in the DEP Mitigation Certification Program indicated a much higher success in reducing radon levels to below 4 pCi/l than did data compiled from DEP post-remediation surveys.

Post-remediation testing should be regarded as an important step in the final solution of reducing indoor radon levels below 4 pCi/l.

The average cost of mitigation charged to New Jersey residents by certified firms was $1,300.

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5. Watson, M.R., J.P. Reese and A.R. Adams, "The Radon Service Industry in Selected Northeastern States", presentation at 81st Annual Meeting, Air Pollution Control Association, Dallas, Texas, 6/88.

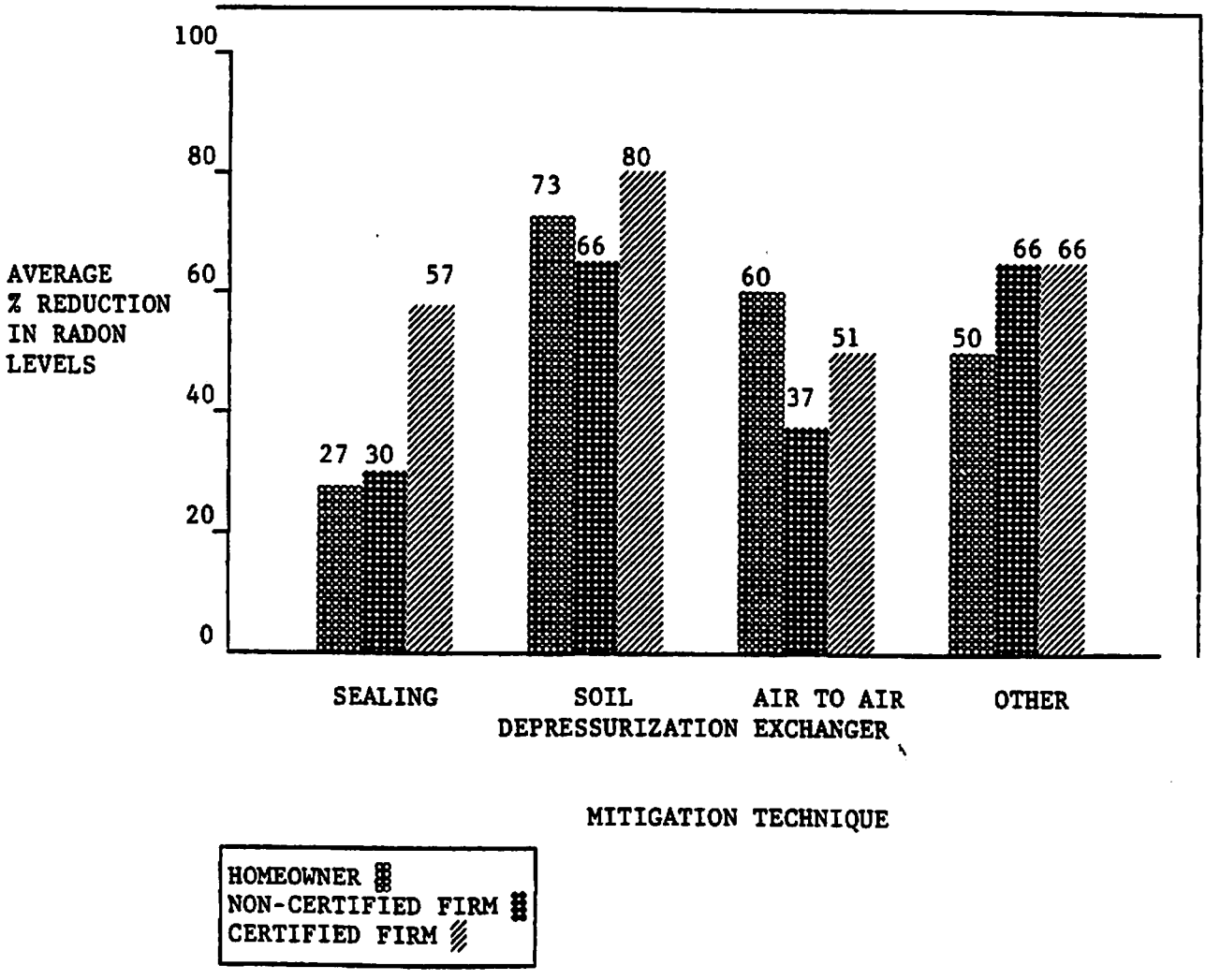
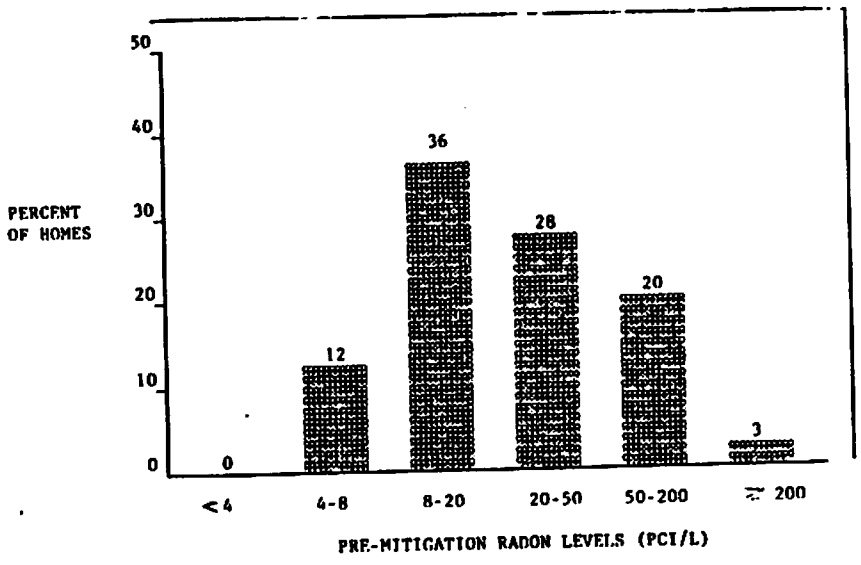


FIGURE 1. EFFECTIVENESS OF MITIGATION MEASURES INSTALLED BY HOMEOWNERS, CERTIFIED AND NON-CERTIFIED FIRMS IN 716 HOMES.



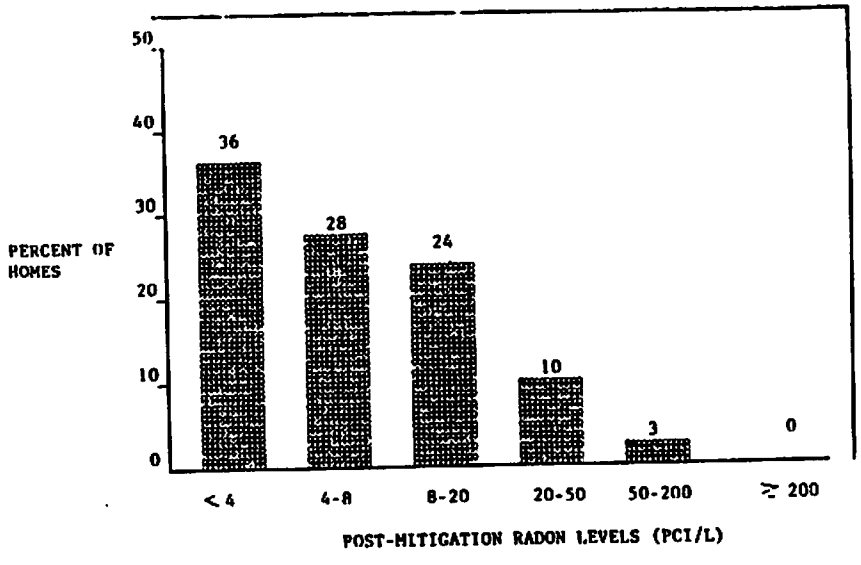
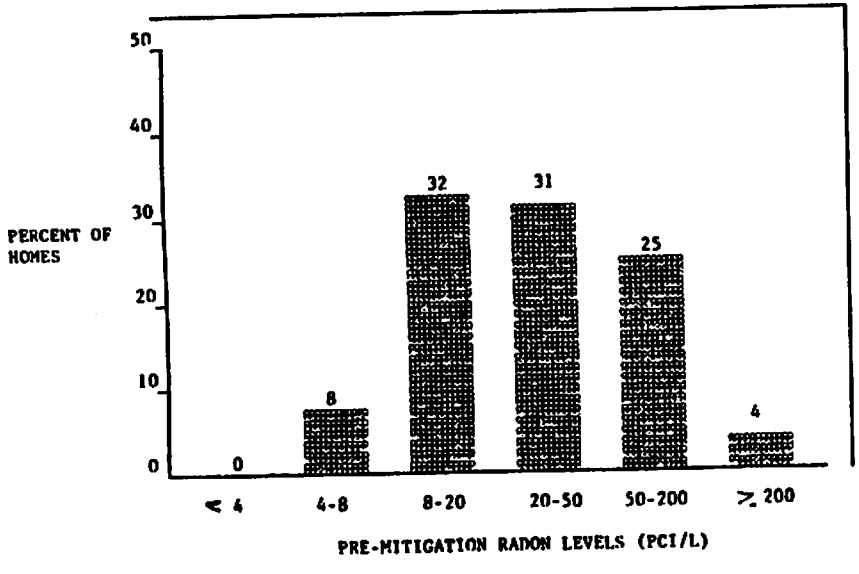


FIGURE 2. PRE - AND POST-MITIGATION RADON LEVELS IN 716 HOMES REMEDIATED BY HOMEOWNERS, NJDEP CERTIFIED FIRM AND NON-CERTIFIED CONTRACTORS BY ALL METHODS.



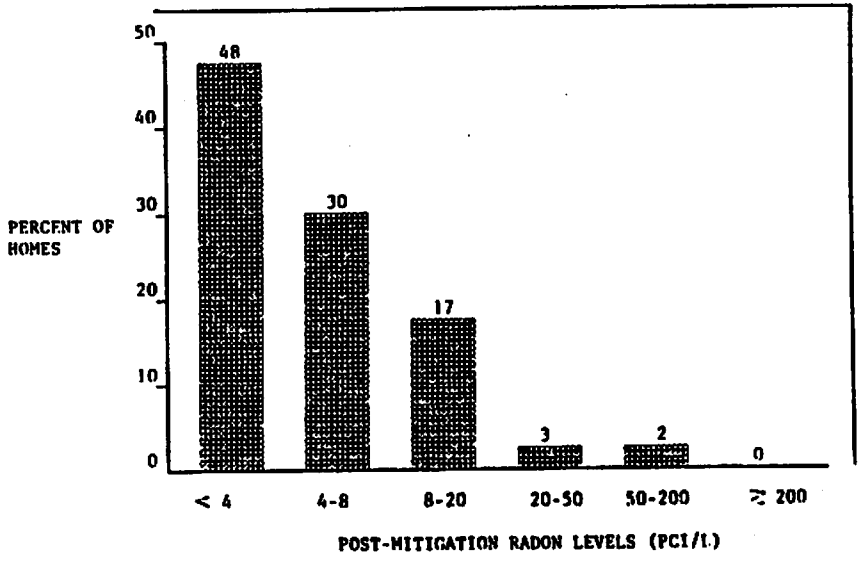


FIGURE 3. PRE - AND POST-MITIGATION RADON LEVELS IN 382 HOMES REMEDIATED BY NJDEP CERTIFIED FIRMS BY ALL METHODS.

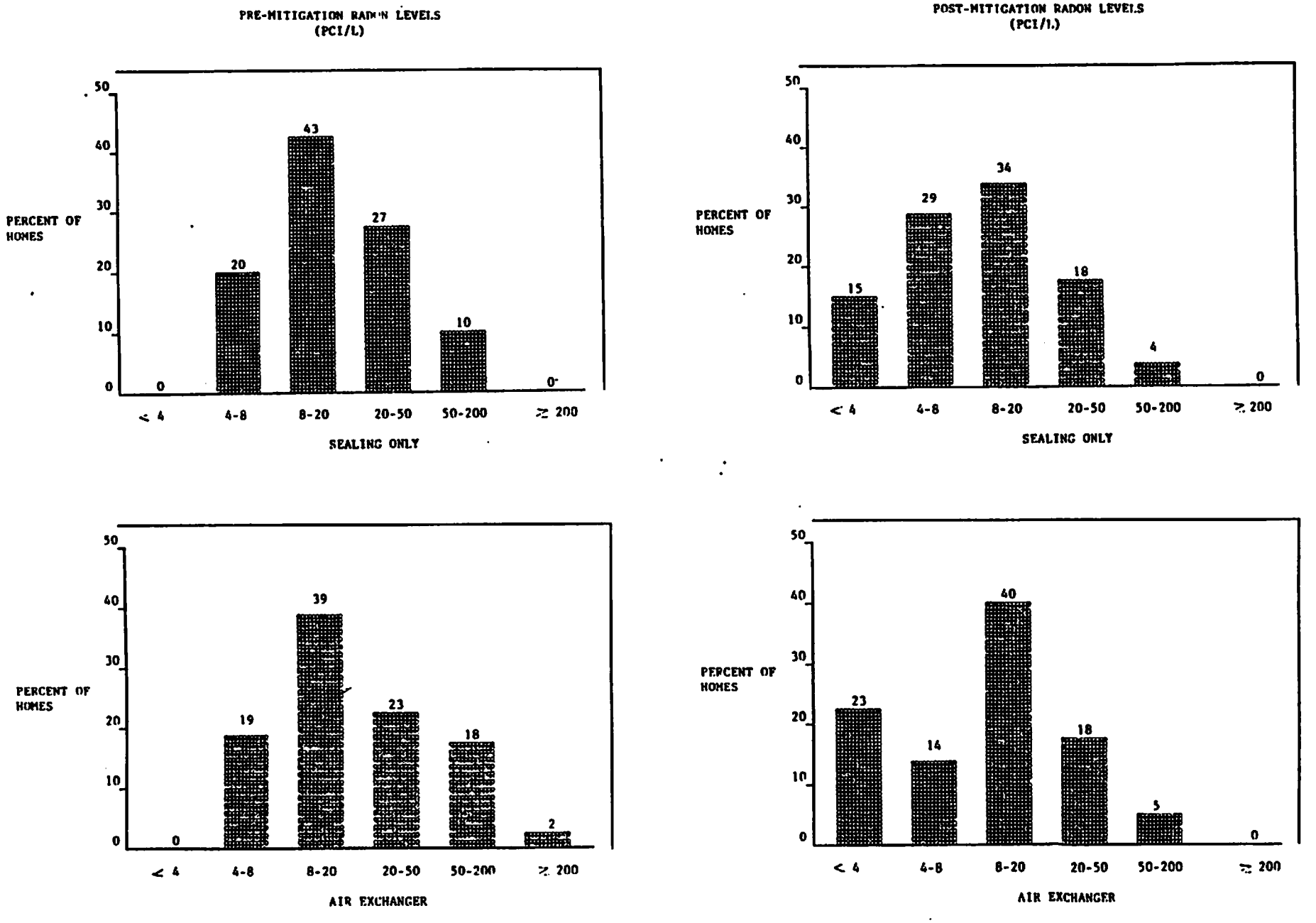
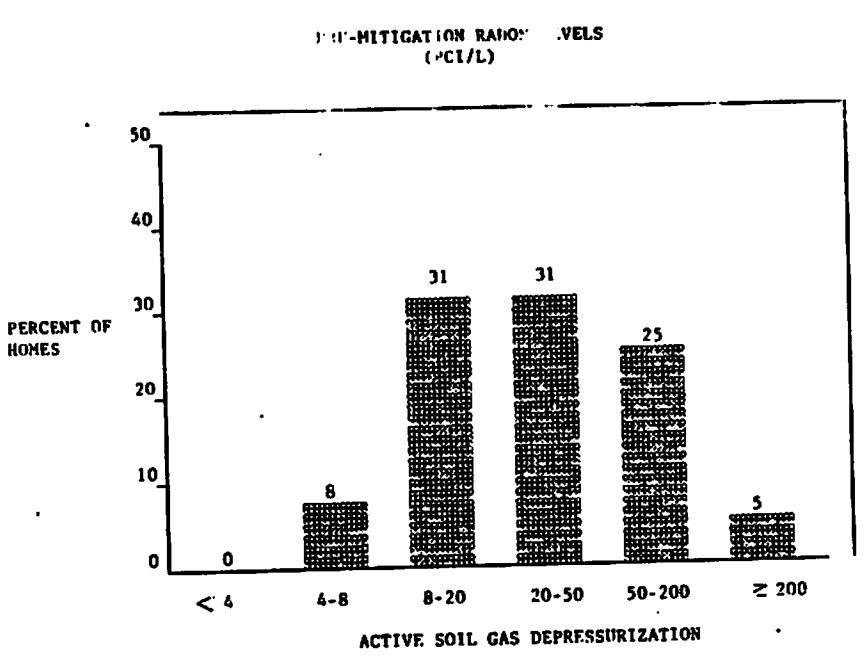
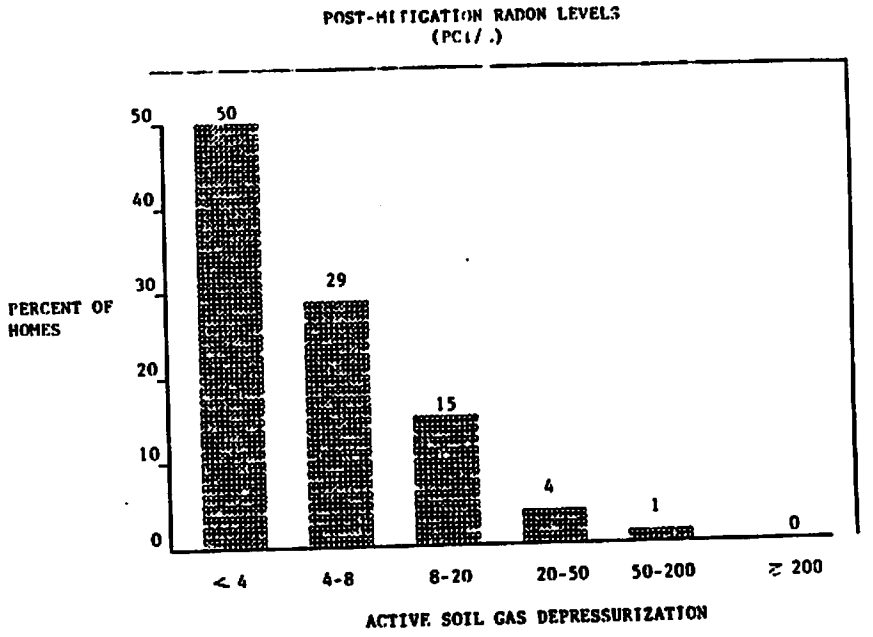
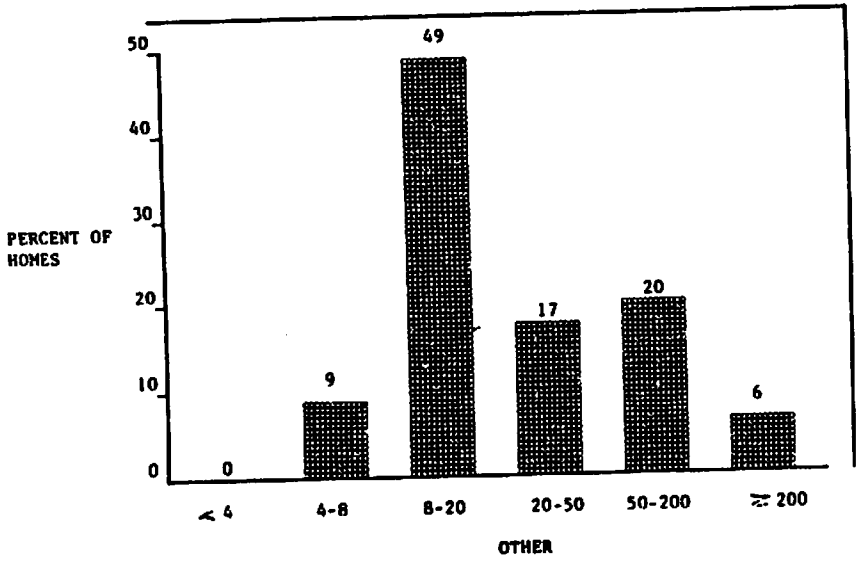


FIGURE 4 . PRE- AND POST-MITIGATION RADON LEVELS FOR HOMES REMEDIATED BY HOMEOWNERS, NJDEP CERTIFIED FIRMS AND NON-CERTIFIED CONTRACTORS USING SEALING ONLY AND AIR EXCHANGERS.







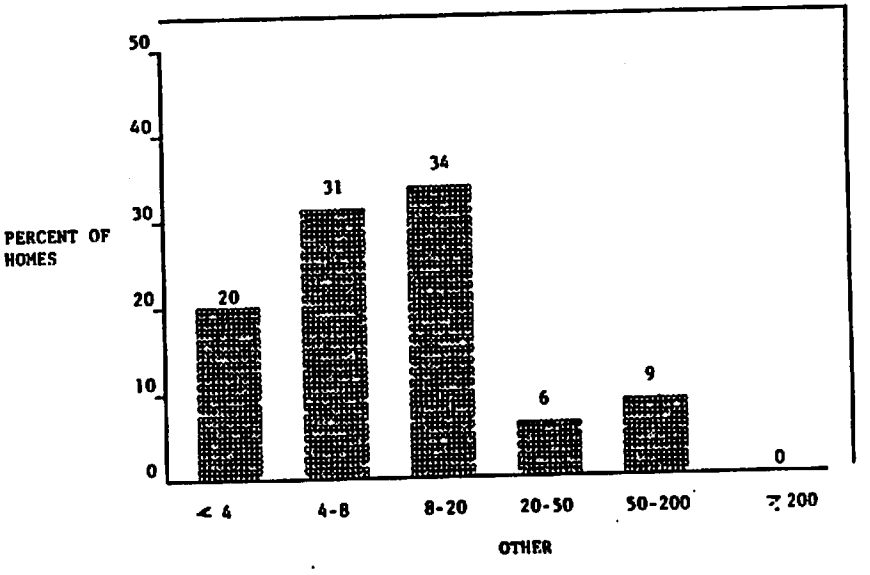


FIGURE 5 . PRE - AND POST-MITIGATION RADON LEVELS FOR HOMES REMEDIATED BY HOMEOWNERS, NJDEP CERTIFIED FIRMS AND NON-CERTIFIED CONTRACTORS USING ACTIVE SOIL GAS DEPRESSURIZATION AND OTHER METHODS.

Table 1. Homeowner, DEP Certified Firm and Non-Certified Firm Mitigation Installations in 716 Homes.[a]

	SEALING ONLY	SOIL DEPRESSURIZATION	AIR TO AIR EXCHANGERS	OTHER	TOTAL
HOMEOWNER	158	64	4	17	243 [34]
DEP CERTIFIED FIRMS	27	326	14	15	382 [53]
NON-CERTIFIED FIRMS	18	31	39[b]	3	91 [13]
TOTAL	203 [28]	421 [59]	57 [8]	35 [5]	716 [100]

[a]Bracketed numbers represent percent of total homes.

[b]23 of the 39 installations were performed by one mitigation firm.

Table 2. Number of Homes Mitigated with Several Ranges of Radon Levels and Various Methods.

	RADON LEVEL (pCi/1)				
	4-8	8-20	20-50	50-200	200
SEALING ONLY	40	87	55	21	-
SOIL DEPRESSURIZATION	34	131	130	105	21
AIR TO AIR EXCHANGERS	11	22	13	10	1
OTHER	3	17	6	7	2
TOTAL	88	257	204	143	24

TABLE 3. Proportion of homes with post-mitigation radon 4 pCi/l for several ranges of initial radon levels (proportions indicated are % of homes, bracketed numbers represent total homes).

MITIGATION METHOD	INITIAL RADON LEVEL (pCi/l) 4-8	8-20	20-100	100
SEALING	75 [40]	88 [87]	97 [70]	83 [6]
SOIL DEPRESSURIZATION	21 [34]	47 [131]	52 [195]	67 [61]
AIR TO AIR EXCHANGERS	91 [11]	86 [22]	95 [19]	100 [5]
OTHER	33 [3]	81 [17]	83 [12]	100 [3]
OVERALL	55 [88]	66 [257]	67 [296]	72 [75]

Table 4. Average Percent Reductions in Radon Levels and Proportion of Homes with Post-Mitigation Radon Levels ≥ 4 pCi/l For Several Mitigation Techniques (bracketed numbers represent total number of homes in which mitigation technique was used).

MITIGATION METHOD	QUARTERLY REPORTS FROM RADON MITIGATION FIRMS		DEP POST-REMEDIATION TESTING PROGRAM[a]	
	Average Reduction	Proportion of Homes with Post-Mitigation Radon Levels ≥ 4 PCi/l (%)	Average Reduction	Proportion of Homes with Post-Mitigation Radon levels ≥ 4 pCi/l (%)
SEALING ONLY	52 [66]	24	57 [27]	67
ACTIVE SOIL GAS DEPRESSURIZATION	85 [805]	10	80 [326]	48
AIR EXCHANGE	74 [60]	13	51 [14]	71
OTHER	79 [11]	18	66 [15]	67
OVERALL AVERAGE	82 [942]	11	75 [382]	50

[a]Reductions are given for mitigation installations by certified firms only and are based on DEP post-remediation testing.

Table 5. Estimated Costs[a] of Radon Mitigation ($)

MITIGATION TECHNIQUE	NJ DEP[b] AVERAGE	NJ DEP[b] RANGE	NYSEO SURVEY[c] AVERAGE	EPA SURVEY RANGE
SEALING	730	100-5,000	261	50-1,500
SOIL DEPRESSURIZATION	1,270	200-8,600	1,060	400-2,500
AIR TO AIR EXCHANGERS	2,000	1,200-3,300	1,509	1,200-3,000
OTHER	1,900	900-4,400	NA	NA
OVERALL AVERAGE	1,300	NA	NA	500-1,500

[a]Average costs computed from reports submitted in 1987 by firms participating in the DEP Mitigation Certification Program.

[b]Estimated average costs from a survey of mitigation firms conducted by the New York State Energy Office in 1987.

[c]Estimated costs from pilot survey of firms conducted by the EPA Office of Radiation Programs.